PROBLEMS AND THEIR SOLUTIONS FOUND IN THE CONSTRUCTION OF CONCRETE BINS FOR HERMETIC STORAGE.

KAMEL, A.H.[*], FAM, E.Z.[*] and JAY, E.G.[**]

* Stored Product Pest Research, Plant Protection Research Institute, Ministry of Agriculture, Dokki, Cairo, Egypt.

** Stored Product Insects Research and Development Laboratory, AR-SEA-USDA, Savannah, Georgia, U.S.A.

ABSTRACT

Concrete double-wall bins were designed and constructed to study the hermetic storage of grain. These bins have a sandwich of bitumin and PVC sheeting between the walls and have two openings fitted with rubber gaskets for filling and discharge of the grain. When construction was completed, the bins were tested for leaks by purging them with carbon dioxide (CO_2). Heavy initial losses of this gas were observed and attempts were made to further seal the bins. The final approach was to reseal the cracks in the bins and then to paint the inside with two coats of CIBA-GEIGY LTD.'s Araldite epoxy resin. A layer of glass wool cloth was placed between these two coats of epoxy. The opening covers were also caulked with a 1:1 mixture of Araldite and zinc oxide after they were secured in place. These modifications stopped the high CO_2 losses and resulted in the bins being satisfactory for hermetic storage.

INTRODUCTION

The majority of grain is currently stored in Egypt in open air shounas which subjects it to attack by various biological factors. Rainfall and infiltration of soil water also can damage the grain. Total annual losses in storage can amount to 24 million Egyptian pounds.

Tremendous damage and resultant losses also occur when jute bags used for grain storage are exposed for a long time to the sun, especially during the summer. Rodents and birds also severely damage the jute bags. A lot of grain is scattered in situ and during transportation due to these damaged bags.

During storage grain has to be treated with protectants to keep the infestation away for short periods. When the insect infestation starts, fumigation of infested stocks is essential. The chemical and mechanical means for rodent control is also essential whenever populations become apparent. The use of chemicals for grain intended for human and animal consumption is not desirable for the protection of such materials. Despite the fact that all chemicals are used within tolerances, treated grains are generally considered contaminated and toxic effects may occur at a later time.

Hermetic storage has several advantages when compared with other systems of storage. The most important advantages is its efficiency in pest control without the use of toxic chemicals. A joint project between the U.S. Department of Agriculture, SEA, AR, Savannah, Georgia, U.S.A, and Cairo, Egypt was financed under PL 480 in 1975 to study the hermetic storage of grain under Egyptian conditions. This project was aimed at:

1. Protection of stored grain with the least possible use of toxic chemicals.
2. Avoidance of rodent and bird attack.
3. Saving the majority of jute bags.

The experimental bins were constructed according to specifications and were tested for gas-tightness by purging them with CO_2. A considerable amount of this CO_2 escaped in a very short time. Therefore, this paper described the detection of the leaks and the modifications made to try to overcome leaks.

SPECIFICATION OF THE EXPERIMENTAL BINS

The experimental bins were constructed according to the following specifications:

1. Cylindrical in shape, with a top cone about 1/2 meter high from the top end to the cylinder.
2. Double walls, the inner of concrete and the outer of bricks.
3. A thick layer of polyvinyl chloride sheets were fixed on the outer surface of the inner wall with bitumin (sandwich).
4. Inner walls were smoothed by a concrete-mortar mix.
5. All aperture covers were strengthened to prevent twisting due to weather conditions.
6. Strong and flexible rubber gaskets were fixed firmly around the apertures.

These specifications are shown in figures 1 to 5.

TESTS CONDUCTED TO EVALUATE THE HERMETIC SEALING OF BINS

After the bins had been accepted from the contractor, several trials were conducted to insure that the bins could be hermetically sealed and fit for the purpose of this study. The experimental bins were filled with wheat. They were purged with CO_2 through the lower sampling aperture by using copper tubing connected to a CO_2 cylinder. All other apertures were tightly closed except the relase valve at the top. Each experimental bin was purged with a certain amount of CO_2 by weight, and both openings were then closed. After each test, the wheat was discharged from the bin and bins were refilled with wheat before the next test. Samples of air inside the bins were drawn for CO_2 concentration measurement from two points, i.e. from near the bottom of the bin and from near the upper surface of wheat, through sampling tubes especially fixed for this purpose. Trials were conducted as follows:

Trial n° 1

Bin numbers 3, 4 and 5 which had PVC liners and bin number 1 (control, no PVC liner) were used for the first trial and were completely filled with wheat. After purging with about 5 kgs of CO_2, both openings were tightly closed and the CO_2 concentrations were estimated after different intervals. The results are illustrated in Table 1. Data in this table clearly indicate that the CO_2 escaped from these

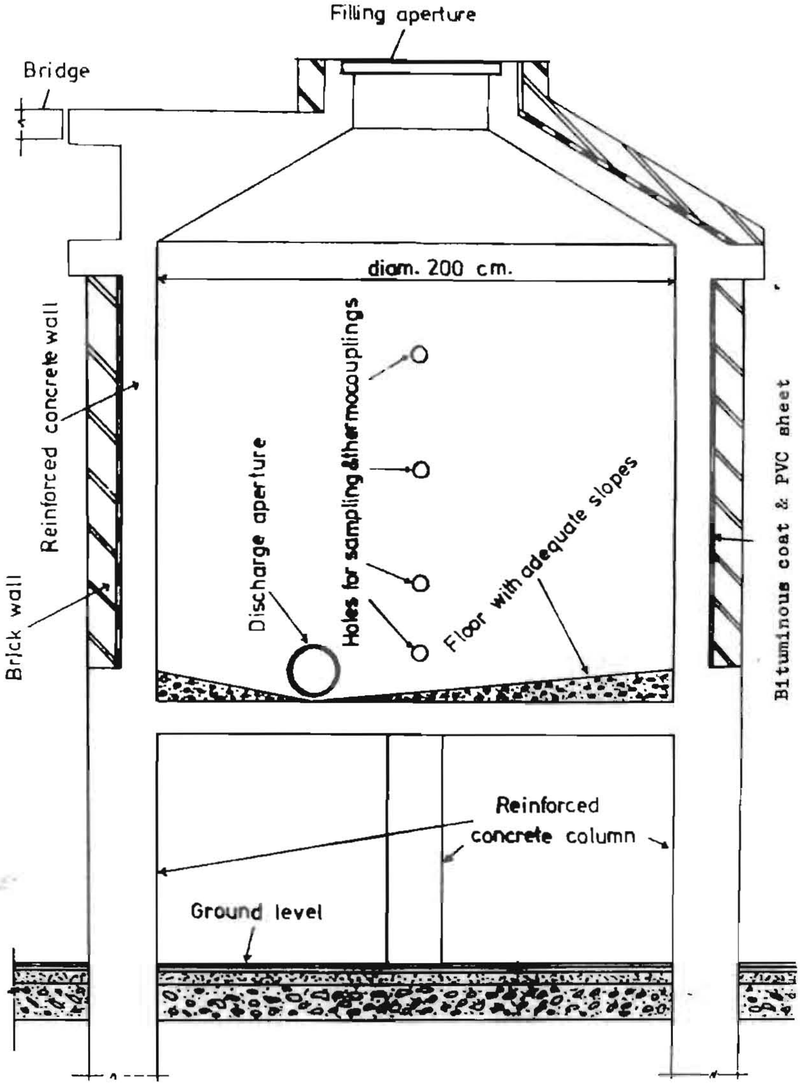

Fig.1. A detailed figure of an experimental bin showing the double wall and the PVC sheeting in between; also, the filling and the discharging apertures and the sampling holes.

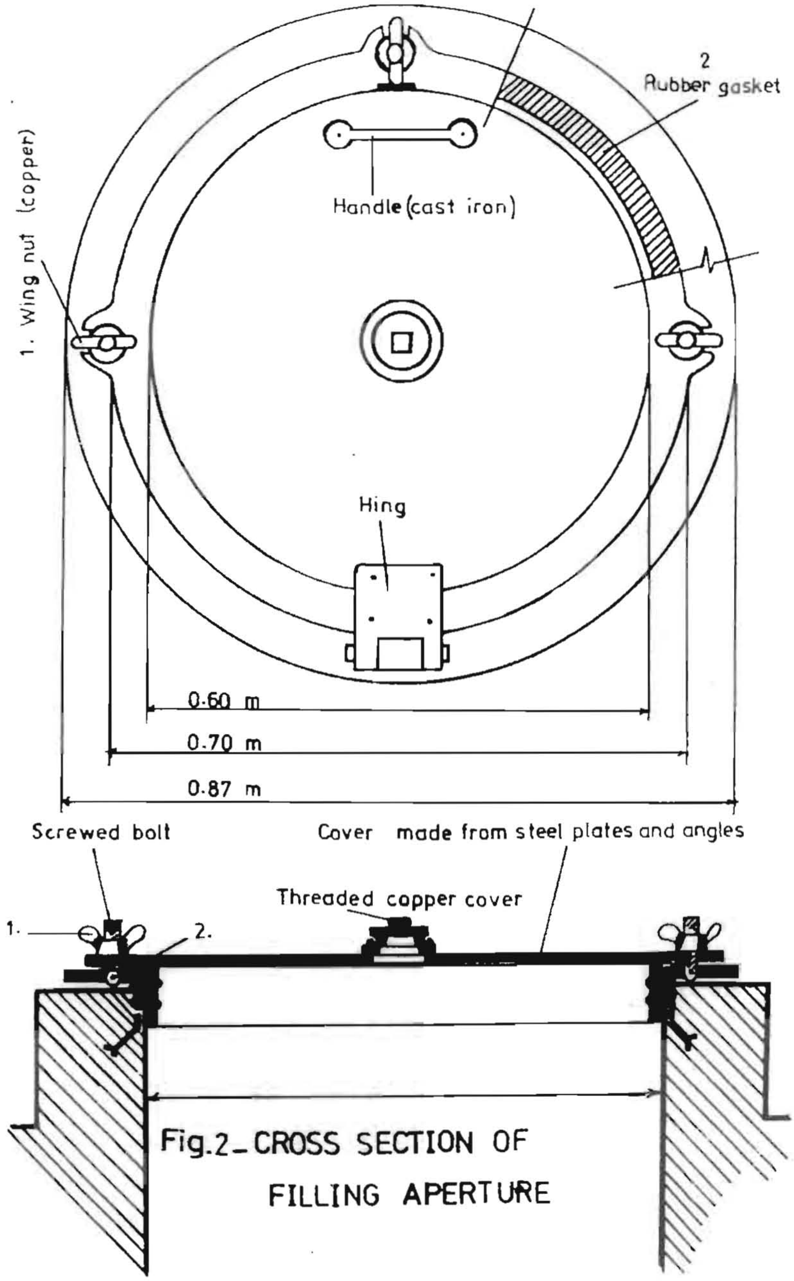

Fig.2. A cross section of the filling aperture and the steel cover.

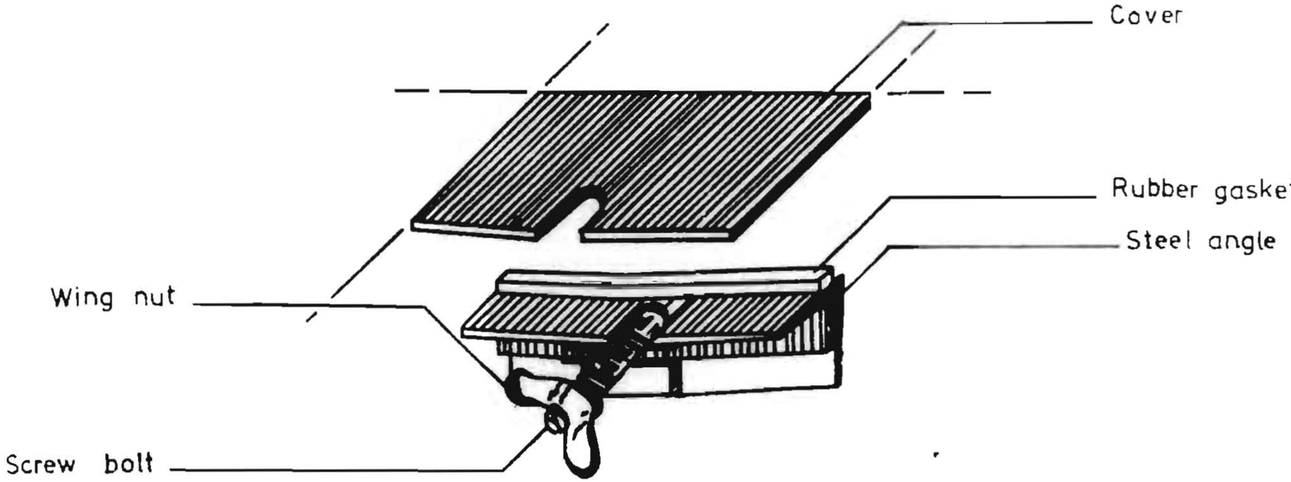

Fig.3. Isometric for the cover of the filling aperture.

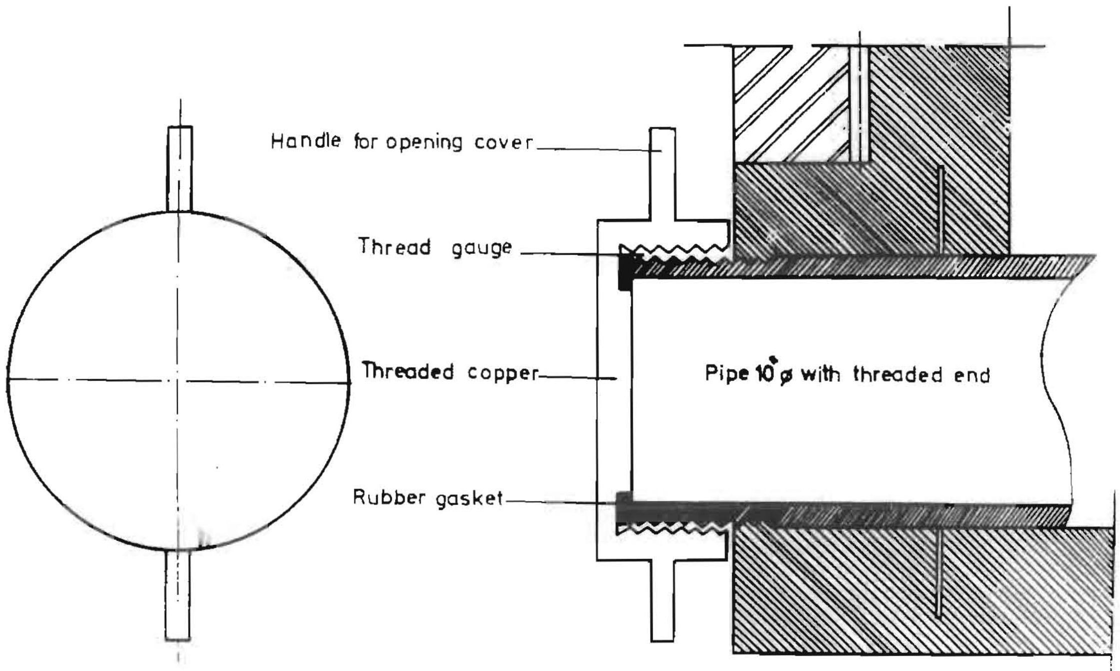

Fig.4. A cross section of the emptying aperture.

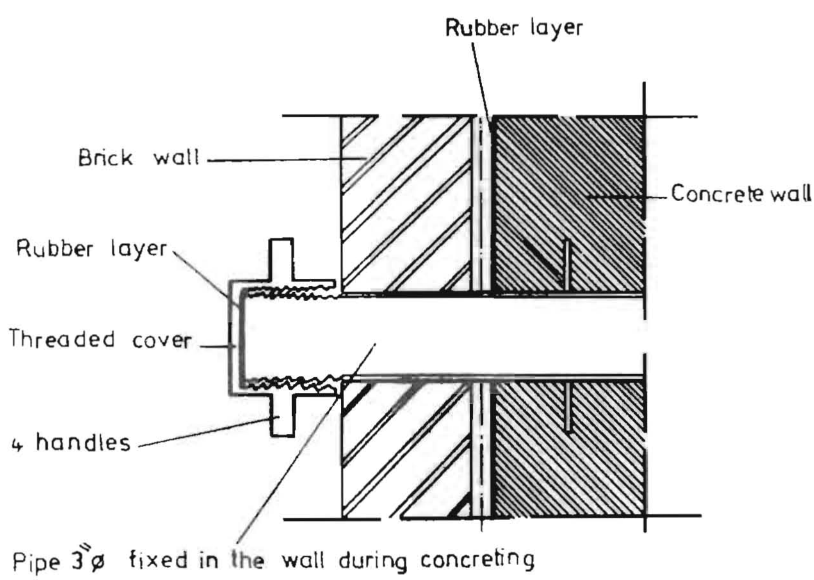

Fig.5. A sampling pipe.

TABLE NO. 1 PERCENTAGE OF CO_2 V/V IN THE PURGED BINS

NO.OF BIN	TYPE OF CONSTRUCTION	LOCATION OF SAMPLE	% AGE OF CO_2 - HOURS AFTER TREATMENT					
			0	1	2	3	4	5
1	Without	Up	25	-	6	4	4	0.2
	PVC	Down	25	-	20	15	10	1.6
	Sheeting	Mean	25	-	13	9.5	7	0.9
3		Up	4	3	0.4	0.4	0.4	0.0
	With	Down	73	40	20	14	10	0.2
	PVC							
	Sheeting	Mean	38.5	21.5	10.2	7.2	5.2	0.1
4	With	Up	24	6.0	4.0	1.8	1.6	0.4
	PVC	Down	78	61.0	42.0	32.0	26	0.8
	Sheeting	Mean	51	33.5	23	16.9	13.8	0.6
5	With	Up	52	20.6	16.4	10	8	1.4
	PVC	Down	88	83	68	54	43	0.4
	Sheeting	Mean	70	51.8	42.2	32	25.5	0.9

bins as well as from the control bin, probably through the inner concrete walls and then to the outside atmosphere from any weak point which was not sealed or from the gaskets of the upper and lower apertures.

Bins having PVC liners had higher initial concentrations in these tests than did Bin n° 1 (control, no liner) but all bins had about the same mean CO_2 concentration after 5 hours. These results caused us to further study the construction of the bins.

Trial n° 2

We were advised by civil engineers and chemists working in the field of the construction of stores for inflammable materials that the inner surface of the bins should be painted with araldite epoxy resin paint (a CIBA-GEIGY product) to get better maintenance of the concentrations.

We chose bin n° 4 for these tests. This bin was emptied of wheat and the inside surfaces of the walls and floor were painted twice using "Topcoat 020" paint. This paint is made up of two compounds, i.e.:

Topcoat 020 resin (white in color)

Topcoat 020 hardener (green in color).

The mixing ratio is 100 parts of resin and 60 parts of hardener by weight.

After painting, the bin was again filled with wheat and the different apertures were tightly closed with a mixture of Chinese zinc, fine sand and cement. CO_2 was then purged in, and concentrations were found to be as shown in Table 2. It is clear from this table that there was still a large (44.8%) loss of the CO_2 concentration within the first 20 hours. This loss could mainly be attribuited to sorption of CO_2 by wheat grains or to leakage or movement of the gas in the intergranular spaces. The loss occurring during the following 6 days was also high indicating that the araldite coating was not effective. The percentage of loss of CO_2 per day during this period was about 13.9%.

These problems led us to additional studies to make the bins tighter.

Trial n° 3

A civil engineer conducted a close inspection of the internal walls of the bins. He detected many very fine deep cracks in the walls of the bins and concluded that in the concrete the sand particle size was too large and the percentage of sand was too high. He then suggested that a partial removal of the inner concrete surfaces of the bins was essential. This step should be followed by filling in the

TABLE NO. 2 CO_2 CONCENTRATIONS (V/V) IN BIN NUMBER 4 AFTER BEING PAINTED WITH ARALDITE

TIME AFTER CO_2 PURGING	CO_2 CONCENTRATION % UP	DOWN	MEAN	% LOSS IN CO_2 CONC.% DAY
1 hr.	68	88	78	
2 hrs.	68	80	74	
3 hrs.	54	70	62	
20 hrs.	32	54	43	44.8
7 days	68	7.5	7.1	13.9

cracks with mortar, then applying a new layer of concrete. The suggested last steps were (1) paint the inner surfaces of the walls with araldite epoxy resin, (2) apply a layer of glass wool fixed with araldite and (3) repaint the walls again with araldite. Tests were first conducted on bin n° 4 after removal of the old paint coat and following the steps outlined above.

Table 3 presents results of CO_2 concentration analysis in bin n° 4 after the modifications, refilling with grain, and repurging with CO_2. These data indicate that the bin was holding CO_2 better than before the changes. The loss in CO_2 concentration during the first day was about 18.4% and the gradual decrease in CO_2 concentration during the following 6 days was about 2.35% per day. These figures correspond to losses of about 44.8% and 13.9% before making these modifications (Table 2). However, losses were still high and further steps were needed to make the bins more gas-tight.

TABLE NO.3 CO_2 CONCENTRATIONS IN BIN NO. 4

AFTER IT WAS REPAIRED AND PAINTED

TIME OF SAMPLING AFTER PURGING WITH CO_2	% CO_2 DOWN	UP	MEAN	LOSS IN CO_2 CONC./DAY
1 hr.	54	12	33	
3 hrs.	52	16	34	
5 hrs.	48	20	34	
7 hrs.	44.4	23.6	34	
22 hrs.	33.2	25.4	29.3	
25 hrs.	29	24.8	26.9	18.48
6 days	25.3	21.6	23.4	
7 days	23.6	22.6	23.1	
11 days	22	20.6	21.3	2.35

Trial n° 4

Several other bins were repaired in the manner described for bin n° 4. Every possible point which might be responsible for CO_2 escape was caulked with a paste composed of Chinese zinc powder (used in wall painting) mixed with araldite HY and araldite impregnation DY at the rate of one part of each of both araldites (H and G). This mixture was then added to the zinc powder in small amounts until it reached the paste stage. This paste was plastered all around the upper and lower opening covers and wherever other CO_2 leaks were detected. These other leaks were found by using the soap bubbling method for gas leak detection. This paste has to cure for 48 hours before it gets hard and effective. After conducting this step, the wheat-filled bins were purged with CO_2 and the resultant concentrations are shown in Table 4. It is clear from this data that a significant drop in CO_2 concentration occurred during the time elapsed between the first two determinations in all bins. This time was as short as a few hours in bin 3 and 4, which may indicate that the high initial drop in CO_2 concentrations was due to the sorption of the gas by the wheat kernels.

The concentration of CO_2 after the second determination remained nearly constant or decreased very steadily and slightly as shown in Table 5. Data in this table indicate that the percentage of decrease ranged between 0 and 0.4% per day. This decrease is considered to be an acceptable level of decrease for hermetic storage and thus these bins under these conditions meet the requirements of the field trials. After the bins became fit for field trials, bins 3, 4 and 5 were left for longer periods of storage and CO_2 concentration was determined at monthly intervals as presented in Table 6. This table shows that there was a CO_2 loss in the three purged bins. The rate of CO_2 depletion was 0.47%, 0.35% and 0.17% per day during the different periods of storage which were 4, 6 and 12 months, respectively. The CO_2 loss in the 3 bins is mainly attributed to two main factors, i.e. CO_2 absorption by wheat kernels or to leaks. In this case the depletion due to absorption may be most prominent, otherwise CO_2 would have escaped gradually.

TABLE NO. 4 AVERAGE PERCENT CO_2 CONCENTRATION (V/V) IN THE INTERGRANULAR SPACES IN THE BINS AFTER DIFFERENT PERIODS OF PURGING (AVERAGE OF TWO LOCATIONS; I.E., NEAR THE TOP AND NEAR THE BOTTOM)

T.E.	BIN 3	T.E.	BIN 4	T.E.	BIN 5	T.E.	BIN6	T.E.	BIN 7	T.E.	BIN 8
1h	67.6	1h	79.9	1h	53.1	1h	75.4	1h	69.6	1h	69.4
2h	57.2	5h	70.3	2d	50	5d	64.8	2d	59.4	7d	49
3d	58.4	6d	70.4	3d	48.5	6d	64.4	3d	59.2	8d	49.4
7d	57.5	8d	69.4	7d	49.1	8d	64.2	7d	59.4	10d	50.6
8d	56.3	12d	69.5	8d	49.2	12d	62.0	8d	60.3	14d	49.8
		13d	66.3			13d	62.6			15d	50.2

T.E. equals TIME ELAPSED AFTER PURGING CO_2

H equals HOURS

D equals DAYS

TABLE NO. 5 PERCENT CO_2 DEPELETION DURING MEASUREMENT PERIOD 6 OR MORE DAYS AFTER THE SECOND DETERMINATION AND PERCENT DEPLETION PER DAY DURING THESE PERIODS.

BIN NO.	3	4	5	6	7	8
TIME ELAPSED BETWEEN SECOND AND LAST DETERMINATION OF CO_2 IN DAYS	7	12	6	8	6	8
% OF DROP IN CO_2 CONCENTRATION	1.6	5.7	1.6	3.4	0.0	0.0
% OF DROP IN CO_2 CONC./ DAY	0.2	0.47	0.26	0.42	0.0	0.0

It can be seen from these studies that a considerable concentrations of CO_2 lethal to all insects could be purged in and maintained in the intergranular spaces for periods of up to one year, as long as the bins are made relatively gas-tight.

SUMMARY OF RESULTS

Satisfactory results in construction could be obtained with very close supervision. It is essential that the construction materials be up to standards, i.e., the sand used must be fine and when mixed with the cement, the standard ratio should be followed.

TABLE NO. 6 THE DEPLETION IN THE CONCENTRATION OF CO_2 FROM BINS DESIGNED FOR HERMATIC STORAGE OF GRAIN DURING STORAGE PERIODS OF UP TO 12 MONTHS

PERIOD OF STORAGE (MONTHS)	BIN. NO. 3 CO_2 CONCENTRATION %	% OF DEPLETION	BIN NO. 4 CO_2 CONCENTRATION %	% OF DEPLETION	BIN NO. 5 CO_2 CONCENTRATION %	% OF DEPLETION
initial*	67.6	-	79.9	-	53.1	-
1	52.7	22.04	64.8	18.90	48.9	7.91
2	39.6	41.42	54.6	31.67	44.4	16.38
3	32.3	52.22	49.8	37.67	39.3	25.99
4	29.5	56.36	41.0	48.69	33.5	36.91
5			38.0	52.44	32.0	39.74
6			30.0	62.45	26.0	51.04
7					27.2	48.78
8					24.2	54.43
9					26.0	51.04
10					24.0	54.80
11					-	-
12					21.0	60.45
CO_2 DEPLETION PER DAY DURING THE PERIOD	0.47%		0.35%		0.17%	

* DIRECTLY AFTER PURGING WITH CO_2

This study also showed that:

1. The construction of a double wall bin with PVC fixed as a sandwich for making them gas-tight was not successful. This problem was solved by painting the inner surfaces with aralditeed epoxy resin two times and placing a layer of glass sheets between the coats of paint.

2. Consideration should be given tc the reduction of the number of apertures to a minimum. A better design for the aperture covers is highly recommended, otherwise caulking the edges of the covers with a paste of zinc-oxide and araldite 1:1 should be considered.

3. Rubber gaskets are not satisfactory for hermetic sealing of apertures especially if they are exposed directly to weather conditions.