MAGNESIUM PHOSPHIDE AS A FUMIGANT FOR CONTROL OF THE CIGARETTE BEETLE, *LASIODERMA SERRICORNE* (F.) AT LOW TEMPERATURE

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Introduction

Tobacco, whether stored, transported or processed, must be protected from economic damage and loss of product caused by the cigarette beetle, *Lasioderma serricorne* (F.) and tobacco moth, *Ephestia elutella* (Hübner). The presence of these insects during any stage of storage or processing is critical, with their consequences being unacceptable if allowed to migrate into marketing channels. Fumigants are one of the chemical means employed to arrest their spread in the most prevalent potentially damaging status, in storage.

For the tobacco industry several fumigants have been evaluated. These include: hydrocyanic acid[1,2,3]; methyl bromide[4]; hydrogen phosphide (PH_3)[5,6,7]; Acritet (acrylonitrile and carbon tetrachloride)[8]; and ethylene oxide[9]. However, research discoveries and related problems suggested that several of these materials were undesirable. On the other hand, PH_3 is biologically active and appears to present little long-term human health hazards, becoming a prime candidate for protecting tobacco and tobacco products.

Phosphine, when generated from aluminum phosphide, is not recommended for use during low temperatures due to the long exposure period required (i.e., at least 336 hours at 4.4°C). As a result, the industry is not likely to recommend its use due to the interference with manufacturing time schedules. Furthermore, since PH_3 produced from aluminum phosphide does not evolve quickly in low temperatures, survival of tolerant species is more likely to occur[10], creating the likelihood for resistance[11]. Tolerance becomes accentuated under these conditions because the beetle is in a quiescent state of development where rates of metabolism and respiration are reduced, in addition to other physiological changes taking place. As a result, the gas acts as a narcotic rather than a lethal agent. Therefore, long exposure improves the opportunity for the gas to terminate the susceptible life stage. A new PH_3 generating composition, magnesium phosphide, evolves gas at a faster rate[12]. Childs and Overby[13] evaluated this composition in a small scale fumitorium at 28°C and 60% RH and found magnesium phosphide does not affect cigarette aroma or taste.

The purpose of the present study was to evaluate magnesium phosphide on a large scale during low temperatures for potential use in warehouses and export freight containers and to monitor the lethal effects of the gas on the various life stages of the cigarette beetle. In addition, the present study attempted to establish the extent to which overwintering of the cigarette beetle provided protection against fumigation with PH_3.

Materials and Methods

Insects

Non-overwintering forms

Lasioderma serricorne were reared in 0.47 litre culture jars containing 40g of medium, which consisted of milled bright leaf tobacco. The beetles were maintained on a 12:12 LD photoperiod regime at 27±2°C and 70±5% RH.

Overwintering forms

Cultures were prepared in the laboratory (as above), however, the jars were placed in an unheated tobacco warehouse in late October to induce overwintering of the 4th instar larvae by exogenous environmental cues. The cultures were checked 6 weeks later to assure the induction of the overwintering stage[14].

Gas Exposure

Effects of PH_3 on L. serricorne were determined by mortality of eggs, larvae, pupae, and adults. Insects were "planted" in the hogsheads by means of stainless steel test spikes[15]. Cages were placed at 5 cm intervals in the test spikes, and the depths of exposure were 50-58 cm from the side of the hogshead. Each spike contained 4 cages, 8 mm in diameter and 19 mm in length of 40-mesh wire gauge. Each cage held only one life stage: 10-50 eggs, larvae, pupae, adults or 4th instar overwintering larvae.

Product

Phosphine is a colorless, toxic gas of about the same density as air. It has an odor like carbide or garlic, a molecular weight of 34.0, a specific gravity as a liquid of 1.336, a freezing point of -133.5°C and a boiling point of -87.7°C[16].

Phosphine was generated from a Fumi-Cel® plate or Fumi-Strip® (Degesch, GMBH, Frankfurt, W. Germany†) containing magnesium phosphide based formulations. The metal phosphide is impregnated in a plastic matrix which is covered by a fibrous moisture permeable paper. The fibers extend into the matrix allowing for atmospheric moisture to react with the phosphide thereby controlling the rate of release. Standard plate size is 280 x 175 x 4 mm, and is reported to release 33g of PH_3. Upon decomposition when exposed to atmospheric moisture, the residues from the spent fumigant are retained within the matrix and are composed mainly

† American Supplier: Degesch America Inc., Weyers Cave, VA 24486.

of phosphate and hypophosphite.

Fumigations

Polyethylene Tarpaulin

Sixteen hogsheads (two rows of eight) containing bright tobacco strips were fumigated under tarpaulin in an unheated warehouse in the study. The day prior to fumigation, alternate hogsheads were "planted" with test spikes containing non-overwintering cigarette beetle forms (eggs, larvae, pupae and adults), while the eight remaining hogsheads were "planted" with the overwintering 4th instar larvae. The hogsheads were then covered with a 4 mil polyethylene sheet which extended out from the side of the floor ca. 1 m giving a total fumigation volume of 38.5 m^3. The polyethylene was secured to the cement floor by a 5 cm strip of Nashua® tape (Nashua, NH) and then covered with 5 cm layer of sand. A single Fumi-Cel® (33g PH_3/28.3 m^3) placed at one end under the tarpaulin was used to give a commercial dosage of 20g PH_3/28.3 m^3.

Phosphine concentrations were determined in samples drawn from the tobacco through 5mm o.d. stainless steel tubing inserted at a depth of 60 cm within the 1.2 m diameter x 1.2 m high tobacco hogshead. Concentrations were monitored from 4 or 6 locations depending upon replicate (Fig. 1). Air space gas concentrations were monitored by polyethylene tubing, 6 mm o.d., located near the phosphide plate and at the opposite end of the hogshead stacks. All lines were purged with ca. 500 mls air, using a vacuum pump, before each gas sample was drawn. Gas samples were taken at 5, 24, 28, 48, 52, 72, 76, and 93 hour intervals from the beginning of the fumigation. Phosphine concentrations were determined by colorimetric changes in Dräger® detector tubes (Drägerwerk AG Lubeck, FRG).

Four hogsheads that were not exposed to the fumigant served as controls. Test spikes containing both non-overwintering and overwintering insect forms were inserted into the control hogsheads. Insect mortality was determined immediately after the 96-hour fumigation period for adults and larvae. A 10-day post-fumigation period was used to determine mortality for egg hatch and pupal emergence.

Warehouse temperature and relative humidity were recorded continuously using a 7-day hygrothermograph positioned on top of the tarpaulin 1.2 m above the floor. A total of three replicates were performed under tarpaulin to evaluate various temperature/ relative humidity regimes. Tobacco temperature was recorded twice daily during the entire fumigation. This was accomplished by inserting a stainless steel temperature monitor unit into a hogshead prior to fumigation.

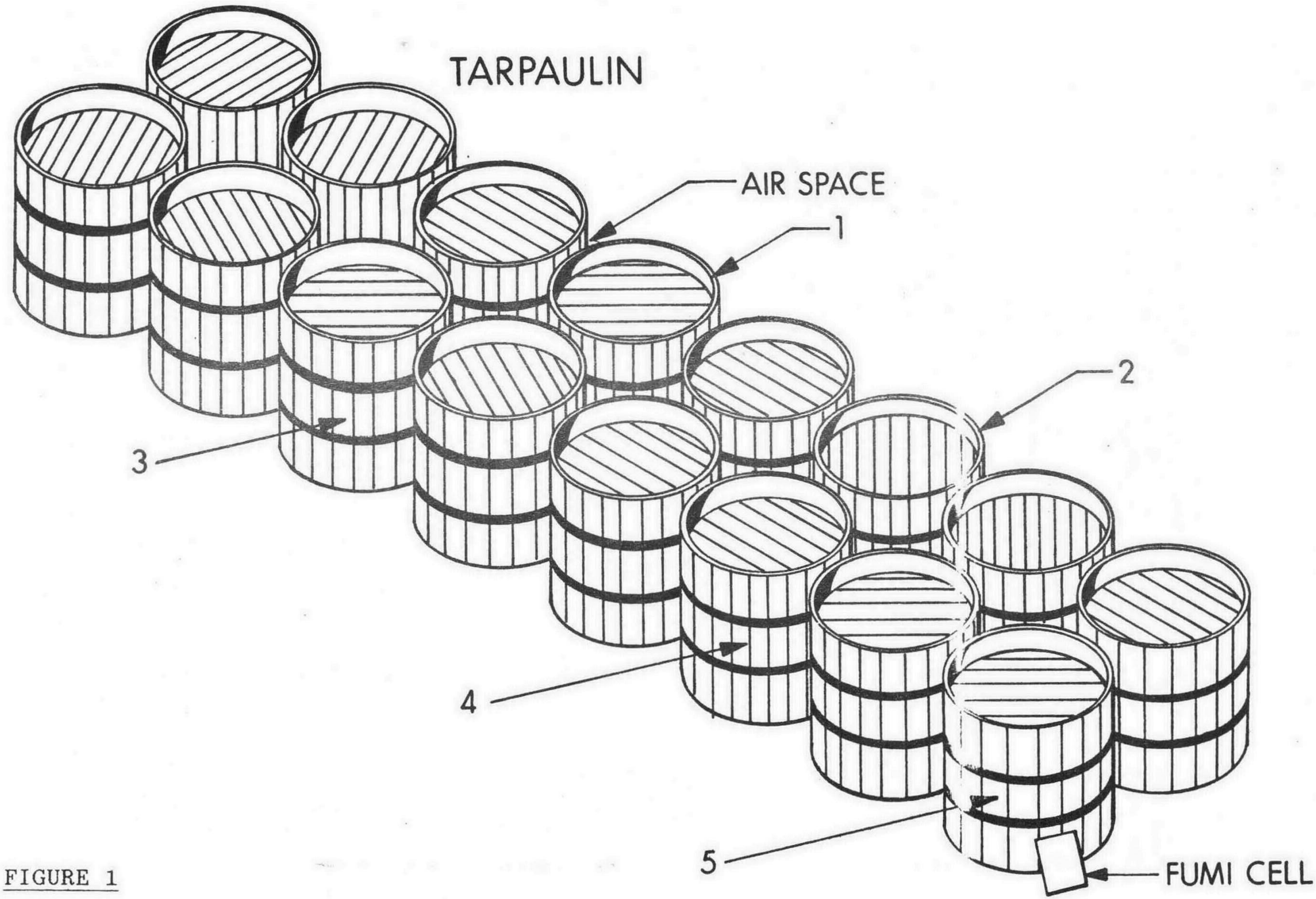

FIGURE 1

Phosphine monitoring points (numbers) for tarpaulin fumigations

Freight Container

The exterior of the freight container was 2.7 m wide x 2.6 m high x 12.2 m long having a volume of ca. 85.6 m^3. The interior was fabricated with a wooden floor and aluminum sheets supported with girders for side-wall and top. The only entrance was through paired doors at one end of the unit. Rubber flexible gaskets were fastened to the perimeter of each door and a locking system securely closed the door against the frame of the container. Prior to introduction of the tobacco, the container was 'smoke tested' using a kerosene aerosol generated from a Dynafog® apparatus (Westfield, IN). Leaks were sealed with tape or caulk depending upon location.

The container was then loaded with 34 hogsheads containing bright and burley strip tobacco and 8 corrugated cardboard cases containing tobacco strips. The case outside dimensions were 71 x 77 x 122 cm (199 kg/case). The hogsheads, when loaded, were staggered since they would not fit side-by-side. This created some open space throughout the container. The day prior to the fumigation, 6 hogsheads and 2 cases were "planted" with test spikes containing non-overwintering cigarette beetle forms (Fig. 2). Three Fumi-Cels® were used to give a dosage of 33g PH_3/28.3 m^3.

Gas concentrations were monitored from three sections within the container (Fig. 2). An air space concentration was taken from the front section (opposite the doors). The gas was drawn through 6 mm Tygon® tubing. Also, a stainless steel probe was inserted at the front section into a hogshead to monitor commodity gas concentrations from the opposite end of the plate placement. A third monitoring point was taken from the commodity near the doors. All lines were purged with approximately 500 mls air prior to taking gas samples. Samples were removed at 18, 21, 42, 48, 69, 72 and 96 hour intervals. Insect mortality was determined in the same manner as in the tarpaulin study.

Warehouse

The experiment was conducted at one of the Richmond, Va. Alleghany Warehouse Storage complex 11,326.7 m^3 warehouses. The facility has concrete floor, composition roof, and sheet metal siding. Hogsheads of bright and burley tobacco strip were stacked 4 tiers high filling the house to 2/3 capacity. Prior to the fumigation, the warehouse was taped and sealed (Automatic Spray Systems, Richmond, Va.).

For the fumigation, 7 Fumi-Strips® (32 plates/strip) and 18 Fumi-Cels® were used to give a commercial dosage of 20g PH_3/28.3 m^3. It took five workers approximately 2-5 minutes to distribute the strips in the center aisle of the warehouse.

After the fumigation, the plates and strips containing the residues from the spent fumigant were disposed of (in a certified sanitary landfil) under safety protocol procedures.

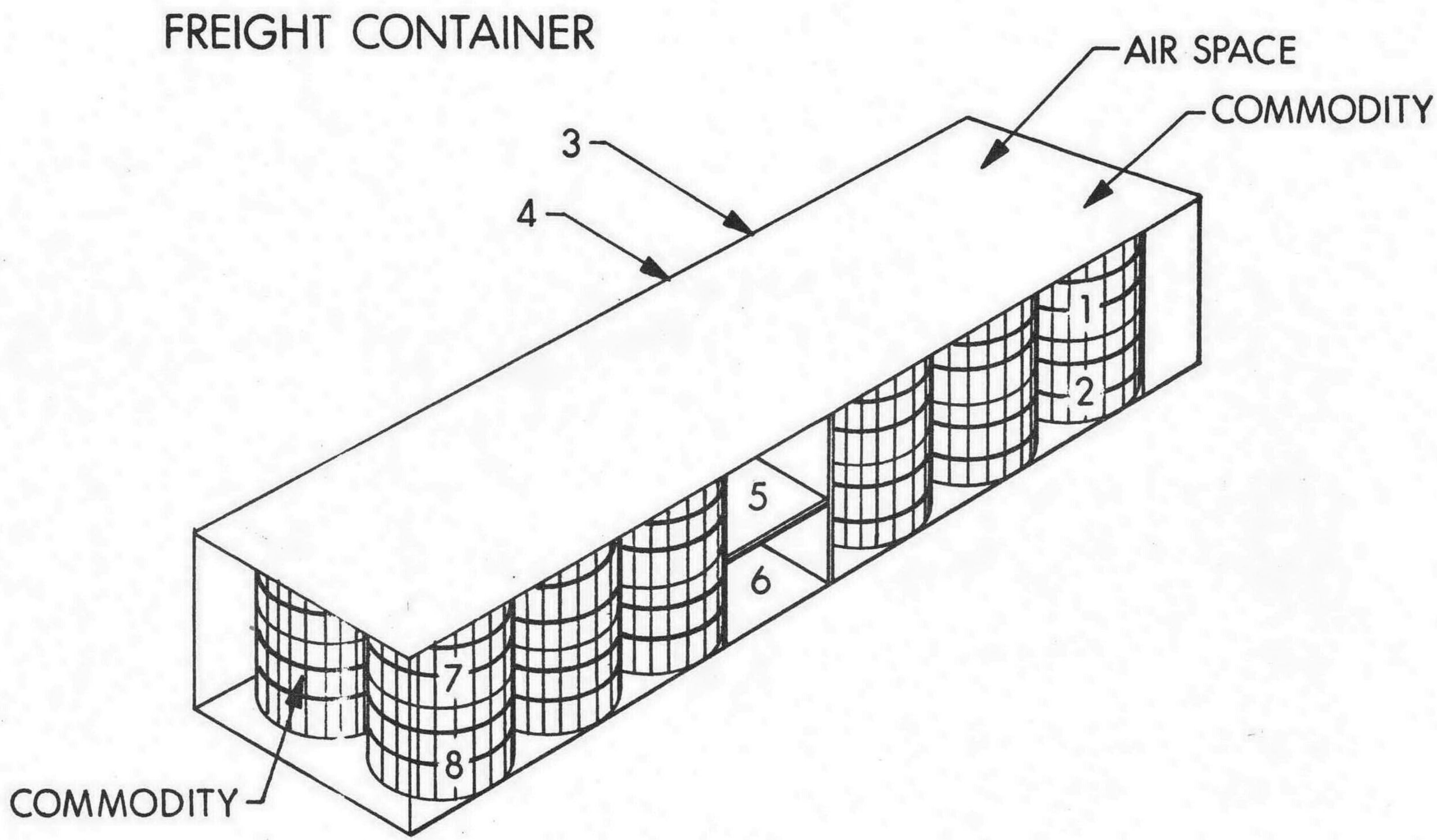

FIGURE 2

Phosphine monitoring points for the freight container fumigation and the position of the insect containing spikes (numbers)

Commodity gas concentrations were monitored at intervals during the 96-hour fumigation by using 6 mm o.d. polyethylene tubing placed within hogsheads positioned at the four corners of the warehouse (Fig. 3). Gas samples were taken at 8, 24, 48, 72, and 96 hours after the beginning of the fumigation. Commodity gas samples were taken for 48 hours post-fumigation. The PH_3 concentrations were taken at 64 cm depth within the center of the hogshead. The 4 hogsheads sampled were on the bottom of the four-tiered stacks.

The effects of PH_3 were determined by planting test spikes containing non-overwintering cigarette beetle forms and overwintering 4th instar larvae. One test spike was inserted into hogsheads at 12 locations within the warehouse (Fig. 3). Spikes were planted in bottom, as well as top tiered hogsheads. Control test spikes were handled in a similar manner, however, they were planted in hogsheads within a non-fumigated warehouse at the same complex. Larvae and adult mortality was determined immediately following the 96-hour fumigation. A 10-day post-fumigation period was used to determine mortality for egg and pupal forms.

A hygrothermograph was used to continuously monitor warehouse temperature and relative humidity during the fumigation.

RESULTS

Tarpaulin

The average ambient temperature in the first replicate was 4.2°C (L 0;H 7.8°C) (Table 1). The average relative humidity was 47.3±11.8%. All temperature averages shown in tables are based upon 33 monitoring points taken from the hygrothermograph.

In previous studies the critical level of 200 ppm of PH_3 was found to be the lethal concentration for cigarette beetle control in tobacco hogsheads. Concentrations increased rapidly for the duration of the experiment. The maximum air space gas concentration recorded was 600 ppm at 93 hours (Table 1).

Phosphine penetrated to the center of all the hogsheads monitored. Approximately 30 hours were required to reach the critical level. The average commodity gas concentration was 497 ppm after 93 hours (Figure 4). The mean tobacco temperature recorded during the first replicate was 5.9°C (L 6.6; H 5.3°C). In general, little variation in gas concentration existed between monitoring points.

In the second replicate the average ambient temperature was 9.4°C (L 5; H 14.4°C), and the average relative humidity was 52.0±14.7%. Rain was the predominant weather condition during the initial 30 hours of this experiment.

The critical level of PH_3 was reached in the air space after ca. 12 hours (Figure 5), after which time the gas levels reached

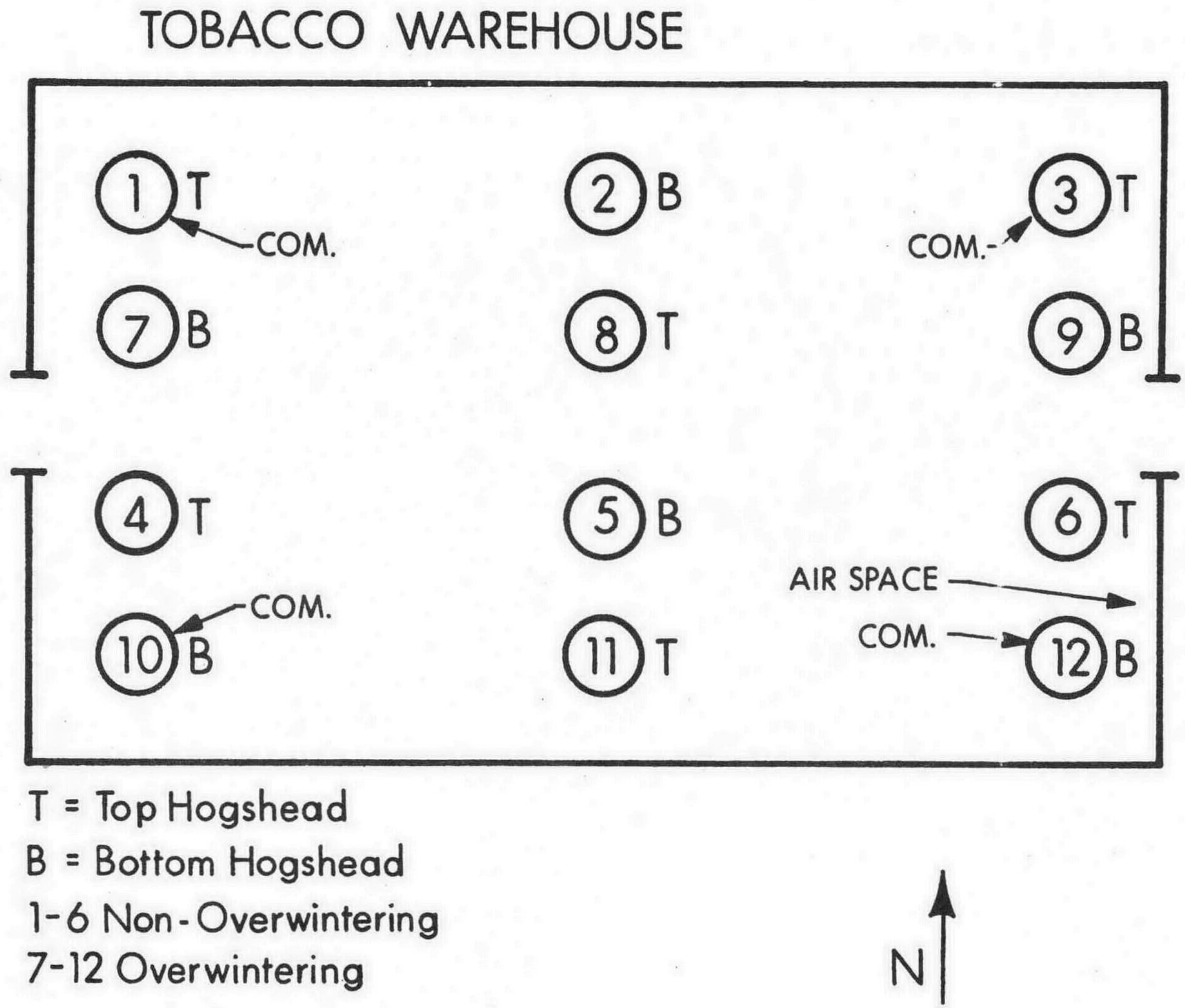

Figure 3.

Phosphine monitoring points from the commodity (com.) and air space within a tobacco warehouse and the location of insect containing spikes in the top (T) and bottom (B) hogsheads. Both non-overwintering (1-6) and overwintering (7-12) forms were tested

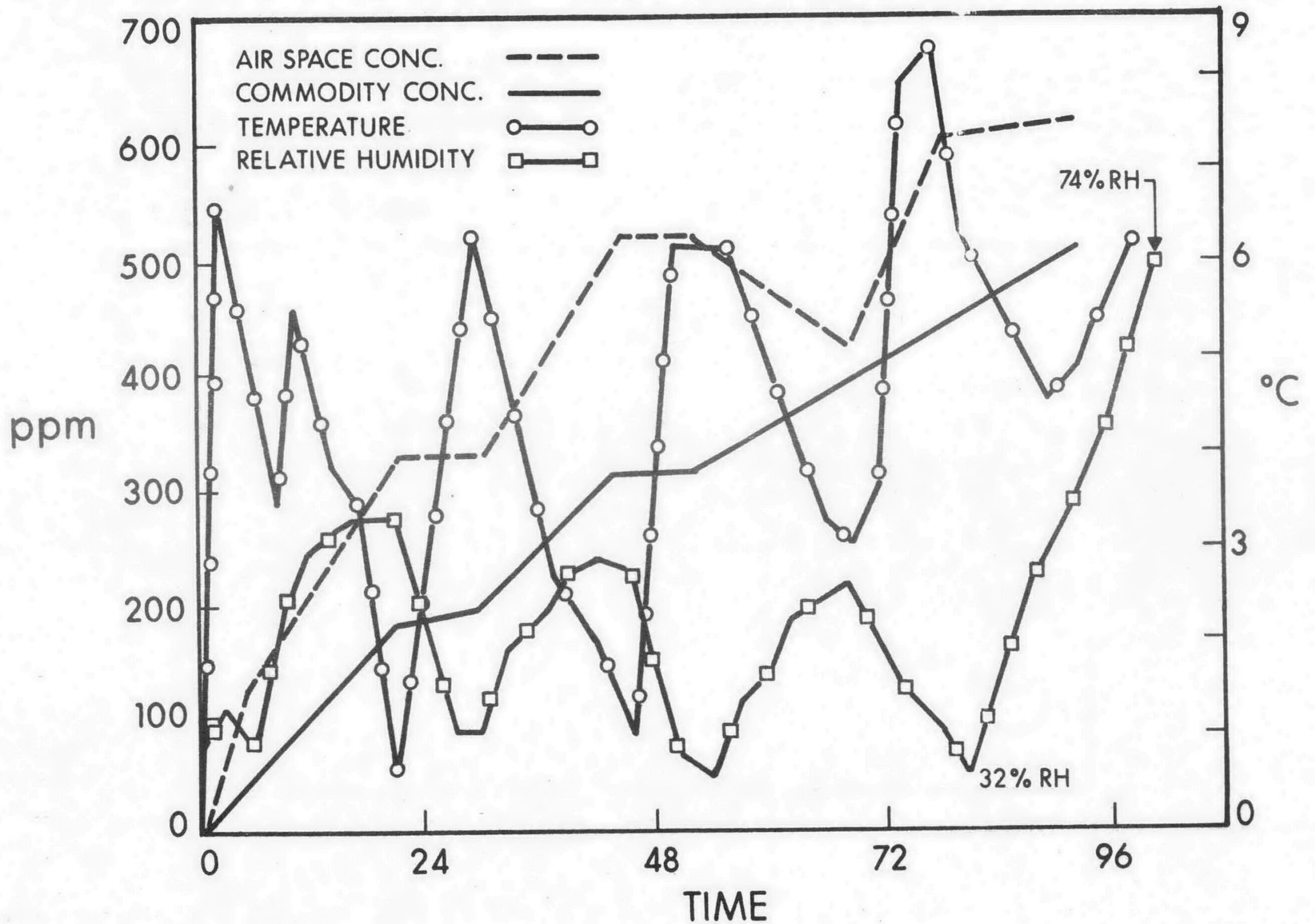

FIGURE 4

Phosphine concentrations (ppm) in the air space and hogsheads under tarpaulin fumigated at 4.2°C - replicate 1

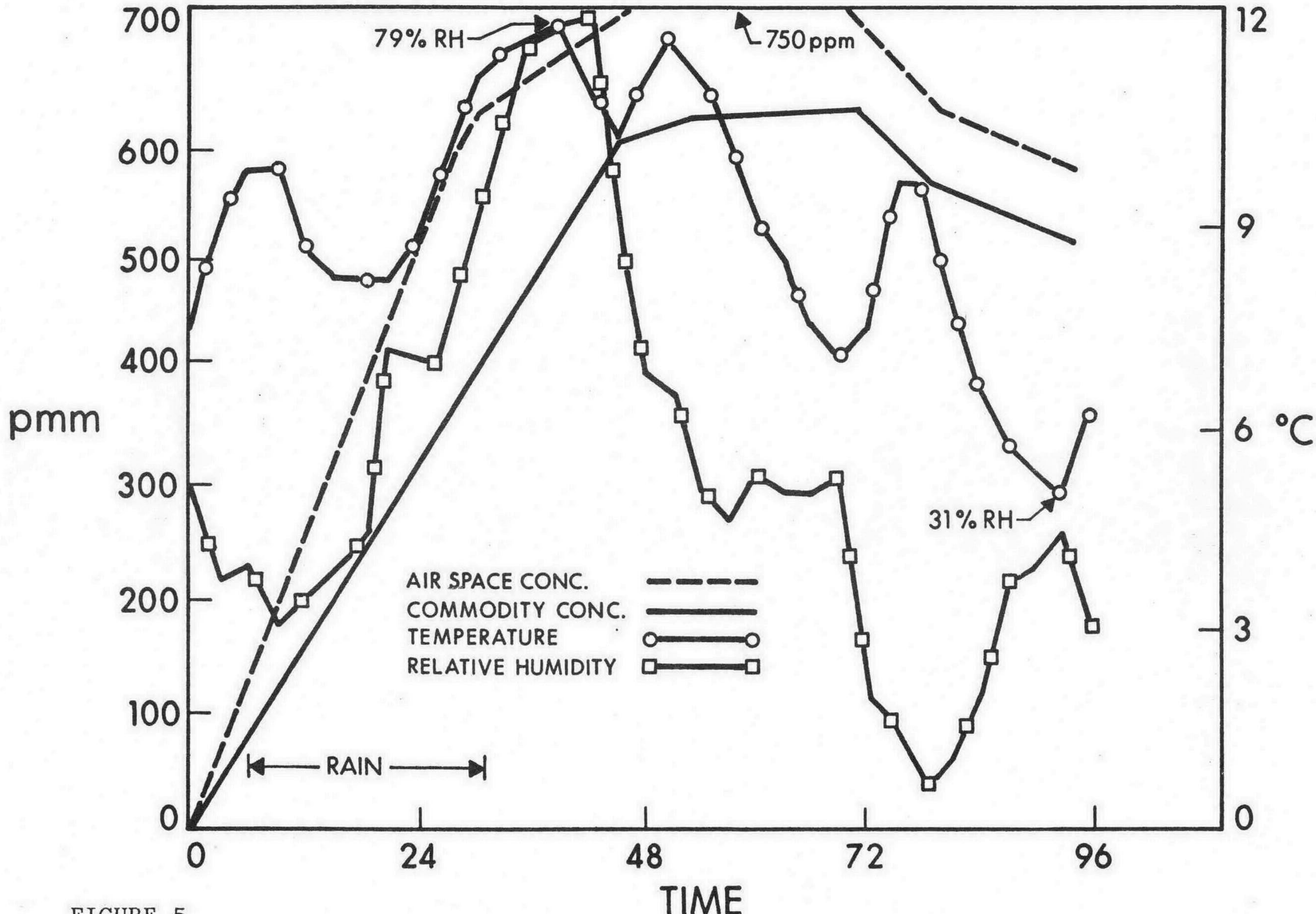

FIGURE 5

Phosphine concentrations (ppm) in the air space and hogsheads under tarpaulin fumigated at 9.4°C - replicate 2

Table 1 - Phosphine concentrations (ppm) in the air space and hogsheads under tarpaulin fumigated with magnesium phosphide at 20 grams/28.3 m^3 at 4.2°C.

Hours Fumigated	Hogshead (ppm) Middle A†	Middle B	Middle C	Middle D	Corner E	Air Space F	Temp. °C
5	-	-	-	-	-	100	6.7
24	190	210	75*	100	200	310	0
29	200	200	100	125	210	310	5
48	390	325	150	200	310	500	0.6
53	400	300	125	190	325	500	5.6
72	400	425	150	225	500	400	2.2
78	400	525	200	200	500	575	7.8
93	575	600	225	225	590	600	4.4
Average	365	369	146	180.7	376	456**	4.2°C

* Stainless steel probe plugged with tobacco (could not purge).
**Average based upon readings beginning with 24 hours.
† Letter refers to hogshead.

an average concentration of 750 ppm at 55 hours (Table 2). When the tarpaulin was removed at 94 hours the average gas concentration was 560 ppm.

Again, PH_3 concentrations penetrated to the center of all hogsheads monitored. The critical level was reached after 18 hours (Figure 5). The maximum commodity gas concentration recorded was 616 ppm at 70 hours (Figure 5). There was a slight variation observed in gas concentrations recorded opposite the point where the magnesium phosphide plate was located. However, this variation was slight and equilibrated after 70 hours. The mean tobacco temperature recorded during the second replicate was 6.9°C.

In a related study, gas concentrations were monitored in two polyethylene bags with 13.6 kg of cut filler. This was performed to observe the rate at which PH_3 exits polyethylene bags during post-fumigation. Approximately 54 hours were required to reach the critical level. The maximum average gas concentration within the polyethylene bags was 387 ppm at 94 hours (Table 2). Three weeks of degassing was required to reach the threshold limit value (TLV) of 0.3 ppm (0.4 mg/m^3).††

†† American Conference of Governmental Industrial Hygienists, 1981.

Table 2. Phosphine concentrations (ppm) in the air space, polyethylene bags, and hogsheads under tarpaulin fumigated with magnesium phosphide at 70 grams/ 28.3 m^3 at 9.4°C. - second replicate

Hours Fumigated	Cut-filler		Hogshead (ppm)				Air Space		
	Poly A**	Poly B	Middle C†	Middle D	Middle E	Corner F	G	H	Temp.°C
7	-	-	-	-	-	-	110	150	11.7
22	75	50	300	300	300	350	350	550	9.4
30	90	55	390	390	450	490	500	700	13.3
46	200	110	650	650	600	700	600	800	12.2
55	200	175	650	625	600	725	700	800	13.3
70	325	350	675	690	700	700	690	700	6.7
79	400	350	590	600	600	625	600	650	11.1
94	425	350	525	550	500	500	550	575	5.0
Average	245	205.7	540	543	535	584	570*	682*	9.4°C

* Average based upon readings beginning with 22 hours.
** Letter refers to polyethylene bag filled with cut-filler.
† Letter refers to hogshead.

The average ambient temperature in the third replicate was 14.2°C (L 9.4; H 22.2°C), and the average relative humidity was 48.7±16.3% (Table 3).

An estimated critical level was reached in the air space after 7 hours (Figure 6). This was followed by a sharp increase in concentration to 650 ppm within 28 hours (Table 3). The maximum mean air space concentration detected was 725 ppm (52 hours). The final concentration monitored prior to tarpaulin removal was 537 ppm. Again, variation in gas concentration existed with levels being higher at the monitoring points closest to the magnesium phosphide plate.

PH_3 concentrations reached the minimum critical level after 12 hours in the hogsheads (Figure 6). This was followed by a sharp increase to 695 ppm at 72 hours (Table 3) where a decrease

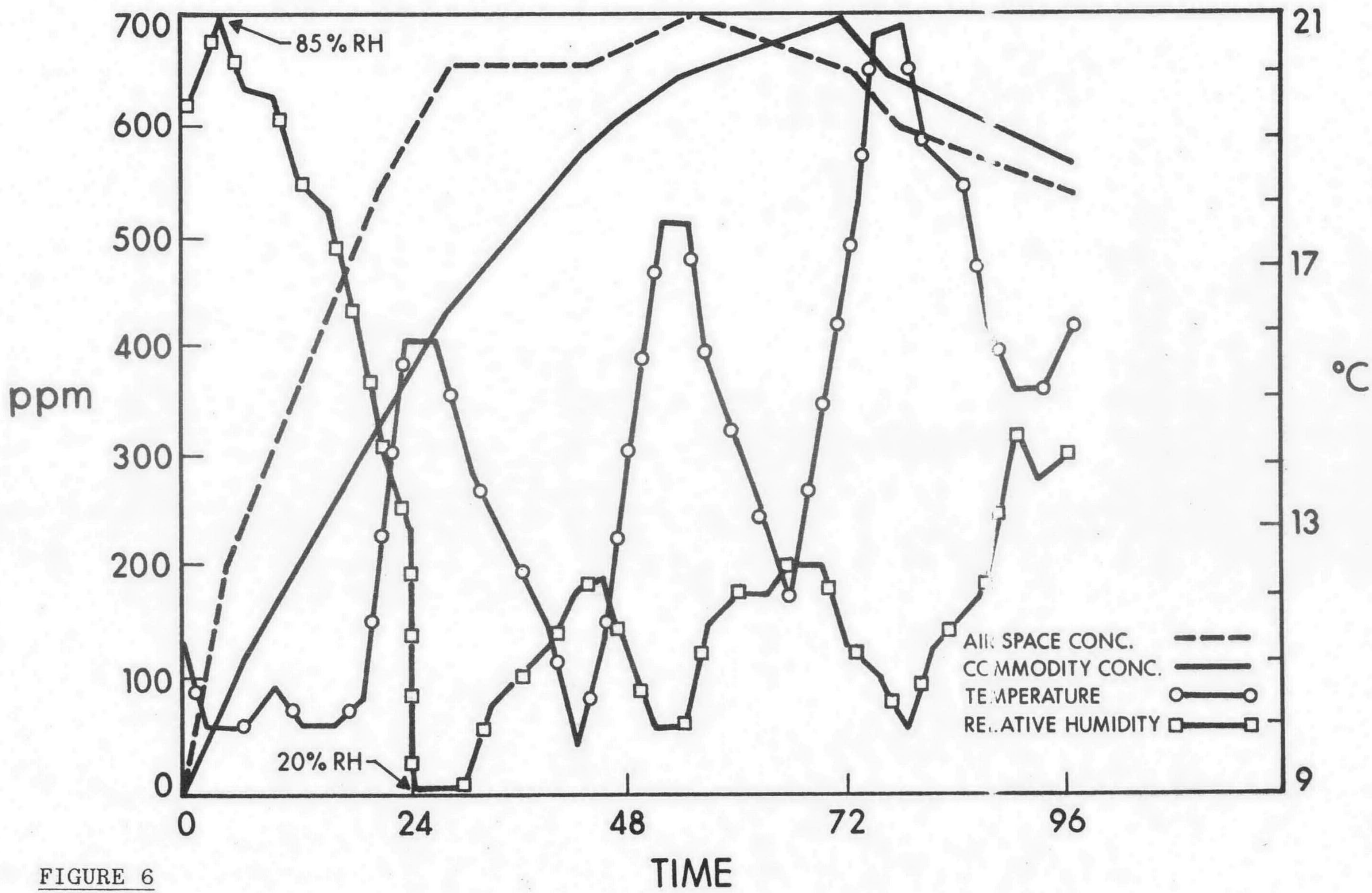

FIGURE 6

Phosphine concentrations (ppm) in the air space and hogsheads under tarpaulin fumigated at 14.2°C - replicate 3

Table 3. Phosphine concentrations (ppm) in the air space and hogsheads under tarpaulin fumigated with magnesium phosphide at 20 grams/28.3 m^3 at 14.2°C. - third replicate

Hours Fumigated	Hogshead (ppm) Middle A	Middle B	Middle C	Corner D	Air Space E	F	Temp. °C.
5	75	125	50	200	300	100	10.5
20	200	300	200	600	800	250	10.8
28	400	425	300	600	800	500	16.7
44	400	600	500	850	800	500	10.5
52	650	650	500	750	800	650	18.3
72	650	700	680	750	600	700	17.2
76	650	650	600	700	600	600	21.7
96	600	625	500	550	575	500	15.5
Average*	507	564	468	685	710	528	14.2

* Average based upon readings beginning with 20 hours.

in concentration was recorded to 569 ppm (96 hours) at tarpaulin removal. Variation of gas concentrations existed within the hogsheads (Table 3). This variation was attributed to hogshead proximity in relation to the phosphide plate. After 48 hours aeration the concentrations were less than the TLV of 0.3 ppm. The mean tobacco temperature recorded during the third replicate was 8.4°C (L 7.3; H 9.5°C).

No insect life stage (eggs, larvae, pupae, adults) survived any of the tarpaulin fumigations. The fumigant (PH_3) also killed the overwintering 4th instar larval form. Mortality in the control non-overwintering forms never exceeded 5%, while the overwintering larvae reached 8%. The overwintering control larvae were returned to the laboratory and allowed to continue through adult emergence.

The average ambient temperature recorded during the 96 hour fumigation period was 7.4°C (L 2.8; H 14.4°C), and the average relative humidity was 50.1±1.3% (Table 4).

Phosphine concentrations were higher in the commodity at the door end of the container for the first 48 hours of fumigation (Table 4). The maximum concentration of 700 ppm occurred in 48 hours. After this period of fumigation, PH_3 concentrations

Freight Container

Table 4. Phosphine concentration (ppm) in the air space of a 12.1 m freight container loaded with tobacco hogsheads and cases fumigated with magnesium phosphide at 33 grams/28.3 m^3 at 7.4°C.

Hours Fumigated	Hogshead (ppm) Rear A	Front B	Air Space C	Temp. °C.
18	390	300	500	2.8
24	425	400	500	5.0
42	550	650	500	14.4
48	700	690	500	11.1
69	500	525	500	5.5
72	490	500	500	6.7
96	380	225	405	6.1
Average*	507	498	484	7.4

* Average based upon readings beginning with 24 hours.

gradually decreased. At the end of the 96 hour fumigation, approximately 400 ppm of PH_3 remained in the air space. The critical level was reached in the air space after 9 hours.

Hogshead centers monitored for PH_3 concentrations showed detectable levels. Approximately 9 hours was required to reach the critical level. The average commodity PH_3 concentration was 502 ppm (Table 4) which persisted through the duration of the test. Little variation in gas concentrations existed between monitoring points. The degassing event required 48 hours for open top hogsheads and 72 hours for sealed hogsheads to reach the TLV of 0.3 ppm.

All insect life stages exposed to PH_3 were dead. None of the insects were moribund, indicating that death probably occurred during the fumigation and prior to aeration. This included insects that had been planted in tobacco cases and hogsheads containing bright and burley leaf tobacco.

Warehouse

The average ambient temperature during the warehouse fumigation was 8.2°C (L 3.3; H 16.1°C), and the average relative humidity was 49.0±6.5% (Table 5). Rain occurred prior to fumigation and intermittent showers fell for the first 24 hours.

Hydrogen phosphine generated from magnesium phosphide strips was uniformly distributed 48 hours after deployment (Table 5). The critical level was recorded after 48 hours (Figure 7). The peak concentration of PH_3 in the air space was 275 ppm (96 hours).

Phosphine penetrated to the center of the four outside corner hogsheads monitored (Table 5). Approximately 72 hours was

Table 5. Phosphine concentrations (ppm) in the air space and hogsheads of a tobacco warehouse located in Richmond, Va. fumigated with magnesium phosphide at 20 grams/ 28.3 m^3 at 8.2°C.

	Hogshead (ppm)					
Hours Fumigated	NE Corner A	SE Corner B	SW Corner C	NW Corner D	Air Space E	Temp. °C.
7	35	25	35	40	75	11.8
25	100	65	150	105	150	7.8
49	210	165	165	185	200	6.7
72	210	190	200	200	235	6.7
96	250	200	200	200	275	10.0
Average*	192.5	155	179	172	215	8.2

* Average based upon readings beginning with 24 hours.

required to reach the critical level of 200 ppm. The average commodity gas concentration was 212 ppm at 96 hours. The mean tobacco temperature recorded during the fumigation was 4.3°C. Concentrations in the hogsheads 4 hours after aeration ranged between 150-180 ppm. Aeration of PH_3 from the commodity required 48-72 hours to reach the TLV of 0.3 ppm.

No insect stage survived the fumigation in any location including the overwintering 4th instar larvae. Mortality of the control non-overwintering forms was 5%, while the overwintering larvae was 21%.

DISCUSSION

This study shows that PH_3 generated from magnesium phosphide plates was effective in killing the cigarette beetle during low temperatures. In a previous study, Childs and Overby[13] evaluated magnesium phosphide plates in a fumitorium and found PH_3 to be emitted rapidly. Furthermore, their study was conducted at 28°C and 60% RH. In past studies conducted by the U.S.D.A. using aluminum phosphide at low temperatures (4.4°C) required 240 hours exposure to achieve 100% cigarette beetle mortality. Childs et.

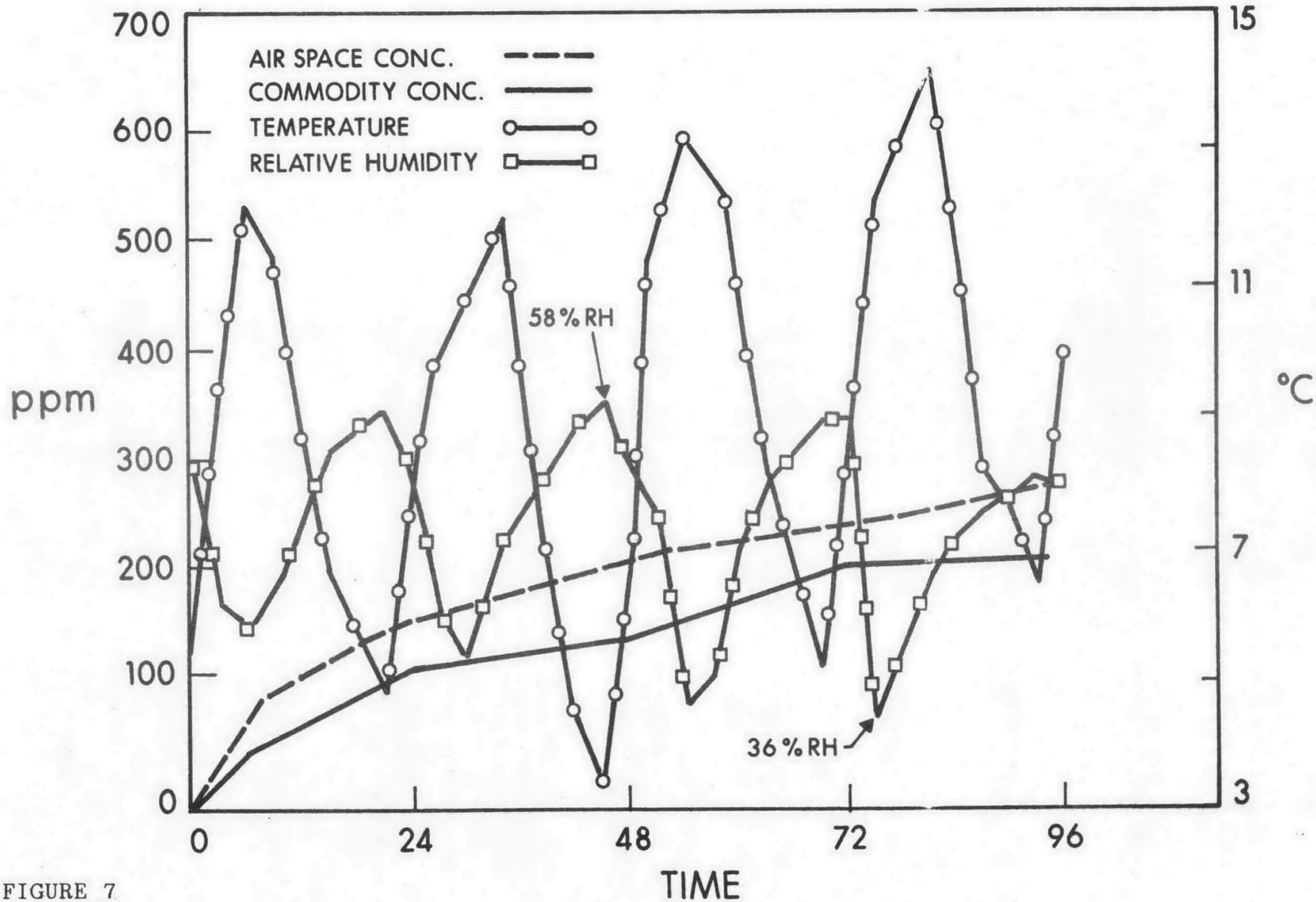

FIGURE 7

Phosphine concentrations (ppm) in the air space and hogsheads of a tobacco warehouse fumigated at 8.2°C al.[17] suggested that fumigation of tobacco with PH_3 be conducted in temperatures above 20°C. In temperatures less than 20°C, they found that a longer exposure period was required to achieve 100% cigarette beetle mortality. Although the aluminum product is suitable for warmer temperatures, it is not recommended for use in low temperatures due to a required long exposure period. On the other hand, as seen in the present report, the magnesium plate allows for a more rapid evolution of gas when used at low temperatures.

Results also indicate that PH_3 produced from magnesium plates can be used to fumigate hogsheads or cases loaded in overseas freight containers. In a comparable study, Childs et. al.[18] suggested that phosphine produced from aluminum phosphide pellets showed a retarded rate of decomposition due to cooler temperatures (6.1°C). These results indicate the magnesium-matrix releases the gas at a faster rate. This is promising and suggests that the U.S.D.A. Plant Quarantine Division should consider that fumigation be recommended for freight containers employing 33g $PH_3/28.3m^3$ for 96 hours. This would allow the industry to export tobacco year round under a phytosanitary certificate lending a faster response time.

The results in the tobacco warehouse are unlike those obtained in previous studies using aluminum phosphide in louvered[6] and closed[5] warehouses in warmer temperatures. The low concentrations obtained in the present study were attributed to some leakage around doors and between sheet metal walls. The latter could be a result of metal contraction due to the cold temperatures. Nonetheless, PH_3 concentrations in the tobacco hogsheads were sufficient to kill all stages of the cigarette beetle.

Of more than passing interest was the mortality effects of PH_3 observed on the overwintering 4th instar larvae. This finding suggests promise for altering the biotic potential of the cigarette beetle. This multi-voltine species undergoes three generations per year in tobacco warehouses in Richmond, Va. Although various races are capable of more generations in tropical regions, voltinism is reduced along the Atlantic Coast due to temperate conditions. By eliminating the overwintering quiescent form during the winter months, those beetles that would have "normally" emerged in May-June would not occur since they would have been eliminated during fumigation. Subsequently, hogsheads, cases, etc., would have to then be contaminated by outside transients to initiate propagation of future generations. Theoretically, only two generations would occur in Richmond tobacco storages. Since most populations grow exponentially, this would suggest that less tobacco would be prone to cigarette beetle damage. Furthermore, continuing along biological lines, the physiological state of overwintering in the cigarette beetle indicates that although metabolism is lowered, spiracular openings may allow for lethal concentrations of PH_3 to penetrate these forms.

Most insect species undergo a daily straightforward circadian rhythm of oxygen consumption. These bursts of oxygen uptake are often coordinated with behavioral activity patterns[19]. However, when the insect overwinters or enters diapause the oxygen consumption rate is decreased considerably as the metabolism becomes lowered. An insect in the state of diapause might not consume O_2 for 2-3 days[20], whereas, an overwintering form would consume O_2 even more frequently. Therefore, the length of exposure to a toxic atmosphere oftentimes has to be increased to assure susceptability[10]. In the present study, it appears that the concentrations used were sufficient to render the quiescent form susceptable.

Childs and Overby[13] reported that PH_3 generated from magnesium phoshide plates did not impart an off-taste or aroma to flue cured or Turkish tobacco. Panel smoking of cigarettes made of tobacco treated with PH_3 generated from magnesium phosphide demonstrated no off-flavor.[13]

Conclusions

Fumigation with magnesium phosphide during low temperatures offers several advantages:

(1) Shorter residence time when compared to aluminum phosphide under the same conditions.

(2) Winter fumigation will ultimately effect development of subsequent beetle generation, yielding less potential leaf damage.

(3) Overwintering larvae, the most prevalent stage during the winter, are affected by the gas.

(4) Philip Morris export tobacco can be fumigated year round without requiring heated buildings.

(5) Fumigations can be staggered, lessening the strain of a large, annual fumigation resulting in less gas being released into the atmosphere.

(6) The results are encouraging for the potential use in combating stored product insects other than those found in tobacco.

(7) Aeration of air space can be completed within 48 hours and the TLV in tobacco can be reached 48-72 hours post-fumigation, if solid plastic liners (with exception to Tyvek®) are not involved.

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