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AMBIENT VINYL CHLORIDE EXPOSURES FROM RESIDUAL VINYL CHLORIDE IN PVC RESINS AND COMPOUNDS

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ABSTRACT

Previously, 8.5 ppm (weight basis) residual vinyl chloride (RVCM) in resins and compounds was set as the upper limit to assure that workers not contact more than 0.5 ppm 8 hour time weighted average (volume basis) ambient vinyl chloride (AVCM) in breathing air. The 8.5 ppm RVCM was based on models which assumed instant dispersion of VCM from the source into the whole room. One model assumed a material balance on measured RVCM would account for the VCM in the air. It is the conclusion of this study that the assumptions were in error.

AVCM levels are not assured by RVCM alone, but are the joint responsibility of the supplier to control RVCM and the user to adequately ventilate.

The previous practice of controlling RVCM to <8.5 ppm with a ventilation rate of 5 air turn-overs per hour, does result in an AVCM level <0.5 ppm.

AVCM concentrations are higher in plumes than in the surrounding air. Thus the VCM is not uniformly distributed in the room.

Material balances showed that AVCM levels should have been significantly higher than were detected in the sealed lab with controlled ventilation. More than 90% of the RVCM that was lost from the resin during powder compounding had disappeared. One explanation is that the VCM reacted with residual catalyst in the resin, or stabilizers, or air, or another ingredients in the compound, to form a chemical not detected as VCM in the compound or the air.

Our new data indicate <0.5 AVCM is adequately met with existing commercial resins and compounds for processes including lab processing, commercial compounding, commercial processing, and warehousing. One exception was a warehouse situation where resins are normally stored at >8.5 ppm RVCM and action is required to reduce AVCM.

Laboratory powder mixing and extrusion in a room where the air turn-over was turned down to 1/hr, showed AVCM at 0.01 ppm.

Monitoring the oven lab during the fusion of plastisols gave widely varying AVCM results. Most Reiszner badge results were at or below the detectable limit. However, duplicate badge samples on the lab operator were 0.24 ppm AVCM, higher than the material balance predicted values, indicating the operator had been in a plume.

The AVCM level above a rail-car manway was tested just after opening and found to be non-detectable. The AVCM level inside the

car did exceed the 15 minute exposure ceiling level of 5 ppm. This indicates a need to warn about entering closed shipping containers before adequate ventilation.

Commercial compounding process monitoring showed 38 samples <0.5 AVCM and 1 sample >0.5 AVCM. The high reading, 1.08 ppm

AVCM, was on a packager operating a fork-lift and is suspected to be high because of hydrocarbon interference.

Commercial warehouses in Henry, and ALGC showed <0.5 ppm AVCM, however Pedricktown, which ages dispersion resins containing above 8.5 ppm RVCM, showed readings >0.5 ppm AVCM, a situation being corrected.

Air monitored by pumped charcoal tubes (OSHA acceptable) and by Reiszner badges was analyzed by headspace-gas chromatography. Residual vinyl chloride in resin, compound, and product was measured by direct injection- or headspace-gas chromatography. These methods have been shown to be accurate and precise under laboratory conditions. False negative readings for both air and PVC measurements would be unlikely. However, false positives could occur since other chemicals could elute with vinyl chloride in the gas chromatography analyses.

Most competitors label their resins with a VCM warning.

A summary of the experimental results is listed in the following tables.

LABORATORY OPERATIONS

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
NIOSH & Reiszner badge	area	2.5	1/93	1.0 air turn-overs/hour, no point source ventilation, 55 lbs/hr	103(1)	powder mixing	8 samples <0.01 to 0.01
Reiszner badge	personal	2.5	1/93	"	"	"	2 samples <0.01
"	area	0.25	1/93	In the sealed resin drum	"	storage	0.55
"	"	0.25	1/93	"	1.15	storage	1.5
NIOSH & Reiszner badge	area	2.5	1/93	1.0 air turnovers/hr, no point source ventilation, 2.9 lbs/hr	45(1)	sheet extrusion	8 samples <0.01
Reiszner badge	personal	2.5	1/93	"	"	"	2 samples <0.01 to 0.01
"	area	0.25	1/93	In sealed powder mix drum	"	storage	<0.01
"	area	3	1/93	1.0 air turn-overs/hour, no point source ventilation	102(1)	plastisol fusion	8 samples <0.01 to 0.04
"	personal	3	1/93	"	"	"	0.24

(1) RVCM was purposefully higher than normal in this study.

(3)

COMMERCIAL WAREHOUSES

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
Reiszner badge	2 area & 2 personal	8	2/93	-	some >10(2)	Henry Dispersion resin aging	4 samples 0.11 to 0.14
"	area	8	2/93	-	-	Avon Lake Bldg. 438 Warehouse	6 samples 0.02 to 0.11
"	"	8	2/93	-	-	Avon Lake Bldg. 452	4 samples 0.02 to 0.11
"	13 area & 2 personal	8	2/93	-	-	Avon Lake Bldg. 421	15 samples <0.25
"	"	8	2/93	-	some >10(2)	Pedricktown Warehouse and dispersion resin aging	15 samples <0.036 to 1.0 with 10 samples <0.5 & 5 samples >0.5(3)

(2) Aging to remove RVCM so later users do not need to monitor.
(3) Rectification is underway to reduce AVCM levels.

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COMMERCIAL BULK SHIPPING

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
hv meter	area	instant	92	Inside an unvented bulk rail car with lid just opened; operator exposure only if he sticks his head in the car[4].	1.4	unloading	2 readings 1.5 to 2.5
"	"	"	92	"	1.8	"	2 readings 1.5 to 2.0
"	"	"	92	"	1.3	"	2 readings 1.0 to 3.5
"	"	"	92	"	3.1	"	2 readings 3.5 to 4.0
"	"	"	92	"	0.03	"	0.0
"	"	"	92	"	3.0	"	2 readings 9 to 15

(4) AVCM outside the railcar manhole was not detectable.

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COMMERCIAL COMPOUNDING OPERATION

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
NIOSH & Reiszner badge	area	24	1/93	ALGC Bldg. 441, Buss and FCM operation 1.3 air turn-over/hr, point source ventilation.	8 ppm note[1]	ALGC Buss Rigid PVC compounding	9 samples <0.01 to 0.07
Reiszner badge	personal	24	1/93	"	"	" - weighman	0.04
"	"	24	1/93	"	"	" - powder mixer operator	0.05
"	"	24	1/93	"	"	" - operator	0.04
"	"	24	1/93	"	"	" - packager, fork lift operator	1.08 note[5]

(1) RVCM was purposefully higher than normal for this study.
(5) Suspected hydrocarbon interference to the VCM measurement.

COMMERCIAL COMPOUNDING OPERATION

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
Reiszner badge	personal	8	1/93	Louisville compounding	0.03	PVC compounding: stock change cleaner, control room, supervisor, rover, packager	10 samples <0.05 to 0.28
"	"	8	1/93	Henry compounding on FCM & mill	2.9	rigid PVC compounding, powder mixer, packager, operator	3 samples 0.02 to 0.05
"	"	8	1/93	Henry compounding on FCM & mill	0.38	rigid PVC compounding, operator	2 samples <0.01 to 0.14
"	"	8	1/93	Henry compounding on FCM & mill	3.6	"	0.16
"	"	8	1/93	Pedricktown compounding on FCM & mill	2.5	PVC compounding, operator, weighman, powder mixer	10 samples <0.01 to 0.02

COMMERCIAL VINYL PROCESSING

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
OSH	personal	0.5	1975	trailer just opened.	<1.0	unloading flexible pellet compound from trailer	2 samples <0.01
"	"	2	1975	-	<1.0	flexible profile extrusion, operator, packager	4 samples <0.01
"	"	1 to 4	1975	-	<1.0	rigid cellular powder extrusion, operator, material handler, mixer	3 samples <0.01
"	"	1 to 3	1975	-	1.0	flexible pellet extrusion, operator, lift driver	4 samples <0.01
"	"	1.5	1975	-	<1.0	flexible powder extrusion, mixer operator	2 samples <0.01
"	"	1.2	1975	just opening trailer.	35	opening & sampling truck	0.02
"	"	1 to 2	1975	-	<1.0	flexible powder extrusion, powder mixer, operator,	4 samples <0.02 to 0.40
"	"	0.25	1975	just opened trailer.	<1.0	rigid pellets, unloading	<0.01
"	"	3	1975	-	<1.0	rigid pellet extrusion, lift operator, operator	3 samples <0.01
"	"	0.25	1975	just opened railcar.	0.55	opening resin railcar	0.46
"	"	1	1975	-	0.55	rigid powder extrusion, mixer operator	2 samples <0.01 to 0.23
"	"	1 & 5	1975	-	0.05	rigid pellet extrusion, lift operator, operator	2 samples <0.01
"	"	3	1975	-	<1.0	flexible pellet extrusion, operator	2 samples <0.03 to <0.04
"	"	1	1975	-	<1.0	flexible pellet extrusion, operator, material handler	4 samples 0.06 to 0.31
"	"	0.5 to 4	1975	-	<1.0	flexible pellet extrusion, lift operator, operator	3 samples 0.04 to 0.07

INTRODUCTION

A statistical model for ambient vinyl chloride monomer (AVCM) in warehouse situations correlates this AVCM to residual vinyl chloride monomer (RVCM) content of the stored suspension PVC resins [1,2]. This model indicates that an RVCM less than 8.5 ppm is sufficient to assure an AVCM of less than 0.5 ppm (the OSHA action level for vinyl chloride). Critical assumptions are that the AVCM is uniformly and instantly distributed throughout the whole building and that the air turn-over is 0.6 times per hour.

A physical model for AVCM in PVC processing buildings calculates that at an RVCM less than 15 ppm, the AVCM would be less than 0.5 ppm [3]. This model assumes that the AVCM is uniformly and instantly distributed throughout the whole building and calculates that the air turn-over is at least five times per hour. It also assumes all VCM lost from the resin goes to the room air.

Neither of the above papers address dispersion resin storage nor processing.

Investigation of the variations in AVCM within a building or room shows that VCM is highly variable and is concentrated in plumes coming from the point source [4].

Measurements of AVCM in various commercial processes were made in the mid-1970s, however, few measurements were made where both RVCM and AVCM were known. When RVCM was below 1 ppm, personal monitored AVCM was always below 0.5 ppm [5].

EXPERIMENTAL

POWDER MIXING AND EXTRUSION IN THE ALTC LAB.

Since the initial experiments run with plant resins yielded no detectable AVCM, a second trial was run with pilot plant produced resin with very high levels of RVCM.

Suspension - Pilot plant resins typically have high porosities, which means that they strip easily and end up with low RVCM levels. Geon 110X334 is a low I.V., low porosity resin. The pilot plant recipe and stripping conditions were adjusted to produce a resin with high RVCM. Results are listed below.

LOT	RVCM (ppm)	weight (lb)
193-637-088	163	30
193-637-090	30	28
193-637-092	7	27
193-637-128	208	27
Average	103	

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A 6021 ft^3 room was ventilated at 1.0 air turn-over/hr. The exhaust was in the center of the room and the powder mixing in the corner. Geon 110X334 resin, specially made at 103 ppm RVCM and well above the normal production level, was Henshel mixed in a generic rigid PVC compound that contained 85% resin. The compound was mixed to 160°F, the lid opened and filler added, then continued mixing to 180°F. This compound was dropped to a cooler, cooled to 130°F, then dropped to a drum. The rate was 55 lbs/hr. Monitoring was done with both Reiszner Badges and carbon tube and pumps. Placement of monitoring was in several positions in order to try to find the plumes.

An 8928 ft^3 room was ventilated at 1.0 air turn-over/hr. The exhaust was in the center of the room and the Brabender extrusion in the corner. The above generic compound at 45 ppm RVCM, was extruded at 2.9 lbs/hr at a melt temperature of 400°F. Monitoring was done with both Reiszner Badges and carbon tube and pumps. Placement of monitoring was in several positions in order to try to find the plumes.

PLASTISOL MIXING AND FUSION IN THE ALTC LAB.

Plastisol #1 contained 67 PPM VCM.
Plastisol #2 contained 137 PPM VCM.

Plastisol Recipe - PHR

	#1	#2
Geon® 136, Lot P29N012		9998
Geon® 217, Lot H2B0708		1 2
DOP	57	57
ESO	3	3
Synpron 940	2	2

Fusion Conditions:
- Forced draft Blue-M oven
- 375 F for 5 minutes
- 100g plastisol in 9"X13" aluminum cake pans
- 3 pans in oven at one time
- Fused samples cut from slab and placed hot in a 4 oz. jar then sealed with electricians tape. Testing was done 3 days later.
- The fusion lab was exhausted at 1 air turn-over/hour.

COMMERCIAL COMPOUNDING ON ALGC Z-LINE.

The Geon Company commercial resin with the highest typical RVCM content is 110x377. This resin is currently produced at ALGCP. The polymerization is run at 82°C, which is close to the glass transition temperature. The resin has very low porosity and is very difficult to strip. In addition, this resin is used frequently on Z-line.

For the plant monitoring trial conducted in ALGCP, the resin plant made two lots of 110x377 with RVCM in the range of 7-10 ppm. The resin sat in a silo for several days before the monitoring test was run. RVCM data for the resin as used is listed below.

Date	1/26/93		1/27/93
Time	18:00	24:00	08:00
RVCM (ppm)	4.75	3.87	2.36

BULK RAIL MONITORING

Several rail-cars of resin were allowed to sit in the sun at Deer Park for several days. They were opened and immediately monitored with an h-nu meter for instantaneous levels of AVCM. The AVCM reading was taken in the center of the manway opening, just above the resin, and two feet above the manway. Weather conditions the day of the test were sunshine, 70°F, slight breeze.

COMMERCIAL WAREHOUSE MONITORING

Five Warehouses were selected for this study. Forty area and four personal monitorings were conducted, which was based on facility size and resin storage quantities. Warehouse storage included both suspensions and dispersion resins.

ANALYTICAL METHODS

Charcoal from badges and tubes was analyzed at Brecksville Research Center using a headspace-gas chromatography method[6]. This is the same method used for routine determination of AVCM in plants and warehouses.

For residual vinyl chloride analysis, resin was taken at the start of the Henschel mixing or plastisol preparation. Compound was taken as it came from the Henschel and, again, before extrusion; plastisol was sampled before curing. Sheet samples were taken at the exit of the extruder, and plastisol product was taken as it came from the oven. All samples were stored in completely filled and sealed glass jars. Most were analyzed within eight hours of being taken; if not, they were stored at 36°C until analyzed. Analysis was by gas chromatography using either a direct injection method[7] at ALTC for RVCM levels above 1 mg/kg (ppm) or a headspace method (Standard Test Procedure 1005H) at ALGC for levels below 1 mg/kg. Results for samples analyzed by both methods were comparable.

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DISCUSSION

CONTROL OF AVCM EXPOSURE

There are many factors affecting AVCM exposure. 1) The amount of VCM supplied to the process or the RVCM of the resin or compound. 2) The general ventilation or air turn-overs per hour, which removes AVCM. 3) Local point source ventilation, which removes the VCM before it can come into the room. 4) The rate of resin or compound processed. 5) The percentage of VCM lost from the resin or compound during processing (Many previous measurements indicate that about 60% of the RVCM is lost during processing [3], however lost VCM could be lost to the air or could be chemically reacted to non-VCM products.) 6) Worker nearness to the VCM source or plume. 7) Air volume in a room for the dilution scenario where the room air is well mixed.

Of the above factors, the RVCM is controlled by the Geon Company on resins and compound, but several other factors are controlled by the resin or compound processor. Thus it is a joint responsibility of The Geon Company and the user to control AVCM exposure.

MODELS FOR AVCM EXPOSURE

There are models for calculating AVCM exposure. One model uses statistically fitted data for warehouse exposure [1], however this model is only for suspension resins in a well mixed warehouse and is not applicable to melt processing. Uniformly mixed room models [3,4] were considered, however, most processes are not well mixed rooms and concentrated VCM in plumes often exist [4]. It was therefore decided to measure AVCM exposures under well controlled conditions to find the relationship of AVCM to RVCM in the resin or compound.

Some of the assumptions in the new model are:

$$\text{AVCM} \approx \frac{\text{(RVCM) (rate=lbs/hr)}}{\text{(ventilation turn-over/hour)}}$$

These above assumptions are the same for the old [2] and new models. Other assumptions which differ from the old model are:

OLD vs NEW MODEL COMPARISONS

	NEW MODEL	OLD MODEL [2]
VENTILATION	1 air turn-over/hour	5 air turn-overs/hour
AVCM	as measured	from a material balance
DILUTION	find AVCM concentrations in a plume	instant distribution of AVCM into the whole room
EXPOSURE	highest measurement in a plume	average calculated for the room

Scale-up of AVCM to manufacturing scale involves RVCM in the resin or compound and the rate in lbs/hr. Worst case ventilation is assumed to be 1 air turn-over per hour. We find that air in a powder mixing operation or extrusion operation is quite stuffy at 1/hour, a plastisol fusion operation is quite smoggy, therefore 1/hour is expected to be the worst case acceptable. It is important to make several AVCM measurements so as to be able to find concentrations in plumes.

POWDER MIXING PROCESS

AVCM results are listed in Table 1 for a powder mixing operation. The highest readings are 0.01 ppm above the mixer and 3 feet from the mixer. Since we started with an uncontaminated room, these measurements may be 60% of equilibrium values and were corrected for scale-up (see Figure 1.) A summary of results and scale-up follows:

POWDER MIXER/COOLER	LAB VALUES	SCALED COMMERCIAL			
AIR turn-over/hour	1	1			
RATE, lbs/hour	55	18,000 for a 1500 lb Henshel on a 5 minute cycle			
RVCM, ppm	103	1,	3,	8.5,	9
MEASURED AVCM, ppm	0.01				
CALCULATED AVCM, ppm		0.05,	0.2,	0.45,	0.5

This indicates that RVCM in resin could be as high as 9 ppm before the AVCM would be expected to reach 0.5 ppm in a commercial powder mixing process.

EXTRUSION PROCESS

AVCM results are listed in Table 1 for a sheet extrusion process. The highest readings are 0.01 ppm on the personal monitor of Juan Rodriguez. Since we started with an uncontaminated room an equilibrium consideration was made as was made for powder mixing. A summary of results and scale-up follows:

EXTRUSION	LAB VALUES	SCALED COMMERCIAL			
AIR turn-over/hour	1	1			
RATE, lbs/hour	2.9	1500 for a siding extrusion			
Compound RVCM, ppm	45	1,	2.6,	3,	8.5
MEASURED AVCM, ppm	0.01				
CALCULATED AVCM, ppm		0.2,	0.5,	0.6,	1.6

This indicates that RVCM in compound could be as high as about 3 ppm before the AVCM would be expected to reach 0.5 ppm in a commercial extrusion process. This also corresponds to a starting resin RVCM of 6 ppm.

PLASTISOL FUSION IN THE LAB.

Production samples of Geon 217 blending resin and Geon 136 dispersion were chosen to make the plastisol. In order to have sufficient quantities of VCM present in the plastisol to produce measurable AVCM levels, an artificially high RVCM Geon 217 sample was prepared. The 217 had 12,450 PPM of vinyl chloride monomer. Two plastisols were made, the first contained 67 PPM RVCM and the second 137 PPM RVCM.

The plastisols were fused in aluminum cake pans at 375 F for 5 minutes in a standard Blue-M oven. Each pan contained 100g plastisol. 1900g of plastisol was fused each hour. One oven was used with about 3 pans being fused at a time. Plastisol #1 @ 67 PPM RVCM was fused during the first hour and plastisol #2 @ 137 PPM RVCM during the second hour.

Duplicate Reiszner static badges were placed in locations near the oven door, in the oven exhaust hood, on the operator, on the floor and in the room corners. The exhaust hood was dampened such that there was only 1 air change per hour in the room. The lab had a volume of approximately 6300 cubic feet.

The fused slabs from plastisol #1 were tested at 30 PPM RVCM and the #2 slabs at 79 PPM. The area was monitored during the 2 hours of actual fusing of plastisol, plus 30 minutes after fusion was completed. Based on air flow rates and plastisol RVCM vs slab RVCM, and assuming that all the VCM went into the room, then the average AVCM reading for the 2.5 hour period should have been 0.084 PPM on a volume basis by material balance.

The duplicate lab operator samples measured 0.20 PPM. The monitor on the floor measured 0.04 PPM. All the other monitors tested at 0.01 PPM or less. The H-NU meter registered 0 to 5 PPM at various locations in the room. High readings were noted near the stack of fused slabs.

This lab data was scaled to a rotocaster at 130 lbs/hr and is summarized in the following table.

PLASTISOL FUSION	LAB VALUES	SCALED COMMERCIAL
AIR turn-over/hour	1	1
RATE, lbs/hour	2.6	130 for a rotocaster
Compound RVCM, ppm	102	1, 2.6, 3, 8.5
MEASURED AVCM, ppm	0.24	
CALCULATED AVCM, ppm		0.2, 0.5, 0.6, 1.6

BULK CONTAINER OPENING AND SHORT TERM EXPOSURE

One area of concern for AVCM exposure was the opening of PVC rail-car manways. RVCM in the resin could be released as the rail-car sits in the sun, resulting in a "blast" of air high in AVCM reaching an operator as he opens a manway on the car.

Several rail-cars of resin were allowed to sit in the sun at Deer Park for several days. They were opened and immediately monitored with an h-nu meter for instantaneous levels of AVCM. The AVCM reading was taken in the center of the manway opening, just above the resin, and two feet above the manway. Weather conditions the day of the test were sunshine, 70°F, slight breeze.

Readings at the manway level and just above the resin were the same. No RVCM was detected two feet above the manway. Results are listed on the next page.

Lot#	Certificate of Analysis RVCM (ppm)	RVCM reading, ppm Compartment	at manway	2' above
BFGX1339	1.42	B	2.5	0
		BC	1.5	0
ACFX55986	1.81	B	1.5	0
		BC	2.0	0
BFGX1582	1.27	A	1.0	0
		AC	3.5	0
BFGX1385	3.13	A	4.0	0
		AC	3.5	0
BFGX1228	0.03	B	0	0
(x500)		BC	0	0
BFGX1018	3.01	B	9	0
		BC	15	0

AVCM levels at any point above the manway opening on a rail-car were consistently zero. As long as operators do not place their heads inside the manway, they should not be exposed to any measurable level of AVCM. If someone puts his head inside the rail-car, he could be exposed to an AVCM level above the 5ppm ceiling for 15 minute exposure. This would be a violation of the OSHA confined space entry rule, so this is not something that should ever occur.

COMMERCIAL COMPOUNDING

Building 441, ALGC Compound East was selected as the test location. This PVC compounding facility has two independent production lines consisting of a Farrel Continuous Mixing (FCM) operation and a Buss Extrusion line. The exposure area around the FCM was chosen for this study.

The air exchange rate in B/441 was approximately 1.3/hr. Major ventilation equipment included: mill hood exhaust, RS to GS screw, GS outlet, pelletizer and strip tank exhaust. The building size is approximately 38,000 FT^2 on floor level one.

The sample duration selected for this study was 24 hours. During this time, 87241 Black and 87371 was produced using 110x377 resins stored in silo 202. Certificate of analysis RVCM was 8ppm for the PVC resin. An RVCM was also run on a silo sample prior to compounding. That result was 4ppm.

A test area audit was conducted prior to the study. Based on projected emissions source points, (16) area locations and (4) personnel monitorings were selected. The two sampling methods were as follows:

1)
Area monitoring using a Dupont model 2500 pump with SKC 6x70 or 10x110 charcoal tubes. Established flow rates of 45cc/minutes for eight hour and 500 cc/minute for twenty-four hour monitorings.

2)
Area and personnel monitoring using a Reiszner "Mini-Monitor" passive docimeter badge. Device weight of 35 grams plus 1.35 g of unexposed activated charcoal granules.

ALGC Plant Monitoring
Buss Line

LOCATION	# OF SAMPLES	RESULT (PPM)
1. Buss Line 1st Floor	9	<.01 - 0.006
2. Weighman	1	.04
3. Henschel Operator	1	.05
4. Line Operator	1	.04
5. Packager	1	1.08
6. Mill Area	3	.05
7. Z Line Henschel	1	<.01
8. Henschel Feed Hopper	1	.03
9. Pellet Cooling	1	.01
10. 4th Floor Resin Station	1	<.06

Also monitored was Louisville, Pedricktown mill line, and Henry mill line. These results are summarized in the following table.

COMMERCIAL COMPOUNDING OPERATION

SAMPLING METHOD	TYPE MONITOR	DURATION hours	TEST DATE	ENVIRONMENTAL CONDITIONS	RVCM ppm	OPERATION	AVCM, ppm
Reiszner badge	personal	8	1/93	Louisville compounding	0.03	PVC compounding: stock change cleaner, control room, supervisor, rover, packager	10 samples <0.05 to 0.28
"	"	8	1/93	Henry compounding on FCM & mill	2.9	rigid PVC compounding, powder mixer, packager, operator	3 samples 0.02 to 0.05
"	"	8	1/93	Henry compounding on FCM & mill	0.38	rigid PVC compounding, operator	2 samples <0.01 to 0.14
"	"	8	1/93	Henry compounding on FCM & mill	3.6	"	0.16
"	"	8	1/93	Pedricktown compounding on FCM & mill	2.5	PVC compounding, operator, weighman, powder mixer	10 samples <0.01 to 0.02

COMMERCIAL WAREHOUSE

Five Warehouses were selected for this study. Forty area and four personal monitorings were conducted, which was based on facility size and resin storage quantities. Warehouse storage included both suspensions and dispersion resins. Please note that 5 results at Pedricktown were above the section limit for Vinyl Chloride. Appropriate plant follow-up is in progress as of this writing.

Warehouse Results

LOCATION	# OF SAMPLES	RESULTS (PPM)
1. Henry B/735	4	0.11 - 0.14
2. Avon Lake B/438	6	<.02 - .11
3. Avon Lake B/452	4	<.02 - .11
4. Avon Lake B/421	15	<.25
5. Pedricktown Main Warehouse	15	<.036 - 1.0
		5 results >.5 ppm*

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* Appropriate plant follow-up is in progress as of this writing.

MATERIAL BALANCE

A material balance was done for the low air exchange rate experiments run in ALTC using a CSTR (continuous stirred tank reactor) model. The model assumes instantaneous and complete mixing of any VCM released from the compounding process with the air in the room.

The mathematical equations for powder compounding of the suspension resin and for curing of the plastisol are listed in the Appendix.

For powder compounding, the material balance shows that there should have been a significant level of AVCM in the room. The average level throughout the room for the two hour test would have been about 1.7 ppm AVCM.

Since we know that the well-mixed model does not accurately model compounding processes, we can apply the results of the calculations in a qualitative manner to the plume theory. Any badge near the Henschel mixer should have read an AVCM level significantly higher than 1.7 ppm AVCM. However, no reading near

1 ppm was recorded. The RVCM that disappeared from the resin in the compounding process had to go somewhere. An explanation, based on the data we have, is that the RVCM reacts with residual resin catalyst, stabilizers or other ingredients to form something not detected as RVCM in the compound or AVCM in the air. The data seems to indicate that at least 90% of the RVCM simply reacts in this manner.

The analysis of the material balance for dispersion Plastisol curing follows the same pattern. According to the well-mixed model, there should have been an average of about 0.16 ppm AVCM throughout the room over the course of the 2.5 hour experiment. The actual results included one reading of 0.24 ppm AVCM, which must have been in a plume.

MANUFACTURING CONCERNS

Tables 1 and 2 are a summary of the resin records used in the RVCM study to determine the effect that changes in RVCM specifications would have on current BFG production. The focus was on the poundage that would be effected by any specification changes. In some instances the actual poundage estimates for the given period analyzed were not available, however, the size of the sample for which poundage figures were available was large enough that is doubtful these missing poundage numbers would greatly influence the final estimates given below. Indeed, during the early phases of this analysis, with one quarter of the data presented in the final analysis available, the percentages that were being computed were quite close to the numbers shown below. The following tables can be summarized as follows:

I. The current data analysis is based on a TOTAL production of 1316 MM mass and suspension resin pounds.

A. If the RVCM threshold limit is reduced to 5 ppm and manufacturing practices remain the same, the amount of product having levels above this value would increase by 3.5%.

1. Since bag-by-bag selection of material is not economical, any resin with production pounds in excess of 5 ppm would be affected. Thus the TOTAL poundage affected would represent 55.6% of the current poundage.

In a similar fashion

B. If the RVCM threshold limit is reduced to 3 ppm and manufacturing practices remain the same, the amount of product having levels above this value would increase by 7%.

1. Since bag-by-bag selection of material is not economical, any resin with production pounds in excess of 3 ppm would be affected. Thus the TOTAL poundage affected would represent 64.5% of the current poundage.

and

C. If the RVCM threshold limit is reduced to 1 ppm and manufacturing practices remain the same, the amount of product having levels above this value would increase by 29%.

1. Since bag-by-bag selection of materials is not economical, any resin with production pounds in excess of 1 ppm would be affected. Thus the TOTAL poundage affected would represent 78% of the current poundage.

RVCM SUMMARY FOR 5 AND 3 PPM RVCM

PLANT	RESIN	Records	MEAN	MEDIAN	MIN	MAX	Specs (ppm)	Total Lbs (millions)	Est.Total Lbs (millions) >5ppm	Est.Total Lbs (millions) >3ppm
ALGC	101X9	12	155.08	0.20	0.01	1857.00		1.42	0.12	0.12
ALGC	102EPF5	365	0.03	0.02	0.00	2.73		32.69	0.00	0.00
ALGC	110X334	460	1.36	0.59	0.01	47.41		43.50	1.70	3.69
ALGC	110X377	588	2.54	1.46	0.06	172.55	0-2	46.18	2.43	5.97
ALGC	110X388	20	0.04	0.01	0.00	0.62	0-2	2.08	0.00	0.00
ALGC	110X394	8	0.01	0.01	0.00	0.01	0-2	0.79	0.00	0.00
ALGC	110X412	43	0.01	0.01	0.00	0.10	0-8.5	3.94	0.00	0.00
ALGC	110X432	59	0.03	0.01	0.00	1.19		5.45	0.00	0.00
ALGC	110X450	121	0.05	0.04	0.01	0.52		11.27	0.00	0.00
ALGC	G-3400	44	0.36	0.05	0.00	4.84	0-2	2.14	0.00	0.05
DPARK	102EPZ	131	0.03	0.02	0.00	0.20	0-8.5	19.45	0.00	0.00
DPARK	X426LD	126	1.07	0.70	0.01	6.47	0-8.5	12.59	0.20	0.90
DPARK	X4300	639	1.16	0.56	0.00	35.70		276.53	6.92	15.58
DPARK	X450FY	175	0.06	0.03	0.00	1.79	0-1	22.76	0.00	0.00
DPARK	X470W	157	0.07	0.05	0.00	0.51	0-8.5	22.72	0.00	0.00
DPARK	X471W	4	0.03	0.02	0.00	0.06		0.52	0.00	0.00
DPARK	X500FB	206	0.11	0.05	0.01	10.82		30.76	0.15	0.15
DPARK	X500FG	88	0.05	0.02	0.00	0.54	0-.99	11.42	0.00	0.00
HENRY	123A	63	5.14	4.60	0.30	11.40		2.58	1.19	1.84
HENRY	170X100	1	0.48	0.48	0.48	0.48		.	0.00	0.00
HENRY	171	171	1.41	0.66	0.00	8.50		6.68	0.39	0.90
HENRY	171B	19	3.38	2.21	0.33	11.55		.	.	.
HENRY	173	199	0.99	0.58	0.00	7.58		0.18	0.00	0.01
HENRY	178	344	1.55	0.86	0.00	8.50		15.07	0.96	2.45
HENRY	178B	50	4.19	2.38	0.08	60.79		1.80	0.40	0.72
HENRY	179	101	0.74	0.46	0.00	6.76		4.41	0.13	0.17
HENRY	190X100	1	0.95	0.35	0.95	0.95		.	0.00	0.00
HENRY	193	1	3.93	3.93	3.93	3.93		.	0.00	.
HENRY	198	70	1.98	1.78	0.05	6.13		2.94	0.17	0.59
HENRY	199	63	1.94	1.58	0.05	8.50		2.72	0.17	0.43
HENRY	213	177	3.41	1.95	0.00	21.23		6.53	1.33	2.58
HENRY	217	63	30.13	8.00	0.00	480.46		1.92	1.40	1.74
HENRY	250X100	16	0.11	0.12	0.07	0.17		.	0.00	0.00
LVILLE	110X440	19	4.82	3.75	0.40	14.14		2.80	1.18	1.62
LVILLE	F-76TRD	21	0.09	0.07	0.00	0.40		116.00	0.00	0.00
LVILLE	G-26D	13	0.16	0.02	0.00	1.62	0-8.5	10.00	0.00	0.00
LVILLE	G-27D	73	0.68	0.20	0.00	4.31	0-8.5	120.00	0.00	9.86
LVILLE	G-30D	35	0.03	0.03	0.00	0.16	0-8.5	38.00	0.00	0.00
LVILLE	G-37D	71	1.61	1.16	0.00	7.73	0-8.5	23.00	1.62	2.92
LVILLE	G27LIVD	27	0.18	0.15	0.00	0.50	0-8.5	48.00	0.00	0.00
NIAGARA	100C13	82	1.52	1.19	0.16	9.76	0-10	19.02	0.46	1.39
NIAGARA	110X334	149	3.53	1.28	0.00	48.74	0-2	23.69	3.02	5.09
NIAGARA	110X380	852	0.88	0.68	0.00	13.29	0-8.5	117.00	0.96	2.06
NIAGARA	110X429	49	0.04	0.00	0.00	0.45	0-8.5	.	0.00	0.00
NIAGARA	GEON30N	145	0.14	0.12	0.00	1.21	0-8.5	19.70	0.00	0.00
NIAGARA	GEON30W	325	0.09	0.00	0.00	2.70	0-8.5	78.23	0.00	0.00
PTOWN	110X426G	623	0.36	0.17	0.02	7.81	0-8.5	.	.	.
PTOWN	110X433G	76	0.18	0.09	0.02	1.23	0-8.5	.	0.00	0.00
PTOWN	110X450F	447	0.08	0.05	0.01	0.93	0-1	.	0.00	0.00
PTOWN	121	295	3.19	1.21	0.00	34.77		14.17	2.69	4.23
PTOWN	121A	130	0.88	0.43	0.01	7.26		4.84	0.07	0.26
PTOWN	121AR	164	0.39	0.30	0.00	1.94		6.11	0.00	0.00
PTOWN	121X10	358	0.58	0.26	0.01	5.90		10.28	0.03	0.17
PTOWN	121X10B	23	0.46	0.30	0.01	1.78		.	0.00	0.00

CONT'RVCM SUMMARY FOR 5 AND 3 PPM RVCM

PLANT	RESIN	Records	MEAN	MEDIAN	MIN	MAX	Specs (ppm)	Total Lbs (millions)	Est.Total Lbs (millions) >5ppm	Est.Total Lbs (millions) >3ppm
PTOWN	123A	452	6.86	2.84	0.00	458.00		6.64	2.31	3.28
PTOWN	124	102	6.86	4.36	0.00	52.06		.	.	.
PTOWN	124A	129	3.25	2.46	0.00	14.49		2.40	0.63	0.99
PTOWN	125A	262	6.19	3.07	0.00	283.70		7.22	2.73	3.67
PTOWN	136	90	5.03	4.36	0.00	17.88		3.41	1.63	2.08
PTOWN	137	152	0.35	0.33	0.00	1.35		3.23	0.00	0.00
PTOWN	138	478	6.17	2.86	0.00	373.00		15.91	4.76	7.72
PTOWN	180X10	285	3.75	2.22	0.00	92.00		14.91	4.03	6.43
PTOWN	180X5	202	2.51	1.00	0.00	20.68		7.95	1.34	2.09
PTOWN	180X7	38	2.42	2.09	0.00	14.02		1.12	0.15	0.27
PTOWN	184	21	8.64	3.41	0.00	33.30		0.73	0.31	0.42
PTOWN	186A	48	4.85	2.49	0.00	42.97		1.36	0.43	0.62
PTOWN	GEON30	405	0.08	0.05	0.01	0.98	0-8.5	.	0.00	0.00
PTOWN	GEON31	140	0.43	0.05	0.01	50.17	0-8.5	.	.	.
SCOT	1267	1073	15.19	1.00	0.07	1254.37		.	.	.
SCOT	1467	141	3.96	2.80	0.25	72.83		.	.	.
SCOT	G86	72	1.63	1.60	0.20	5.44		.	.	.

RVCM SUMMARY FOR 1 PPM ~M

PLANT	RESIN	Records	MEAN	MEDIAN	MIN	MAX	Specs (ppm)	% Total Records >1ppm	Total Lbs (millions)	Est.Total Lbs (millions) >1ppm
ALGC	101X9	12	155.08	0.20	0.01	1857.00		25.00	1.42	0.36
ALGC	102EPF5	365	0.03	0.02	0.00	2.73		0.27	32.69	0.09
ALGC	110X334	460	1.36	0.59	0.01	47.41		35.87	43.50	15.60
ALGC	110X377	588	2.54	1.46	0.06	172.55	0-2	68.71	46.18	31.73
ALGC	110X388	20	0.04	0.01	0.00	0.62	0-2	0.00	2.08	0.00
ALGC	110X394	8	0.01	0.01	0.00	0.01	0-2	0.00	0.79	0.00
ALGC	110X412	43	0.01	0.01	0.00	0.10	0-8.5	0.00	3.94	0.00
ALGC	110X432	59	0.03	0.01	0.00	1.19		1.69	5.45	0.09
ALGC	110X450	121	0.05	0.04	0.01	0.52		0.00	11.27	0.00
ALGC	G-3400	44	0.36	0.05	0.00	4.84	0-2	11.36	2.14	0.24
DPARK	102EPZ	131	0.03	0.02	0.00	0.20	0-8.5	0.00	19.45	0.00
DPARK	X426LD	126	1.07	0.70	0.01	6.47	0-8.5	34.13	12.59	4.30
DPARK	X4300	639	1.16	0.56	0.00	35.70		26.76	276.53	74.00
DPARK	X450FY	175	0.06	0.03	0.00	1.79	0-1	1.14	22.76	0.26
DPARK	X470W	157	0.07	0.05	0.00	0.51	0-8.5	0.00	22.72	0.00
DPARK	X471W	4	0.03	0.02	0.00	0.06		0.00	0.52	0.00
DPARK	X500FB	206	0.11	0.05	0.01	10.82		0.49	30.76	0.15
DPARK	X500FG	88	0.05	0.02	0.00	0.54	0-.99	0.00	11.42	0.00
HENRY	123A	63	5.14	4.60	0.30	11.40		95.24	2.58	2.46
HENRY	170X100	1	0.48	0.48	0.48	0.48		0.00	.	0.00
HENRY	171	171	1.41	0.66	0.00	8.50		39.77	6.68	2.66
HENRY	171B	19	3.38	2.21	0.33	11.55		63.16	.	.
HENRY	173	199	0.99	0.58	0.00	7.58		32.16	0.18	0.06
HENRY	178	344	1.55	0.86	0.00	8.50		45.06	15.07	6.79
HENRY	178B	50	4.19	2.38	0.08	60.79		76.00	1.80	1.37
HENRY	179	101	0.74	0.46	0.00	6.76		19.80	4.41	0.87
HENRY	190X100	1	0.95	0.95	0.95	0.95		0.00	.	0.00
HENRY	193	1	3.93	3.93	3.93	3.93		100.0	.	.
HENRY	198	70	1.98	1.78	0.05	6.13		68.57	2.94	2.02
HENRY	199	63	1.94	1.58	0.05	8.50		69.84	2.72	1.90
HENRY	213	177	3.41	1.95	0.00	21.23		67.80	6.53	4.43
HENRY	217	63	30.13	8.00	0.00	480.46		98.41	1.92	1.89
HENRY	250X100	16	0.11	0.12	0.07	0.17		0.00	.	0.00
LVILLE	110X440	19	4.82	3.75	0.40	14.14		73.68	2.80	2.06
LVILLE	F-76TRD	21	0.09	0.07	0.00	0.40		0.00	116.00	0.00
LVILLE	G-26D	13	0.16	0.02	0.00	1.62	0-8.5	7.69	10.00	0.77
LVILLE	G-27D	73	0.68	0.20	0.00	4.31	0-8.5	16.44	120.00	19.73
LVILLE	G-30D	35	0.03	0.03	0.00	0.16	0-8.5	0.00	38.00	0.00
LVILLE	G-37D	71	1.61	1.16	0.00	7.73	0-8.5	53.52	23.00	12.31
LVILLE	G27LIVD	27	0.18	0.15	0.00	0.50	0-8.5	0.00	48.00	0.00
NIAGARA	100C13	82	1.52	1.19	0.16	9.76	0-10	60.98	19.02	11.60
NIAGARA	110X334	149	3.53	1.28	0.00	48.74	0-2	59.73	23.69	14.15
NIAGARA	110X380	852	0.88	0.68	0.00	13.29	0-8.5	26.64	117.00	31.17
NIAGARA	110X429	49	0.04	0.00	0.00	0.45	0-8.5	0.00	.	0.00
NIAGARA	GEON30N	145	0.14	0.12	0.00	1.21	0-8.5	0.69	19.70	0.14
NIAGARA	GEON30W	325	0.09	0.00	0.00	2.70	0-8.5	1.54	78.23	1.20
PTOWN	110X426G	623	0.36	0.17	0.02	7.81	0-8.5	6.10	.	.
PTOWN	110X433G	76	0.18	0.09	0.02	1.23	0-8.5	1.32	.	.
PTOWN	110X450F	447	0.08	0.05	0.01	0.93	0-1	0.00	.	0.00
PTOWN	121	295	3.19	1.21	0.00	34.77		54.92	14.17	7.78
PTOWN	121A	130	0.88	0.43	0.01	7.26		29.23	4.84	1.41
PTOWN	121AR	164	0.39	0.30	0.00	1.94		6.71	6.11	0.41
PTOWN	121X10	358	0.58	0.26	0.01	5.90		19.83	10.28	2.04
PTOWN	121X10B	23	0.46	0.30	0.01	1.78		13.04	.	.

CONT'RVCM SUMMARY FOR 1 PPM RVCM

PLANT	RESIN	Records	MEAN	MEDIAN	MIN	MAX	Specs (ppm)	% Total Records >1ppm	Total Lbs (millions)	Est.Total Lbs (millions) >1ppm
PTOWN	123A	452	6.86	2.84	0.00	458.00		73.23	6.64	4.86
PTOWN	124	102	6.86	4.36	0.00	52.06		65.69	.	.
PTOWN	124A	129	3.25	2.46	0.00	14.49		64.34	2.40	1.54
PTOWN	125A	262	6.19	3.07	0.00	283.70		70.61	7.22	5.10
PTOWN	136	90	5.03	4.36	0.00	17.88		75.56	3.41	2.58
PTOWN	137	152	0.35	0.33	0.00	1.35		1.97	3.23	0.06
PTOWN	138	478	6.17	2.86	0.00	373.00		74.90	15.91	11.92
PTOWN	180X10	285	3.75	2.22	0.00	92.00		69.12	14.91	10.31
PTOWN	180X5	202	2.51	1.00	0.00	20.68		50.00	7.95	3.98
PTOWN	180X7	38	2.42	2.09	0.00	14.02		60.53	1.12	0.68
PTOWN	184	21	8.64	3.41	0.00	33.30		61.90	0.73	0.45
PTOWN	186A	48	4.85	2.49	0.00	42.97		60.42	1.36	0.82
PTOWN	GEON30	405	0.08	0.05	0.01	0.98	0-8.5	0.00	.	0.00
PTOWN	GEON31	140	0.43	0.05	0.01	50.17	0-8.5	0.71	.	.
SCOT	1267	1073	15.19	1.00	0.07	1254.37		48.37	.	.
SCOT	1467	141	3.96	2.80	0.25	72.83		90.78	.	.
SCOT	G86	72	1.63	1.60	0.20	5.44		84.72	.	.

[illegible]

ANALYTICAL RELIABILITY

Vinyl chloride in the air is absorbed by charcoal in pumped tubes or in Reiszner badges; pumped tubes are approved by OSHA for air sampling. The charcoal is then removed and analyzed by headspace-gas chromatography. The precision and accuracy of the combination of air sampling and GC analysis has been studied earlier [9,10] "Recoveries of vinyl chloride by the Reiszner Badge compare favorably with results via carbon tube sampling. (Recovery=badge result/tube result expressed as per cent.) In addition, the precision of testing expressed by the coefficient of variation (standard deviation/average) looks good, relative to OSHA requirements." "OSHA requirements for combined precision and accuracy are easily met at all concentrations, despite the tendency for Reiszner results to be slightly higher at very low monomer levels. The following 95% confidence limits were determined for the Badge."

VCM Range ppm	Observed 95% limits	Allowed 95% limits
less than 0.5	7.8% less than to 36.4% greater than the "true" value	Plus or minus 50% of "true" value
0.5 to 10	1.9% less than to 17.5% greater than "true" value	Plus or minus 35% of "true" value
greater than 1.0 ppm	7.7% less than to 10.3% greater than "true" value	Plus or minus 25% of "true" value

These results were based on tubes and badges prepared in the laboratory under controlled conditions. Extensive testing under actual plant conditions showed much poorer precision for both badges and tubes (see reference 9 for complete details). However, this probably indicated an actual variability of analyte concentration in the air. Similar variability was seen in a study done by the University of Utah Research Institute [11]: "Comparative measurements of organic vapors with active (pumped charcoal adsorption tubes) and passive (diffusion) monitors showed good agreement in steady-state laboratory chamber tests but considerable discrepancies in field trails on painters, in which the monitors were worn on opposite labels under fluctuating conditions of vapor concentrations and air movement." "Continuous recordings by an I.R. gas analyzer of air samples drawn from the left and right lapels of a painter working under simulated field conditions showed large differences in concentration corresponding to the differences found between monitors." It is important to note that this variability occurred with the pumped tubes, which are accepted by OSHA for air monitoring, as well as with the Reiszner badges.

Area monitoring provided additional confirmation that variability of the personnel monitoring results was due to variability of the air and not to problems with the monitors. In these tests the monitors and air were stationary; for the personnel monitoring tests, they were in motion. Sixteen badges were attached to a rack and exposed in building 461 of the Avon Lake General Chemical Plant. This was done eleven times. The mean concentration ranged from 0.34 to 4.94 ppm and the coefficient of variation (relative standard deviation) ranged from 5.2 to 10.0%3 , which are similar to those for the laboratory tests.

The relative standard deviation of Standard Test Procedure 1005H for residual vinyl chloride monomer in PVC is 2.63% at 2.09 ppm and 4.16% at 62.66 ppm[12]. The precision of the direct injection analysis for vinyl chloride has not been determined but the relative standard deviation is expected to be less than 5% for levels above 10 ppm.

FALSE READINGS

There has been a concern about false positive and false negative results for both air and PVC testing. False positives are possible for both analyses since gas chromatography can not identify components. Therefore, if one or more other components elute with, or instead of, vinyl chloride, the peak area and concentration will be artificially high. False negatives are less likely for analysis of PVC and the charcoal in badges and tubes. However, the tubes and badges may not accurately sample the air to which they are exposed. Results, discussed above, show this to be unlikely.

LABELING PRACTICES IN THE U.S.

The following table summarizes the practices of Geon competitors. Many label all resins.

PVC LABELING IN U.S.

Company	Labeling Policy	Comments
Borden (BCP)	All Blending & Susp. Resins are labeled. Signal label not used in Canada.	Lawyers overruled rest of company. Even bottle resin is labeled.
Carbide	No warnings in MSDS or labels because RVC <10ppm.	Policy partially based on BFG's 8.5ppm limit
GG	Emulsion & Disp. resins labeled per "OSHA Std" language. Susp. resin labeled on hopper cars on tag, so hatch is ventilated first. No labels on compounds.	Revising policy and labels with help from industrial hygienist.
mosa		May move to labeling disp. and susp. resin (and maybe compound) in a very conservative fashion due to USEPA citations for VCM releases.
Oxy	Bottle resin not labeled ("mother's milk"). All other resins labeled. Compounds not labeled. "Dust & Fines & VCM can be hazardous at processing temperatures" Not haz. mtl. under Sara III.	Warning label language is not OSHA language. Policy driven by lawyers. Monitoring 2 years ago showed 5 ppm RVCM in resin gives 99% confidence of being below OSHA limits. Can talk to Oxy's people & inspect their data. Oxy monitors customer plants on demand and always finds AVCM ND.
Vista	Label all resin and compound.	Driven by responsible care and liability issues. VCM Warning OSHA Std.

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4. A. G. Andreopoulos, A. N. Karayannis, N. C. Markatos, Trans IChemE, 70 Part B, 75 (May 1992).

5. R. Kruszynski, "OSHA - NIOSH - APA, 2nd Quarter 1975 Update", Inter-Organization Correspondence, July 8, 1975. (Appendix).

6. Born, J.W.; "Method of Test for Vinyl Chloride Monomer in Air Using Activated Charcoal Monitors and Headspace-Gas Chromatographic Analysis"; BFGTD; January 30, 1986.

7. Samples were dissolved in tetrahydrofuran (½ gram in 10mL); 1uL of the solution was injected into a Hewlett Packard 5890A GC equipped with a flame ionization detector and a 10 foot by ¼ inch (2mm ID) glass column packed with 1% SP1000 on Carbopack B. A response factor was determined by standard addition of VCM to the PVC solutions.

8. F.M. Galloway, "Diffusion Modeling of VCM Concentrations in Air",BFG Inter-Organization Correspondence, Jan. 15, 1993. (appendix).

9. Born, J.W.; "Evaluation of the Reiszner MiniMonitor Charcoal Badge as a VCM Monitor - Part II"; Status Report; August 12, 1985.

10. Fairlie, A.M.; "Evaluation of the Reiszner MiniMonitor Charcoal Badge as a VCM Monitor - Validation"; BFGTR; November 18, 1985.

11. Division, University of Utah Research Institute, December, 1981.

12. Environmental Reporter, PP 120:1088 through 120:1091, October 7, 1988, EPA Method 107.

APPENDIX

BFGoodrich INTER-ORGANIZATION CORRESPONDENCE

TO: J.Summers | FIELD POINT OR DEPT & BLDG NO | DATE YOUR LETTER

FROM: F.M.Galloway | FIELD POINT OR DEPT & BLDG NO: ALTC PSC-N | DATE THIS LETTER: 1/15/93

SUBJECT

Diffusion Modeling of VCM Concentrations in Air

This is to summarize my ideas concerning the possibilities of modeling the concentration of VCM in the air within compartments once it has been released from PVC during processing.

SUMMARY

The well-mixed model is a reasonable approach toward establishing general guidelines for VCM levels. Modeling of warm plumes containing higher VCM concentrations from some points of a process could be done, but would be rather specific from one example to the next. Handling these with local forced convection (e.g., suck up the plume into an exhaust) is an obvious answer anyway. Computational fluid dynamics would be appropriate only in an extreme case. If, in the process of data collection, some anomalies turn up, I would be happy to help try to interpret them in terms of some of these ideas, but I do not see any approach toward a general model, other than the well-mixed one, that would be of any value at this time.

DISCUSSION

The simplest approach is to assume that within a given compartment the concentration is uniform; i.e., the air is well mixed. I understand that your current approach is based on this assumption. There is a lot of justification for this assumption in most practical situations. I have reviewed the work of Gary Huvard, for example, (G.S.Huvard, "Tremco's Mono® Acrylic Sealant: Modeling the Release of Controlled Exposure Monomers and Solvent in Indoor Environments", Corporate Research Report, February 9, 1983), in which he modeled the air concentrations in rooms of solvents and monomers released from caulking material. He used the well-mixed assumption, citing several HVAC sources for support. He was primarily concerned with domestic environments where typically every effort is made to minimize air exchanges with the surroundings. In most manufacturing environments, effort is made to promote air exchange with the surrounding, thus leading to more forced convection currents and making the well-mixed assumption even more justifiable.

The next level of complexity would be to define sub-compartments, or zones, within a given total compartment, which are regions that are partially isolated from each other but still have some opportunity for air exchange. Examples of this are the so-called "zone models" used in modeling transport of smoke from fires in multi-compartment buildings, where typically each compartment, or room, has two zones; an upper hot layer and a lower cool layer. The well-mixed assumption is made for each layer, but mixing between the layers is assumed to be negligible (except for some well defined conditions). The volume of gas in each zone in a given compartment is computed from models for fire-driven (buoyant) flows. There is a slight analogy between the smoke transport models and the release of VCM from PVC during processing in that most of the VCM is probably released in areas of the process where the PVC is hot. Thus, a hot buoyant plume, transporting released VCM, would tend to form above the process. If this was relatively undisturbed, it would form a hot layer at the top of the compartment which would then contain most of the released VCM. However, it is likely that the temperature is not high enough to give enough energy to the plume to overcome the forced convection currents that exist in most manufacturing environments; thus, the plume would be dispersed before it could form a distinct "hot zone" at the top of the compartment. However, there could be local areas where this might be a consideration. For example, as we were touring the PVC compounding building at ALGC on 1/12/93, at one point we were on a mezzanine above a hot extruder machine. Molten PVC was exposed to the air as it went into the machine. There was also a partial ceiling above the mezzanine. It was distinctly warmer on the mezzanine than on the floor level where the machine was; you could feel a rather sharp thermal gradient as you came down the stairs. In a situation like that, if VCM is being released from the molten PVC it is likely that it would be concentrated in the hot air at the mezzanine level. Anyone in that area might be exposed to a concentration much higher than the average concentration in the whole room. In fact, warm zones like that above processing equipment are probably a pretty good tip-off to likely places to look for higher concentration levels as well, since the mechanisms for dispersion of temperature and concentration differences are similar. Local zones like this could probably be modeled to give at least a ball-park estimate of what the VCM concentration levels might be, but the correction for a situation like that is obvious; i.e., local forced convection near the extruder to break up that hot plume.

The last level of modeling complexity would be to use computational fluid dynamics to compute in detail the velocity, temperature and concentration profiles existing in the room, or some part of the room. This would only be appropriate for looking at one specific case in which the results are deemed to be very important (e.g., a litigation case). It would not produce general results which could be used to establish guidelines.

F.M.Galloway

Distribution: RVCM Label Team

Inter-Organization Correspondence

BFGoodrich

DISTRIBUTION	FIELD POINT OR DEPT. & BLDG. NO. R. C. Wiging	DATE YOUR LETTER
RICHARD J. KRUSZYNSKI	FIELD POINT OR DEPT. & BLDG. NO. CLEVELAND D/5401 (RJK-061-75)	DATE THIS LETTER 7/8/75

SUBJECT

OSHA - NIOSH - EPA
2nd Quarter, 1975 Update

This report is presented as a quarterly effort to keep the plastics group informed of current activities in product-related environmental affairs.

OSHA-NIOSH:

Well, April 1st, 1975 came, April 1st 1975 saw and April 1st, 1975 finally conquered. The new OSHA guidelines have been set and it looks like they're here to stay. Within the past few weeks, the Supreme Court refused to hear an appeal from plastics industry representatives who attempted to have the Occupational Safety and Health Administration standards for employee exposure to vinyl chloride monomer eliminated.

Many new inroads have taken place by the B.F.Goodrich Chemical Co. in regards to lowering residual vinyl chloride monomer levels of our resins. Although the levels have been reduced drastically in most of the resins, these changes are being related to compound problems that are occurring in our customers' plants. These problems are being studied and, hopefully, a quick solution can be worked out.

In my last quarterly report, I discussed our Bag Labeling Program and our objective to obtain "Real World Data." The objective of the Bag Labeling Committee was to collect enough data from customers' plants and laboratory testing so as to obtain an exclusion from OSHA in regards to elimination of the PVC warning stickers from bags and boxes of compound and resin.

Our program has just been completed. The results of our monitoring programs and lab testing are now being compiled. Jerry Cohan will write up the formal report and this will then be forwarded to OSHA for review. I have included a copy of a rough summary of sampling results. The data that has been taken from our customers' operations shows that 49 out of 52 static or area samples showed levels that were either non-detectable or within the OSHA "action level" of 0.50 ppm. Our lower limit of detection at our Avon Lake Labs is 0.01 ppm. The remaining three area samples that showed higher levels of AVCM were taken in areas where direct workmen's breathing zones were not involved. Another plus factor is that all 42 personal samples taken fell within the OSHA "action level" and in most cases, were less than our lower limit of detection of 0.01 ppm.

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JLY 8, 1975

Envoronmental Protection Agency

As was stated in my first quarter report, the primary concern of EPA is to develop an air emissions standard for vinyl chloride. It was originally reported that EPA intended to publish the proposed standard by June 20, 1975 in the Federal Register. However, as of this writing (July 8, 1975), the proposed standard has not been published. Perhaps the final standard will be pushed up a bit also. This is the only plastics related EPA information that I have to report at the present time.

My next report in Fall of 1975, should contain the results of OSHA's actions regarding our Bag Labeling Program. Also, more definite statements regarding EPA's actions should be available.

Richard J. Kruszynski

Richard J. Kruszynski

RJK:cjs

: JJS/GRT/DAP/WTR
RJJ/DLA/RJA
JDT/BFT/TAG
File

2522803

THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

TITLE
JOB NO.
DATE

Tie in with job – make orderly and with notes so anyone can follow.

CUSTOMER: TAYTEC COLUMBUS, OHIO
DATE: 4/18/75 and 4/21/75
PACKAGE TYPE: Box

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
FLEX Geon 83741-132 Lot 00073 (Louisville, Ky)	<1.0	Static	Inside rear of the trailer immediately upon opening doors	29	0.32
		Personal	Forklift operator	29	<0.01
		Personal	Forklift operator	29	<0.01
		Static	Above hot extrudate at extrusion die	138	<0.01
		Personal	Packer packaging finished parts	138	<0.01
		Personal	Extruder operator	138	<0.01
		Personal	Raw materials handler	213	<0.01
		Static	At cut-off saw	138	<0.01
		Personal	General extrusion area	107	<0.01
		Static	General warehouse area	95	<0.01

[illegible]

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

CUSTOMER: Duracoord Corporation Urbana, Ohio
DATE: 4/23/75 and 4/24/75
PACKAGE TYPE: Box

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
RIGID CELLULAR Lind 85721-020 Lot 26049 (Van Lue, Ohio)	<1.0	Personal	Forklift operator	49	<0.01
		Static	Area sample around printing operation	240	<0.01
		Static	Hopper platform above extruder	240	<0.01
		Personal	Color mixer operator	57	<0.01
		Static	Above hot extrudate at extrusion die	229	<0.01
		Static	At the guillotine cutter	209	<0.01
		Personal	Extruder operator	240	<0.01

Tuck in with job - make orderly and with notes so anyone can follow.

2252038

THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

Type in with job no. and clearly and with notes so anyone can follow.

CUSTOMER: Pierce Tool and Die Elkhart, Indiana
DATE: 4/29/75
PACKAGE TYPE: Bag

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
FLEX 83HI-02 t 00111 sville, Ky)	1.0	Static	Inside nose of the trailer immediately upon opening doors.	55	< 0.01
		Personal	Forklift operator	55	< 0.01
		Personal	Forklift operator	55	< 0.01
		Personal	Extrusion operator	190	< 0.01
		Personal	General extrusion area	190	< 0.01
		Static	Above hot extrudate at extrusion die	129	< 0.01
		Static	At cut-off saw	129	< 0.01
RICHP m 5702A-35 t 25101 n Lake, Ohio)	< 1.0	Static	Above hot extrudate at extrusion die	51	< 0.01
n 92 Resin t 22339 n Lake, Ohio)	< 1.0	Static	General extrusion area	75	< 0.02
		Static	On top of mixer	95	< 0.01
		Personal	Dry blend operator	95	< 0.01
		Personal	Dry blend operator	95	< 0.01
		Static	Above hot extrudate at extrusion die	75	< 0.01

60038228

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

CUSTOMER: Johnson Plastics Chagrin Falls, Ohio
DATE: 4/30/75
PACKAGE TYPE: Bulk Truck

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
Firm 92 resin Lot 21088 (Avon Lake, Ohio)	35	Personal	Technician sampling resin from truck	74	0.02
		Static	Opening on top of storage silo	74	19.32
Powder compound based on above resin	<1.0	Static	Above the mixer	60	1.09
		Personal	Mixer operator	60	0.40
		Personal	Mixer operator helper	60	0.06
		Personal	Extruder operator feeder	156	0.10
		Static	Above hot extrudate at extrusion die	123	<0.01
Powder compound based on Firm 102EP F-5	<1.0	Static	Above hot extrudate at extrusion die	76	<0.01
		Personal	Mill operator	75	<0.02
		Static	Above the mill	70	<0.03

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THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

Tuck in with job - make orderly and with notes so anyone can follow.

CUSTOMER: Standard Products Cleveland, Ohio
DATE: 5/6/75
PACKAGE TYPE: Bag

ATERIAL	RVCM (ppm	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (minutes)	AVCM (ppm
n 92 resin t 22343 on Lake, Ohio)	<1.0	Static	Inside nose of the trailer immediately upon opening doors	51	0.12
		Personal	Forklift operator	51	<0.01
n 103EP resin t 01921 nsville, Ky)	<1.0	Personal	Mixer operator - mixing 50/50 ratio of Geon 92/Geon 103EP	90	<0.01
		Static	Above the mixer	90	<0.01
		Static	Above the floor hopper	132	0.43
		Static	Above hot extrudate at extrusion die	132	0.52
		Personal	Extruder operator	132	0.24
		Personal	Heat seal operator	134	0.41
		Static	General area around heat seal operation	134	0.46

Note: Competitive PVC resin was also being processed in this operation. The RVCM content of this resin is unknown and the extent to which this may have influenced AVCM results is also not known.

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THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

JOB NO.

DATE

ITLE

CUSTOMER : Bird and Son   Bardstown, Kentucky
DATE : 5/16/75
PACKAGE TYPE : Box and Bulk Truck

'ATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
RIGID					
n 85802-578	<1.0	Personal	Forklift operator	49	<0.01
t 950510		Static	Above extruder hopper	193	<0.01
ury, Illinois)		Static	Above hot extrudate at extrusion die	187	<0.01
		Static	General extrusion area	185	<0.01
		Personal	Extruder operator	184	<0.01
		Static	At cut-off saw	184	<0.01
RIGID					
n 7082-138	<1.0	Personal	Operator sampling compound from truck	15	<0.01
Bulk Truck					
Louisville, Ky)		Personal	Extruder operator	106	<0.01
		Static	Above hot extrudate at extrusion die	109	<0.01
		Static	At cut-off saw	101	<0.01

2-0388252

THE B. F. GOODRICH COMPANY
SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

Turn in with job - make orderly and with notes so anyone can follow.

Customer : Andersen Windows, Hastings, Minnesota
Date : June 3, 1975
Package : Rail Car, Bulk

Material	RVCM (ppm)	Sample Type	Sample Point or Operation Monitored	Sampling Time (min)	AVCM (ppm)
300X6 Rail Car #ACFX 56226	0.55	Static	Die Area of Sheet Line	300	0.18
		Static	General Processing area	300	0.09
		Personal	Foreman opening hopper lid of rail car	11	0.46
		Personal	Mixing operator	67	<0.01
		Static	Die area of Sheet Line	165	0.11
		Personal	Mixing Operator	96	0.23
		Static	On stairway leading to blending and mixing area	99	0.34

THE B. F. GOODRICH COMPANY
SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

Turn in with job - make orderly and with notes so anyone can follow.

Customer : Profile Extrusions Hastings, Minnesota
Date : June 2, 1975
Package : Bags

Material	RVCM (ppm)	Sample Type	Sample Point or Operation Monitored	Sampling Time (min.)	AVCM (ppm)
RIGID W 7081-136 t 910769	0.05	Personal	Forklift Operator	72	<0.01
		Static	General Processing Area	360	<0.01
		Static	Above extruder die	348	<0.01
		Static	At cut-off saw	348	<0.01
		Personal	Extruder Operator	307	<0.01
		Static	Cutting and Packing Area	332	<0.01

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

Turn in with job ... and with notes so anyone can follow.

CUSTOMER: Sackner Products Grand Rapids, Michigan
DATE: 5/19/75
PACKAGE TYPE: Bag

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
FLEX Rm 83700-290 Lot 263 Louisville, Ky)	<1.0	Static	Inside nose of the trailer immediately upon opening doors	36	<0.02
		Personal	Material handler and processor	154	<0.04
		Personal	Extruder operator	180	<0.03
		Static	Above hot extrudate at extrusion die	132	<0.02
		Static	Above extrusion take-off	132	<0.03
		Static	General warehouse area	118	<0.01

STORAGE

THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

JOB NO.

TITLE

DATE

Take in with pen – make clearly and with notes so anyone can follow.

CUSTOMER: Cooley, Inc. Pawtucket, Rhode Island
DATE: 5/7/75
PACKAGE TYPE: Bag

MATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
(GEX ...-83789-021 ...t 00216 ...uisville, Ky)	<1.0	Static	Inside nose of the trailer immediately upon opening doors.	48	0.15
		Personal	Material handler operating electric cart	48	0.66
		Personal	Hopper feeder	128	0.12
		Personal	Extrusion foreman	160	0.31
		Static	General storage area	53	0.14
		Personal	Extruder operator	88	0.20
		Static	Above hot extrudate at extrusion die	85	0.07

9-038856

THE B. F. GOODRICH COMPANY

SKETCHES AND COMPUTATIONS

TITLE

JOB NO.

DATE

CUSTOMER: Tenex Elk Grove Village, Illinois
DATE: 5/12/75
PACKAGE TYPE: Box and Bulk Rail Car

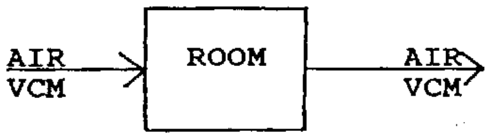
...ATERIAL	RVCM (ppm)	SAMPLE TYPE	SAMPLE POINT OR OPERATION MONITORED	SAMPLING TIME (MINUTES)	AVCM (ppm)
(NB)					
...n 83457-001	<1.0	Static	Above bulk storage hopper	111	0.11
...ulk Car		Static	Above extruder hopper	111	0.07
...ville, Ky)		Static	Above hot extrudate at extrusion die	112	0.19
FLEX					
...n 83714-004		Static	Inside nose of the trailer immediately upon opening doors	33	0.13
Lot 41	<1.0				
Lot 43	<1.0	Personal	Forklift operator	33	0.04
...ville, Ky)		Personal	Extruder Operator	195	0.07
		Personal	Production manager – 80% on production lines; 20% in the office	220	0.07
		Static	At cut-off saw	101	0.03
		Static	Above open 83714 box at the extruder	93	0.02

L 030322

MATERIAL BALANCE

APPENDIX--

<u>SUSPENSION RESIN - POWDER COMOUNDING</u>



<u>ASSUMPTIONS</u>

1. Complete mixing of VCM-Air in room.
2. 1# mol VCM = 359 cu. ft at room T,P.

$$V \frac{dc}{ct} = Q(c_{in} - c_{out})$$

$$c_{out} = c_{in} + (c_{t-0} - c_{in}) \exp \left(\frac{-Qt}{V}\right)$$

$$c_{t-0} = 0$$

$$c_{out} = c_{in} \left(1 - \exp \left(\frac{-Qt}{V}\right)\right)$$

B416/Lab 103

V = 6021 cu ft

Q = 100 cfm, 1 volume change air per hour.

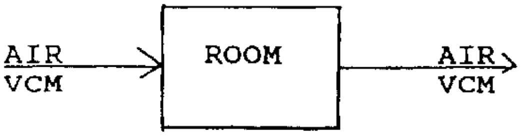
$$c_{in} = \frac{55\#\ \text{cmpd}}{\text{hr}} \Big/ \frac{0.85\#\ \text{resin}}{\#\text{cmpd}} \Big/ \frac{(103-45)\#\ \text{VCM}}{10^6\#\text{resin}} \Big/ \frac{\#\text{Mol}}{62.5\#\text{VCM}} \Big/ \frac{359\text{scf}}{\#\text{Mol}} \Big/ \frac{\text{Min}}{100\text{cf air}} \Big/ \frac{\text{Hr}}{60\ \text{Min}}$$

= 2.60 ppm

$$c_{out} = 2.60 \left(1 - \exp \left(\frac{-100t}{6021}\right)\right)$$

<u>t(min)</u>	<u>c_{out} (ppm)</u>	(=c room)
0	0	
30	1.02	
60	1.64	
90	2.01	
120	2.24	

DISPERSION - PLASTISOL FUSION



ASSUMPTIONS

1. 1# mol VCM cu ft @ room T,P.
2. Complete mixing of air-VCM in room.

$$V\frac{dc}{dt} = Q_i c_i - Q_o c_o = Q(c_i - c_o)$$

$$c_{out} = c_{in} + (c_{t=0} - c_{in})\exp\left(\frac{-Qt}{V}\right)$$

$$c_{t=0} = 0$$

$$c_{out} = c_{in}\left(1 - \exp\left(\frac{-Qt}{V}\right)\right)$$

B413/Lab 115

V = 4743 cu ft

Q = 80 cfm, 1 volume change air per hour.

RVCM = 38PPM, VCM released by plastisol during compounding

1ST HOUR

$$c_{in} = \frac{38\#\ \text{VCM}}{10^6\#\ \text{Plast-1 hr}} \Bigg/ \frac{960*2\ \text{g Plastisol}}{} \Bigg/ \frac{\#}{453.6\text{g}} \Bigg/ \frac{\#\text{Mol}}{62.5\#} \Bigg/ \frac{359\text{scf}}{\#\text{Mol}} \Bigg/ \frac{\text{Min}}{80\text{cf air}} \Bigg/ \frac{\text{Hr}}{60\ \text{min}}$$

= 0.192ppm VCM

$$c_{out} = 0.192\left(1 - \exp\left[\frac{-80t}{4743}\right]\right)$$

t(min)	c_{out}(ppm)
0	0
30	0.076
60	0.122

2ND HOUR

$$[c_{t=0} = .122] \qquad c_{out} = c_{in} + [.122 - c_{in}]\exp\left(\frac{-80t}{4743}\right)$$

RVCM = 67

$$c_{in} = \frac{67\#\text{VCM}}{10^6\#\ \text{plast}} \Bigg/ \frac{960*2\text{g plast}}{} \Bigg/ \frac{\#}{453.6\text{g}} \Bigg/ \frac{\#\text{Mol}}{62.5\#} \Bigg/ \frac{359\text{scf}}{\#\text{Mol}} \Bigg/ \frac{\text{Min}}{80\ \text{cfm}} \Bigg/ \frac{\text{Hr}}{60\ \text{Min}}$$

= 0.339 ppm VCM

$$C_{out} = 0.339 + [.122 - .339]\exp\left(\frac{-80t}{4743}\right)$$

$$= 0.339 - 0.217\exp\left(\frac{-80t}{4743}\right)$$

t(min)	C_{out}(ppm)
0	.260
30	.157

3RD HOUR
(1/2 hour)

$$C_{out} = C_{in} + (C_{t=0} - C_{in})\exp\left(\frac{-Qt}{V}\right)$$
$$C_{in} = 0$$

$$C_{out} = 0.260\exp\left(\frac{-80t}{4743}\right)$$

t(min)	C_{out}(ppm)
0	.260
30	.157