COOLING TOBACCO STORAGES DURING THE WINTER SEASON FOR CONTROL OF THE CIGARETTE BEETLE

by
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At the Second International Conference on Stored-Product Entomology, we discussed procedures used to determine the thermal conductivity and specific heat of cured flue-cured tobacco leaf. Further, we outlined how these properties and physical properties of a sheet-metal tobacco storage were used to build a computer model to predict throughout the year temperature of tobacco packed in hogsheads and stored in the warehouse. Specifics of this research are given in Part I (1) of a three-part report series.

By modeling, we were able to predict the cooling requirements of a 5500-hogshead capacity storage located in North Carolina at latitude of 34°41'. Then we examined cooling systems for their applicability to chill tobacco during the winter season to 4°C or less over a period of 56 days. We found wind energy at the warehouse location insufficient to power adequately any type of cooling system. Solar cells for direct conversion of sunlight to electricity to drive vapor-compression refrigeration equipment are currently too expensive. Rankine engines driven by solar energy have poor conversion efficiency and cannot compete with electrical powered compression refrigeration equipment during the winter season. It became apparent that if solar energy was used to drive a cooling system, the collectors must operate throughout the year with the energy stored in a hot reservoir or converted into ice for storage. Because the storage to ground temperature differential is less with ice than with the hot fluid (90°C), cold storage is more efficient.

Solar-driven aqua-ammonia absorption refrigeration system: The proposed system, as illustrated in Figure 1, appeared to be technically feasible for cooling tobacco storages during the winter season for control of the cigarette beetle, *Lasioderma serricorne* (F.). By modeling we determined that 173 m^2 of double-glazed, selective surface, flat-plate solar collector area would be needed to produce enough ice annually to cool the 19,480-m^3 tobacco storage to 4°C for a period of 56 days. Solar-heated fluid in the storage tank is circulated through the generator of an aqua-ammonia absorption refrigerator, and under high pressure the gaseous fluid is condensed by means of a water cooling tower. Liquid ammonia passes through an expansion valve and changes into a gaseous state in the evaporator and then returns to the absorber where it is chilled and mixed with water before its return to the generator.

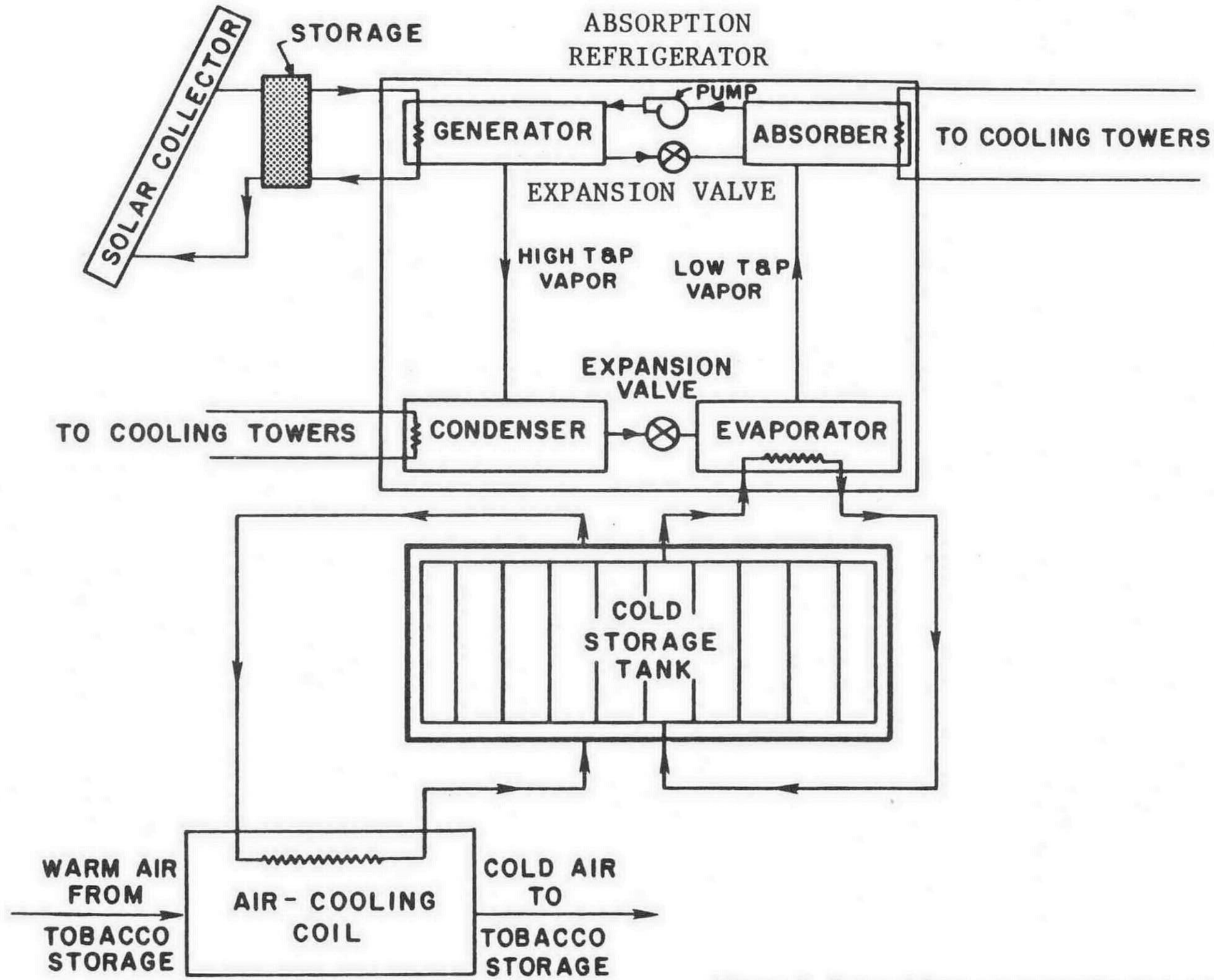

Figure 1. Solar-driven aqua-ammonia absorption refrigeration system.

In the evaporator, brine is chilled to a temperature below the freezing point of water. The cold brine is circulated through vertical tubes in a 118,000-liter (31,300 gallon) cold/water storage tank. Annually, by December, tubes in the cold-storage tank are incased by ca. 0.38 m of ice. During January and February when warehouse air at the storage center exceeds 4°C, ice water from the storage tank is circulated through air-cooling coils located below the ceiling of the warehouse. Air cooled by the coils circulates throughout the warehouse to maintain tobacco in the hogsheads at temperatures of less than 4°C. Water from the coil is returned to the bottom of the cold-storage tank where it is again cooled by contact with ice. When outside ambient air is cooler than the inside air of the warehouse (December-March), ventilation is provided if no rain or snow is falling, to allow natural cooling of the tobacco.

Economic evaluation: The solar-driven cooling system was compared with two mechanical refrigeration systems and chemical pesticides for cost of insect control in the test warehouse amortized over a 25-year period. Tax advantages and inflation were computed according to U.S. regulations and the inflation rate occurring between 1979-81. Owner of the storage was assumed to be a profit-making corporation. One mechanical refrigeration system included a 15-ton compressor which operated only when the demand for chilled air occurred, and the other system included a 1-ton compressor that operated continuously to make ice in the underground cold-storage tank. The chemical pesticides were phosphine and dichlorvos and assumed to be applied by a commercial pest control operator. The annualized (25 yr) life-cycle cost for the four systems are:

Solar cooling system	Chiller with ice storage	Conventional chiller	Chemical control
$ 9,155	$ 6,243	$ 6,272	$ 5,226

The solar system was more expensive than the other two chilling systems or chemical pesticides for control of insects in stored tobacco. The two mechanical refrigeration systems were more competitive with chemical pesticides. Greater detail of the solar-powered refrigeration system and its economic feasibility is given in Part II (2) of the three-part report series.

It was apparent that for insect control methods, the capital and operational costs of the solar system and even the conventional chilling systems were less attractive than chemical pesticides to owners of stored commodities.

Controlled ventilation cooling system: Further experience with the computer model indicated greater consideration should be given to active and passive ventilation for cost-effective systems to chill tobacco storages during the winter season. In early winter of 1981, we installed in the burnish gold-colored, uninsulated, sheet-metal warehouse four ventilation fans, additional air-intake louvers ca. 0.5 m above ground level and a fan weatherguard controller. The controller stops fan operation when (a) it is raining or snowing, (b) the outside ambient air temperature is above 4°C, or (c) the tobacco temperature adjacent to a stave of a hogshead centrally located in the storage is equal to or less than the outside air temperature.

The 0.9-m roof vent, propeller fans were rate at 1 hp with an output of 26 m^3 of air/sec and in the 19,480-m^3 warehouse provided for 14 air exchanges/hr. The fans did not operate at all opportune times during February of 1981 because of occasional controller malfunction. Nevertheless, the number of cigarette beetles trapped in five storages surrounding the test warehouse ranged from 14,350 to 167 insects/storage. In the controlled fan-ventilated storage, only 26 insects were caught in the suction-light traps.

The winter of 1982-83 was very mild at the test storage site. The fans operated 550 hr between mid-December and end of March. Temperature at the center of tobacco hogsheads located near midplane of a non-controlled ventilated warehouse (no. 13) and a controlled ventilated warehouse (no. 14) are given in Figure 2. There was a sharp temperature increase during the late December and again during early February. These warm periods decreased efficacy of the controlled ventilation system largely because the storage was not insulated and solar absorptivity of the outside paint was high.

Cigarette beetles were planted inside hogsheads stored in warehouses 13 and 14 in early October of 1982 and were removed from the hogsheads in May of 1983. Generally, more insects were found in the first 6 inches of the hogsheads than at depths of 6-12 inches. The insects did not survive the winter as adults in either storage. In the roof-ventilated storage, there was survival of 448 pupae versus none in the controlled van-ventilated warehouse. Apparently, the larvae did not pupate in storage 14 as neither dead nor living specimens were found, but many of the larvae in warehouse 13 pupated as we found 448 living and 20 dead. There was larval survival in both storages but less in warehouse 14 (71 alive) than in warehouse 13 (713 alive). Or, 8% of the larvae from cultures planted in warehouse 14 were living, whereas in warehouse 13 larval survival was 64%.

Effects of low temperature upon native insects in the two storages are given in Table 2. Increase in the number of cigarette beetles caught at 2-week intervals was greater in warehouse 13 than in 14. To protect the quality of the stored tobacco, warehouse 13 was fumigated. However, more than four thousand insects were caught in storage 14 during September.

Modeling predicted wall and roof insulation of R-4 or higher rating and coating of outside walls with white paint could have held the hogshead centerline temperature near 4°C from mid-January through most of February. Larval survival under these conditions would have been unlikely.

Table 1.--Number of cigarette beetles found in culture that over-wintered, 1982-83, in tobacco stored in a controlled fan ventilated warehouse no. 14 and in warehouse no. 13 ventilated via roof vents.[1]

Live and dead insects inside hogshead	Type of storage ventilation and insect stage					
	Controlled fan			Roof		
	Larval	Pupal	Adult	Larval	Pupal	Adult
Live						
at depth of						
0-6 inches	56	0	0	405	309	0
6-12 inches	15	0	0	308	139	0
Total	71	0	0	713	448	0
Dead						
at depth of						
0-6 inches	440	0	33	195	5	23
6-12 inches	375	0	6	202	15	12
Total	815	0	39[2]	397	20	35[2]

1/ Insects from wheat flour cultures exposed inside hogsheads in screened cages.

2/ Adults may have been in media prior to hogshead exposure.

Table 2.--Number of cigarette beetles trapped during the summer of 1983 in the controlled fan, no. 14, and roof, no. 13, ventilated warehouses.

Date of insect count		Number of insects caught by suction-light traps	
		no. 14	no. 13
May-June	17	0	0
June	24	1	4
July	8	4	5
	22	0	9
August	5	64	56
	19	27	320
September	2	41	3840
	16	2560	fumigated
	30	1696	0

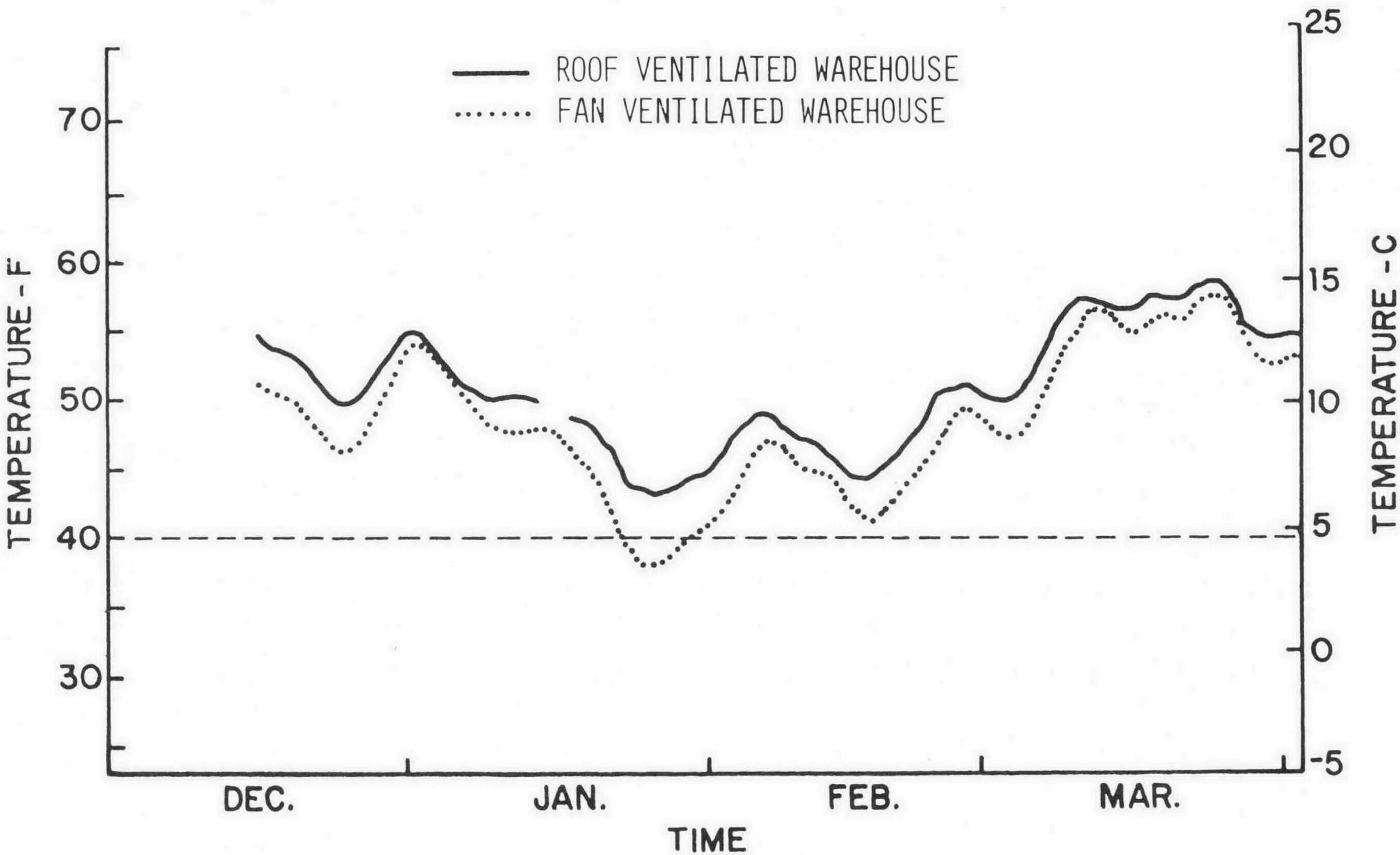

Figure 2. Observed centerline temperature of hogshead in roof-ventilated storage 13 and of hogshead in fan-ventilated storage 14.

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(2) Beard, J. T., F. A. Iachetta, D. P. Childs, and L. W. Fletcher. 1983. Cooling tobacco in warehouses during the winter to kill cigarette beetles. Part II: Model analysis of solar-driven refrigeration. Tob. Sci. (In press)

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