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Agricultural Research Service
Pacific Basin Area
2021 South Peach Avenue
Fresno, CA 93727
Horticultural Crops Research Laboratory
(Protection & Quarantine Research Unit)

December 12, 1984

Project No. 84-W8 - Tree and Crop Research
Modified Atmosphere Field Tests
(Continuation of Project No. 83-Q7)

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Objectives: (1) To conduct a comparative field test of carbon dioxide versus low oxygen atmosphere for insect control in stored almonds and to determine cost effectiveness and time for insect mortality. (2) To analyse the effectiveness, and costs associated with improving the seal on the test fumigation chamber.

Interpretive Summary:

A low-oxygen atmosphere (0.5% O_2) and a carbon dioxide-enriched atmosphere (60% CO_2) were tested in a concrete tilt-up almond storage. The storage had a capacity of 112,500 cubic feet and was filled with inshell Nonpareil almonds. Prior to filling, all interior seams and cracks were sealed and a U-shaped gas distribution manifold was placed on the floor of the storage room.

Low oxygen atmosphere: Using a Gas Atmosphere Inc. exothermic generator, and having a storage inflow rate of 9500 cubic feet per hour, the storage atmosphere's oxygen content was reduced to 0.5 percent oxygen in 18 hours. The inflow was then reduced to 500 cubic feet per hour to maintain the atmosphere. With an average internal temperature in the rooms headspace of 88°F., Indianmeal moth pupae were killed within 6 hours and navel orangeworm pupae within 24 hours after the purge phase was completed.

Carbon Dioxide Atmosphere: Carbon dioxide was supplied from a tank, vaporized with an electric heater and metered into the storage room. At an average flow of 500-600 pounds per hour of CO_2, a storage atmosphere of 83% CO_2 was obtained in 18 hours. After the purge, a recirculation system was used to equalize the CO_2 throughout the room. Additional CO_2 was added as necessary to maintain the CO_2 concentration above 60 percent. The overhead airspace temperature averaged 77°F in this experiment. At this temperature Indianmeal moth pupae were killed within 60 hours and navel orangeworm pupae within 72 hours after the purge phase was completed.

Experimental Procedure:

Navel orangeworm and Indianmeal moth pupae were exposed in the laboratory to modified atmospheres under 70°F, and 40 and 60% relative humidity. Insect pupae were exposed to atmospheres containing 0.5% oxygen, 10% carbon dioxide and 89.5% nitrogen, or to 60% carbon dioxide in air. Test insects were exposed to these atmospheres for various periods of time to determine the time required for their kill.

Field research was conducted to evaluate the suitability of a concrete tilt-up almond storage for use in conjunction with modified atmospheres for insect control. An almond storage room of ca. 112, 500 ft^3 volume was evaluated for its capability of holding fumigants and modified atmospheres. A pressure decay test was used for evaluation of the rooms gas holding capacity. To do this, air pressure was increased within the room with an air blower, and the time required for the pressure to decrease was measured. Further testing using soap bubbles was used to locate air leakage sites. These seal quality tests were conducted before and after the room was filled with approximately 2 million pounds of inshell Nonpareil almonds.

A low oxygen atmosphere, and a high carbon dioxide atmosphere were tested for insect control. The room, as described above, had a U-shaped manifold placed on its floor for release of the atmospheres. Sample lines were placed strategically throughout the storage room to allow atmospheric concentrations to be determined throughout the test. Insect kill times were determined by placing navel orangeworm and Indianmeal moth pupae in containers that were hung in the overhead airspace near the ceiling. These insects were exposed to the modified atmospheres for predetermined time periods.

Low oxygen atmosphere was produced with an exothermic generator of 10,000 ft^3/h capacity. The generated atmosphere consisted of ca. 0.5% oxygen, 13% carbon dioxide and 86% nitrogen. During the initial "purge" phase, the modified atmosphere was introduced into the test room at 9,500 ft^3/h. After the purge was completed, the modified atmosphere inflow was reduced to 1000 ft^3/h for two days then further reduced to 500 ft^3/h until the end of the test. Oxygen content of the atmosphere in the room was determined by use of a paramagnetic oxygen meter.

Carbon dioxide testing was in cooperation with Airco Industrial Gases, who supplied equipment and personnel, and Dr. Edward Jay, an expert in carbon dioxide application for insect control. Carbon dioxide was held in a receiver, piped through an electrical heater, measured and introduced into the storage room. The CO_2 was introduced at 500-600 lb/h during the purge period and then shut off. Three additional applications were made during the next 3 days to maintain ca. 60% CO_2 concentration in the room during the maintenance period. The insect test was as described above for the low oxygen test.

Results:

The time required to kill navel orangeworms and Indianmeal moth with low oxygen (0.5%) or 60% carbon dioxide enriched atmospheres at 70°F were as shown in Table 1. These data are supplemented with other data from last years tests. At these temperatures, control of Indianmeal moth required less exposure time than control of navel orangeworm. Control of both insects required less exposure time with elevated low oxygen than with carbon dioxide atmospheres.

Pressure decay tests showed that the almond storage room was much improved over last year. The results of this testing is given in Figure 1 and shows that the recommended U. S. quarantine seal standard for fumigation chambers was far exceeded. However, our room was less tight than modified atmosphere storages for wheat recommended by the Australians.

The concrete storage room was purged to an atmosphere of 0.5% O_2 within 18 hours (Figure 2). At a purge rate of 1,000 ft^3/h, the room's oxygen content rose slightly. At a temperature of 88°F in the headspace, all insects were killed in one day after the purge was completed. These mortality times agree with times extrapolated from laboratory data (Table 1).

Purging with carbon dioxide at a rate of 500-600 lbs/h required 18 hours to reach an atmosphere with ca. 83% CO_2 (Figure 3) . Additional CO_2 was added 3 times to maintain a 60% minimum concentration. At a temperature of 77°F, all insects were killed within 3¼ days after purging was complete. This data also agrees with estimates calculated from data obtained in the laboratory (Table 1).

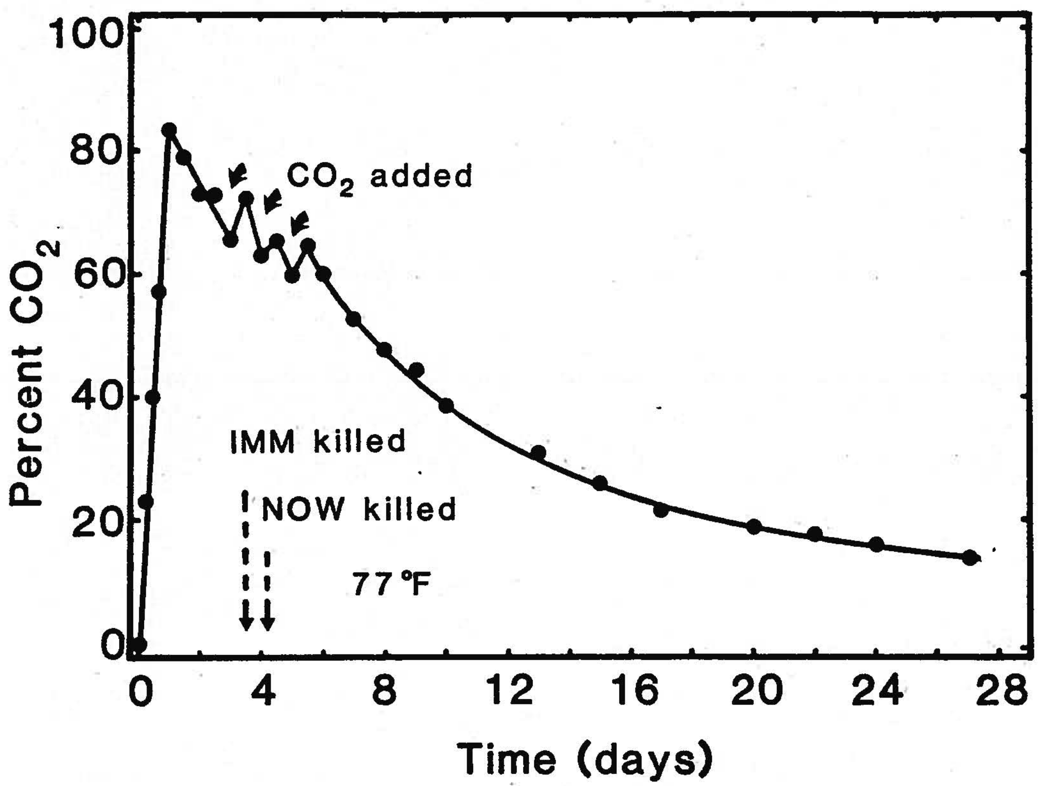
These tests show that modified atmospheres can be maintained in a commercial storage at a level suitable for protecting almonds from insect pests.

Table 1. Time to kill navel orangeworm and Indianmeal moth with oxygen deficient or carbon dioxide enriched atmospheres at three temperatures and two relative humidities.

Insect	Storage Temperature	LT 95 1/			
		Low O_2 2/		High CO_2 3/	
		40% RH	60%RH	40% RH	60% RH
	°F	Hr.	Hr.	Hr.	Hr.
Navel Orangeworm	60	153	210	177	196
	70	92	117	104	120
	80	51	63	54	66
Indianmeal moth	60	111	132	126	126+
	70	67	69	94	95
	80	33	33	50	50

1/ Obtained from eyefit of percent mortality vs time curves.
2/ 0.5% O_2
3/ 60%

Figure 3. Average CO_2 concentration in a concrete almond storage treated with carbon dioxide.



84-W8 Soderstrom Baritelle

1984 SUMMARY OF COSTS TO SEAL 50' X 50' X 42' ROOM
AT T. M. DUCHE CONCRETE TILT UP FACILITY, EARLIMART

	Materials	Manlift	Labor	Total
Caulking, duct taping joints and cracks in ceiling and walls	$ 282.60	$ 349.43	$ 453.49	$1,085.52
110' Bantam liner along wall to floor joint	$1,228.15	---	$1,132.68	$2,360.83
Gaco Western Neoprene strips along corner joints and one upright (252 linear ft.)	$ 835.25	$ 357.19	$ 590.13	$1,782.57
Gaco Western Elastomeric Acrylic Emulsion with polyester backing on ceiling-to--wall, wall-to-floor, and upright joints; and cracks and joints in floor (1004 linear ft.)	$ 607.85	$ 446.49	$ 663.79	$1,718.13
	$2,953.85	$1,153.11	$2,840.09	$6,947.05

MANLIFT RENTAL

	Rental		Delivery/ Pickup		Gas		Total
August 2 and 3, 1984	$260	+	$45			=	$ 305.00
August 6 to 9, 1984	$500	+	$45			=	545.00
August 17 to 20, 1984	$250	+	$45	+	$8.10		303.10
							$1,153.10

		Prorated Charge
Neoprene strip	46 labor hours	$ 357.19
Polyester strip wall & ceiling	57.5 labor hours	446.49
Wall and ceiling caulk & duct tape	45 labor hours	349.43
	148.5 labor hours	$1,153.11

$1,153.10/148.5 = $7.765/manlift - labor hour

BANTAM LINER

MATERIALS

Quantity	Description	Unit Price	Total Cost
1 roll	2 1/2' x 56' long bantam liner1/	$224.00	$ 224.00
1 roll	2 1/2' x 48' long bantam liner1/	$192.00	192.00
3100 (31 boxes)	3" Gripcon nails with bits2/	$20.00/box	620.00
14 rolls	1/8" x 2" x 30' Rubatex tape	$7.20/roll	100.80
225'	2" x 4" lumber	$0.23/foot	51.75
18 tubes	caulking	$2.20	39.60
			$1,228.15

1/Liner strips were cut longer than described and 110 feet of liner was installed.

2/Majority of nails not used, 31 bits (1 per box) used.

LABOR MAN HOURS

	Number Men - Hourly Rate	Total Hours	Wages
I & W Crop Care	4 at 13.5 hours each, $20/hour	54	$1,080.00
T. M. Duche	2 at 3 hours each, $8.78/hour (includes benefits)	6	52.68
Total		60 hours	$1,132.68

Total cost - labor and materials = $2,360.83

AREAS OF APPLICATION & COSTS PER 100 LINEAR FEET

Description	Man Hours/100 Linear Ft.	Labor/100 Linear Ft.	Material & Equipment Cost/100 Linear Ft.	Total Cost/ 100 Linear Ft.
*	54.5	$1,029.71	$1,116.50	$2,146.21

* 110 linear ft. of wall to floor joint on west and south walls and portions of north and east walls

GACO WESTERN ELASTOMERIC ACRYLIC EMULSION WITH POLYESTER BACKING STRIP

MATERIALS FOR WALL AND CEILING JOINTS, AND FLOOR CRACKS AND JOINTS

Quantity	Description	Unit Price	Total Cost
2 - 5 gallon	A 5411 acrylic emulsion	$21.47/gallon	$ 214.70
2 - 5 gallon	A 5616 acrylic emulsion	$25.76/gallon	257.60
3 - 1 gallon	A 5616 acrylic emulsion	$29.40/gallon	88.20
4 - 300' rolls	66B polyester tape	$11.10/roll	44.40
1 bag	walnut shell		n/c
	masking tape		
1	4" brush		2.95
			$ 607.85
Manlift usage			446.49
Total materials & manlift usage			$1,054.34

WALL AND CEILING JOINTS - LABOR

	Labor ($8.78/hr-includes benefits)			Supervisory ($9.75/hr-includes benefits)		
Date	# of Men	Total Hours	Wages	# of Men	Total Hours	Wages
8-2-84	2	8		1	2	
	2	2*		1	1*	
8-3-84	1 or 2	9.5		1	2.4	
8-6-84	2	16		1	4	
8-7-84	2	12		1	3	
8-8-84	2	10		1	2.5	
Subtotal	regular	55.5	$487.29	regular	13.9	$135.53
Subtotal	overtime	2*	26.34	overtime	1	14.63
Total	hours	57.5	$513.63	hours	14.9	$150.16

Total man hours - labor and supervisory = 72.4 hours

Total manpower cost - labor and supervisory = $663.79

*Overtime at 1.5 x regular hourly rate.

GACO WESTERN ELASTOMERIC ACRYLIC EMULSION WITH POLYESTER BACKING STRIP

FLOOR POUR JOINTS AND CRACKS - LABOR

Labor ($8.78/hr-includes benefits)				Supervisory ($9.75/hr-includes benefits)		
Date	# of Men	Total Hours	Wages	# of Men	Total Hours	Wages
8-10-84	2	4		1	1	
8-13-84	2	10		1	2.5	
Total		hours 14	$122.92		hours 3.5	$34.13

Total man hours - labor and supervisory = 17.5 hours

Total labor cost - labor and supervisory - $157.05

AREAS OF APPLICATION & COST PER 100 LINEAR FEET

Description	Man Hours*/ 100 Linear Ft	Labor* Cost/100 Linear Ft.	Material & Lift Cost/100 Linear Ft.	Total Cost/ 100 Linear Ft.
Ceiling & Walls				
200 linear ft. ceiling to wall joint				
90 linear ft. wall to floor joint				
294 linear ft. concrete uprights				
584 linear ft.	12.39	$113.66	$55.16 material $64.34 lift	$233.16
Floor				
300 linear ft. pour seams				
120 (approx.) linear ft. cracks				
420 linear ft.	4.17	$37.39	$68.07 material -0- lift	$105.46

* Includes supervisory

GACO WESTERN NEOPRENE STRIP

MATERIALS

Quantity	Description	Unit Price	Total Cost
100 linear ft.	12" wide field curing neoprene	$2.48/foot	$ 248.00
100 linear ft.	9" wide field curing neoprene	$1.89/foot	189.00
100 linear ft.	9" black cured neoprene	$1.60/foot	160.00
1 - 5 gallon	N7R adhesive	$20.27/gallon	101.35
4 - 1 gallon	N7R adhesive	$23.87/gallon	95.48
1 - 1 gallon	thinner/cleaner	$15.97/gallon	15.97
1	4" brush	$2.95	2.95
1	stitcher 1/4" x 2"	$11.10	11.10
1	roller 2" x 2"	$11.40	11.40
			$835.25
Manlift usage			357.19
Total materials and manlift usage			$1,192.44

LABOR

	Labor ($8.78/hr-includes benefits)			Supervisory ($9.75/hr-includes benefits)		
Date	# of Men	Total Hours	Wages	# of Men	Total Hours	Wages
8-2-84	2	8		1	2	
	2	2*		1	1*	
8-3-84	2	4		1	1	
8-7-84	2	4		1	1	
8-8-84	2	6		1	1.5	
8-9-84	2	4		1	1	
	2	6*		1	3*	
8-10-84	2	12		1	3	
Subtotal	regular	38	$333.64	regular	9.5	$ 92.63
Subtotal	overtime	8*	105.36	overtime	4	58.50
Total	hours	46	$439.00	hours	13.5	$151.13

Total hours - labor and supervisory = 59.5

Total manpower cost - labor and supervisory = $590.13

*Overtime at 1.5 x regular hourly rate.

CAULKING EXPANSION JOINTS IN CEILING; AND DUCT TAPING CEILING EXPANSION JOINTS AND CRACKS IN SIDE WALLS

CAULK AND DUCT TAPE FOR CEILING AND WALLS - MATERIALS

Quantity	Description	Unit Price	Total Cost
36 tubes	PRC 6000 caulk	$5.19	$186.84
24 rolls	Duct tape	$3.99	95.76
			$282.60
Manlift usage			$349.43

LABOR

Labor ($8.78/hr-includes benefits)				Supervisory ($8.78/hr-includes benefits)		
Date	# of Men	Total Hours	Wages	# of Men	Total Hours	Wages
8-2 & 3-84	2 (caulking)	12		---	---	
8-17-84	2 (taping)	16		1	2.7	
8-20-84	2 (taping)	16		1	2.7	
	2 (taping)	1*		1	0.5*	
Subtotal	regular	44	$386.32	regular	5.4	$47.41
	overtime	1	13.17	overtime	0.5	6.59
Total	hours	45	$399.49	hours	5.9	54.00

Total Labor $453.49

* Overtime at 1.5 x regular hourly rate.

Total cost for materials, lift and labor $1,085.52

GACO WESTERN NEOPRENE STRIP

AREAS OF APPLICATION & COSTS PER 100 LINEAR FEET

Description	Man Hours*/100 Linear Ft.	Labor*/100 Linear Ft.	Material & Lift Cost/100 Linear Ft.	Total Cost/ 100 Linear Ft.
12" wide field curing 42' S.W. corner 42' N.E. corner 84' Total	not available (n/a)	n/a	$531.52	n/a
9" wide field curing 42' N.W. corner 42' West wall upright 84' Total	n/a	n/a	$461.29	n/a
9" wide cured strip 84' S.E. corner	n/a	n/a	$426.76	n/a
Combined 252 linear ft.	23.6	$234.18	$473.19	$707.37

*Includes supervisory

12TH ANNUAL ALMOND RESEARCH CONFERENCE, DECEMBER 4, 1984, SACRAMENTO

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ALMOND BOARD

Project No. 84-W8 - Tree and Crop Research
Controlled Atmosphere

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Objectives: (1) To conduct a comparative field test of carbon dioxide versus low oxygen atmosphere for insect control in stored almonds and to determine cost effectiveness and time for insect mortality. (2) To analyse the effectiveness, and costs associated with improving the seal on the test fumigation chamber.

Interpretive Summary: Yes, there are alternatives to chemical fumigants for disinfestation of insects in stored products. But of critical importance is the sealing of your facilities regardless of the method used for disinfestation. Sealing of structually sound buildings can be accomplished under most circumstances. Our experiment demonstrated we could reduce leakage rates by over 2.5 times and we could exceed state standards. We tried different techniques and materials with cost ranging from over $100 per 100 linear feet to over $2,000 per 100 linear feet of sealed surface. Cost and adoption consideration will depend on the following: application, cost of material, labor requirements, durability of material, repairability, food grade certification of material, and reaction to chemical fumigants. By working with existing companies on specific applications, we should be able to find a means of adequately sealing many of our structually sound flat storage buildings.

Generally we have found the alternatives to chemical fumigants will cost somewhat more than current methods and they will take more time to kill insects. Of the alternatives, for high volume and repeated applications, the inert gas generator looks favorable. For more modest volumes and single application carbon dioxide treatment looks favorable. There are still other alternatives to be considered such as refrigeration, irradiation, heat, and various combinations. There is no easy solution but our research indicates the situation is far from helpless.

COST ANALYSIS OF ALTERNATIVE METHODS OF DISINFESTATION OF ALMONDS IN FLAT STORAGE

A COST ANALYSIS WAS PERFORMED ON FOUR TYPES OF DISINFESTATION TREATMENT: METHYL BROMIDE, PHOSPHINE, CARBON DIOXIDE, AND AN INERT GAS GENERATOR. COST DATA WAS OBTAINED FROM VARIOUS SOURCES. THE COST OF THE CAPITAL EQUIPMENT WAS PREDOMINATELY OBTAINED FROM MANUFACTURERS, THE COST OF LABOR WAS ESTIMATED BY THE WAREHOUSE MANAGER, AND PRICE OF THE MATERIALS INCLUDING ELECTRICITY, PROPANE, CHEMICALS ARE THE STANDARD COMPETITIVE PRICE IN THE AREA. ACTUAL QUANTITIES OF MATERIALS USED WERE VERIFIED BY ON SITE TESTING FOR THE INERT GAS GENERATOR AND CARBON DIOXIDE GENERATOR. EXPERIENCE AND LABEL RECOMMENDATIONS WERE USED TO DETERMINE THE AMOUNTS REQUIRED FOR PHOSPHINE AND METHYL BROMIDE. IT SHOULD BE NOTED THAT METHYL BROMIDE WAS NOT USED IN THE TEST BUT PREVIOUS EXPERIENCE DICTATED ITS COST. THE COST OF METHYL BROMIDE WAS DETERMINED FOR COMPARISON PURPOSES.

DATA WERE GATHERED FROM TREATING ONE QUADRANT OF THE STORAGE FACILITY AND EXTRAPOLATED TO THE ENTIRE BUILDING. THE RESULTS OF THE EXPERIMENT ARE LISTED IN TABLE 1 THROUGH TABLE 4 AND SUMMARIZED IN TABLE 5.

TABLE 5 SHOWS THAT IN THIS APPLICATION THE LEAST EXPENSIVE TREATMENT WAS ALUMINUM PHOSPHIDE AT $1.37 PER TON AND THE MOST EXPENSIVE TREATMENT THE INERT GAS GENERATOR AT $3.67 PER TON OF TREATED PRODUCT. THE GREATEST COST FACTOR WITH THE INERT GAS GENERATOR IS THE COST OF CAPITAL. IT SHOULD BE NOTED THAT THE MANUFACTURER MAINTAINS THAT A MACHINE NOT USING A WATER COOLING TOWER OR REMOTE HOOK-UP ELECTRICITY IS UNDER DEVELOPMENT AND IT IS ESTIMATED THAT THE CAPITAL COST OF THIS MACHINE WILL BE ROUGHLY HALF THE PRESENT MACHINE.

THE RESULTS OF THIS YEAR'S EXPERIMENTS WOULD INDICATE THAT FOR MODEST VOLUMES OF ALMONDS, IN THIS CASE 4,000 TONS, CARBON DIOXIDE COSTS LESS THAN THE INERT GAS GENERATOR. AND NEITHER OF THE ALTERNATIVES IS AS INEXPENSIVE AS METHYL BIOMIDE OR ALUMINUM PHOSPHINE. ON THE BASIS OF PREVIOUS YEARS' WORK, HIGH VOLUME AND REPEATED APPLICATIONS THE INERT GAS GENERATOR LOOKED FAVORABLE. IN ALL CASES BETTER SEALING WOULD HAVE REDUCED THE COST OF THE INERT GAS GENERATOR OR CARBON DIOXIDE OVER WHAT THEY WERE THIS YEAR.

Table 1: Estimated Cost of Treating Flat Storage With Methyl Bromide

Capital Equipment	Initial Cost	Years Life	Annual Cost	Maintenance	Total	
Cart	$1,000	10	$100	$ 10	$ 110	
Evaporator-Exchange	500	5	100	100	200	
Fan	5,000	10	500	1,000	1,500	
Storage Shed	5,000	20	500		500	
Safety Equipment Self Contained Breathing, Face Shields - Bottled Air - Other	2,000	5	400	200	600	
	$13,500		$1,600	$1,300	$2,910	
Interest on Investment 12%					1,620	
Total Annual Cost Capital Equipment						$4,530
Labor						
Sealing, Application Monitoring, Training 2 People - 24 hours total @ $11.00/hr.					$264	$264
Total Annual Labor Cost						
Materials						
Methyl Bromide 3.5 lbs/1,000 cubic feet 420,000 cubic feet = 1,470 lbs. @ $0.65/lb.					$956	
Tape (polyethylene, electricity, misc.)					200	
Total Annual Material Cost						$1,156
Sample for Residues						
Sample $35.00/sample - 8 samples					$280	
Labor 1 hour/sample - 8 hours					88	
Total Sampling						$368
Total Annual Cost						$6,315
Cost per delivered ton - 4,000 tons						$1.58

Table 2: Estimated Cost of Treating Flat Storage With Aluminum Phosphide

Capital Equipment	Initial Cost	Years Life	Annual Cost	Maintenance	Total	
Trays	$ 500	5	$100		$ 100	
Fan	5,000	10	500	$1,000	1,500	
Storage Shed	5,000	20	500		500	
Safety Equipment Self Contained Breathing, Face Shields, Bottled Air Other	2,000	5	400	200	600	
	$12,500		$1,500	$1,200	$2,700	
Interest on Investment 12%					1,500	
Total Annual Cost Capital Equipment						$4,200

Labor		
Sealing, Application Monitoring, Training 2 People - 20 hours @ $11.00/hr.	$220	
Total Annual Labor Cost		$220

Materials		
Magnesium Phosphide 100 Pellets/1,000 cubic feet 420,000 cubic feet = 420,000 pellets @ $30.00/1,610 pellets	$783	
Tape (polyethylene, electricity, misc.)	200	
Total Annual Material Cost		$983
Total Annual Cost		$5,403
Cost per delivered ton - 4,000 tons		$1.55

Table 3: Estimated Cost of Treating Flat Storage with Carbon Dioxide

Capital Equipment	Initial Cost	Years Life	Annual Cost	Maintenance	Total	
Injection System	$2,500	15	$167	$125	$ 392	
Recirculation System	4,000	15	267	200	467	
Gas Analyzer	1,200	15	80	60	140	
Safety Equipment Self Contained Breathing Face Shields, Bottled Air, Other	2,000	5	400	200	600	
	$9,700		$914	$585	$1,599	
Interest on Investment 12%					1,164	
Total Annual Cost Capital Equipment						$2,653
Rental of Equipment - 1 Month						
Total Annual Rental Cost					$ 570	
						570
Removal and Installation of Stationary Equipment						
Total Annual Removal and Installation Cost					$2,000	
						2,000
Labor						
Sealing, Application, Monitoring, Training 2 people - 24 hours total at $11/per hr.					$ 264	
Total Annual Labor Cost						264
Materials						
Electricity 3 H.P. Compressor	302.4 KWH @ $.093/KWH				$ 28	
Vaporizer	2450.0 KWH @ $.093/KWH				228	
Carbon Dioxide 53680 lbs. @ $.06/lb.					3,200	
Tape, polyethylene, misc.					200	
Total Annual Material Costs						3,677
Total Cost 4,000 Tons						$9,164
Cost/Ton inshell						$2.29

Table 4: Cost of Treating Flat Storage Using An Inert Gas Generator

Capital Equipment	Initial Cost	Years Life	Annual Cost	Maintenance	Total	
Generator	$30,600	15	$2,040	$1,530	$3,570	
Refrigerant Dryer	12,700	15	847	635	1,482	
Cooling Tower	5,000	15	333	250	583	
Gas Analyzer	1,200	15	80	60	140	
Plumbing	4,000	15	267	200	467	
Safety Equipment Self Contained Breathing Face Shields, Bottled Air, Other	2,000	5	400	200	600	
	$55,500		$3,967	$2,875	$6,842	
Interest on Investment 12%					6,660	
Total Annual Cost of Capital Equipment						$13,502
Labor						
Sealing, Application, Monitoring, Training 2 people, 24 hours, total @ $11/hr.					$ 264	
Total Annual Labor Cost						264
Materials						
Propane 640.1 Gallons at $.80/Gallon					$ 512	
Electricity Generator 192 hours 5.7 KWH = 1094.44 @ $.093					102	
Cooling Tower 1.4 KWH = 268.80 @ $.093					25	
Dryer 3.8 KWH = 729.60 @ $.093					68	
Tape, polyethylene, misc.					200	
Total Annual Material Cost						907
Total Annual Cost						$14,673
Total Cost/Ton						$3.67

Table 5: Summary of Estimated Costs Per Ton for Almonds in Flat Storage

	Methyl Bromide	Aluminum Phosphide	Carbon Dioxide	Generator
Capital	$1.1325	$1.0500	$.6633	$3.3800
Rental	0	0	.6425	0
Labor	.0660	.0550	.0660	.0660
Materials	.2890	.2455	.9193	.2268
Sampling	.0920	0	0	0
	$1.5792	$1.3507	$2.2911	$3.6728