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TEMPERATURE, MOISTURE, AND RELATIVE HUMIDITY
OF STORED TOBACCO X

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TEMPERATURE, MOISTURE, AND RELATIVE HUMIDITY

OF STORED TOBACCO · X

Dana P. Childs, J. E. Overby, and B. J. Watkins^{1/}

SUMMARY

Flue-cured tobacco is aged for a minimum of 2 or 3 years. During this period, the tobacco mellows, develops a characteristic aroma and color, and improves in burning quality. Despite the many years that have passed since producers first began aging tobacco, the amount of published data on the temperature and moisture of the commodity during storage is meager. While in storage, tobacco is subject to attack by insects. To better understand the ecology of insects that attack tobacco, we obtained data on outside and warehouse temperatures and relative humidities, and on the effects of these factors on temperature and moisture of tobacco in storage. These data were obtained during 1967 from a tobacco warehouse in Wilson, N. C.

INTRODUCTION

Tobacco is normally aged for a few years before it is considered ready for use. The length of the aging or storage period depends on the type of tobacco, and the demand for raw tobacco. While in storage, tobacco is exposed to possible invasion and damage by insects.

One of the types of tobacco aged for 2 to 3 years or often longer is flue-cured. In the United States it is stored primarily in the Middle Atlantic States. The tobacco is usually prized in wooden hogsheads 4 feet long and 4 feet in diameter to a net weight of approximately 950 pounds. The hogsheads are stored in unheated warehouses. One of the most common structures used for tobacco storage consists of a composition flat roof, concrete floor, and sheet-metal sidewalls. Side and roof vents are the main source of ventilation.

Although the tobacco industry considers the storage period essential for fermentation of raw tobacco, temperature and moisture conditions during this period are

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practically unknown, or at least have not been published. Dixon, Darkis, Wolf, and others^{2/} reported on the natural aging of flue-cured tobacco, but they used open-louvered storage in their experiment -- a type that is no longer the universal standard.

Laboratory and field experiments by Runner^{3/} and Swingle^{4/} indicated that low temperature may control the cigarette beetle, a prime pest of stored tobacco. Howe^{5/} lists the cigarette beetle as moderately cold hardy, needing a relative humidity of about 30 percent for survival. Solomon^{6/} believes that insect density-dependent regulation must occur in all populations that persist for any considerable number of generations. He states that weather factors themselves generally are not responsible for population density and they cannot exercise such regulation alone, but only in conjunction with density-dependent processes. He thinks that insect infestations that persist manage temperature and moisture conditions favorable to the organism. Armstrong^{7/} and others follow this theory, indicating that insects in grain may multiply sufficiently to heat the mass, thereby retarding or preventing cooling by natural convection currents and conduction.

Flue-cured tobacco enters storage practically void of living insects. Most ecologists agree that temperature affects the insect more when the population density and moisture level are low and microenvironment inhabitants are at a minimum. These conditions prevail when flue-cured tobacco first enters storage. Data are needed on the effects of outside temperature and relative humidity on conditions inside the tobacco warehouse during storage, and on the effects of these conditions on the temperature and moisture of the tobacco in the hogsheads. These conditions were monitored during 1967 at a warehouse in Wilson, N. C.

^{2/}Dixon, L. F., Darkis, F. R., Wolf, F. A., and others. Natural aging of flue-cured cigarette tobaccos. *Indus. Engin. Chem.* 28(2): 180-9. 1936.

^{3/}Runner, G. A. The tobacco beetle: an important pest in tobacco products. U. S. Dept. Agr. Bul. 737, 77 pp. 1919.

^{4/}Swingle, M. C. Low temperature as a possible means of controlling the cigarette beetle in stored tobacco. U. S. Dept. Agr. Cir. 462, 8 pp. 1938.

^{5/}Howe, R. W. A summary of estimates of optimal and minimal conditions for population increase of some stored-products insects. *J. Stored Prod. Res.* 1(2): 177-84. 1965.

^{6/}Solomon, M. E. Status of the idea that weather can control insect populations. *XI Internatl. Cong. Ent. Bul. Proc. Vol. 2, sect. 7, pp. 126-30.* 1962.

^{7/}Armstrong, M. T. Preventing infestations of farm stored grain without using chemicals. *XII Internatl. Cong. Ent. Bul. Proc. Vol. 1, sect. 9B, p. 628.* 1965.

PROCEDURES

The tobacco warehouse (fig. 1) used in this study was approximately 180 feet long, 130 feet wide, and 20 feet high. The side walls were constructed of sheet metal; the roof was sheet metal with outside surface coated with tar; and the floor was concrete. Five roof vents were located along the peak of the shallow A-frame roof. Vents along the sides of the building were closed throughout the year. Ventilation in the building was restricted primarily to leakage around the side vents and aisle doors, and air moved from these points toward the roof vents. Throughout the year, the warehouse held nearly its full capacity of 3,696 hogsheads.

The hygrothermographs used to monitor outside and warehouse temperature and relative humidity were equipped with 7-day clocks and hair sensors for humidity detection. An official U. S. Weather Bureau Station was used to house the outside instrument. The station was located approximately 30 feet from a side of the warehouse.

A central aisle 12 feet wide separated the warehouse into two equal sections. Space near the center of one section was allotted for a monitoring station. At this station, warehouse temperature and relative humidity were monitored at elevations of 2, 8, and 16 feet above floor level. From a row of hogsheads nested four tiers high near the station, a hogshead from each tier along a diagonal line was selected for monitoring

Figure 1.--Tobacco warehouse used in climatic study.

tobacco temperature and moisture. The top of the hogshead on the upper tier coincided with the 16-foot elevation used to monitor conditions inside the warehouse. The hogsheads monitored were prized in October with 1966-crop tobacco, type 11-A, grade B4F.

In each of the four selected hogsheads, tobacco temperature was monitored at 4-, 12-, and 20-inch depths. Copper-constantan thermocouples were used to detect temperature, and readout was made with a 24-point transistorized recorder. The recorder was automatically activated daily at noon for about 6 minutes. Measurements were accurate to within $\pm 0.5^{\circ}\text{F}$.

Tobacco moisture was monitored with dial-stem hygrometers having animal membrane as the moisture detector. Moisture was monitored in each of the four hogsheads at depths of 4 and 12 inches. The hygrometers remained in the tobacco continuously, but readings were made only weekly. Moisture accuracy was within ± 0.5 percent calculated on a wet basis.

All instruments were checked for calibration at 4-week intervals. At each calibration, the hygrometers were rejuvenated with moisture. The field instruments were calibrated to an electric hygrometer indicator using sensors of bifilar windings of palladium hygroscopically coated with lithium chloride.

RESULTS

The data have been condensed into tabular and graphic form for presentation. Detailed data are available for inspection at the Tobacco Insects Investigations Laboratory, Richmond, Va.

Figures 2-4 show the outside temperature range and the related mean warehouse temperature data. During the year, the mean warehouse temperature in a reduced fluctuating pattern followed closely the higher temperatures recorded outside the building. In the warehouse, the maximum temperature at the 16-foot elevation was usually several degrees higher than at 2 feet above floor level (table 1). With few exceptions, temperature recorded at the 8-foot elevation was near the average of temperatures at 2 and 16 feet. The minimum daily temperature monitored at the three stations was consistently within a range of 3°F . This indicates that daily, after sunset or when there was a cloud cover, the warehouse temperature approached uniformity at the monitoring stations.

Temperature difference in tobacco among the four vertically stacked hogsheads was minimal. Temperature in the top hogshead was usually slightly higher than the next-in-line unit. Tobacco temperatures at 12- and 20-inch depths in the top and bottom hogsheads generally did not vary more than 2°F . At the 4-inch depth, the temperature variation rarely exceeded 4°F . Fluctuation of tobacco temperature within any hogshead was greatest at the 4-inch depth in the top hogshead. (Figures 5-16 show these data.)

Figure 2.--Outside temperature range and mean warehouse temperature during JANUARY, FEBRUARY, MARCH, and APRIL.

Figure 3.--Outside temperature range and mean warehouse temperature during MAY, JUNE, JULY, and AUGUST.

Figure 4.--Outside temperature range and mean warehouse temperature during SEPTEMBER, OCTOBER, NOVEMBER, and DECEMBER.

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967

Date	:	Temperatures (°F.) at --							
	:	2 feet above		:	8 feet above		:	16 feet above	
	:	floor level		:	floor level		:	floor level	
	:	Maximum	Minimum	:	Maximum	Minimum	:	Maximum	Minimum

January:

1	:	50	48	50	48	50	47
2	:	52	48	54	48	60	47
3	:	53	50	53	50	56	49
4	:	51	49	51	49	51	48
5	:	51	46	52	46	56	44
6	:	52	45	54	45	61	43
7	:	52	47	54	47	58	46
8	:	54	52	55	53	58	54
9	:	54	52	54	52	55	51
10	:	53	49	54	49	56	48
11	:	52	46	55	46	60	44
12	:	51	44	54	44	59	42
13	:	53	46	59	46	67	44
14	:	52	51	53	51	53	50
15	:	53	50	53	51	54	50
16	:	54	49	60	50	66	49
17	:	54	46	60	47	67	44
18	:	53	46	58	47	64	45
19	:	48	45	48	45	47	44
20	:	45	44	45	44	44	43
21	:	50	44	53	44	58	43
22	:	54	48	62	47	74	46
23	:	56	49	64	49	72	48
24	:	58	51	68	51	79	50
25	:	58	54	66	54	75	54
26	:	59	54	68	54	76	53
27	:	59	56	65	55	70	56
28	:	56	51	60	51	64	50
29	:	55	49	59	49	65	48
30	:	54	50	54	49	61	48
31	:	55	47	60	47	68	46
Average	:	53	49	57	49	61	48

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	: Maximum	: Minimum	: Maximum	: Minimum	: Maximum	: Minimum

February:

1	:	58	55	66	57	76	56
2	:	58	53	65	54	71	52
3	:	57	50	60	51	61	50
4	:	56	49	62	50	70	48
5	:	56	50	63	50	70	49
6	:	55	50	60	50	66	48
7	:	52	49	53	48	54	47
8	:	50	44	55	45	60	45
9	:	46	44	48	45	45	43
10	:	47	44	48	45	48	43
11	:	50	45	53	45	56	43
12	:	50	48	52	47	54	46
13	:	52	45	58	45	66	43
14	:	53	45	60	45	67	44
15	:	55	52	62	53	68	52
16	:	56	54	62	56	68	56
17	:	54	48	56	47	56	47
18	:	48	46	48	46	47	45
19	:	49	45	49	45	50	45
20	:	48	45	48	44	47	43
21	:	52	46	55	46	61	46
22	:	50	43	53	43	58	42
23	:	51	46	54	46	60	44
24	:	50	45	54	45	58	44
25	:	46	40	47	40	50	38
26	:	48	39	51	39	58	37
27	:	48	40	49	40	54	38
28	:	51	46	57	46	65	45
Average	:	52	47	55	47	50	46

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
March:						
1	50	45	55	45	52	43
2	50	42	56	42	64	50
3	54	48	64	48	74	47
4	57	50	67	50	81	49
5	58	52	67	52	77	51
6	63	56	74	60	80	61
7	61	56	69	58	76	59
8	58	54	66	54	74	52
9	59	52	68	52	78	51
10	58	53	66	53	72	52
11	60	57	69	60	78	49
12	58	57	64	58	65	58
13	60	56	66	56	73	55
14	62	58	70	60	80	59
15	63	59	75	60	88	59
16	60	55	67	56	76	55
17	57	51	62	51	67	51
18	56	48	60	48	68	47
19	56	47	61	47	71	46
20	54	48	55	47	58	46
21	53	51	53	51	53	50
22	58	50	64	50	74	50
23	57	49	64	49	71	48
24	58	51	65	52	75	50
25	59	54	66	54	76	53
26	62	54	73	54	87	53
27	60	57	67	56	75	57
28	61	56	69	56	79	56
29	63	58	70	60	78	60
30	62	56	69	55	80	54
31	62	54	72	54	86	53
Average	58	53	66	53	74	52

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	: Maximum	: Minimum	: Maximum	: Minimum	: Maximum	: Minimum
April:						
1	: 64	56	75	56	88	55
2	: 66	59	68	60	93	60
3	: 68	62	82	64	94	64
4	: 66	61	75	63	86	63
5	: 66	58	75	58	85	58
6	: 66	63	78	66	87	66
7	: 68	64	79	68	87	69
8	: 67	62	76	64	86	63
9	: 66	60	74	59	84	59
10	: 67	62	77	62	86	62
11	: 67	62	76	65	86	65
12	: 66	59	73	59	84	58
13	: 61	59	64	59	66	58
14	: 67	60	76	60	86	60
15	: 68	64	77	66	86	66
16	: 71	63	83	65	97	64
17	: 70	65	80	68	88	67
18	: 71	66	81	68	91	68
19	: 69	64	77	64	86	63
20	: 67	61	78	62	88	61
21	: 67	64	77	61	87	61
22	: 65	62	75	68	83	68
23	: 67	61	70	63	70	64
24	: 66	60	76	62	87	62
25	: 62	60	75	60	86	60
26	: 63	61	62	59	63	61
27	: 63	59	66	59	70	59
28	: 63	57	70	57	80	56
29	: 64	56	74	56	86	56
30	: 65	58	73	59	82	59
Average	: 66	61	75	62	84	62

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
May:						
1	67	62	78	64	90	65
2	69	64	80	66	92	67
3	69	65	79	64	90	65
4	65	61	71	63	77	63
5	66	61	76	61	87	63
6	66	62	74	64	80	64
7	66	64	74	68	80	67
8	66	60	75	61	85	61
9	65	60	72	61	79	60
10	67	64	76	60	87	60
11	67	63	75	64	82	65
12	69	65	79	68	90	68
13	66	64	70	65	71	65
14	68	63	78	64	89	64
15	70	65	81	68	91	68
16	69	64	79	66	90	66
17	72	67	79	63	92	63
18	71	64	82	65	95	66
19	71	65	81	66	93	67
20	73	67	85	71	97	71
21	69	67	77	69	81	70
22	66	63	69	64	70	64
23	64	62	67	62	69	62
24	63	61	65	61	67	61
25	67	59	76	59	89	59
26	69	62	79	63	92	63
27	70	63	83	64	98	64
28	73	66	89	69	105	70
29	75	69	89	73	105	74
30	70	68	79	72	80	72
31	66	65	68	67	72	67
Average	68	64	77	65	86	65

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperature (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
June:						
1	66	64	69	64	72	65
2	65	63	67	64	70	64
3	69	63	79	63	90	63
4	70	65	79	67	88	67
5	71	66	81	68	90	68
6	72	67	83	69	94	69
7	73	67	84	69	95	69
8	75	67	82	69	102	69
9	76	69	89	71	103	72
10	77	70	90	72	106	72
11	76	71	89	73	104	74
12	78	71	91	74	104	74
13	79	73	92	77	107	78
14	78	73	90	76	100	77
15	78	72	90	75	102	76
16	79	72	92	76	105	75
17	76	73	85	78	90	76
18	76	73	85	76	90	77
19	77	73	87	75	99	74
20	78	72	89	76	99	74
21	79	73	91	77	104	76
22	79	74	89	79	101	79
23	81	75	93	78	106	79
24	82	76	95	80	109	80
25	80	77	92	82	102	83
26	78	75	84	78	87	79
27	76	72	84	73	91	74
28	78	75	87	72	99	72
29	76	72	82	73	89	73
30	76	73	84	76	92	76
Average	76	71	86	73	96	73

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperature (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
July:						
1	79	73	91	75	104	75
2	77	75	85	77	93	78
3	80	74	91	77	103	77
4	81	76	93	79	105	80
5	80	74	92	76	104	77
6	80	74	91	76	108	77
7	78	75	87	78	95	79
8	79	75	89	78	101	78
9	81	75	92	78	104	78
10	81	76	91	79	101	80
11	81	77	91	81	101	82
12	82	77	94	81	104	81
13	81	78	90	82	97	82
14	77	76	83	79	85	79
15	76	75	79	76	81	77
16	79	73	89	74	102	75
17	79	74	87	75	97	76
18	80	75	90	73	102	78
19	82	76	90	78	101	79
20	85	79	89	78	98	79
21	84	80	93	78	107	78
22	83	79	95	79	108	80
23	81	78	97	80	111	81
24	83	76	96	81	109	82
25	84	80	94	83	105	84
26	81	79	94	82	105	82
27	80	76	97	81	110	82
28	82	75	94	83	103	84
29	83	77	92	83	100	84
30	84	77	88	80	94	80
31	84	78	94	77	106	78
Average	81	76	91	79	101	79

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperature (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
August:						
1	84	79	96	81	109	82
2	86	78	97	81	111	82
3	86	81	98	83	110	84
4	86	81	97	84	109	85
5	82	81	89	84	94	85
6	84	78	94	80	105	85
7	84	79	93	81	104	86
8	84	78	95	79	108	80
9	86	78	96	81	108	81
10	84	81	91	83	99	84
11	81	78	83	77	83	78
12	78	75	78	76	78	76
13	76	74	78	74	80	74
14	80	73	87	73	99	73
15	80	74	89	74	99	74
16	82	75	92	75	104	75
17	82	77	92	78	103	79
18	88	78	93	80	106	80
19	84	79	94	81	106	81
20	84	79	94	82	104	83
21	83	79	93	81	105	81
22	80	78	85	80	88	80
23	80	77	85	78	90	78
24	82	78	90	78	101	78
25	85	77	95	78	111	78
26	84	77	95	81	107	81
27	83	80	93	81	103	81
28	83	79	92	80	102	80
29	83	77	92	80	103	78
30	83	77	91	78	101	78
31	82	78	93	84	96	84
Average	83	78	91	80	101	80

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum

September:

1	:	79	76	83	78	89	77
2	:	79	72	81	73	94	72
3	:	79	71	87	72	97	71
4	:	77	72	81	72	85	72
5	:	79	72	88	72	98	72
6	:	80	73	89	73	99	73
7	:	82	73	90	73	102	73
8	:	80	73	89	73	101	73
9	:	78	76	83	77	86	77
10	:	76	75	79	75	83	75
11	:	75	73	79	73	85	73
12	:	74	71	76	71	80	71
13	:	76	71	82	71	90	70
14	:	77	69	83	69	94	68
15	:	77	69	85	69	97	69
16	:	76	72	81	72	89	72
17	:	74	73	76	74	77	73
18	:	78	73	87	74	98	73
19	:	79	73	90	73	103	73
20	:	80	74	90	76	102	76
21	:	--	--	86	76	95	76
22	:	--	--	88	76	98	76
23	:	--	--	84	72	92	72
24	:	--	--	83	68	92	68
25	:	--	--	83	70	94	70
26	:	--	--	85	68	97	68
27	:	76	68	82	76	89	73
28	:	76	68	84	75	92	75
29	:	77	68	85	73	94	73
30	:	75	68	87	68	90	68
Average	:	77	72	84	73	93	72

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
October:						
1	76	66	84	67	96	67
2	76	69	84	69	95	69
3	77	69	86	69	98	69
4	77	69	87	70	100	71
5	78	71	88	71	100	71
6	78	72	87	72	100	72
7	73	72	74	73	74	72
8	72	70	74	71	76	70
9	75	71	82	72	93	72
10	75	72	82	73	91	73
11	74	69	80	69	88	69
12	72	69	74	69	77	69
13	72	66	78	66	85	66
14	73	65	80	65	91	65
15	73	67	80	67	90	67
16	72	67	77	68	85	67
17	75	69	84	69	97	68
18	73	71	77	72	82	72
19	71	64	76	64	83	64
20	71	62	77	62	86	62
21	71	62	77	62	87	62
22	70	63	77	63	86	63
23	70	62	76	62	84	62
24	71	64	78	64	83	63
25	70	66	77	66	83	66
26	69	64	76	64	85	65
27	69	61	76	61	85	61
28	67	63	70	64	74	63
29	67	58	73	59	82	58
30	67	59	74	59	83	59
31	66	59	70	59	76	59
Average	72	66	78	66	87	66

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum

November:

1	:	70	62	75	62	85	62
2	:	67	65	69	65	77	65
3	:	68	62	74	63	82	62
4	:	67	62	73	62	80	62
5	:	65	58	69	58	76	58
6	:	62	55	62	56	67	55
7	:	61	53	62	53	70	53
8	:	60	51	64	51	68	51
9	:	60	51	64	52	71	51
10	:	62	54	69	54	80	54
11	:	62	55	65	55	72	55
12	:	63	56	70	56	78	56
13	:	62	59	64	59	69	59
14	:	62	56	67	56	79	56
15	:	62	54	65	54	72	53
16	:	58	51	60	51	65	50
17	:	58	50	61	50	66	50
18	:	59	52	65	53	71	52
19	:	59	53	64	54	70	53
20	:	58	51	63	52	71	51
21	:	58	53	62	54	69	53
22	:	58	55	58	56	59	54
23	:	61	57	65	57	72	57
24	:	55	53	55	53	55	53
25	:	61	56	67	55	76	55
26	:	61	54	69	64	79	53
27	:	59	58	60	58	62	58
28	:	58	52	61	52	66	52
29	:	57	49	62	49	69	49
30	:	53	52	54	53	53	52
Average	:	61	55	65	57	71	55

TABLE 1.--Maximum and minimum temperatures at three elevations in a tobacco warehouse, 1967 -- Continued

Date	Temperatures (°F.) at --					
	2 feet above		8 feet above		16 feet above	
	floor level		floor level		floor level	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
December:						
1	55	50	57	51	63	50
2	55	48	58	48	65	47
3	57	53	58	54	62	54
4	57	50	62	51	71	50
5	57	48	64	48	73	48
6	57	50	62	50	70	50
7	58	52	63	52	71	52
8	59	55	64	55	71	55
9	58	54	60	54	65	54
10	57	56	57	56	58	56
11	56	54	56	55	57	55
12	59	56	64	56	70	56
13	59	52	65	53	74	52
14	59	51	65	51	74	51
15	59	56	61	55	68	56
16	57	50	60	49	68	49
17	57	48	62	48	71	48
18	57	53	56	53	59	53
19	59	57	61	56	68	57
20	59	57	62	57	66	58
21	60	56	66	57	69	57
22	61	58	69	60	75	59
23	58	49	60	55	59	50
24	54	46	58	48	64	47
25	54	47	58	49	62	48
26	54	49	59	51	65	50
27	54	47	57	48	62	48
28	52	50	52	50	52	50
29	53	48	57	48	62	48
30	53	46	56	46	63	46
31	50	47	50	47	50	47
Average	56	51	59	52	65	52

Figure 5.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during JANUARY.

Figure 6.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during FEBRUARY.

Figure 7.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during MARCH.

Figure 8.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during APRIL.

Figure 9.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during MAY.

Figure 10.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during JUNE.

Figure 11.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during JULY.

Figure 12.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during AUGUST.

Figure 13.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during SEPTEMBER.

Figure 14.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during OCTOBER.

Figure 15.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during NOVEMBER.

Figure 16.--Temperatures of tobacco prized in hogsheads racked 4 high in a warehouse during DECEMBER.

The relative humidity inside the warehouse was nearly identical at all three monitoring stations. The relative humidity range inside the warehouse throughout the year was consistently between 40 and 60 percent (figs. 17-20). The daily average outside relative humidity fluctuated widely; whereas, the warehouse relative humidity remained more stable. The average outside relative humidity generally was over 60 percent, but humidity was rarely this high inside the warehouse.

Moisture in flue-cured tobacco increases during the first 2 or 3 years in storage if moisture is between 10 and 11 percent when tobacco is prized. According to Dixon, Darkis, Wolf, and others^{8/} the peak moisture gain coincides with the peak development of natural aroma. Data from our study show that during the first year of storage, the tobacco moisture in the hogsheads at the depths monitored increased from 0.6 to 2.9 percent (table 2). During the year, tobacco in each hogshead gained moisture. Moisture content increased gradually and in a consistent pattern. Throughout the year, the hogshead second from the top was lowest in moisture content. The hogshead third from the top was consistently the highest in moisture content. However, if the moisture gain for hogsheads in each of the four heights is averaged, the units with the highest moisture gain are the hogsheads second from the top and on the bottom. The hogsheads with the least gain are those that had the highest moisture level soon after being stacked. The greatest moisture gain of any point monitored was at a depth of 12 inches in the bottom hogshead.

^{8/} See footnote 2.

Figure 17.--Percent relative humidity in the air space of a tobacco warehouse and the daily average, outside humidity during JANUARY, FEBRUARY, and MARCH.

Figure 18.--Percent relative humidity in the air space of a tobacco warehouse and the daily average, outside humidity during APRIL, MAY, and JUNE.

Figure 19. --Percent relative humidity in the air space of a tobacco warehouse and the daily average, outside humidity during JULY, AUGUST, and SEPTEMBER.

Figure 20.--Percent relative humidity in the air space of a tobacco warehouse and the daily average, outside humidity during OCTOBER, NOVEMBER, and DECEMBER.

TABLE 2.--Percentage of moisture, wet basis, of grade B4F, 1966-crop flue-cured tobacco packed in hogsheads and stored in Wilson, N. C.

		Percentage of moisture (wet basis) from --							
Date of registry			Second		Third				
	Top		hogshead		hogshead		Bottom		
	hogshead		from top		from top		hogshead		
	4 in.	12 in.	4 in.	12 in.	4 in.	12 in.	4 in.	12 in.	
		deep	deep	deep	deep	deep	deep	deep	
January	4	10.4	--	9.4	--	12.3	--	12.1	--
	11	10.4	--	9.4	--	12.3	--	12.1	--
	18	10.4	10.8	9.8	10.0	12.3	11.2	12.3	9.8
	25	11.0	11.7	10.0	10.8	12.5	12.3	11.7	10.8
:									
February . . .	1	11.2	11.9	10.0	11.0	12.5	12.3	11.7	10.8
	8	11.5	11.9	10.2	11.2	13.7	12.3	11.9	11.0
	15	11.5	11.9	10.4	11.2	12.7	12.5	11.9	10.8
	22	11.2	11.7	10.2	10.4	12.3	11.9	12.5	11.0
:									
March	1	11.2	11.9	10.2	10.6	12.5	12.1	12.5	11.0
	8	11.2	11.5	10.2	10.4	12.3	11.9	12.5	11.0
	15	11.2	11.7	10.0	10.4	12.3	11.9	12.5	10.8
	22	11.2	11.0	10.4	10.8	12.3	12.1	12.3	11.5
	29	11.2	11.0	10.4	10.6	12.3	12.1	12.3	11.5
:									
April	5	11.5	11.0	10.4	10.6	12.3	12.1	12.3	11.5
	12	11.5	11.0	10.4	10.8	12.3	12.1	12.3	11.5
	19	11.5	11.2	10.6	10.8	12.3	12.1	12.5	11.7
	26	11.9	11.7	10.8	11.0	12.5	12.3	12.5	11.9
:									
May	3	11.7	11.5	10.8	11.0	12.5	12.5	12.5	12.1
	10	11.9	11.7	10.8	11.2	12.5	12.5	12.5	12.1
	17	10.8	11.2	10.6	10.8	12.5	12.1	11.9	11.0
	24	11.2	11.9	10.8	11.2	12.7	12.5	12.3	11.5
	31	11.5	11.9	10.6	11.0	12.5	12.3	12.3	11.5
:									
June	7	11.2	11.9	10.8	11.0	12.7	12.5	12.1	11.5
	14	11.5	11.7	10.6	11.0	12.3	12.1	12.1	11.7
	21	11.7	11.9	10.8	11.2	12.5	12.3	12.3	11.9
	28	11.5	12.3	11.0	11.7	12.5	12.7	12.3	12.1
:									
July	5	11.9	12.3	11.2	11.7	12.5	12.7	12.3	12.1
	12	11.7	12.3	10.8	11.9	12.5	12.7	12.3	12.1
	19	11.7	12.5	11.0	11.9	12.7	12.9	12.5	12.3
	26	11.7	12.5	11.2	11.9	12.7	12.9	12.5	12.3

TABLE 2.--Percentage of moisture, wet basis, of grade B4F, 1966-crop flue-cured tobacco packed in hogsheads and stored in Wilson, N. C. -- Continued

		Percentage of moisture (wet basis) from --								
Date of registry	:	Top		Second		Third		Bottom		
	:	hogshead		hogshead		hogshead		hogshead		
	:	from top		from top		from top		from top		
	:	4 in.	12 in.	4 in.	12 in.	4 in.	12 in.	4 in.	12 in.	
		deep	deep	deep	deep	deep	deep	deep	deep	
<hr/>										
August	2	: 12.1	12.9	11.5	12.1	12.9	12.9	12.7	12.3	
	9	: 12.3	12.7	11.5	11.9	12.7	12.7	12.7	11.9	
	16	: 12.3	12.7	11.5	11.9	12.9	13.1	12.7	12.1	
	23	: 12.3	12.9	11.7	12.1	13.1	13.1	12.9	12.3	
	30	: 12.3	12.9	11.9	12.1	13.1	13.3	12.9	12.1	
	:									
September . .	7	: 12.1	12.7	11.5	12.3	12.9	13.3	12.7	11.9	
	13	: 12.3	12.9	11.7	12.3	13.1	13.3	12.9	12.1	
	20	: 12.3	12.9	11.9	12.3	13.3	13.5	12.9	12.1	
	27	: 12.3	12.9	11.9	12.3	13.3	13.7	12.9	12.1	
	:									
October	4	: 12.3	12.9	11.7	12.3	12.9	13.5	12.7	12.3	
	11	: 12.5	12.9	11.9	12.5	13.1	13.5	12.7	12.3	
	18	: 12.5	13.1	11.9	12.5	13.1	13.5	12.7	12.3	
	25	: 12.5	13.1	11.9	12.7	13.1	13.5	12.7	12.3	
	:									
November . .	1	: 11.9	12.7	11.5	11.9	12.9	13.3	12.9	12.3	
	8	: 12.3	12.9	11.7	12.3	13.1	13.9	12.9	12.3	
	15	: 12.5	12.9	11.7	12.3	13.1	13.9	13.1	12.3	
	22	: 12.5	12.9	11.7	12.3	13.1	13.7	13.1	12.3	
	29	: 11.9	12.7	11.5	11.9	13.1	13.7	13.3	12.7	
	:									
December . .	6	: 12.1	12.7	11.5	11.9	13.3	13.7	13.3	12.7	
	13	: 12.1	12.7	11.5	12.1	13.1	13.5	13.1	12.7	
	20	: 12.1	12.7	11.5	12.1	13.1	13.5	13.1	12.7	
	27	: 12.1	12.9	11.5	12.1	12.9	13.5	13.3	12.7	
	:									
Moisture gain for year	:	1.7	2.1	2.1	2.1	0.6	2.3	1.2	2.9	
	:									
Average gain of both depths	:	1.9		2.1		1.4		2.0		
	:									

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