$ECO_2FUME^{®}$ Fumigant Gas

Hopper Car Fumigation Trial

Rev. C

August 28, 2003

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1. Executive Summary

The hopper car fumigation trial demonstrated that it was feasible and effective to add Cytec's $ECO_2FUME^{®}$ fumigant gas into the top of a sealed hopper-type railcar of finished rice for in-transit fumigation. The gas was added within five to eight minutes to each car, with the flow of $ECO_2FUME^{®}$ controlled at about 2 pounds per minute by a 1/16" nozzle tip. After 5 to 8 days in transit, readings above 100 ppm of phosphine were seen in the headspace and the rice mass in 20 of the 21 compartments measured in the hopper cars that were fumigated with this method. This indicated that lethal concentrations had been maintained for the duration of the fumigation. This was comparable to an identical hopper car that had been fumigated with metallic phosphides.

2. Purpose of the Trial

The purpose of the trial was to demonstrate that $ECO_2FUME^{®}$ fumigant gas is an effective alternative to metal phosphides for the fumigation of hopper-type railcars, and that $ECO_2FUME^{®}$ is safe, environmentally friendly, cost effective and easy to use. $ECO_2FUME^{®}$ fumigant gas does not produce any waste by-products, and does not require the removal of partially spent material from the railcar. It also eliminates the handling, deactivation and eventual disposal of the waste by-products associated with metallic phosphides.

3. Overview of Hopper Car Fumigation Trial

A total of eight hopper-type railcars were provided for this fumigation trial. Four cars were fumigated on July 15th, and four more were fumigated on July 16th. The railcars contained finished "Fancy" rice, and were destined for a customer in Memphis, TN. Final gas readings were taken from the headspace and the rice mass on July 21st and July 23rd respectively.

$ECO_2FUME^{®}$ fumigant gas was added by weight to each hopper car, using a nozzle tip inserted through the poly seal along the top opening of the hopper car. Two dosage levels were tested: 500 ppm phosphine and 400 ppm. These levels correspond to 20 grams of phosphine per 1000 cubic feet and 16 grams per 1000 cubic feet respectively.

The dose was either split up between compartments, or added all at once to a single compartment.

4. Experimental

All eight hopper cars provided for this trial were identical in construction, with three separate compartments open to each other at the top where there is a small opening in the metal plate between them. Figure 1. shows the top of the open hopper car while it is being filled with rice.

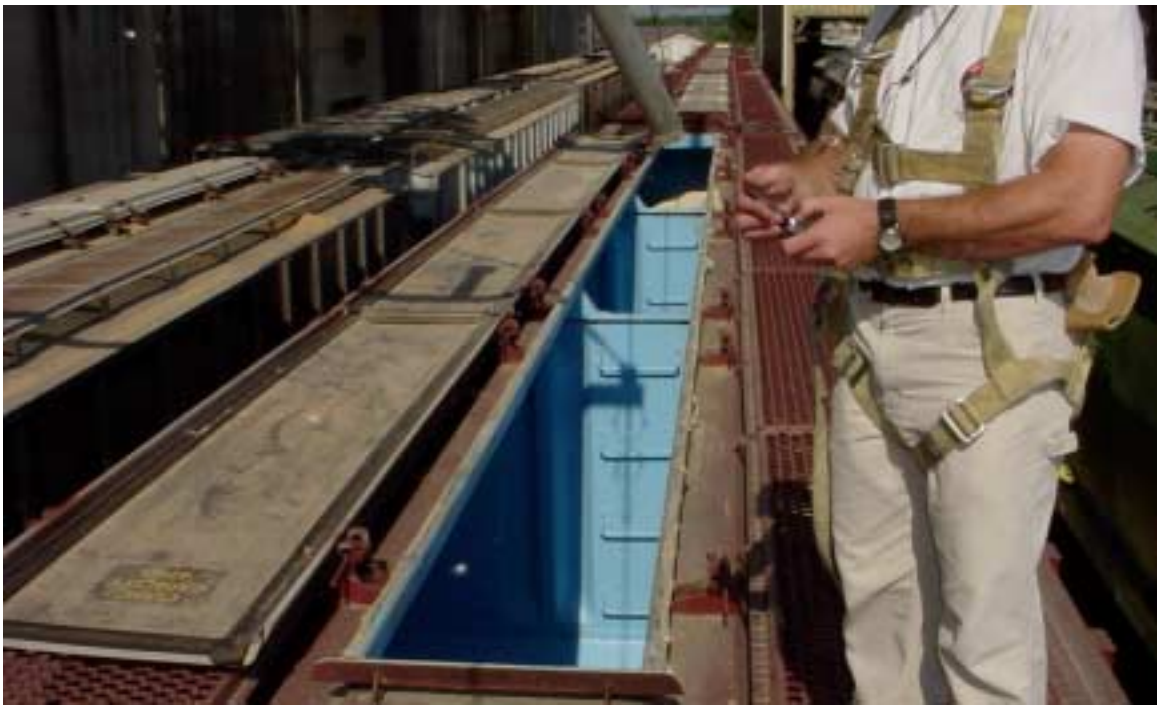

Figure 1. View of hopper car compartments during filling

The three compartments were labeled A, C and B, with C being in the middle. The compartment sizes were as follows: A = 1656 ft^3, C = 1438 ft^3, B = 1656 ft^3, for a total of 4750 ft^3 per car. The cars each had one long opening on top that ran the length of the car for filling, with interleaving hatches for normal sealing. Prior to fumigation and after filling, this opening is sealed with poly sheeting and masking tape. Figure 2. shows the top of the hopper car after sealing.

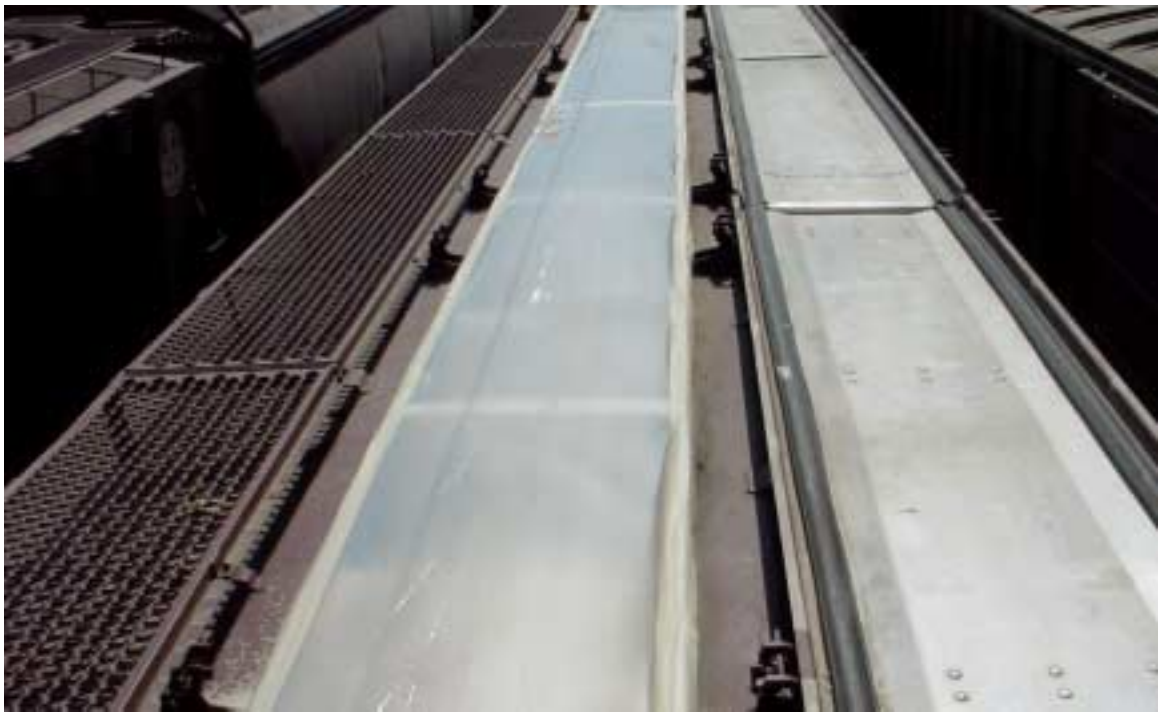

Figure 2. Top of the hopper car after filling and sealing.

$ECO_2FUME^{®}$ fumigant gas can be added either to the headspace or to the bottom of rail cars. Previous testing on “pressure differential” type flour cars has shown that gas added at the bottom of the car will make its way to the top in transit. In this case, however, addition at the top of the car was identified as being the preferred route, since there was no convenient location at the bottom of the car to which to add gas.

Figure 3. shows the nozzle tip assembly that was used to inject $ECO_2FUME^{®}$ into the top of the hopper car. The assembly consisted of a fitting attached to the high pressure hose from the cylinder, a 3000# steel tee with a pressure gauge, and a 1/16" x 0.04"ID stainless steel nozzle tip.

Figure 3. $ECO_2FUME^{®}$ nozzle tip assembly

The cylinder of $ECO_2FUME^{®}$ fumigant gas was located on a portable scale at ground level at one location for each hopper car. The cylinder was moved between cars using a wheeled cylinder cart, and rolled onto the scale using an aluminum ramp. A fifty foot length of high pressure dispensing hose complete with the nozzle tip assembly was attached to the cylinder fitting at each car. An operator opened the cylinder valve when the fumigator indicated that the nozzle tip was inserted through the poly sheeting, and closed it when the calculated required weight of gas had been added. The cars were dosed at either 500 ppm (the maximum label rate allowed) or 400 ppm, either split up between compartments or added all at once to a single compartment. For the 500 ppm dose, approximately 10.5 lbs. of gas were added. For the 400 ppm dose, approximately 8.5 lbs. of gas were added. These levels correspond to 20 grams of phosphine per 1000 cubic feet and 16 grams per 1000 cubic feet respectively. A summary of applied

dosages is given in Table 1 in the Results section of this report. Figure 4. shows the gas being dispensed by the fumigator. Figure 5. shows the scale and operator on the ground.

Figure 4. Addition of $ECO_2FUME^{®}$

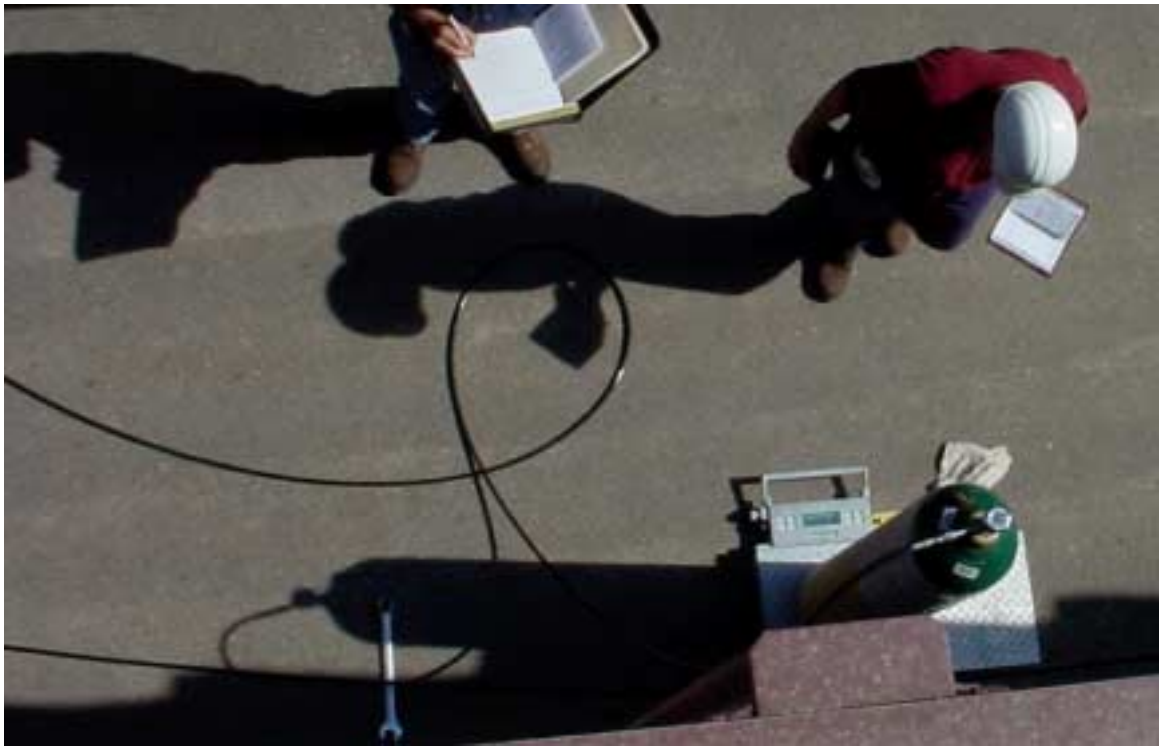

Figure 5. $ECO_2FUME^{®}$ cylinder and scale during addition

The addition of ECO_2FUME® was achieved in approximately 5 to 8 minutes per car, depending on whether the dose was split up or added all at once. During addition, the poly sheeting puffed up slightly due to the volume increase caused by the expanding gas, but the tape seals were not challenged. Personal monitoring on top of the car was performed using either a Lumidor or a Pac III personal phosphine monitor.

Once the required amount of ECO_2FUME® had been added, the nozzle was removed from the plastic and the resulting small hole was sealed with tape. The hatches were closed, latched and safety sealed, and the cars were shipped to the customer on July 17.

For comparison purposes, a ninth railcar (469261) identical to the eight hopper cars fumigated with ECO_2FUME® was fumigated with metallic phosphide Prepacs, at a dosage of about 28 grams of phosphine per 1000 cubic feet.

Residual phosphine gas readings were taken using Draeger tubes in seven of the eight hopper cars fumigated with ECO_2FUME® on July 21 and July 23. Gas readings were taken either directly from the headspace of each compartment, or using a sampling probe placed several feet below the surface of the rice mass. Readings were also taken for the ninth car that was fumigated with metal phosphides. The residual gas reading data are shown in Table 2 in the Results section of this report.

5. Results

Table 1 shows the summary of applied dosages for each car. Table 2 shows the summary of residual gas readings taken in either the headspace or the rice mass after either 5 or 8 days in transit.

Generally, the longer the transit time, the less gas was left in the cars. This was predictable, since some leakage is expected to occur over time. Also, there was generally a higher concentration in the headspace of the car than in the rice mass. This is likely due to the fact that the gas is added at the top of the car, and most of the leakage is expected to occur at the bottom slide gate.

Table 1. Summary of Fumigation Dosages Applied July 15 – 16, 2003

No.	BNSF	Date Fumigated	Applied Dose by Compartment (Lbs. of ECO2FUME)			Applied Dose by Compartment (g PH3)			Total Dose (Lbs. ECO2FUME)	Total Dose (g PH3)	Total Dose (g PH3 / 1000ft3)	Target conc. (ppm)	Comments
			A	C	B	A	C	B					
1	469230	15-Jul-03	3.9	3.2	3.5	35	29	32	10.6	96	20	500	3 add points
2	469493	15-Jul-03	-	10.5	-	-	95	-	10.5	95	20	500	1 add point
3	469093	15-Jul-03	3.0	2.7	2.9	27	25	26	8.6	78	16	400	3 add points
4	469346	15-Jul-03	-	8.5	-	-	77	-	8.5	77	16	400	1 add point
5	469191	16-Jul-03	3.6	3.3	3.5	33	30	32	10.4	94	20	500	3 add points
6	469447	16-Jul-03	-	10.6	-	-	96	-	10.6	96	20	500	1 add point
7	469125	16-Jul-03	4.2	-	4.3	38	-	39	8.5	77	16	400	2 add points
8	469370	16-Jul-03	4.2	-	4.3	38	-	39	8.5	77	16	400	2 add points
9	469261	16-Jul-03	-	-	-	-	132	-	-	132	28	-	Metal phosphide, 1 add point

Table 2. Summary of Residual Gas Readings July 21 – 23, 2003

No.	BNSF	Target conc. (ppm)	Number of Add Points	Date Fumigated	Date Sampled	Transit days	Residuals by Compartment				
							Readings in Headspace (ppm)		Readings in Rice Mass (ppm)		
							A	B	A	C	B
1	469230	500	3	15-Jul-03	-	8	-	-	-	-	-
2	469493	500	1	15-Jul-03	23-Jul-03	8	150	150	100	100	150
3	469093	400	3	15-Jul-03	23-Jul-03	8	160	180	100	50	100
4	469346	400	1	15-Jul-03	23-Jul-03	8	150	175	125	100	190
5	469191	500	3	16-Jul-03	21-Jul-03	5	360	390	300	300	280
6	469447	500	1	16-Jul-03	21-Jul-03	5	290	350	220	100	125
7	469125	400	2	16-Jul-03	21-Jul-03	5	180	250	200	150	200
8	469370	400	2	16-Jul-03	21-Jul-03	5	280	260	280	210	200
9	469261	690	1	16-Jul-03	21-Jul-03	5	200	200	100	60	80

Generally, those cars that had good gas retention also had good gas distribution. Retention of gas is expected to be a function of the individual cars and their sealing. Distribution of gas is expected to be a function of the load distribution, the number of addition points and the ability of the car to retain gas.

The number of addition points seems to affect the gas distribution somewhat. For the 5-day cars, two or three addition points resulted in a more even distribution of gas than with one addition point. The opposite effect was noted for the 8-day cars, however. The small number of data points makes it difficult to draw a firm conclusion regarding the relationship between the number of addition points and the gas distribution in each car.

6. Conclusions

Introduction of $ECO_2FUME^{®}$ fumigant gas into the headspace of the hopper cars proved to be effective. After 5 to 8 days of transit time, the gas was distributed fairly evenly in all cars, and all cars retained enough gas to maintain lethal concentrations of phosphine.

The addition rate of about 2 lbs. of $ECO_2FUME^{®}$ fumigant gas per minute was fast enough to keep the addition time to an acceptable 5 – 8 minutes per car, while allowing accurate dosing with a portable scale.

During addition, pressure increase in the headspace of the hopper car did not challenge the tape and plastic seal around the opening.

The number of addition points seems to be less important than the ability of the individual car to retain gas for good gas distribution. For the cars tested, gas retention and distribution indicated that a dose lower than the minimum 400 ppm that was used would still maintain acceptable levels within the hopper car.

Overall, the fumigation of hopper cars with $ECO_2FUME^{®}$ fumigant gas was safe, easy and effective. The end result compared favorably with the results from an identical car fumigated with metal phosphides. The customer has requested help with the design of a permanent, centrally installed system to add $ECO_2FUME^{®}$ fumigant gas to the hopper cars at the point of filling.