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# TECHNICAL DISCUSSION OF PER CAPITA EMISSIONS FOR SEVERAL AREA SOURCES OF VOLATILE ORGANIC COMPOUNDS

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TECHNICAL DISCUSSION OF PER CAPITA EMISSION FACTORS FOR  
**SEVERAL** AREA SOURCES OF VOLATILE ORGANIC COMPOUNDS

OVERVIEW:

The purpose of this paper is to document the development of several per capita emission factors to be used in 1982 State Implementation Plan (SIP) Volatile Organic Compound (VOC) emissions inventories. The per capita VOC emission factors were released to local, State, and Regional control program offices through three vehicles: (1) Final Emission Inventory Requirements For 1982 Ozone State Implementation Plans'; (2) Procedures For The Preparation Of Emissions Inventories, Volume I, 2nd Edition'; and (3) three Regional workshops." Inventories which will use the recommended factors are to be compiled for calendar year 1980 and submitted completed to the Environmental Protection Agency by December 31, 1981. By assuring agencies that these factors are the best available, the application of **uniform** per capita factors in SIP VOC emission inventories can be promoted.

EMISSIONS PER CAPITA INVENTORY METHOD:

VOC emission inventory methods identify emissions from individual point sources using permit files, plant visits and questionnaires mailed to **facilities**. However, several emissions categories cannot readily be inventoried by point source methods. Sources such as service stations, drycleaners, cold cleaning degreasing and architectural surface coating are better inventoried collectively as area sources.

Area source inventory methods include a gamut of techniques. Considerable emphasis is placed on methods which obtain local data specific to an inventory area. Still, certain source categories remain which are difficult to inventory using solvent distribution data, and employment, and tax statistics. For the difficult to inventory source categories, emissions per capita factors have been developed using national emissions data and national population statistics.

Emissions per capita factors are relatively easy to develop. Researching several references produces emissions data on source categories of interest. The data can be segregated into two types: (1) national emissions or national consumption data from which national emissions can be derived, and (2) locally derived emissions data usually modified to a per capita factor using the local population base. National emissions are converted to a per capita factor by dividing the emissions, by the appropriate data base year national population. To compute area source emissions with the factor, multiply the inventory area population by the per capita **factor** which produces total emission. **Then** point source emissions are subtracted from total emissions to arrive at the area source emission totals for use in a VOC emissions inventory.

An alternative approach is to identify national emissions from sources which are readily identifiable using point source inventory methods and then to divide the remaining national **emissions** by national population. The resulting per capita emission factor would apply to only smaller sources. Emission estimates derived with the factor would be added to point source emissions data to arrive at the total emission estimate for the particular source category.

#### FACTOR DATA BASE:

Several problems are inherit with emission data which hinder the designation of factors for specific source categories. First and foremost is determining which emission data should be used in developing factors. National emissions data are more representative of all national urban areas as a whole but may not be directly applicable to local conditions. Locally derived factors reflect local conditions, but may be unacceptable nationally due to being unrepresentative. A range of locally derived factors would be acceptable but is often unavailable on a nationwide basis. Thus, the tendency is to employ factors based on national emissions or consumption data.

Determining which national emissions or consumption data to use is **itself a problem**. The two most reliable information sets from which national emissions or consumption data can be derived are (1) documents developed for or in support of New Source Performance Standards (NSPS) and Control Techniques Guideline (CTG) documents;<sup>4-10</sup> and (2) End Uses Of Solvents Containing Volatile Organic Compounds.<sup>11</sup> These data sets differ by 0-50 percent for the four source categories that both cover. In addition, both data sets have several specific limitations in estimating solvent use. Therefore, there is considerable uncertainty over which data set is a better basis for the development of per capita factors.

#### "END USES"

Reference 11, referred to as "End Uses", has three major drawbacks. First, the document reports consumption of solvent by end use, not emissions data. This technicality can be side stepped by making some appropriate assumptions on solvent release to the atmosphere to estimate national emissions. The second problem is that  $910 \times 10^6$  kg ( $200 \times 10^6$  lbs/ yr) are considered unaccountable in "End Uses". TRC believes that allocating this unaccountable use to identified uses will lead to less errors in inventories. The rationale for allocation is based on the assumption that unidentified solvent consumption primarily ends up as minor components in solvent mixtures in the industrial (80 percent) and consumer/commercial (20 percent) sectors.<sup>11</sup> This appears to be a logical assumption which provides a solution to the problem. Lastly, "End Uses" suffers from a lack of "hard" documentation and bases most of its estimates on simple discussion with industry. ~~However, the report does~~ approach solvent use by attempting to identify the end product or use of all the organic solvents produced for use in the United States. This document also represents the most current EPA work on identifying organic solvent use.

CTG/NSPS Data

Control Technology Guidelines (CTG) documents and reports supporting New Source Performance Standards (NSPS) for the respective area source categories also have several advantages and drawbacks. These documents are oriented towards specific subsections of a particular industry thus allowing analysis of emissions at the subcategory level, as in the drycleaning industry. One problem, however, is that gaps in-emissions information may result from the narrow perspective of CTG/NSPS work. This is the case for-graphic arts where data must be augmented with information from other sources. Another problem is that emissions data were not obtained with the idea of a closed loop mass balance. Emissions data were obtained to identify the most important sources of VOC emissions, not all VOC emissions. Third, the emissions estimates in some CTG/NSPS documents are up to 12 years old. On the other hand, CTG/NSPS documents are the result of considerable research and are a foundation of VOC regulations nationwide.

Both data bases were used in deriving per capita factors. Factors derived from CTG/NSPS data were recommended for use in four of the six source categories. Factors derived from "End Uses" were recommended in the remaining two categories. Specific reasons on why one reference was used over another are given with each derivation.

DISCUSSION AND DERIVATION OF FACTORS:

National emissions data that are proposed for use in inventory guidance are listed in Table 1. The table lists per capita emission factors that are derived from national emissions totals, as well as a range of per capita factors included for comparison with selected values. All recommended factors are derived and compared with the data range in the discussion of this Section.

TABLE 1. VOC EMISSIONS AND PER CAPITA VOC EMISSION FACTORS FOR THE U.S.<sup>a</sup>

Category	Recommended Value'		Range of Per Capita Factors kg/cap-yr
	x 10 <sup>b</sup> kg/yr	kg/cap-yr	
<b>Drycleaning</b>			
Coin-op	48	0.2	0.1 - 0.3
Commercial	130	0.6 <sup>b</sup>	0.3 - 0.8
Cold cleaning degreasing	285	1.4 <sup>b</sup>	1.3 - 1.7
Architectural surface coating	446	2.1	1.7 - 3.8
Auto refinishing	160	0.8	0.2 - 0.8
Graphic arts small facilities	75	0.4	0.3 - 0.4 <sup>c</sup>
Consumer/commercial solvent use	618	2.9 <sup>b</sup>	N/A <sup>d</sup>

<sup>a</sup>References 4 - 27.

<sup>b</sup>Includes adjustments to exclude compounds exempted under EPA policy.

<sup>c</sup>Only two values.

<sup>d</sup>Only one value.

The discussion and derivation of factors presented in Table 1 is organized by source categories to allow independent review of factors for each category. However, for all categories, two equations are used repetitively throughout the review and for **convinnence** are defined here.

$$PF = \frac{E}{P} \times EAF \quad (\text{Equation 1}) \qquad PF = \frac{SC}{NP} \times AF \times RF \times EAF \quad (\text{Equation 2})$$

Where: PF = Per capita factor, kg/cap-yr  
 E = Emissions in kg/yr  
 P = Population for area where emission estimates are applicable.  
 SC = National solvent consumption, kg/yr  
 NP = National population, x 10<sup>6</sup> people  
 AF = Adjustment factor which allocates unknown consumption into identified solvent end use categories as previously discussed. For industrial categories AF = 1.13 and for consumer/commercial categories A?? = 1.17.  
 RF = Release factor to convert **consumption** data into emission data.  
 EAF = Exempt compound adjustment fraction

Equation 1 employs emissions data to compute a per capita factor while Equation 2 uses national solvent consumption data.

TABLE 2. LIST OF COMPOUNDS EXEMPT FROM EPA'S VOC POLICY<sup>28,29</sup>

Methane	Ethane
Trichlorotrifluoroethane	Methylene chloride
Trichlorofluoromethane	Dichlorodifluoromethane
Chlorodifluoromethane	Trifluoromethane
Dichlorotetrafluoroethane	Chloropentafluoroethane
1,1,1-Trichloroethane (methyl chloroform)	

The adjustment factor (AF) was determined by taking an adjusted major category consumption, such as industrial uses, and dividing by the respective unadjusted major category total. The adjustment to major categories was undertaken in "End Uses" by adding 80 percent of the unknown solvent to industrial uses, or 720 x 10<sup>6</sup> kg and allocating 20 percent to consumer/commercial uses, or 80 x 10<sup>6</sup> kg.<sup>5</sup> Equation 2 is primarily used on data 'extracted from "End Uses". The EAF multiplier excludes the exempt compounds listed in Table 2 and are considered nonreactive as defined by EPA's VOC policy. For most solvent use categories EAF will be equal to 1.

These two equations will apply for most of the derived factors below. Where other equations are used to develop per capita factors, a note is included in the derivation discussion.

DRYCLEANING:

Recommended factors - The recommended factors were derived from data developed for CTG/NSPS documents. Emissions from perchloroethylene (**perc**) drycleaning plants were derived from national consumption data in Reference 20 and allocated to **commercial and** coin operated (coin-op) plant categories from emission rate data for typical plants contained in Reference 9. Emissions from commercial petroleum solvent **drycleaning** plants are derived in Reference 21 based on data in References 8 and 22 on the number of plants, clothes throughput per year, and emission rate. By Equation 1, for coin-op plants:

$$\text{Per Capita Factor (PF)} = \frac{48 \times 10^6 \text{ kg/yr}}{220 \times 10^6} = 0.2 \text{ kg/cap-yr}$$

For commercial drycleaning, Equation 1 is applied to **perc** and petroleum solvent (PS) emissions with summation producing a combined factor.

$$\text{PF} = \frac{E_{\text{perc}} + E_{\text{ps}}}{P} = \frac{130 \times 10^6 \text{ kg/yr}}{220 \times 10^6} = 0.6 \text{ kg/cap-yr}$$

An estimated population of 220 million was used for the late 1970's, the data base time of reference. These factors were considered to be superior because the data base is recent and because emissions can be calculated separately for commercial and coin-op facilities as area sources, independent of industrial drycleaning plants which should be inventoried as point sources.<sup>2</sup>

Other Factors - Three additional data sources complete the range of per capita emission factors for drycleaning.

"End Uses" - A factor was calculated from national consumption data presented on page 1-21 of Reference 11 and a recommended population figure on page 3-23. The industrial adjustment factor (IF) of 1.13 was used to allocate unidentified solvent use. By Equation 2:

$$\begin{aligned} \text{Per Capita Factor (PF)} &= \frac{290 \times 10^6 \text{ kg/yr} \times 1.13 \times 1.0 \times 1.0}{215 \times 10^6} = \frac{328}{215} \\ &= 1.5 \text{ kg/cap-yr} \end{aligned}$$

This factor includes solvent consumption at industrial drycleaning plants. Assuming that industry profile data in support of CTG/NSPS applies, 55 percent and 20 percent of above factor can be attributed to commercial and coin-op facilities.

$$\text{PF coin-op} = \frac{328}{215} \times 0.20 = 0.3 \text{ kg/cap-yr}$$

$$\text{PF commercial} = \frac{328}{215} \times 0.55 = 0.8 \text{ kg/cap-yr}$$

These factors include petroleum solvents and perchloroethylene but no compounds which are exempt under EPA's nonreactive policy (see Table 2) so that **EAF** = 1. Because little destructive emission control is practiced within the industry it was assumed that solvent emissions would equal solvent consumption, making the release factor 1.

These factors are inferior since a direct association cannot be made between solvent consumption and the commercial and coin-op dry cleaning subcategories. In addition, "End Uses" data are older (1974 and 1977) than the CTG/NSPS data (1979).

The two remaining data sets are based on local surveys in Tulsa, Oklahoma and Florida. For comparison, emissions have been allocated to commercial and coin-op subcategories applying the 55/20 splits described above.

Tulsa - Reference 12 uses Equation 1 to develop a factor for Tulsa, Oklahoma. Both the emissions and population data are 1977 base year,

$$\text{PF commercial} = \frac{1,183,000 \text{ lbs/yr}}{428,700} \times 0.45 \text{ kg/lb} \times 0.55 = 0.7 \text{ kg/cap-yr}$$

$$\text{PF coin-op} = \frac{1,183,000 \text{ lbs/yr}}{428,700} \times 0.45 \text{ kg/lb} \times 0.2 = 0.3 \text{ kg/cap-yr}$$

Florida - Reference 13 provides no calculations but rather summarizes emission data which must be manipulated to derive per capita factors. Factors are for five urban counties in Florida.

#### PER CAPITA FACTORS FOR SEVERAL FLORIDA COUNTIES, kg/cap-yr

<u>Subcategory</u>	<u>Broward</u>	<u>Dade</u>	<u>Duval</u>	<u>Orange</u>	<u>Palm Beach</u>
Coin-op	0.1	0.2	0.2	0.3	0.1
Commercial	0.3	0.5	0.5	0.8	0.4

Reference 13 also mentions an independent survey in Duval County which produces conflicting factors of 0.4 kg/cap-yr and 0.1 kg/cap-yr for commercial and coin-op subcategories respectively.

The locally derived factors cause some concern in that they are considerably less than the recommended values of 0.8 kg/cap-yr and 0.3 kg/cap-yr for commercial and coin-op drycleaning, respectively. However, the lower Florida values may be the result of climate on clothing usage. Also, to base a national factor on data from only two regions of the county would not be sound. Thus, the larger national value is still recommended.

#### COLD CLEANING DEGREASING:

Recommended Factor - A CTG document, Reference 5, was used in developing a per capita emissions factor for cold cleaning degreasing. The rationale in selecting the CTG document was that it contained a breakdown of degreasing emissions by type of operation, such as vapor degreasing, cold cleaning and conveyORIZED degreasing. Other references did not provide a breakdown of emission by process. Emissions data are from Appendix B of Reference 5 while population is a 1974 interpolation from Statistical Abstract. Equation 2 is used to calculate a factor.

$$PF = \frac{380 \times 10^6 \text{ kg/yr}}{211 \times 10^6} = 1.8 \text{ kg/cap-yr}$$

However, this factor includes exempt compounds according to the breakdown on page 2-5 of the CTG document.

TABLE 3. EMISSIONS SPECIES DATA FOR COLD CLEANING DEGREASING

	Solvent Consumption $10^6$ kg/yr	
	Nonexempt	Exempt
Halogenated:		
Trichloroethylene	25	
<b>1,1,1 Trichloroethane</b>		82
Perchloroethylene	13	
Methylene chloride		23
Trichlorotrifluoroethane		<u>10</u>
	<u>38</u>	<u>115</u>
Aliphatics		
Aromatics		
Benzene	7	
Toluene	14	
<b>Xylene</b>	12	
Cyclohexane	1	
Heavy aromatics	1	2
	46	
Oxygenated		
Acetone	10	-
<b>Methy ethyl ketone</b>	8	-
Butyl	5	-
Ethers	<u>6</u>	-
	29	
TOTALS	335	115
PERCENTAGE	75%	25%

Based on the species data in Table 3, nonexempt compounds are only 75 percent of the cold cleaning solvent consumption. Therefore the EAF = 0.75 and a reactive per capita factor can be calculated:

$$PF = 1.8 \times 0.75 = 1.4 \text{ kg/cap-yr}$$

This is the value which appears in Table 1 as the recommended factor for estimating cold cleaning emissions.

Other Factors - Two additional factors are derived for comparison with the CTG document based factor.



"End Uses - Reference 11 can also be used to develop a per capita factor but requires that an assumption be made. "End Uses" provides total solvent use for metal cleaning which includes all types of degreasing. On page 2-7 of Reference 5 the cold cleaning fraction of degreasing emissions is 55 percent. Assuming that this fraction applies to the solvent *consumption* from "End Uses" the per capita factor can then be derived from Equation 2.

$$PF = \frac{(660 \times 10^6 \text{ kg/yr}) \times 0.55 \times 1.13 \times 1.0 \times 0.75}{215 \times 10^6} = 1.4 \text{ kg/cap-yr}$$

The population is recommended by "End Uses" and the industrial apportioning adjustment factor is used. Since few facilities utilize destructive control techniques, the release factor is assumed to be 1.0. The exempt compound adjustment factor is based on the CTG species data. This factor was not recommended in that the assumption made in applying the cold cleaning fraction may not be valid. Thus, the CTG based factor is recommended over the TRC based factor.

Oklahoma Inventory - An additional approach yields another factor by combining data from Reference 5 and AP-42.<sup>18</sup> This method is used in the Oklahoma inventory assistance to estimate area source emission from cold cleaning operations.<sup>14</sup>

$$PF = \frac{N-U \times EF}{NP}$$

Where NU is the estimated number of units in operation nationally from Reference 5, EF is the emission factor from AP-42, and NP is national population.

$$PF = \frac{1,220,000 \times 300 \text{ kg/yr}}{211 \times 10^6} = 1.7 \text{ kg/cap-yr}$$

Then the factor must be adjusted to exclude exempt compounds using the CTG species data.

$$PF = 1.7 \times 0.75 = 1.3 \text{ kg/cap-yr}$$

This approach is based on data developed in CTG documents and thus the CTG based factor is recommended over this indirectly derived factor.

#### ARCHITECTURAL SURFACE COATING:

Recommended Factor - A CTG draft document was used to develop a per capita factor for architectual surface coating emissions. Emissions include solvents contained in paint formulations as well as thinning and cleanup solvent associated with the use of paints. From Reference 6, page 4 and Equation 1:

$$PF = \frac{340 \times 10^6 \text{ kg/yr} + 106 \times 10^6 \text{ kg/yr}}{213 \times 10^6} = \frac{446 \times 10^6 \text{ kg/yr}}{213 \times 10^6} = 2.1 \text{ kg/cap-yr}$$

Emission tonnage is for the respective coatings and associate solvent use. Population is for 1975 from Statistical Abstract.<sup>14</sup>

Under the exempt compound list, no solvents used in architectural surface coatings are classified as unreactive. A list of compounds is included in Reference 6 which was used to derive the per capita emission factor. The list is **summaried** in Table 4.

TABLE 4. ORGANIC SPECIES DATA FOR ARCHITECTURAL SURFACE COATING EMISSIONS

	<u>x 10<sup>6</sup> kg/yr</u>	<u>Percent</u>
Aliphatic Hydrocarbons	224.7	66
Aromatics	20.3	6
Alcohols	10.7	3
Acetone	6.2	2
Methyl Ethyl Ketone (MEK)	5.1	2
Methyl Isobutly Ketone (MIBK)	4.5	1
Acetates	4.9	1
Other ketones/esters	5.9	2
Glycols	34.1	10
Glycol ethers/ether esters	21.9	6
Other miscellaneous	<u>1.5</u>	<u>&gt;1</u>
TOTAL	340	~100

Since **nonreactives** are included, the exempt compound adjustment fraction (EAF) is 1.0 and the per capita factor is unchanged.

Other Factors - A number of data points are available for comparison with the recommended value.

"End Uses" - From Reference 11, using Equation 2, the following factor is derived:

$$PF = \frac{320 \times 10^6 \text{ kg/yr}}{215 \times 10^6} \times 1.17 \times 1.0 \times 1.0 = 1.7 \frac{\text{kg}}{\text{cap-yr}}$$

The release factor is assumed to be one as is the exempt adjustment fraction. The apportioning factor of 1.17 for the consumer/commercial sector is used. This factor does not specify if associated solvent use is included with coating solvent use. Thus, the CTG derived factor is preferred over the ~~TRC-based~~ factor.

California - Several values are available for California urban areas and the entire State. The State value is particularly well derived while the other values are primarily present for comparison.

<u>Per Capita Factor</u>	<u>State-wide<sup>15</sup></u>	<u>San Francisco/Oakland<sup>15</sup></u>	<u>San Diego<sup>15</sup></u>	<u>LA/Orange Co.<sup>17</sup></u>
kg/ cap-yr	3.0	2.9	3.8	3.2

These values are higher than the recommended factor which may be a result of a greater rate of housing construction in California relative to the rest of the country. Therefore, the recommended factor is still supported.

#### AUTO REFINISHING:

Recommended Factor - Limited data are available on which a per capita factor can be developed. The only data easily obtained is from the "End Uses".<sup>11</sup> Using Equation 2 a factor can be computed.

$$PF = \frac{160 \times 10^6 \text{ kg/yr}}{215 \times 10^6} \times 1.13 \times 1.0 = 0.8 \text{ kg/cap-yr}$$

An apportionment factor of 1.13 for the industrial sector is used. The release factor is assumed to be 1.0 since little known destructive control is-practiced in this industry.

No speciation data is presented in this reference for auto refinishing coatings but is only available for coatings in general. Thus the distribution for architectural coatings in Table 4 may be used or a breakdown can be found in Appendix A of Reference 11. Both distributions show that no exempt solvents are included in the derived emission factor. Accordingly the per capita factor is unchanged since EAF is equal to 1.

Other Factor - One other factor is presented for comparison with the recommended factor.

Florida - A per capita factor derivation based on older data in Reference 13 is shown below:

$$PF = \frac{52 \times 10^3 \text{ tons/y-r} \times 2000 \text{ lb/ton} \times 0.45 \text{ kg/lb}}{215 \times 10^6} = 0.2 \text{ kg/cap-yr.}$$

This value is based on a similar data base discussed in Reference 16 and is considered an under estimate. The estimate may be affected by regional variations in automobile finish wear. Therefore the factor based on "End Uses is preferred over this factor.

#### GRAPHIC ARTS:

Recommended Factor - Graphic arts traditionally has been inventoried as a point source category. However, a large number of small source do exist in this category in addition to major printing plants. Thus, an area source per capita factor has been suggested. Using data developed for use in CTG/NSPS work a per capita factor for small graphic arts operations (less than 250 kg/day or 100 tons/year) was derived in Reference 26. Equation 1 was employed, however the emission input was modified to exclude major sources. National graphic arts emissions from Reference 7 are reduced by major publication and packaging emissions from References 10, 23 and 24. Non-emissions from letterpress and web offset printing are also excluded based on Reference 25. By Equation 1:

$$PF = \frac{75 \times 10^6 \text{ kg/yr}}{215 \times 10^6} = 0.4 \text{ kg/cap-yr}$$

Population used in 'computing the factor is assumed to be representative of the data base development period. While requiring numerous assumptions, this factor is considered superior due to the availability of industry profile data.

Other Factor - Another factor was developed and is presented for comparison. Using "End Uses"<sup>11</sup> a factor can be developed with Equation 2.

$$PF = \frac{270 \times 10^6 \text{ kg/yr} \times 1.13}{215 \times 10^6} = 1.4 \text{ kg/cap-yr}$$

This factor would be applied to both major and minor graphic arts sources. By applying industry profile data from the CTG/NSPS data base, the factor can be reduced to represent small graphic arts sources for comparison with the recommended factor.

$$PF = 1.4 \times 0.2 = 0.3 \text{ kg/cap-yr}$$

An apportionment factor of 1.13 for industrial solvent use is employed with population data also from "End Uses". Speciation data in Appendix A of this report indicates that special naphthas represent 98 percent of solvent used in graphic arts. Another 1 percent consists of glycol esthers. Therefore, **EAF** = 1.0 and the factor is unaltered since no exempt compounds are included. This factor is not preferred due to **incompatibility** with industrial profile data. When emission adjustments from the CTG/NSPS data are subtracted from national solvent consumption data in Reference 11, a negative emissions value results.

#### CONSUMER/COMMERCIAL SOLVENT:

Recommended Factor - "End Uses" provides the most comprehensive breakdown of consumer/commercial solvent. National consumption data is excerpted from page 1-21 of the **report**.<sup>11</sup>

TABLE 5. NATIONWIDE CONSUMER/COMMERCIAL SOLVENT USE

USE	Nationwide Consumption	
	kg x 10 <sup>6</sup> yr.	
	Unadjusted	Adjusted
Aerosol products	292	342
Household products	160	183
Toiletries	113	132
Rubbing compounds	53	62
Windshield washing	52	61
Polishes and waxes	41	48
Nonindustrial adhesives	25	29
Space deodorant	15	18
Moth control	12	16
Laundry detergent	3	4
<b>TOTAL</b>	<b>765</b>	<b>895</b>

$$PF = \frac{895 \times 10^6 \text{ kg/yr}}{215 \times 10^6} = 4.2 \text{ kg/cap-yr (including exempt compounds)}$$

The unadjusted column represents only identified consumption data while the adjusted column includes unidentified solvent use allocated using a factor of 1.17 which has been discussed previously. The already adjusted total emissions are then used in Equation 1 to compute a per capita factor. A release factor of 1.0 is assumed since no control of these emissions is practiced. Speciation data indicates that a considerable quantity of the factor emissions consists of exempt compounds. Using Appendix A of the report, the following breakdown can be constructed.

TABLE 6. ORGANIC SPECIES DATA FOR CONSUMER/COMMERCIAL SOLVENT USE EMISSIONS

Compound	Nationwide Consumption x 10 <sup>6</sup> kg/yr	
	Exempt	Non-exempt
Special naphthas	-	234
Fluorocarbons	74	
Chlorocarbons	102	-
Methylene chloride	50	
Isopropanol	-	89
Ethanol	-	113
Methanol.	-	52
1,1,1-Trichloroethane	13	
MIBK	-	3
MEK	-	2
Butyl acetates	-	1
P-Dichlorobenzene	-	27
Perchloroethylene	-	3
TOTAL	239	524
PERCENTAGE	31%	69%

Since non-exempt compounds represent only 69 percent of the consumer/commercial solvent consumption, EAF is equal to 0.69. Thus, the factor must be adjusted.

$$PF = 4.2 \times 0.69 = 2.9 \text{ kg/cap-yr}$$

This factor is based on the most recent speciation data available. However, compound usage within the consumer/commercial category can rapidly change over a period of only a few years. For example, the degree of substitution of chlorinated/fluorinated hydrocarbons with parafins is unknown. Thus, while the factor is recommended for inventory use, these substitution trends must be identified.

#### SUMMARY:

The above derived per capita emission factors for release of organics into the atmosphere represent the best available data for area source per capita inventorying. However, while these factors are corrected for exempt

solvents, they do not reflect possible changes in substitution patterns between the mid 1970's and the present. Changes in consumption need to be identified in the future to improve the available data base. In conclusion, the factors should be used in emission inventory development as they represent an improvement over per capita factors previously recommended for use in VOC emission inventories.

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TECHNICAL DISCUSSION OF PER CAPITA EMISSION FACTORS  
FOR SEVERAL AREA SOURCES OF VOLATILE ORGANIC COMPOUNDS

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TECHNICAL DISCUSSION OF PER CAPITA EMISSION FACTORS FOR  
SEVERAL AREA SOURCES OF VOLATILE ORGANIC COMPOUNDS

OVERVIEW:

The purpose of this paper is to document the development of several per capita emission factors to be used in 1982 State **Implementation Plan** (SIP) Volatile Organic Compound (VOC) emissions inventories. The per. capita VOC emission factors were released to local, State, and Regional control program offices through three vehicles: (1) Final Emission Inventory Requirements For 1982 Ozone State Implementation Plans'; (2) Procedures For The Preparation Of Emissions Inventories, Volume I, 2nd Edition<sup>2</sup>; and (3) three Regional workshops.' Inventories which will use the recommended factors are to be compiled for calendar year 1980 and submitted completed to the Environmental Protection Agency by December 31, 1981. By assuring agencies that these factors are the best available, the application of uniform per capita factors in SIP VOC emission inventories can be promoted.

EMISSIONS PER CAPITA INVENTORY METHOD:

VOC emission inventory methods identify emissions from individual point sources using permit files, plant visits and questionnaires mailed to facilities. However, several emissions categories cannot readily be inventoried by point source methods. Sources such as service stations, drycleaners, cold cleaning degreasing and architectural surface coating are better inventoried collectively as area sources.

Area source inventory methods include a gamut of techniques. Considerable emphasis is placed on methods which obtain local data specific to an inventory area. Still, certain source categories remain which are difficult to inventory using solvent distribution data, and employment, and tax statistics. For the difficult to inventory source categories, emissions per capita factors have been developed using national emissions data and national population statistics.

Emissions per capita factors are relatively easy to develop. Researching several references produces emissions data on source categories of interest. The data can be segregated into two types: (1) national emissions or national consumption data from which national emissions can be derived, and (2) locally derived emissions data usually modified to a per capita factor using the local population base. National emissions are converted to a per capita factor by dividing the emissions, by the appropriate data base year national population. To compute area source emissions with the factor, multiply the inventory area population by the per capita factor which produces total emission. Then point source emissions are subtracted from total emissions to arrive at the area source emission totals for use in a VOC emissions inventory.

An alternative approach is to identify national emissions from sources which are readily identifiable using point source inventory methods and then to divide the remaining national emissions by national population. The resulting per capita emission factor would apply to only smaller sources. Emission estimates derived with the factor would be added to point source emissions data to arrive at the total emission estimate for the particular source category.

#### FACTOR DATA BASE:

Several problems are <sup>or</sup> **inherit** with emission data which hinder the designation of factors for specific source categories. First and foremost is determining which emission data should be used in developing factors. National emissions data are more representative of all national urban areas as a whole but may not be directly applicable to local conditions. Locally derived factors reflect local conditions, but may be unacceptable nationally due to being unrepresentative. A range of locally derived factors would be acceptable but is often unavailable on a nationwide basis. Thus, the tendency is to employ factors based on national emissions or consumption data.

Determining which national emissions or consumption data to use is itself a problem. The two most reliable information sets from **which** national emissions or consumption data can be derived are (1) documents developed for or in support of New Source Performance Standards (NSPS) and Control Techniques Guideline (CTG) **documents**; <sup>4-10</sup> and (2) End Uses Of Solvents Containing Volatile Organic Compounds.<sup>11</sup> These data sets differ by 0-50 percent for the four source categories that both cover. In addition, both data sets have several specific limitations in estimating solvent use. Therefore, there is considerable uncertainty over which data set is a better basis for the development of per capita factors.

#### "END USES"

Reference 11, referred to as "End Uses", has three major drawbacks. First, the document reports consumption of solvent by end use, not emissions data. This technicality can be side stepped by making some appropriate assumptions on solvent release **to the atmosphere to estimate national emissions**. The second problem is that  $910 \times 10^6 \text{ kg} (200 \times 10^6 \text{ lbs})/\text{yr}$  are considered **unaccountable** in "End Uses". **TRC believes that allocating this** unaccountable use to identified uses will lead to less errors in inventories. The rationale for allocation is based on the assumption that unidentified solvent consumption - primarily ends up as minor components in solvent mixtures in the industrial (80 percent) and **consumer/commercial (20 percent) sectors**.<sup>11</sup> This appears to be a logical assumption which provides a solution to the problem. Lastly, "End Uses" suffers from a lack of "hard" documentation and bases most of its estimates ~~-on-simp discussion with industry. However, the report does~~ approach solvent use by attempting to identify the end product or use of all the organic solvents produced for use in the United States. This document also represents the most current EPA work on identifying organic solvent use.

$$.2 \times 2006 \times 10^6 / 16 = 401.24 \times 10^6$$

CTG/NSPS Data

Control Technology Guidelines (CTG) documents and reports supporting New Source Performance Standards (NSPS) for the respective area source categories also have several advantages and drawbacks. These documents are oriented towards specific subsections of a particular industry thus allowing analysis of emissions at the subcategory level, as in the drycleaning industry. One problem, however, is that gaps in-emissions information may result from the narrow perspective of CTG/NSPS work. This is the case for graphic arts where data must be augmented with information from other sources. Another problem is that emissions data were not obtained with the idea of a closed loop mass balance. Emissions data were obtained to identify the most important sources of VOC emissions, not all VOC emissions. Third, the emissions estimates in some CTG/NSPS documents are up to 12 years old. On the other hand, CTG/NSPS documents are the result of considerable research and are a foundation of VOC regulations nationwide.

Both data bases were used in deriving per capita factors. Factors derived from CTG/NSPS data were recommended for use in **four** of the **six** source categories. Factors derived from "End Uses" were recommended in the remaining two categories. Specific reasons on why one reference was used over another are given with each derivation.

DISCUSSION AND DERIVATION OF FACTORS:

National emissions data that are proposed for use in inventory guidance are listed in Table 1. The table lists per capita emission factors that are derived from national emissions totals, as well as a range of per capita factors included for comparison with selected-values. All recommended factors are derived and compared with the data range in the discussion of this Section.

TABLE 1. VOC EMISSIONS AND PER CAPITA VOC EMISSION FACTORS FOR THE U.S.<sup>a</sup>

Category	Recommended Value for National Emissions		Range of Per Capita Factors
	x 10 <sup>6</sup> kg/yr	kg/cap-yr	kg/cap-yr
<b>Drycleaning</b>			
Coin-op	48	0.2	0.1 - 0.3
Commercial	130	0.6	0.3 - 0.8
Cold cleaning degreasing	285	1.4 <sup>b</sup>	1.3 - 1.7
Architectural surface coating	446	2.1	1.7 - 3.8
Auto refinishing	160	0.8	0.2 - 0.8
Graphic arts small facilities	75	0.4	0.3 - 0.4 <sup>c</sup>
Consumer/commercial solvent use	618 (1362 x 10 <sup>6</sup> kg)	2.9 <sup>b</sup> 6.293 <sup>d</sup> 1.667 <sup>d</sup>	N/A <sup>d</sup>

<sup>a</sup>References 4 - 2770742

<sup>b</sup>Includes adjustments to exclude compounds exempted under EPA policy.

<sup>c</sup>Only two values.

<sup>d</sup>Only one value.

The discussion and derivation of factors presented in Table 1 is organized by source categories to **allow independent** review of factors for each category. However, for all categories, **two** equations are used repetitively throughout the **review** and for **convincence** are defined here.

$$PF = \frac{E}{P} \times EAF \quad (\text{Equation 1}) \quad PF = \frac{SC}{NP} \times AF \times RF \times EAF \quad (\text{Equation 2})$$

Where: PF = Per capita factor, kg/cap-yr  
 E = Emissions in kg/yr  
 P = Population for area **where** emission estimates are applicable.  
 SC = National solvent consumption, kg/yr  
 NP = National population,  $\times 10^6$  people  
 AF = Adjustment factor which allocates unknown consumption into identified solvent end use categories as previously discussed. For industrial categories (AF = 1.13 and for consumer/commercial categories (AF = 1.17.:  
 RF = Release factor to convert consumption data into emission data.  
 EAF = Exempt compound adjustment fraction

Equation 1 employs emissions data to compute a per capita factor while Equation 2 uses national solvent consumption data.

TABLE 2. LIST OF COMPOUNDS EXEMPT FROM EPA'S VOC POLICY<sup>28,29</sup>

Methane	Ethane
Trichlorotrifluoroethane	Methylene chloride
Trichlorofluoromethane	Dichlorodifluoromethane
Chlorodifluoromethane	Trifluoromethane
Dichlorotetrafluoroethane	Chloropentafluoroethane
1,1,1-Trichloroethane (methyl	chloroform)

The adjustment factor (AF?) was determined by taking an adjusted major category consumption, such as industrial uses, and dividing by the respective unadjusted major category total. The adjustment to major categories was undertaken in "End Uses" by adding 80 percent of the unknown solvent to **industrial uses, or  $720 \times 10^6$  kg** and allocating 20 percent to consumer/**commercial uses, or  $80 \times 10^6$  kg**. Equation 2 is primarily used on data extracted from "End Uses". The EA?? multiplier excludes the exempt compounds listed in Table 2 and are considered nonreactive as defined by EPA's VOC policy. For most solvent use categories **EAF** will be equal to 1.

These two equations will apply for most of the derived factors below. **Where other equations** are used to develop per capita factors, a note is included in the derivation discussion.

$\frac{920}{8} = 900 \times 10^6$  kg, on page 2 the value given is  $910 \times 10^6$  kg/yr  
 This value,  $80 \times 10^6$  kg, is in error.  $\frac{80}{100} \times 720 \times 10^6$  kg =  $720 \times 10^6$  kg  
 $\times 900 \times 10^6$  kg  
 Then 20% of  $900 \times 10^6$  kg =  $\frac{20}{100} \times 900 = 180 \times 10^6$  kg  
 which quantity is to be used?

DRYCLEANING:

Recommended factors - The recommended factors were derived from data developed for CTG/NSPS documents. Emissions from perchloroethylene (**perc**) drycleaning plants were derived from national consumption data in Reference 20 and allocated to **commercial and** coin operated (coin-op) plant categories from emission rate data for typical plants contained in Reference 9. Emissions from commercial petroleum solvent drycleaning plants are derived in Reference 21 based on data in References 8 and 22 on the number of plants, clothes throughput per year, and emission rate. By Equation 1, for coin-op plants :

$$\text{Per Capita Factor (PF)} = \frac{48 \times 10^6 \text{ kg/yr}}{220 \times 10^6} = 0.2 \text{ kg/cap-yr}$$

For **commercial** drycleaning, Equation 1 is applied to **perc** and petroleum solvent (PS) emissions with summation producing a combined factor.

$$\text{PF} = \frac{E_{\text{perc}} + E_{\text{ps}}}{P} = \frac{130 \times 10^6 \text{ kg/yr}}{220 \times 10^6} = 0.6 \text{ kg/cap-yr}$$

An estimated population of 220 million was used for the late 1970's, the data base time of reference. These factors were considered to be superior because the data base is recent and because emissions can be calculated separately for commercial and coin-op facilities as area sources, independent of industrial drycleaning plants which should be inventoried as point sources.<sup>2</sup>

Other Factors - Three additional data sources complete the range of per capita emission factors for drycleaning.

"End Uses" - A factor was calculated from national consumption data presented on page 1-21 of Reference 11 and a recommended population figure on page 3-23. The industrial adjustment factor (IF) of 1.13 was used to allocate unidentified solvent use. By Equation 2:

$$\begin{aligned} \text{Per Capita Factor (PF)} &= \frac{290 \times 10^6 \text{ kg/yr} \times 1.13 \times 1.0 \times 1.0}{215 \times 10^6} = \frac{328}{215} \\ &= 1.5 \text{ kg/cap-yr} \end{aligned}$$

This factor includes solvent consumption at industrial drycleaning plants. Assuming that industry profile data in support of CTG/NSPS applies, 55 percent and 20 percent of above factor can be attributed to commercial and coin-op facilities.

$$\text{PF coin-op} = \frac{328}{215} \times 0.20 = 0.3 \text{ kg/cap-yr}$$

$$\text{PF commercial} = \frac{328}{215} \times 0.55 = 0.8 \text{ kg/cap-yr}$$

These factors include petroleum solvents and perchloroethylene but no compounds which are exempt under EPA's nonreactive policy (see Table 2) so that EAF = 1. Because little destructive emission control is practiced within the industry it was assumed that solvent emissions would equal solvent consumption, making the release factor 1.

These factors are inferior since a direct association cannot be made between solvent consumption and the **commercial** and coin-op dry cleaning subcategories. In addition, "End Uses" data are older (1974 and 1977) than the **CTG/NSPS** data (1979).

The two remaining data sets **are based** on local surveys in Tulsa, Oklahoma and Florida. For comparison, emissions have been allocated to **commercial** and coin-op subcategories applying the **55/20** splits described above.

**Tulsa** - Reference 12 uses Equation 1 to develop a factor for Tulsa, Oklahoma. Both the emissions and population data are 1977 base year.

$$\text{PF commercial} = \frac{1,183,000 \text{ lbs/yr}}{428,700} \times 0.45 \text{ kg/lb} \times 0.55 = 0.7 \text{ kg/cap-yr}$$

$$\text{PF coin-op} = \frac{1,183,000 \text{ lbs/yr}}{428,700} \times 0.45 \text{ kg/lb} \times 0.2 = 0.3 \text{ kg/cap-yr}$$

Florida - Reference 13 provides no calculations but rather summarizes emission data which must be manipulated to derive per capita factors. Factors are for five urban counties in Florida.

PER CAPITA FACTORS FOR SEVERAL FLORIDA COUNTIES, kg/cap-yr

<u>Subcategory</u>	<u>Broward</u>	<u>Dade</u>	<u>Duval</u>	<u>Orange</u>	<u>Palm Beach</u>
Coin-op	0.1	0.2	0.2	0.3	0.1
Commercial	0.3	0.5	0.5	0.8	0.4

Reference 13 also mentions an independent **survey** in Duval County which produces conflicting factors of 0.4 kg/cap-yr and 0.1 kg/cap-yr for commercial and coin-op subcategories respectively.

The locally derived factors cause some concern in that they are considerably less than the recommended values of 0.8 kg/cap-yr and 0.3 kg/cap-yr for commercial and coin-op drycleaning, respectively. However, the lower Florida values may be the result of climate on clothing usage. Also, to base a national factor on data from only two regions of the county would not be sound. Thus, the larger national value is still recommended.

COLD CLEANING DEGREASING:

Recommended Factor - A CTG document, Reference 5, was used in developing a per capita emissions factor for cold cleaning degreasing. The rationale in selecting the CTG document was that it contained a breakdown of degreasing emissions by type of operation, such as vapor degreasing, cold cleaning and conveyORIZED degreasing. Other references did not provide a breakdown of emission by process. Emissions data are from Appendix B of Reference 5 while population is a 1974 interpolation from Statistical Abstract. Equation 2 is used to calculate a factor.

$$PF = \frac{380 \times 106 \text{ kg/yr}}{211 \times 10^6} = 1.8 \text{ kg/cap-yr}$$

However, this factor includes exempt compounds according to the breakdown on page 2-5 of the CTG document.

TABLE 3. EMISSIONS SPECIES DATA FOR COLD CLEANING DEGREASING

	Solvent Consumption $10^6$ kg/yr	
	Nonexempt	Exempt
Halogenated:		
Trichloroethylene	25	
<b>1,1,1</b> Trichloroethane		82
Perchloroethylene	13	
Methylene chloride		23
Trichlorotrifluoroethane		10
	<u>38</u>	<u>115</u>
Aliphatics	222	
Aromatics		
Benzene	7	
Toluene	14	
Xylene	12	
<b>Cyclohexane</b>	1	
Heavy aromatics	<u>12</u>	-
	<u>46</u>	
Oxygenated		
Acetone	10	-
<b>Methy</b> ethyl ketone	8	-
<b>Butyl</b>	5	-
Ethers	<u>6</u>	-
	<u>29</u>	
TOTALS	335	115
PERCENTAGE	75%	25%

Based on the species data in Table 3, nonexempt compounds are only 75 percent of the cold cleaning solvent consumption. Therefore the EAF = 0.75 and a reactive per capita factor can be calculated:

$$PF = 1.8 \times 0.75 = 1.4 \text{ kg/cap-yr}$$

This is the value which appears in Table 1 as the recommended factor for estimating cold cleaning emissions.

Other Factors - Two additional factors are derived for comparison with the CTG document based factor.



"End Uses - Reference 11 can also be used to develop a per capita factor but requires that an assumption be made. "End Uses" provides total solvent use for metal cleaning which includes all types of degreasing. On page 2-7 of Reference 5 the cold cleaning fraction of degreasing emissions is 55 percent. Assuming that this fraction applies to the solvent consumption from "End Uses" the per capita factor can then be derived from Equation 2.

$$PF = \frac{(660 \times 10^6 \text{ kg/yr}) \times 0.55 \times 1.13 \times 1.0 \times 0.75}{215 \times 10^6} = 1.4 \text{ kg/cap-yr}$$

The population is recommended by "End Uses" and the industrial apportioning adjustment factor is used. Since few facilities utilize destructive control techniques, the release factor is assumed to be 1.0. The exempt compound adjustment factor is based on the CTG species data. This factor was not recommended in that the assumption made in applying the cold cleaning fraction may not be valid. Thus, the CTG based factor is recommended over the TRC based factor.

Oklahoma Inventory - An additional approach yields another factor by combining data from Reference 5 and AP-42.<sup>18</sup> This method is used in the Oklahoma inventory assistance to estimate area source emission from cold cleaning operations.<sup>14</sup>

$PF = \frac{NU \times EF}{NP}$ : Where NU is the estimated number of units in operation nationally from Reference 5, EF is the emission factor from AP-42, and NP is national population.

$$PF = \frac{1,220,000 \times 300 \text{ kg/yr}}{211 \times 10^6} = 1.7 \text{ kg/cap-yr}$$

Then the factor must be adjusted to exclude exempt compounds using the CTG species data.

$$PF = 1.7 \times 0.75 = 1.3 \text{ kg/cap-yr}$$

This approach is based on data developed in CTG documents and thus the CTG based factor is recommended over this indirectly derived factor.

#### ARCHITECTURAL SURFACE COATING:

Recommended Factor - A CTG draft document was used to develop a per capita factor for **architectual** surface coating emissions. Emissions include solvents contained in paint formulations as well as thinning and cleanup solvent associated with the use of paints. From Reference 6, page 4 and Equation 1:

$$PF = \frac{340 \times 10^6 \text{ kg/yr} + 106 \times 10^6 \text{ kg/yr}}{213 \times 10^6} = \frac{446 \times 10^6 \text{ kg/yr}}{213 \times 10^6} = 2.1 \text{ kg/cap-yr}$$

Emission tonnage is for the respective coatings and associate solvent use. Population is for 1975 from Statistical Abstract.<sup>14</sup>

Under the exempt compound list, no solvents used in architectural surface coatings are classified as unreactive. A list of compounds is included in Reference 6 which was used to derive the per capita emission factor. The list is **summarized** in Table 4.

TABLE 4. ORGANIC SPECIES DATA FOR ARCHITECTURAL SURFACE COATING EMISSIONS

	<u>x 10<sup>6</sup> kg/yr</u>	<u>Percent</u>
Aliphatic Hydrocarbons	224.7	66
Aromatics	20.3	6
Alcohols	10.7	3
Acetone	6.2	2
Methyl Ethyl Ketone (MEK)	5.1	2
Methyl Isobutly Ketone (MIBR)	4.5	1
Acetates	4.9	1
Other ketones/esters	5.9	2
Glycols	34.1	10
Glycol ethers/ether esters	21.9	6
Other miscellaneous	<u>1.5</u>	<u>&gt;1</u>
TOTAL	340	~100

Since **nonreactives** are included, the exempt compound adjustment fraction (**EA**) is 1.0 and the per capita factor is unchanged.

Other Factors - A number of data points are available for comparison with the recommended value.

"End Uses" - From Reference 11, using Equation 2, the following factor is derived:

$$PF = \frac{320 \times 10^6 \text{ kg/yr}}{215 \times 10^6} \times 1.17 \times 1.0 \times 1.0 = 1.7 \text{ ~~lbs~~ <sup>kg</sup>/cap-yr}$$

The release factor is assumed to be one as is the exempt adjustment fraction. The apportioning factor of 1.17 for the consumer/commercial sector is used. This factor does not specify if associated solvent use is included with coating solvent use. Thus, the CTG derived factor is preferred over the ~~TRC-based~~ factor.  
"End Uses"

California - Several values are available for California urban areas and the entire State. The State value is particularly well derived while the other values are primarily present for comparison.

<u>Per Capita Factor</u>	<u>State-wide<sup>15</sup></u>	<u>San Francisco/Oakland<sup>15</sup></u>	<u>San Diego<sup>15</sup></u>	<u>LA/Orange Co.<sup>17</sup></u>
kg/cap-yr	3.0	2.9	3.8	3.2

These values are higher than the recommended factor which may be a result of a greater rate of housing construction in California relative to the rest of the country. Therefore, the recommended factor is still supported.

#### AUTO REFINISHING:

Recommended Factor - Limited data are available on which a per capita factor can be developed. The only data easily obtained is from the "End Uses".<sup>11</sup> Using Equation 2 a factor can be computed.

$$PF = \frac{160 \times 10^6 \text{ kg/yr}}{215 \times 10^6} \times 1.13 \times 1.0 = 0.8 \text{ kg/cap-yr}$$

An apportionment factor of 1.13 for the industrial sector is used. The release factor is assumed to be 1.0 since little known destructive control is practiced in this industry.

No speciation data is presented in this reference for auto refinishing coatings but is only available for coatings in general. Thus the distribution for architectural coatings in Table 4 may be used or a breakdown can be found in Appendix A of Reference 11. Both distributions show that no exempt solvents are included in the derived emission factor. Accordingly the per capita factor is unchanged since EAF is equal to 1.

Other Factor - One other factor is presented for comparison with the recommended factor.

Florida - A per capita factor derivation based on older data in Reference 13 is shown below:

$$PF = \frac{52 \times 10^3 \text{ tons/yr} \times 2000 \text{ lb/ton} \times 0.45 \text{ kg/lb}}{215 \times 10^6} = 0.2 \text{ kg/cap-yr.}$$

This value is based on a similar data base discussed in Reference 16 and is considered an under estimate. The estimate may be affected by regional variations in automobile finish wear. Therefore the factor based on "End Uses is preferred over this factor.

#### GRAPHIC ARTS:

Recommended Factor - Graphic arts traditionally has been inventoried as a point source category. However, a large number of small source do exist in this category in addition to major printing plants. Thus, an area source per capita factor has been suggested. Using data developed for use in CTG/NSPS work a per capita factor for small graphic arts operations (less than 250 kg/day or 100 tons/year) was derived in Reference 26. Equation 1 was employed, however the emission input was modified to exclude major sources. National graphic arts emissions from Reference 7 are reduced by major publication and packaging emissions from References 10, 23 and 24. Non-emissions from letterpress and web offset printing are also excluded based on Reference 25. By Equation 1:

$$PF = \frac{75 \times 10^6 \text{ kg/yr}}{215 \times 10^6} = 0.4 \text{ kg/cap-yr}$$

Population used in computing the factor is assumed to be representative of the data base development period. While requiring numerous assumptions, this factor is considered superior due to the availability of industry profile data.

Other Factor - Another factor was developed and is presented for comparison. Using "End Uses"<sup>11</sup> a factor can be developed with Equation 2.

$$PF = \frac{270 \times 10^6 \text{ kg/yr} \times 1.13}{215 \times 10^6} = 1.4 \text{ kg/cap-yr}$$

This factor would applied to both major and minor graphic arts sources. By applying industry profile data from the CTG/NSPS data base, the factor can be reduced to represent shall graphic arts sources for comparison with the recommended factor.

$$PF = 1.4 \times 0.2 = 0.3 \text{ kg/cap-yr}$$

An apportionment factor of 1.13 for industrial solvent use is employed with population data also from "End Uses". Speciation data in Appendix A of this report indicates that special naphthas represent 98 percent of solvent used in graphic arts. Another 1 percent consists of **glycol** esthers. Therefore, **EAF** = 1.0 and the factor is-unaltered since no exempt compounds are included. This factor is not preferred due to **incompatability** with industrial profile data. When emission adjustments from the **CTG/NSPS** data are subtracted from national solvent consumption data in Reference 11, a negative emissions value results.

#### CONSUMER/COMMERCIAL SOLVENT:

Recommended Factor - "End Uses" provides the most comprehensive breakdown of consumer/commercial solvent. National consumption data is excerpted from page 1-21 of the **report**.<sup>11</sup>

TABLE 5. NATIONWIDE **CONSUMER/COMMERCIAL** SOLVENT USE

USE	Nationwide Consumption	
	kg x 10 <sup>6</sup> yr.	
	Unadjusted	Adjusted
Aerosol products	292	342
Household products	160	183
Toiletries	113	132
Rubbing compounds	53	62
Windshield washing	52	61
Polishes and waxes	41	48
Nonindustrial adhesives	25	29
Space deodorant	15	18
Moth control	12	16
Laundry detergent	3	4
<b>TOTAL</b>	<b>765</b>	<b>895</b>

$$PF = \frac{895 \times 10^6 \text{ kg/yr}}{215 \times 10^6} = 4.2 \text{ kg/cap-yr (including exempt compounds)}$$

The unadjusted column represents only identified consumption data while the adjusted column includes unidentified solvent use allocated using a factor of 1.17 which has been discussed previously. The already adjusted total emissions are then used in Equation 1 to compute a per capita factor. A release factor of 1.0 is assumed since no control of these emissions is practiced. Speciation data indicates that a considerable quantity of the factor emissions consists of exempt compounds. Using Appendix A of the report, the following breakdown can be constructed.

TABLE 6. ORGANIC SPECIES DATA FOR **CONSUMER/COMMERCIAL**  
SOLVENT USE EMISSIONS

Compound	Nationwide Consumption x 10 <sup>6</sup> kg/yr	
	Exempt	Non-exempt
Special naphthas	-	234
Fluorocarbons	74	
Chlorocarbons	102	-
Methylene chloride	50	
Isopropanol	-	89
Ethanol	-	113
Methanol	-	52
<b>1,1,1-Trichloroethane</b>	<b>13</b>	
MIBK	-	3
<b>MEK</b>	-	2
Butyl acetates	-	1
P-Dichlorobenzene	-	27
Perchloroethylene	-	3
TOTAL	<b>239</b>	524
PERCENTAGE	31%	69%

Since non-exempt compounds represent only 69 percent of the consumer/commercial solvent consumption, **EAF** is equal to 0.69. Thus, the factor must be adjusted.

$$PF = 4.2 \times 0.69 = 2.9 \text{ kg/cap-yr}$$

This factor is based on the most recent speciation data available. However, compound usage within the consumer/commercial category can rapidly change over a period of only a few years. For example, the degree of substitution of chlorinated/fluorinated hydrocarbons with parafins is unknown. Thus, while the factor is recommended for inventory use, these substitution trends must be identified.

#### SUMMARY:

The above derived per capita emission factors for release of **organics** into the atmosphere represent the best available data for area source per capita inventoring. However, while these factors are corrected for exempt

solvents, they do not reflect possible changes in substitution patterns between the mid 1970's and the present. -Changes in consumption need to be identified in the future to improve the available data base. In conclusion, the factors should be used in emission inventory development as they represent an improvement over per capita factors previously recommended for use in VOC emission inventories.

#### ACKNOWLEDGEMENTS:

The author expresses his gratitude for the contributions of many individuals within the Monitoring and Data Analysis Division and the Emissions Standards and Engineering Division of the U.S. Environmental Protection Agency, Research Triangle Park, NC, in the compiling of data necessary to develop these emission factors.

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4.9.6  
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Can coating  
Reference 4

AIR POLLUTION CONTROL TECHNOLOGY APPLICABLE  
TO 26 SOURCES OF VOLATILE ORGANIC  
COMPOUNDS

Prepared By

Emission Standards and Engineering Division  
Office of Air Quality Planning and Standards

May 27, 1977

U. S. Environmental Protection Agency  
Research Triangle Park, North Carolina 27711



## INTRODUCTION

In recent months, OAQPS has redirected much of its effort to a review of control technology for principal sources of volatile organic compounds (VOC). The output of these studies will be control technology guidelines (CTG) documents and, where appropriate, new source performance standards. CTG documents identify the effectiveness of alternative control technologies as well as costs, applicability, and energy and environmental considerations. CTG documents are now available in preliminary or final form for degreasing, dry cleaning, gasoline bulk terminals, five specific surface coating operations, and miscellaneous petroleum refinery sources.

Since much of the requisite control technology and related information is available for several other VOC sources, it was deemed desirable to prepare statements which highlight air pollution control aspects for 26 VOC sources cited herein. The statements briefly describe technologies which are applicable and cite costs, energy and environmental impacts and factors which may limit applicability of the technologies along with principal references. It is OAQPS intention to finalize CTG documents for these VOC sources over the next 12 months.

The VOC sources for which control technology summaries are prepared cover a broad spectrum of industry ranging from petroleum refining through gasoline marketing, surface coating, and solvent-use industries. Current emissions from the 26 sources are estimated to be approximately 6,500,000 metric tons per year. This total represents 23 percent of all VOC sources and 37 percent of stationary sources.

A number of major VOC sources (representing an additional 38 percent of the stationary source emissions) are under study but are not included in this summary. Five specific surface coating industries (automobile assembly, can, coil, paper, and fabric coating) and the dry cleaning industry were not summarized since CTG documents will be available in the very near term. Chemical manufacturing operations are also not included since OAQPS has just initiated a major contract effort in this area which will not yield initial results until mid-1978. Work has also been initiated to assess VOC emissions from ship and barge transfer operations+ Stage II (vehicle fueling) service station controls are not included because comments on the November 1, 1976, proposal are under review. The remaining 25 percent of the VOC emissions from stationary sources are emitted from combustion sources, other manufacturing processes, and small solvent users. Should you be aware of major VOC sources which have not been scheduled for review, please bring them to the attention of Mr. Robert T. Walsh, Chief, Chemical and Petroleum Branch, Emission Standards and Engineering Division, MD-13, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

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## STORAGE OF CRUDE OIL AND GASOLINE

### Process Description

The floating roof tank is most commonly used for storage of gasoline and crude oil. The tank consists of a welded or riveted cylindrical vessel equipped with a deck or roof which floats on the liquid surface and rises and falls according to the liquid level in the tank. The liquid surface is completely covered by the roof except for the space between the roof and the wall. A sliding seal(s) attached to the roof contacts the tank wall and covers this space. Escape through this seal is the primary source of hydrocarbon emissions.

### Base Line Emissions

Base line (current control) hydrocarbon emissions nationwide from gasoline and crude oil storage tanks calculated from correlations in API Bulletin 2517 are 1,540,000 metric tons per year.<sup>1,2</sup> This represents 8.9 percent of the estimated 1975 national emissions from stationary sources.<sup>3</sup> Approximately 60 percent or 926,000 metric tons per year are from floating roof tanks. The new source performance standard promulgated March 8, 1974, and many State and local regulations require floating roofs for storage of gasolines and crude oils after the point of crude oil custody transfer. The remaining 614,000 metric tons per year emissions are primarily from the storage of crude oil and gasoline in fixed roof tanks where floating roof tank control is not required.

### Control Technology

A floating roof tank with a single (primary) sliding seal, either a metallic-shoe-type seal or nonmetallic-resilient-type seal, is the most commonly used control technology. While this technology has the potential for

reducing emissions by 70-90 percent compared to storage in a fixed roof tank, nevertheless there are still substantial emissions largely through the seal system. Seal losses increase if there is an improper fit between the single seal and wall which creates gaps through which vapors are released, leakage through the fabric cover that is used to bridge the space between the shoe seal and the floating roof, or gaps caused by rivet heads in the older riveted tanks.

While good maintenance and inspection programs may be effective in reducing emissions through the single seal, recent industry tests have indicated that significant reductions can be achieved by using double seal technology.<sup>4</sup> This consists of installing a second seal (secondary) over the single shoe or resilient type seal (primary). Limited test data indicate that losses with tight secondary and tight primary resilient type seals are 10 to 25 percent of the loss with a tight primary only. Double seal technology will not eliminate the need for frequent maintenance and inspection programs.

#### Cost of Control

Since most gasoline and crude oil storage tanks already are equipped with single seals, the cost of control will be limited to the additional cost for installing a secondary seal on new tanks or the cost of retrofitting existing tanks. Retrofit will be more costly.

Secondary seals cost about \$16 per linear foot installed for retrofit applications.<sup>5</sup> For a tank 200 feet in diameter and 44 feet high with a capacity of 250,000 barrels the capital cost to retrofit a secondary seal is \$9,800 and the annualized cost \$3,000 per year excluding value of the recovered product. The total capital cost of a floating roof tank with a



primary seal installed at an East Coast location is \$9.80 per barrel or \$2,450,000.<sup>6</sup> Emission reduction and hence cost effectiveness of secondary seals over and above primary seals will vary with the wind velocity and the true vapor pressure of the stored product. This is illustrated in the table below.

	4 MPH		8 MPH	
	3.0 psia <sup>2</sup>	6.0 psia	3.0 psia	6.0 psia
Hydrocarbon emission reduction, metric tons/yr	3.6	7.2	10.9	21.8
Value <sup>3</sup> of hydrocarbon saved	\$400	\$800	\$1,200	\$2,300
Annual cost to retrofit minus saving	\$2,600	\$2,200	\$1,800	\$700
Cost of emissions controlled, \$/metric ton	\$722	\$305	\$165	\$ 32

<sup>1</sup> Wind velocity, miles per hour.

<sup>2</sup> Vapor pressure of stored liquid product, pounds per square inch absolute.

<sup>3</sup> Value of recovered hydrocarbons is assumed to be \$110 per metric ton.

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## TANK TRUCK GASOLINE LOADING TERMINALS

### Process Description

Motor gasoline produced at petroleum refineries is transferred primarily by pipeline, ship or barge to intermediate storage at loading terminals. Various grades of gasoline are dispensed through loading facilities into tank trucks. From terminals the gasoline is delivered to bulk plants or to commercial or retail accounts (service stations). It is estimated that there are approximately 2000 tank truck gasoline loading terminals in the United States. At uncontrolled terminals the truck compartments are vented to the atmosphere during loading operations.

### Base Line Emissions

Base line (uncontrolled) emissions of hydrocarbon nationwide from tank truck gasoline loading terminal operations are estimated to be 300,000 metric tons per year, assuming an emission factor of 1 kilogram per liter (kg/l) and a national throughput of 1065 million liters per day (l/d).<sup>1</sup> This represents 1.8 percent of the estimated 1975 national hydrocarbon emissions from stationary sources.\* Based on sparse data, it is estimated that 25 percent of 2000 tank truck gasoline loading terminals are controlled to some degree.

### Control Technology

Control technology utilized to minimize emissions during tank truck gasoline loading include: 1) top-submerged or bottom loading of gasoline (58 percent efficient); 2) vapor recovery equipment (93+ percent efficient); and 3) thermal oxidation (99+ percent efficient). A well designed vapor recovery system will reduce the hydrocarbon concentration of exhaust gases to less than 5 percent by volume. In a thermal oxidizer system if a firebox temperature of 760°C or greater is maintained, a 99+ percent efficiency for the unit would be anticipated.

When vapor recovery or incineration are used, precautions should be taken to ensure that there are no leaks from the trucks and vapor collection equipment during loading. Leaks can be monitored with portable hydrocarbon detectors. Hatches and pressure relief valves on trucks and all valves and connections leading to the vapor control device should be monitored. An emission level of 80 milligrams per liter (mg/l) of gasoline loaded can be achieved with a vapor recovery system and 27 mg/l with an oxidation system provided good leak prevention is maintained. Emission levels with bottom fill or top-submerged fill will be approximately 610 mg/l.<sup>3</sup> Approximately 300 terminals have been equipped with vapor control equipment; most have retrofitted vapor recovery systems to existing facilities. It is estimated that 10 facilities are equipped with thermal oxidizers.

#### Energy Requirements

The energy requirements for top-submerged or bottom fill are minimal. When vapor recovery is used, the energy required to operate the recovery system is more than offset by the increased gasoline recovery. Thermal oxidizers have about the same energy requirements as vapor recovery systems, but there is no offsetting credit for product recovery. Terminals rarely can utilize waste heat from incinerators.

#### Cost of Control

Estimated capital costs to retrofit an existing top-splash fill, 950,000 l/d terminal, are estimated to be \$1500 where simple drop tubes are installed at two racks (with 3 loading arms per rack); \$194,000 for converting the two loading racks and the trucks from top-splash

loading to bottom loading; plus an additional \$141,000 for thermal oxidizers or \$205,000 where vapor recovery is installed. Estimated annual direct operating costs are negligible for drop tubes or bottom loading. Estimated annual direct operating costs range from \$5,500 per year for thermal oxidizers to \$8,000 per year for vapor recovery systems. For a 950,000 l/d terminal with vapor recovery with 100 percent recovery of vapors from the tank truck, an estimated annual credit of \$48,700 for recovered gasoline would be realized.<sup>3</sup> The estimated cost effectiveness of a 950,000 l/d terminal converted to bottom-fill loading with refrigeration type vapor recovery approximates \$0.18 kilogram of hydrocarbon controlled.

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3. "Control of Hydrocarbon from Tank Truck Gasoline Loading Terminals," EPA guideline document in preparation to be released in 1977.

## BULK GASOLINE PLANTS

### Process Description

Bulk gasoline plants are typically secondary distribution facilities which receive gasoline by large tank trucks, and subsequently distribute it via small tank trucks to farms, businesses, and service stations. A typical bulk plant has three fixed roof storage tanks with a total storage capacity of 185,000 liters and an average daily throughput of 75,700 liters.<sup>1</sup> In 1972 there were approximately 23,000 bulk plants in the U.S.; the number declined by 11.3 percent from 1967 to 1972.<sup>2</sup>

### Base Line Emissions

Hydrocarbon vapors are emitted to the atmosphere during filling of storage tanks and loading of tank trucks. Additionally, breathing losses occur at storage tanks. The estimated nationwide uncontrolled emission from bulk plants is 146,000 metric tons per year (68,000 metric tons per year from tank truck loading losses and 78,000 metric tons per year from storage tank breathing and working losses).<sup>3</sup> Emissions from bulk plants contributed to about 0.8 percent of the total 1975 National hydrocarbon emissions from stationary sources.<sup>4</sup>

### Control Technology

Vapor control techniques currently in use at bulk plants include top-submerged fill, bottom fill, and vapor balance. Bottom and top-submerged loading can reduce truck loading emissions by 58 percent, and can be retrofitted to existing racks and tank trucks. Probably the only vapor control system currently in use is the vapor balance system. Tests on two vapor balance systems indicate that they can achieve 90 to 100 percent efficiencies.<sup>5</sup> Although condensation, adsorption, and incineration systems are commonly used in controlling gasoline bulk terminal emissions, they

have not been installed at bulk plants because of their high costs.

No technical impediments prevent their use at bulk plants.

Vapor leakage from tank truck hatch seals, piping connections, and pressure-relief valves will result in low vapor recovery efficiencies for balance systems. It is particularly important that the tank truck hatches be tightly sealed during all transfer operations. The overall effectiveness of vapor balance systems will depend on efficient recovery or destruction of the vapor collected in the bulk plant delivery truck at the bulk terminal. If bulk terminals are not equipped with vapor recovery or incineration systems there will be some loss in efficiency.

#### Cost of Control

For an existing 75,700 liters per day top-splash fill bulk gasoline plant the estimated capital cost of conversion for top-submerged fill is \$640 or \$71,800 for bottom fill. The approximate annualized cost for conversion from top-splash to bottom fill is \$8,900 or \$270 per metric ton of hydrocarbon recovered. Conversion from top-splash to top-submerged fill will result in an annualized credit of \$4,800 or \$120 per metric ton of recovered hydrocarbon.

The capital and annualized costs of installing a vapor balance control system at an existing 75,700 liters per day plant are \$47,100 and \$1,410 respectively. The cost-effectiveness of a vapor balance system is \$179 per metric ton of HC controlled for plants using top-splash and \$470 per metric ton of HC controlled for plants using bottom or top-submerged fill.

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1. "Study of Gasoline Vapor Emission Controls at Small Bulk Plants," EPA 68-01-3156, October, 1976.

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5. "Control of Volatile Organic Emissions from Bulk Gasoline Plants," EPA guideline document in preparation to be released in 1977.



## GASOLINE SERVICE STATIONS

### UNDERGROUND TANK LOADING

#### Process Description

There are two major emission sources in gasoline service stations; the loading of gasoline into underground storage tanks (Stage I) and the fueling of vehicles (Stage II). In both cases, gasoline vapor is displaced from the tanks by the incoming liquid. A lesser source is breathing losses in storage tanks.

#### Base Line Emissions

Emissions vary with filling rate, filling method, Reid vapor pressure, and system temperatures. Based on an estimated loss of 1.1 grams per liter\* (g/l) of gasoline loaded, national emissions from loading underground tanks at service stations are 400,000 metric tons per year or 2.3 percent of total stationary source emissions in the United States. An additional 0.1 g/l of vapor is lost through breathing vents in underground tanks. This adds 42,000 tons per year bringing the total emissions from the storage tanks to 442,000 tons per year or 2.6 percent of stationary source emissions.

#### Control Technology

Stage I losses can be reduced significantly by returning the displaced vapors from underground storage tanks to the delivery tank truck. The collected vapors are displaced to a vapor recovery system at the bulk terminal when the truck tanks are filled. Thus, vapors from service station storage tanks are ultimately controlled at the terminal. The "vapor balance system" itself (vapor return hose from service station

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\*Submerged fill = 0.88 gram per liter, splash fill = 1.4 grams per liter.

underground storage tanks to tank truck compartments and a submerged fill pipe to reduce vapor generation) is 93 to 100 percent efficient in controlling working losses. The effectiveness of the system is reduced considerably if leaks exist in the vapor collection lines or in the truck tanks or if the truck hatches are not tightly sealed while in transit.

Fifteen air quality control regions have implemented this control strategy (Stage I) in service stations. No devices are used specifically to control breathing losses, however, where Stage II control systems are employed (balance underground tanks and vehicle tank) breathing losses are greatly reduced.

#### Cost of Control

Stage I capital costs have been estimated at \$1900 per station made up as follows:

Drop tubes, vent valves	- \$ 300-500
Installation	- \$100
Trenching, backfill paving	- \$1,300-1,600

Operating costs are insignificant. For a typical service station dispensing about 227,000 liters (60,000 gallons) of gasoline per month, the cost effectiveness of a Stage I is estimated to be a credit of \$77 per metric ton of gasoline recovered.

These do not include minor costs associated with conversion of trucks to balance systems. They do, however, include trenching and backfill paving costs which could be associated with Stage II controls.

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3. "A Study of Vapor Control Methods for Gasoline Marketing Operations," Volume I and II, Radian Corporation for EPA-OAQPS, EPA-450/3-75-046 a and b, April 1975.

## GASOLINE TANK TRUCKS IN TRANSIT

### Process Description

Motor gasoline is loaded into tank trucks for distribution to bulk plants, commercial accounts, and retail service stations. During transit on the return trip from the site of the gasoline drop to the terminal, open or leaking hatches, connections, or pressure-vacuum valves can cause the loss of hydrocarbon vapors.

### Base Line Emissions

Base line (uncontrolled) emissions nationwide from tank truck hatch covers are estimated to be 45 to 90 metric tons per year. This estimate is based on a volume of 1065 million liters per day of gasoline transported in tank trucks; the vapors in the truck being saturated; and a gross estimate of 10 to 20 percent loss of the vapor during transit. EPA source tests indicate that a large loss of vapor from tank trucks has occurred in many instances prior to gasoline loading operations. These losses are 0.25 to 0.5 percent of the estimated 1975 national hydrocarbon emissions from stationary sources and 4.0 to 8.0 percent of the emissions from transportation sources.'

### Control Technology

The installation and maintenance of effective hatch seals and pressure-vacuum vents and ensuring that the hatches are shut and locked prior to transit is all that is required to virtually eliminate the estimated 45 to 90 metric tons or more of hydrocarbon currently being emitted. There will still be some emission, however, due to the effect of diurnal temperature changes on truck compartments causing venting through relief valves to the atmosphere.

### Cost of Control

The cost of control will be limited to the cost of installing and maintaining effective seals, connections, and pressure-vacuum valves. This cost is considered to be minimal compared to the value of the product recovered.

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1. "Control of Hydrocarbon Emissions from Petroleum liquids," EPA-600/Z-75-042, September, 1975.
2. "Control of Volatile Organic Emissions from Stationary Sources Volume I: Control Methods for Surface-Coating Operations," EPA-450/Z-76-028, November, 1976.

## LEAKS FROM MISCELLANEOUS REFINERY SOURCES

### Process Description

Petroleum refining is the third largest industry in the United States and presents a potential hydrocarbon (HC) emission problem by virtue of the large quantities of petroleum liquid refined and the intricacy of the refining process. There are 266 refineries currently operating in the United States. Refineries process crude oil through fractionation, decomposition, rebuilding and rearrangement, extraction, and product finishing into over 2500 products.

### Base Line Emissions

Miscellaneous sources of HC emissions that are considered here include: (1) pipeline valves, flanges, and other connections, (2) pump and compressor seals, (3) pressure relief devices, and (4) sampling systems.

Based on January 1, 1977, refinery capacity' the hydrocarbon emissions from the refinery sources listed above are estimated to amount to over 160,000 metric tons per year<sup>2</sup> or about one percent of the stationary source hydrocarbon emissions. These estimates are based on data obtained by the Los Angeles County Joint Study of petroleum refinery emissions in the late 1950's<sup>3</sup> and EPA studies.<sup>4</sup>

### Control Technology

Controls for refinery hydrocarbon emissions fall into two categories, equipment specifications and monitoring techniques. Proper equipment must be installed and kept in good working order by a regular leak detection

and maintenance program. A component is considered to be in good working order if there is no hydrocarbon concentration above 100 ppm as hexane at 5 centimeters from the surface.

There should be a daily unit area walkthrough inspection to locate leaks. When the ambient hydrocarbon concentration anywhere within the unit area is over 20 ppm, there is probably a leak present in the unit. The component causing the elevated concentration should be located and should be repaired if it exceeds the 100 ppm level.

In addition to the daily unit area monitoring, certain components should be individually checked for leaks and certain components should have specified control equipment installed. The pipeline valves should be individually checked for leaks monthly. Rotating pumps and compressors should be fitted with mechanical seals when possible, and all pumps and compressors should be checked for leaks daily. Pressure relief valves should either be vented to the flare header system, protected by a rupture disc, or inspected monthly. Sampling equipment should be checked daily for leaks. It is estimated that implementation of this program would reduce hydrocarbon emissions from these sources by 91 percent to 14,000 metric tons per year.<sup>2</sup>

### Cost of Control

Since the control equipment discussed above is presently being operated in several refineries, it appears the controls are justifiable either in terms of cost-benefit for recovered product or safety. It is also felt that the cost of the additional instrumentation and personnel needed to implement the leak detection and maintenance plan will be appreciably offset by savings from product recovery. Therefore, no rigorous cost-benefit analysis has been developed since the cost impact will be minimal.

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1. "Annual Refining Survey," The Oil and Gas Journal, March 28, 1977.
2. "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources," EPA guideline document in preparation to be released in 1977.
3. "Joint District, Federal and State Project for the Evaluation of Refinery Emissions," Los Angeles County Air Pollution Control District, Nine reports 1957-1958.
4. U. S. EPA, Office of Air Quality Planning and Standards, MDAD-MRB, "National Air Quality and Emission Trends Report 1975," EPA-450/1-76-002, Research Triangle Park, North Carolina 27711, November 1976.



## REFINERY PROCESS DRAINS AND WASTEWATER SEPARATORS

### Process Description

Petroleum refineries generate large quantities of process wastewater. Depending on many factors, a refinery may generate up to one barrel of wastewater for every barrel of crude oil throughput. Process wastewater originates from several sources in petroleum refineries including, but not limited to, crude desalting, leaks, spills, pump and compressor seal cooling and flushing, sampling, and equipment cleaning. Contaminated wastewater is collected in the process drain system and directed to the refinery treatment system where oil is skimmed in a separator and the wastewater undergoes additional treatment as required.

### Base Line Emissions

The nationwide hydrocarbon emissions from petroleum refinery process drains and wastewater separators are estimated to be 295,000 metric tons per year' based on January 1, 1977, throughput of 2.69 million cubic meters of crude oil per day.<sup>2</sup> This is approximately 1.6 percent of the nationwide stationary source emissions of hydrocarbons.<sup>3</sup>

### Control Technology

Controls for refinery process drains and wastewater separators consist of 1) the refinery operator should perform a monthly monitoring program for detection of hydrocarbon concentrations above 100 ppm as hexane at 5 centimeters from the process drains and wastewater separators and 2) floating roof covers for all forebays and all initial wastewater separators. The monitoring program is necessary to ensure that no excess hydrocarbons have been released into the drain system and that all hatches remain closed

when not in use. The covers are necessary to ensure that the volatile hydrocarbons are returned to the system (crude desalter unit usually) before they can evaporate to the atmosphere. Application of these controls will result in an estimated 90 percent reduction in emissions from these sources.

There are important considerations that need to be taken into account when covering a wastewater separator. When using a floating roof cover, care must be taken to ensure that the cover will not interfere with the operation of the oil skimmer. Fixed roof covers can have a vapor space between the cover and the liquid surface. This vapor space may constitute an explosion hazard unless it is gas-blanketed with hydrocarbon or nitrogen and vented to a flare.<sup>4</sup>

#### Cost of Control

The 1976 estimates for cost-effectiveness of controlling wastewater separators by installing floating roof covers for the **forebay** and main separator are a credit of \$70.48 and \$79.73 per metric ton of emissions reduced for a 9850 and a 31,800 cubic meter per day refinery, respectively.<sup>4,5</sup> The cost of the portable hydrocarbon analyzer needed for the monitoring program should range from \$800 to \$4000 each, depending on the type of instrument used. Although no rigorous cost-effectiveness analysis has been performed for the leak detection plan, it is felt that the costs will be appreciably off-set by savings from product recovery.

#### References

1. "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources," EPA guideline document in preparation to be released in 1977.

2. Annual Refining Survey, The Oil and Gas Journal, March 28, 1977.
3. U. S. EPA, Office of Air Quality Planning and Standards, MDAD-MRB, "National Air Quality and Emission Trends Report 1975," EPA-450/1-76-002, Research Triangle Park, North Carolina 27711, November 1976.
4. "Hydrocarbon Emissions from Refineries," Committee on Refinery Environmental Control, American Petroleum Institute Publication No. 928, July 1973.
5. "Economic Impact of EPA's Regulations on the Petroleum Refining Industry," U. S. EPA, Office of Planning and Evaluation, Report Number 230/3-76-004, April 1976.

## REFINERY VACUUM PRODUCING SYSTEMS

### Process Description

Bottoms from the atmospheric distillation tower can be further fractionated if the temperature is increased and the pressure is lowered. This is performed in the vacuum distillation tower. Three types of vacuum producing devices are used to remove gases and vapor from the tower: steam jets with barometric condensers, steam jets with surface condensers, and mechanical vacuum pumps. The educted vapors and evaporation from the accumulators or hot wells (barometric condensers only) are potential hydrocarbon emissions from refinery vacuum producing systems.

### Base Line Emissions

Based on January 1, 1977, refinery capacity (2.69 million cubic meters per day),<sup>1</sup> The hydrocarbon emissions from the refinery vacuum producing systems are estimated to amount to approximately 127,000 metric tons per year.<sup>2</sup> This is about 0.7 percent of the total stationary source hydrocarbon emissions.<sup>3</sup>

### Control Technology

The non-condensable gases should either be vented directly to a combustion device or compressed and added to the refinery fuel gas system. The hot wells and accumulators should be covered and vented to a combustion device. Implementation of these controls will result in negligible emissions of hydrocarbon to the atmosphere.

### Energy Requirements

There will be an energy requirement for the non-condensable gas compressor if one is used, but this requirement will more than be off-set

by the savings from the recovered hydrocarbons. A 15,900 cubic meter per day refinery will recover the equivalent of 1300 cubic meters of crude oil per day. Other energy requirements for the controls listed are minimal.

#### Cost of Control

Estimates of the cost-effectiveness of compressing the non-condensables and incinerating them in the nearest firebox are a credit of \$31.16 per metric ton of hydrocarbon emissions reduced. This is based on a 15,900 cubic meter per day refinery operating in 1973.<sup>4,5</sup> This estimate does not include the cost of a condensate receiver for a surface condenser or the cost of covering the barometric hot well.

#### References

1. Annual Refining Survey, The Oil and Gas Journal, March 28, 1977.
2. "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources," EPA guideline document in preparation to be released in 1977.
3. U. S. EPA, Office of Air Quality Planning and Standards, MDAD-MRB, "National Air Quality and Emission Trends Report 1975," EPA-450/1-76-002, Research Triangle Park, North Carolina 27711, November 1976.
4. "Hydrocarbon Emissions from Refineries," Committee on Refinery Environmental Control, American Petroleum Institute Publication No. 928, July 1973.
5. "Economic Impact of EPA's Regulations on the Petroleum Refining Industry," U. S. EPA, Office of Planning and Evaluation, Report Number 230/3-76-004, April, 1976.

## REFINERY PROCESS UNIT TURNAROUND

### Process Description

Periodically every refinery processing unit must be shut down for maintenance. The shutting down, purging and restarting of a unit is called a turnaround. In short, when a unit is shut down, the hydrocarbon liquids are pumped to storage and the hydrocarbon gases are purged from the vessel. It is then ventilated to provide a safe atmosphere for workmen. The emissions that occur as a result of the shutting down is called blowdown. Unit turnarounds occur every one to five years depending on many factors.

### Base Line Emissions

The nationwide hydrocarbon emission estimate for refinery **blowdown** systems is 450,000 metric tons per year,<sup>1</sup> based on January 1, 1977, capacity of 2.69 million cubic meters of crude oil throughput per day.<sup>2</sup> This is approximately 2.5 percent of the total stationary source emissions of hydrocarbons.<sup>3</sup>

### Control Technology

Controls for refinery **blowdown** systems consist of combusting the non-condensable vapors. When the vessel is depressurized, the non-condensable vapors can be either added to the refinery fuel gas system or flared. When the pressure in the vessel drops below that of the fuel gas system, the vapors are then combusted in the flare. This should continue at least until the hydrocarbon concentration in the vessel drops below 10 percent by volume. The vessel is then ventilated to atmosphere to allow maintenance personnel to enter. Application of these controls will result in emissions of 2300 metric tons per year from process unit turnaround.

### Cost of Control

Since the control technology described above is presently being applied in several refineries, it appears the controls are justifiable either in terms of recovered product or refinery safety. Piping costs are involved with attaching some of the units to existing fuel gas and flare systems; these costs should be minimal.

### References

1. "Control of Hydrocarbon Emissions from Petroleum Liquids," U. S. EPA Report No. 600/2-75-042, September, 1975.
2. Annual Refining Survey, The Oil and Gas Journal, March 28, 1977.
3. U. S. EPA, Office of Air Quality Planning and Standards, MDAD-MRB, "National Air Quality and Emission Trends Report 1975," EPA-450/1-76-002, Research Triangle Park, North Carolina 27711, November, 1976.

## LEAKS FROM NATURAL GAS AND NATURAL GASOLINE PROCESSING PLANTS

### Process Description

Natural gas is produced in conjunction with crude oil, natural gas liquids, water, carbon dioxide, and hydrogen sulfide. The crude oil and water are generally separated from the gases near the wellhead. Gas free crude and other liquids are stored for eventual transfer to the refinery. The remaining liquids and gases are sent to a gas plant where the liquids, hydrogen sulfide, carbon dioxide, and  $C_2$  to  $C_5$  hydrocarbons are separated from methane before it is placed in the pipeline. The emissions and control techniques described below apply only to the natural gas and natural gasoline plant not to any facilities between the wellhead and the gas plant.

### Base Line Emissions

The nationwide hydrocarbon emission estimate for natural gas and natural gasoline processing plants is 152,000 metric tons per year, based on 1973 estimates of 1.86 billion normal cubic meters of production per day. This is about 0.9 percent of the total stationary source hydrocarbon emissions.<sup>2</sup>

### Control Technology

Oil-water separators, pump and compressor seals, pressure relief devices, and pipeline valves and flanges are the sources of hydrocarbon emissions. These emissions occur as a result of leaks. One of these components is deemed to be leaking if there is a concentration of 100 ppm hydrocarbon as hexane at a distance of 5 centimeters from the component. The leaks will be minimized if the oil-water separators are covered, mechanical seals are used on all rotating pumps and compressors, all pressure relief devices are vented to flares or protected by rupture discs,



and if a regular program of leak detection and maintenance is followed. The frequency with which each type of component should be individually checked for leaks is 1) oil-water separators - monthly; 2) pump and compressor seals - daily; 3) pressure relief devices - monthly; and 4) pipeline valves - monthly. Also the ambient air concentrations should be measured daily throughout the plant using a portable hydrocarbon detector. The source of any ambient hydrocarbon readings over 20 ppm should be located and repaired if the source is in excess of the 100 ppm level. Application of the above controls will result in an estimated 91 percent reduction in hydrocarbon emissions from these sources.<sup>3</sup>

#### Energy Requirements

Implementation of these controls will have a minimum impact on energy use and can result in an energy savings due to decreased losses of hydrocarbon product.

#### Cost of Control

Since the control equipment discussed above are presently being applied in many plants, it appears the controls are justifiable either in terms of cost-benefit for recovered product or refinery safety. Even though additional instrumentation and personnel may be needed to implement the leak detection and maintenance plan, these costs will be off-set by savings from product recovery. The cost of a portable hydrocarbon detector should range from \$800 to \$4000 each, depending on the type of instrument used. Therefore no rigorous cost-benefit analysis has been developed since the cost impact will be minimal.

#### References

1. "Control of Hydrocarbon Emissions from Petroleum Liquids:" U. S. EPA Report No. 600/2-75-042, September, 1975.

2. U. S. EPA, Office of Air Quality Planning and Standards, MDAD-MRB, "National Air Quality and Emission Trends Report 1975," EPA-450/1-76-002, Research Triangle Park, North Carolina 27711, November, 1976.

3. "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources," EPA guideline document in preparation to be released in 1977.

## LEAKS FROM OIL AND GAS PRODUCTION FIELDS

### Process Description

In a producing oil well, there are three basic methods of bringing the oil to the surface: natural flow, steam or water lifting (injection of steam or water into the well), and pumping. Oil and gas production operations include the separating and transferring of oil and gas. The production from each well is sent to a gathering system which consists of the piping, valves, and fittings that are necessary to collect and combine the production from the individual wells.

Crude oil and natural gas liquids are produced in association with gases and water which must then be treated to separate crude oil from gas and water. The gas free crude and other petroleum liquids are stored for eventual transfer to the refinery. The gases are then piped to a gas plant where any remaining liquid hydrocarbon, hydrogen sulfide, carbon dioxide, and  $C_2$  to  $C_5$  hydrocarbons are separated before the methane is placed in the pipeline. The control techniques described below apply to the well head equipment, heater treaters, separators, and the piping and valves up to but not including the gas plant.

### Base Line Emissions

Leaks from pump seals, compressor seals, relief valves, open crude ponds, and pipeline valves are the source of hydrocarbon emissions from production fields. The nationwide hydrocarbon emission estimate of 148,000 metric tons per year<sup>1</sup> for crude and gas production is extremely rough.

### Control Technology

Effective control of potential leaks requires a good detection and maintenance program. Any leak which exceeds 100 ppm at a distance of 5 cm from the source would require maintenance.\* All potential leak sources should be checked monthly with a portable hydrocarbon detector. Ponds or other types of open crude storage should be eliminated and replaced by storage tanks.

### Costs of Control

The cost of the maintenance program is dependent on the size of the field, the number of sources, and the degree of maintenance employed but is not expected to be significant. The hydrocarbon detector would cost about \$800 to \$4,000.

### References

1. "Control of Hydrocarbon Emissions from Petroleum Liquids," Radian Corporation. September 1975.
2. "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources," EPA guideline document in preparation to be released in 1977.

## CUTBACK ASPHALT PAVING

### Process Description

Asphalt is a by-product of petroleum distillation (natural or manmade) which is used in many different paving applications. Asphalts take the form of asphalt cement (the residue of the distillation of crude oils) and liquefied asphalts. Liquefied asphalt is frequently thinned with volatile petroleum distillates (cutbacks) such as naphtha and kerosene. Heat is used with cutbacks to facilitate spraying. The volatiles in cutback asphalts release hydrocarbons into the atmosphere in amounts that vary according to the type of cutback.

### Base Line Emissions

The national hydrocarbon emission estimates from the use of cutback asphalt paving products was 672,000 metric tons per year in 1975.

### Control Technology

The technology to control hydrocarbon emissions from these paving operations consists of substituting emulsified asphalts in place of cutback asphalts. Emulsified asphalts use water and non-volatile emulsifying agents for liquefaction; virtually no pollutants are emitted during the curing of emulsions. Emulsified asphalts are used widely in the construction and maintenance of pavements ranging from high traffic volume highways and airports to low-volume rural roads and city streets. Emulsions have been available since 1903 and used extensively since the 1930's.

### Energy Requirements

The substitution of emulsions for cutbacks could save almost 1.59 billion liters of petroleum distillate annually for use as or conversion to fuels and eliminate the 672,000 metric tons of hydrocarbons currently being emitted to the atmosphere. Also, much of the energy required to heat the cutbacks would be saved.

### Environmental Considerations

There are no adverse environmental effects associated with the substitution of emulsified asphalt for cutback asphalt.

### Costs of Control

The price difference between the two types of liquefied asphalt concrete is insignificant. Therefore, there is no control cost associated with the substitution.

Factors Which Affect Applicability - Emulsified asphalt can be substituted for cutbacks in almost any application. Some emulsified asphalts, however, usually are not used when rain is anticipated or when temperatures fall below 10°C. Emulsified asphalt is not recommended for long-term stockpiling (more than 3-4 weeks) whereas cutback asphalt can be stockpiled indefinitely. The same construction equipment used for cutbacks can be used for emulsions. A moderate amount of training (one or two days) is necessary to familiarize operators with technology for employing emulsions.

References

"Some Air Quality and Energy Conservation Considerations for the Use of Emulsions to Replace Asphalt Cutbacks in Certain Paving Operations," Prepared by Francis M. Kirwan and Clarence Maday, U. S. Environmental Protection Agency, March 1977, draft report.

## COLD CLEANING WITH ORGANIC SOLVENTS

### Process Description

Cold cleaners are tanks of organic solvent used for cleaning or degreasing metal parts at or near room temperature. Metal parts may be cleaned manually by spraying and brushing or automatically by immersion into an agitated solvent bath. Automotive parts cleaning and plant maintenance are normally performed using cold cleaning because it is inexpensive and there is no need for the cleanliness obtainable with vapor degreasing. There are an estimated 1,300,000 cold cleaners in operation in the United States.

### Base Line Emissions

An estimated 360,000 metric tons of organic solvents were emitted as a result of cold cleaning in 1974. Evaporation of disposed waste solvent accounted for over half of the total. The solvents included aliphatic (50 percent), halogenated (34 percent), aromatic (10 percent), and oxygenated (6 percent) **organics**. Three-fourths of the halogenated solvent used were methyl chloroform, methylene chloride, and **trichloro-trifluoroethane** (Freon 113<sup>®</sup>). All three react very slowly in the atmosphere yielding negligible oxidant. However, because of their chemical stability, they pose a threat to the earth's ultraviolet shield in that they may deplete ozone in the stratosphere.

### Control Technology

Emission standards are not practical because degreasing is by nature an open operation that prevents complete capture or measurement of emissions.



Equipment and operating standards appear to be the only viable alternatives.

Emission control is accomplished through both improved operating practices and addition of control equipment. The most important operating improvements are: (1) store and then dispose of or distill waste solvent so as to minimize atmospheric evaporation, (2) close covers on cold cleaner tanks whenever possible, and (3) drain cleaned parts sufficiently. The basic control equipment is the cover and a parts drainage facility. These should be standard on cold cleaners. For cleaners using high volatility solvents (greater than 33 mm Hg vapor pressure at 38°C), important control devices are the water cover (for halogenated solvents) and a high freeboard (the clearance as measured from the solvent level to the top of the cleaner).

Controls on waste solvent disposal can reduce total cold cleaning emissions by 10 to 40 percent; controls on direct emissions can reduce emissions by an additional 10 to 30 percent, for a total efficiency of 20 to 70 percent.

#### Energy Requirements

No significant energy is consumed to control cold cleaners. Distillation consumes approximately 0.3 kilowatt-hour per kilogram of waste solvent compared to approximately 25 kilowatt-hours per kilogram required to produce replacement solvent.

#### References

1. "Control of VOC from Organic Solvent Metal Cleaning Operations," EPA Guideline Document in preparation to be released in 1977.

2. "Study to Support New Source Performance Standards for Solvent Metal Cleaning Operations," Dow Chemical Company, Prepared for EPA under Contract No. 68-02-1329, Task No. 9.

Control Costs

Typical Retrofit Cases

Solvent Used	Control Devices	Capital cost (\$)	Annualized Cost (Credit) (\$/yr)	Cost (Credit) Effectiveness (\$/kg controlled)	Emission Reduction (kg/yr)
Low Volatility (Mineral Spirits)	Drainage Facility	25	0.5	0.3-(0.07)	25
High Volatility (e.g. blended solvent with 60% methyl chloroform)	Drainage Facility, Mechanically assisted cover	65	(25)	(0.08)-(0.3)	100

## VAPOR DEGREASING

### Process Description

A vapor degreaser is a tank in which metal parts are cleansed by the washing action of condensing solvent. Vapors are contained within the tank by means of cooling coils near the top. Only non-flammable halogenated solvents are employed in vapor degreasers. The cleaning process may be assisted by spraying or by immersion into the boiling liquid solvent. Open top vapor degreasers are by definition open and are batch loaded; conveyORIZED degreasers are enclosed and are continuously loaded. The most recent estimates indicate that there are about 4000 conveyORIZED and 22,000 open top vapor degreasers in operation in the United States.

### Base Line Emissions

In 1974, vapor degreasing operations resulted in approximately 300,000 metric tons of organic solvent emissions. One-third came from conveyORIZED and two-thirds from open top degreasing.

Halogenated organics are always used for vapor degreasing because of non-flammability and high vapor density. In decreasing order of usage, the predominant solvents are trichloroethylene, 1,1,1 trichloroethane (methyl chloroform), perchloroethylene, trichlorotrifluoroethane (Freon 113<sup>®</sup>) and methylene chloride.

### Control Technology

For most vapor degreasers, it is difficult or impossible to measure emissions directly. Furthermore, emissions tend to vary widely depending upon the type of parts being degreased, solvents and operating practices.

Thus, losses do not necessarily reflect the degree of control being exercised. For these reasons, equipment and operating standards appear to be the most viable control approaches.

Open Top Vapor Degreasers - Organic emission reductions are accomplished through both improved operating practices and installation of control equipment. The ten most effective operating practice improvements are: (1) keep cover closed whenever possible, (2) minimize solvent carry-out by proper parts racking, convey parts at less than 3.3 meters per second, cook work loads for at least 30 seconds and dry for at least 15 seconds, (3) do not degrease porous materials, (4) do not process work loads that occupy more than 50 percent of the horizontal open area, (5) do not let the vapor level drop more than 10 centimeters below normal, (6) do not spray above the vapor level, (7) repair leaks immediately, (8) store and then dispose of or distill waste solvent so as to minimize atmospheric evaporation, (9) maintain exhaust ventilation below 20 meters per minute per square meter of air/vapor interface, and (10) ensure that the water separator operates properly.

Control equipment and features which reduce emissions are covers, safety switches, increased freeboard, refrigerated chillers, enclosed design and carbon adsorbers. A complete control system would include the first two devices and one of the last three.

Covers may be manually operated, mechanically assisted, powered or automated, but the crucial factor is that they be convenient to operate. Safety switches should be designed to cut off the spray if the vapor level drops too low, and to cut off the sump heater if the sump overheats

or the cooling coils cease functioning. A minimum freeboard ratio (freeboard height divided by degreaser width) of at least 0.5 is recommended by degreaser manufacturers, but it should be as large as possible consistent with ease of inserting and removing parts. Refrigerated chillers cool the air immediately above the vapor zone to impede outward diffusion and convection of vapors. An enclosed design keeps the cover closed at all times except when dry parts are actually entering or exiting the degreaser. Carbon adsorption systems are effective organic vapor control devices but are limited in degreasing by the difficulty in capturing fugitive emissions.

Use of all ten operating practices may reduce emissions by 20 to 40 percent; the control equipment and design features may reduce them by an additional 30 to 60 percent, for an overall efficiency of 45 to 75 percent.

Conveyorized Degreasers - For control of conveyorized units, the most effective operating practices are: (1) repair leaks immediately, (2) store and then dispose of or distill waste solvent so as to minimize atmospheric evaporation, (3) maintain exhaust ventilation below 20 meters per minute per square meter of air/vapor interface, (4) ensure that the water separator operates properly, (5) minimize solvent carry-out by proper parts racking, and (6) convey parts at less than 3.3 meters per second.

Control equipment and features which reduce emissions are safety switches, refrigerated chillers, carbon adsorption, minimized conveyor openings and downtime cover. Safety switches, refrigerated chillers, and carbon adsorption were discussed earlier. The entrance and exit

opening for conveyed parts should be as small as possible to minimize vapor escape; all openings should be covered during shut down to prevent vapors from escaping.

A complete control system for a conveyorized unit with all of the devices listed, i.e., chiller or adsorber (but not both), will reduce VOC emissions by 50 to 70 percent.

#### Energy Requirements

Carbon adsorption requires energy, usually in the form of steam for desorption. The steam requirement is typically 5 kilowatt-hours per kilogram solvent recovered. This energy expenditure is more than offset since production of replacement solvent consumes about 25 kilowatt-hours per kilogram.

#### References

1. "Control of VOC from Organic Solvent Metal Cleaning Operations," OAQPS guideline document to be released in 1977.
2. "Study to Support New Source Performance Standards for Solvent Metal Cleaning Operations," Dow Chemical, prepared for EPA under contract no. 68-02-1329, Task No. 9.

Control Costs (retrofitted)

For Typical Degreaser:	Open Top Vapor (1.67 m <sup>2</sup> area)	Major Control Device Option				
		Manual Cover	Freeboard & Powered Cover	Refrig. Chiller	Enclosed Design	Carbon Adsorption
Capital Costs (\$)		300	8000	6500	16,000	10,300
Avg. Annualized Cost (Credit)(\$/yr)		(300)	310	85	35	800
Cost (Credit) Effectiveness (\$/kg controlled)		(0.4)	0.4-(0.04)	0.03-(0.1)	0.2-(0.1)	0.5-0.06
Emission Reduction (ton/yr)		1.1-3	1.7-3.8	2.3-4.2	6.1-4.2	2.3-4.6

For Typical Degreasers:	ConveyORIZED (3.8 m <sup>2</sup> vapor area)	Major Control Device Option			
		Monorail Adsorber	Deg. Chiller	Cross-Rod Adsorber	Deg. Chiller
Capital Cost (\$)		17,600	8,600	17,600	7,500
Avg. Annualized Cost (Credit) (\$/yr)		(1,600)	(3,700)	(1,500)	(650)
Cost (Credit) Effectiveness (\$/kg controlled)		(0.03)-(0.19)	(0.24)-(0.32)	(0.53)-(0.14)	(0.016)-(0.19)
Emission Reduction (ton/yr)		10-17	10-17	4-7	4-7



GRAPHIC ARTS  
ROTOGRAVURE PRINTING OPERATIONS

Process Description

In the gravure method of printing, the very fluid inks fill the recessed image areas, excess ink is wiped off by a doctor knife, the image is transferred directly to the paper or other substrate and the product is dried. When the paper is fed from a roll, the process is known as rotogravure. Since sheet-fed gravure is slow, it is little used and is not included in this subject category.

Base Line Emissions

The emission from rotogravure presses are estimated to be 140,000 metric tons per year.<sup>1</sup>

Control Technology

Carbon adsorption has been successfully used at several large publication rotogravure plants.<sup>2</sup> Overall recovery efficiency is about 90 percent, giving an emission level of 0.05 kilograms per liter of ink.

Packaging and specialty gravure printers use a wide range of solvents depending upon the substrate to be printed. Carbon adsorption may be more expensive for such operations because of the difficulty or impossibility of reusing the recovered solvents. Fume incineration has been used in a few instances. Overall efficiency is 85 to 90 percent with a resultant emission level of 0.07 kilograms per liter of ink. Although water-borne inks are used

for the use of the material in other uses.

### Cost of units

The cost of a unit of equipment is \$170,000 for a single press, and \$500,000 for a large publication printing plant. Annual production costs are \$30,000 and \$520,000 or \$250 and \$110 per ton of paper, respectively, for a small and large plant. The cost of a unit of equipment would be assured since rotogravure ink is sold at 10 cents per kilogram. Additional details on costs are given in Reference 1.

Installed equipment for heat recovery range from \$100,000 for a small plant to \$525,000 for a large (43 Nm<sup>3</sup>/s) plant.<sup>3</sup> Annual production costs are \$30,000 and \$1,000,000, respectively, or \$275 and \$110 per ton of paper, including secondary heat recovery, installed equipment cost of \$100,000 and \$525,000, respectively. Annual costs would be \$275 and \$110 per ton of paper, or \$120 and \$40 per ton. More details are given in Reference 3.

### References

1. "Control of Air Pollution: Identification of Emissions and Control Technology for the Printing Industry, Phase I," Graphic Arts Technical Institute, 1975.
2. "Energy and Environmental Control Use in Printing Operations," EPA-560/1-73-077, Environmental Criteria Series, U. S. Environmental Protection Agency, 1973.
3. "Control of Air Pollution From Existing Stationary Sources - Industrial Processes - Printing Operations," EPA-450/2-76-001, Environmental Criteria Series, U. S. Environmental Protection Agency, November 1976.

GRAPHIC ARTS  
WEB-OFFSET PRINTING OPERATIONS

Process Description

In offset lithography, the printing and non-printing areas of the image carrier are on the same plane. The image areas are sensitized so as to be ink wettable and water repellent. The image is first transferred to a rubber covered roll (called a blanket) and hence is transferred to the paper. The image carrier is thus "offset" from the substrate. The paper is fed to the press from a roll and forms a continuous "web" as it travels through the printing and drying operations.

Base Line Emissions

It is estimated that web-offset presses emit 100,000 metric tons per year of VOC.<sup>1,2</sup>

Control Technology

A number of direct flame incinerators have been installed to control emissions from web-offset dryers. Nineteen test reports show an average efficiency of 95 percent.<sup>3</sup> Conventional inks average about 45 percent organic solvent by volume, and contain 0.36 kilograms per liter. Allowing for a slight loss of capture, overall efficiency is 90 percent, equivalent to an emission level of 0.036 kilograms per liter of ink used.

Eight test reports on catalytic incinerators averaged 89 percent efficiency. Allowing for a slight lack of capture, overall efficiency is 85 percent. Achievable emission level is 0.054 kilograms per liter of ink.

in brevity, it is not possible to give a full description of solvent. The vehicle of the ink must contain monomers, oligomers and prepolymers which polymerize under the influence of light. The curing time and temperature requirements are less than those for conventional ink, conventional dryers can be used. The ink contains some organic solvent, averaging about 15 percent of the total weight of conventional inks.<sup>4</sup> Emission rates are about 1/10th of those of conventional ink.

A carbon adsorption system has been used in one web-offset printing plant. Conventional operations are used, averaging about 45 percent solvent. Overall recovery efficiency is about 90 percent, equivalent to an emission level of about 0.05 grams per liter of ink used.

#### Cost of Coating

The costs of solvents for unrefined masses are the same as those cited for refined solvents. Additional details on costs are given in Reference 1.

In Reference 1, it is estimated that ultraviolet curing inks cost two or three times as much as conventional inks. The cost of hardware to replace the apparatus used for conventional inks to specific figures are available. However, the cost of the hardware is less than the fuel cost of a conventional ink.

The cost of ultraviolet light is reported to be 140-200 percent of the cost of conventional light. If ultraviolet light can be used, there is no additional charge.

A carbon adsorption system controlling a web-offset printing plant is reported to have a capital cost of 3.3 to 4.7 cents per  $\text{Nm}^3/\text{s}$ .<sup>5</sup> Presumably, installed cost would be 6.6 to 9.4 cents per  $\text{Nm}^3/\text{s}$ . In the desorption and recovery process in this system, electric heaters, vacuum pumps, and refrigerated condensers are used. The cost of conventional systems using steam for desorption are given in Reference 4.

#### References

1. Gadomski, R. R., et.al., "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase I". Graphic Arts Technical Institute, August 1970.
2. Test Report Summaries. Los Angeles County Zone, South Coast Air Quality Management District. El Monte, California.
3. Gadomski, R. R., et.al., "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase II." Graphic Arts Technical Institute, May 1973.
4. "Environmental Aspects of Chemical Use in Printing Operations." EPA-560/1-75-005. Office of Toxic Substances, Environmental Protection Agency, January 1976.
5. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations!" EPA-450/2-76-028. U.S. Environmental Protection Agency, November 1976.

## GRAPHIC ARTS

### WEB LETTERPRESS PRINTING OPERATIONS

#### Description of the Process

In the letterpress method of printing, the image areas are raised relative to the nonimage areas. This is the original method of printing with type. Ink is applied to the image areas and transferred directly to paper or other substrate. The ink is viscous enough not to run into the recessed (nonimage) areas.

Letterpress printing can be divided into three categories. Newspaper printing utilizes ink composed of petroleum oils and carbon black, but no volatile solvent. The ink "dries" by absorption into the porous newsprint paper. Roll-fed (web) presses utilizing nonporous paper employ organic solvent-borne inks which dry by solvent evaporation. Sheet-fed presses utilize a non-solvent ink which dries by air oxidation at room temperature in racks. Only web presses using solvent-borne inks are included in the subject category.

#### Base Line Emissions

The total national annual emissions of VOC web letterpress are estimated to be 78,000 metric tons.

#### Control Technology

A number of incinerators have been installed to control print dryers. Test reports show an average efficiency of 95 percent.<sup>1,5</sup> Allowing for a

slight loss of capture, overall efficiency is 90 percent, comparable to an emission level of 0.036 kilograms per liter of ink used.

Ultra-violet curing inks eliminate the use of volatile solvents. The vehicle of the ink consists entirely of monomers and prepolymers which polymerize to a dry resin film in a few seconds in an ultra-violet light chamber. Emissions are essentially zero.

Heat reactive inks reduce the use of solvents. The vehicle for these inks consists mostly of monomers and prepolymers which polymerize under the influence of heat and a catalyst. Time and temperature requirements are about the same as for drying conventional inks, hence conventional dryers can be used. The inks contain only about 15 percent of the organic solvent content of conventional inks.<sup>3</sup> Emission rates are about 0.054 kilograms per liter.

Conventional heat-set inks averaging about 45 percent solvent can be controlled with carbon adsorption. Overall recover, efficiency is about 90 percent. Achievable emission level is about 0.036 kilograms per liter of ink used.

Water-borne inks are used in some letterpress applications and can achieve an emission level of 0.06 kilograms of VOC per liter of ink (minus water) representing a reduction of 80 percent over a typical heat-set ink.

#### Cost of Control

The cost of incineration for letterpress operations are similar to those cited earlier for rotogravure printing. Additional details are given in Reference 4.

In Reference 1, page 261, it is estimated that ultraviolet curing inks cost 2 to 3 times as much as conventional inks. The cost of the hardware to replace the existing oven would be considerable, but no specific figures are available. However, the cost of operating a UV unit is less than the fuel cost of a conventional oven.

The cost of heat-reactive inks is reported to be 140 to 200 percent of the cost of conventional inks.<sup>3</sup> Since conventional ovens can be used, there is no additional equipment cost for a changeover.

The hardware of a carbon adsorption system controlling a web-offset printing plant is reported to cost 3.3 to 4.7 cents per Nm<sup>3</sup>/s. Presumably installed cost would be 6.6 to 9.4 cents per Nm<sup>3</sup>/s. In the desorption and recovery process in this system, electric heaters, vacuum pumps, and refrigerated condensers are used. The cost of conventional systems using steam for desorption is given in Reference 4.

#### References

1. Gadomski, R. R., "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase II," Graphic Arts Technical Institute, May 1973.
2. Gadomski, R. R., "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase I," Graphic Arts Technical Institute, August 1970.
3. "Environmental Aspects of Chemical Use in Printing Operations," EPA-560/1-75-005, Office of Toxic Substances, U. S. Environmental Protection Agency, January 1975.



4. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations," EPA-450/2-76-028, U. S. Environmental Protection Agency, November 1976.

5. Test Reports from the Los Angeles County Zone, South Coast Air Quality Management District, El Monte, California.

## GRAPHIC ARTS

### FLEXOGRAPHIC PRINTING OPERATIONS

#### Process Description

In flexographic printing, like letterpress, the image areas are raised above the nonimage surface. The distinguishing feature is that the image carrier is made of rubber. Flexographic presses are usually rotary web presses, i.e., roll-fed. The major categories of the flexographic market are: flexible packaging and laminates, multiwall bags, milk cartons, folding cartons, corrugated paper, paper cups and plates, labels, tags, tapes, envelopes and gift wrap.<sup>1</sup>

Flexography uses very fluid inks, typically about 60 percent organic solvent. The inks dry by solvent evaporation, usually in high velocity air dryers at temperatures generally below 121°C.

#### Base Line Emissions

It is estimated that flexographic presses emit 58,000 metric tons per year of VOC.

#### Control Technology

A few flexographic presses are controlled by incineration. One test report of a direct-flame incineration showed a control efficiency of 98 percent.<sup>1</sup> No test reports of catalytic incinerators have been received, but the technique appears to be applicable, unless fouling or poisoning substances are present. No such materials are evident in flexography.

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With a typical ink of 60 percent organic solvent, an incinerator system with an overall efficiency of 85 percent would have an overall efficiency of 85 percent and would have an achievable emission level of 0.07 kilogram per liter of ink.

Water-borne inks are used in several types of flexography applications. A typical water-borne ink can achieve an organic emission level of 0.1 kilogram per liter of ink (minus water), representing a reduction of 80 percent over a typical solvent-borne ink.

Ultraviolet curable and heat reactive inks have not been developed with the low viscosity and other properties required for flexographic inks, but there is a potential for their use. Since most of the solvents used in flexographic inks are water soluble, a carbon adsorption system using conventional steam desorption would require a distillation system to recover the solvents. This would be a deterrent but the method is potentially viable.

#### Cost of Control

The costs of incineration for flexographic presses would be similar to those cited above for rotogravure printing. Additional details are given in Reference 4.

The costs of water-borne inks are comparable to those of solvent-borne inks. Fuel cost for drying may be increased slightly.'

#### References

1. "Environmental Aspects of Chemical Use in Printing Operations", EPA/560/1-75-005. Office of Toxic Substances, Environmental Protection Agency, January 1976.

2. Gadomski, R.R., et al., "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase I. Graphic Arts Technical Institute, August 1976.
3. Test Reports from Los Angeles County Zone, South Coast Air Quality Management District. El Monte, California.
4. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations", EPA-450/2-76-028. U.S. Environmental Protection Agency, November 1976.

## RUBBER TIRE INDUSTRY

### Part I - CAMELBACK OR TREAD END MANUFACTURE

#### Process Description

This operation involves the use of organic solvent-borne cement to "tackify" the tire tread after extrusion but before it is used to build tires. The extruded tread-sidewall is assembled, cut to proper length and the ends are coated with rubber cement. The solvent, generally naphtha, evaporates rapidly as the tread is conveyed through the building.

#### Base Line Emissions

The emission factor for undertread cementing is estimated to be 28 grams per tire. Since 250,000,000 tires are produced annually in this country, these emissions amount to 7,000 metric tons per year.

#### Control Technology

The control system consists of a collection system (to collect the evaporated solvent from organic solvent-borne cement spray originating from the spray operation and conveyors) and a control device (carbon adsorber). Collection efficiency is 90 percent and adsorption efficiency is 95 percent for an overall control efficiency of 85 percent. This technology is not in widespread use in the industry but has been used at several plants.

#### Cost of Control

The costs of carbon adsorption for this source are presented in Table 1. When the recovered solvent is credited at its market value, there is a net cost savings when a carbon adsorber is installed in a Plant.

Table 1. CARBON ADSORPTION COSTS FOR A TYPICAL  
UNDERTREAD CEMENTING OPERATION<sup>a</sup>

Incineration device	Capital cost, \$	Annualized operating cost, \$/year	Control cost, \$/ton of hydrocarbons removed
Case with no credit for recovered solvent	180,000	65,000	160
Case with recovered solvent credited at fuel value	180,000	35,000	85
Case with solvent credited at market value	180,000	(10,000) <sup>b</sup>	(24) <sup>b</sup>

<sup>a</sup> Exhaust rate of 2.3 Nm<sup>3</sup>/s, temperature of 21°C, operation at 25 percent LEL.

<sup>b</sup> Costs in parentheses indicate a net gain.

#### References

1. "Identification and Control of the Hydrocarbon Emissions from Rubber Processing Operations", EPA guideline document in preparation to be released in 1977.
2. "Assessment of Industrial Hazardous Waste Practices, Rubber and Plastics Industry", Chapter III, Rubber Products, Contract 68-02-3194, Foster D. Snell.
3. "Source Assessment Document" No. 24 Rubber Processing, EPA Source Assessment Document in preparation to be released in 1977.

## RUBBER TIRE INDUSTRY

### Part 2 - FABRIC AND WIRE DIP AND CEMENT

#### Process Description

Tire manufacturers dip textiles, cord, and wire into rubber cement or latex dip before calendering with rubber. In this process, sheets of textiles, cord, and wire are fed under controlled tension to a cement or latex dip tank. After dipping, the material is fed past a series of vacuum lines or rotating beater boxes to remove excess rubber or latex. The coated material passes through a drying oven to remove almost all the solvent. There is a trend to perform this operation at the textile mills rather than the tire manufacturing plant.

#### Base Line Emissions

The emission factor for textile, cord, or stranded wire cementing or latex dipping is 100 grams per tire. Since 250,000,000 tires are presently produced annually in this country, these emissions amount to 25,000 metric tons per year. Fabric dipping or cementing is used on other segments of the rubber industry such as the manufacturing of braided hose, braided belts, and rubber footwear. The emission factor for cementing or dipping in these industries is 25 grams per kilogram of product produced.

#### Control Technology

Incineration and carbon adsorption can be employed to control volatile organic emissions from textile and stranded wire cementing or dipping operations. Thermal incineration can reduce the volatile

organic emissions by 95 percent. Catalytic incinerators can reduce the volatile organic emissions by 90 percent. Carbon adsorption can reduce volatile organic emissions by 90 percent. It has not been feasible to replace organic-borne with water-borne or high-solids materials. Space may be a problem since half of the tire manufacturing plants are housed in older buildings with little available vertical space between floor and ceiling.

#### Cost of Control

Cost calculations for incineration and carbon adsorption are shown in Tables 1 and 2.

#### References

1. "Identification and Control of Hydrocarbon Emissions from Rubber Processing Operations." EPA guideline document in preparation to be released in 1977.
2. "Assessment of Industrial Hazardous Waste Practices, Rubber and Plastics Industry." Foster D. Snell, Inc. Florham Park, New Jersey. February 1976.
3. "Source Assessment Document - Rubber Processing." Monsanto Research Corporation. Dayton, Ohio. August 1975. (Draft Document).



Table 1. INCINERATION COSTS FOR A TYPICAL FABRIC CEMENTING OPERATION<sup>a</sup>

Incineration device	Capital cost, \$	Annualized operating cost, \$/year	Control cost, \$/ton of hydrocarbons removed
No heat recovery			
Thermal	100,000	50,000	90
Catalytic	105,000	50,000	90
Primary heat recovery			
Thermal	20,000	35,000	63
Catalytic	120,000	35,000	63
Primary and secondary heat recovery			
Thermal	145,000	28,000 <sup>b</sup>	50 <sup>b</sup>
Catalytic	140,000	30,000 <sup>b</sup>	55 <sup>b</sup>

<sup>a</sup> Exhaust rate of 2.3 Nm<sup>3</sup>/s, temperature of 160°C, operation at 25 percent of the LEL.

<sup>b</sup> Assumes that heat is recovered and used.

Table 2. CARBON ADSORPTION COSTS FOR A TYPICAL FABRIC CEMENTING OPERATION<sup>a</sup>

	Capital cost, \$	Annualized operating cost, \$/year	Control cost, \$/ton of hydrocarbons removed
Case with no credit for recovered solvent	180,000	65,000	160
Case with recovered solvent credited at fuel value	80,000	38,000	90
Case with solvent credited at market value	180,000	(9,000) <sup>b</sup>	(23) <sup>b</sup>

<sup>a</sup> Exhaust rate of 2.3 Nm<sup>3</sup>/s, temperature of 80°C, operation at 25 percent of the LEL.

<sup>b</sup> Costs in parentheses indicate a net gain.

## RUBBER TIRE INDUSTRY

### Part 3 - GREEN TIRE SPRAYING

#### Process Description

Before molding and curing, a "green" (nonvulcanized) tire is sprayed both inside and out with organic solvent-borne release agents (a material that prevents sticking to the vulcanizing mold). The solvent evaporates in the spray and vulcanizing areas.

#### Base Line Emissions

Emissions due to green tire spraying are estimated at 140 grams per tire. Since 250,000,000 tires are produced annually in this country, these emissions amount to 35,000 metric tons of VOC each year.

#### Control Technology

Emissions would be 90 percent reduced by the substitution of water-borne for organic solvent-borne materials for both the inside and outside spray for green tire application. Water-borne materials have been used by several plants but are not in widespread use.

There are no technological impediments to the replacement of organic solvent-borne release agents with water-borne materials.

Adsorption is a feasible option but would likely be higher in cost than use of water-borne materials. Adsorption has not been used for this process.

#### Cost of Control

The switch from organic solvent-borne to water-borne material will not require significant capital investment. Most of the same equipment

usually can be employed. Although the spray parameters are changed, the cost of the water-borne material is less. There are no known factors limiting control technology application.

#### References

1. "Identification and Control of the Hydrocarbon Emissions from Rubber Processing Operations", EPA guideline document in preparation to be released in 1977.
2. "Assessment of Industrial Hazardous Waste Practices, Rubber and Plastics Industry", Chapter III, Rubber Products, under EPA Contract 68-02-3194, by Foster D. Snell.
3. "Source Assessment Document - Rubber". EPA source assessment document in preparation to be released in 1977.

## ADHESIVES

### Process Description

Adhesives are used for joining surfaces in assembly and construction of a large variety of products. Adhesives allow faster assembly speeds, less labor input, and more ability to join dissimilar materials than other fastening methods. Adhesives may be water-borne, organic solvent-borne, hot melt or high-solids.

### Base Line Emissions

Organic solvent usage for various adhesive applications are given below:

<u>Application</u>	<u>Organic Solvent (metric tons/year)</u>
Flooring, tile, wall covering	11,000
Other construction	14,000
Aircraft assembly	900
Automobile assembly	20,000
Plywood and veneer	2,000
Particle Board	1,300
Furniture assembly	7,300
Other wood products	11,800
Textile products	2,000
Footwear	7,300
Pressure sensitive tapes and labels	263,000
Gummed tapes and labels	5,700
Packaging laminates	5,800
Other paper products	14,000
Glass insulation	13,000
Abrasive products	5,900
Printing and publishing	6,300
Rubber Products	21,500
Tires	1,000
Other	67,600
Total	<u>496,800</u>

Essentially all of the organic solvent used in these adhesive applications is emitted to the atmosphere when the adhesive dries.

#### Control Technology

Organic solvent-borne adhesives can, in many instances, be replaced with water-borne adhesives, hot melt adhesives, solventless two component adhesives, or radiation cured adhesives. Organic solvent reduction of 80 to 99 percent per job can be achieved by such replacement.

Water-borne natural adhesives (including animal glue, starches, dextrin and proteins) already account for over 50 percent of the total adhesive volume' and have been in use for a long time. Synthetic water-borne adhesives recently have been developed which have properties comparable to organic solvent-borne adhesives. These water-borne synthetic adhesives can replace organic solvent-borne adhesives for many applications.

#### Cost of Control

Low solvent adhesive may be lower or higher in cost, depending on the product. In any case, the adhesive is only a small part of the cost of the manufactured product and does not substantially affect product cost.

#### References

1. "Adhesives", Predicasfs, Inc., **T37**, May 29, 1975.
2. "Synthetic Adhesives", Connolly, Eleanor, Stanford Research Institute, 1967.

## LARGE APPLIANCES

### Process Description

Large appliance parts typically are stamped from metal sheets, cleaned, and pretreated. Exterior parts are coated with a prime coating by flow or spray coating techniques. Interior parts are coated by flow or dip coating techniques. (Sometimes the prime and interior part coatings are the same.) After curing, interior parts are ready for assembly, and exterior parts are moved to the topcoat application area. The topcoat is applied by automatic electrostatic spraying and manual air spraying for touchup and shading. After curing, the parts are assembled.

### Base Line Emissions

Base line emissions for 1973 were about 32,300 metric tons per year' uncontrolled.

### Control Technology

Table 1 shows the VOC reductions possible with applicable control technology. Powder and electrodeposition provide the greatest reduction of organic emissions but may involve extensive equipment changes. Although water-borne and high-solids coatings do not provide as great a reduction in emissions (60 to 30 percent), they usually may be applied using existing coating application equipment. Add-on control technology (incinerators and adsorbers) may be difficult to install due to the multi-level structure and limited floor space in some existing plants.

### Cost of Control

If new coating application equipment is necessary, capital costs for converting to low-solvent coatings may be appreciable. However, reduced solvent and energy and labor requirements may lower operating costs. Add-on control technology may be the most costly control method (\$450-\$650 per metric ton<sup>2</sup> of organics removed for incinerators for control of ovens and about \$1100 per metric ton<sup>3</sup> of organics removed for carbon adsorbers for control of application and flashoff areas).

### Energy Requirements

Incineration may require additional energy since ovens are often located on the top level of the plant while the processes that can use the recovered heat are often located at ground level.

### References

1. "Sources and Consumption of Chemical Raw Materials in Paints and Coatings - By Type and End Use," Stanford Research Institute, October 1974, page 210.
2. Combustion Engineering, Inc., Wellsville, New York, "Report on Fuel Requirements, Capital Costs, and Operating Expense for Catalytic and Thermal Afterburners," prepared for the U. S. Environmental Protection Agency under Contract No. 68-02-1473, Task 13, EPA-450/3-76-031, September 1976.
3. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations," EPA-450/Z-76-028, November 1976 (OAQPS No. 1.2-067).

Table 1

## Control Technology for Large Appliance Coating

Application	Control Technology	Has Been Used In Large Appliance Plant?	Major Equipment Change Necessary?	VOC Emissions, kilograms per liter of coating (minus water)	Percent Reduction <sup>a</sup>
Primer Application:	Water-Borne	yes	no	0.29 <sup>b</sup>	80 <sup>b</sup>
	Electrodeposition	yes	yes	0.02	99
Interior Part Single Coat Application:	Water-Borne	yes	no	0.29 <sup>b</sup>	80 <sup>b</sup>
	Electrodeposition	yes	yes	0.02	99
	Powder	yes	yes	0.02	99
Topcoat Application:	Water-Borne	yes	no	0.29 <sup>b</sup>	80 <sup>b</sup>
	"Higher" Solids	yes	no	0.44 <sup>c</sup>	57 <sup>c</sup>
	Powder	yes	yes	0.02	99
All Applications:					
Coating Area and Flashoff Tunnel:	Carbon Adsorber	no	no <sup>d</sup>		
				n. 29	91
Oven:	Incinerator	yes	no <sup>d</sup>		

<sup>a</sup> The base case assumed that the previous organic solvent-borne coatings contain 30 volume percent solids.

<sup>b</sup> The water-borne coating is assumed to contain 30 volume percent solids, 14 volume percent organic solvent, and 56 volume percent water. This is equivalent to the 80/20 Rule 66 definition of a water-borne coating.

<sup>c</sup> This is equivalent to about 45-50 volume solids coating presently applied. Research is currently being done to apply high-solids (70-80 volume percent) coatings. Such application techniques should be available in the near future.

<sup>d</sup> Although no change in coating equipment is necessary, perhaps other plant modifications will be necessary in large appliance plants to install such equipment.



## MAGNET WIRE COATING

### Process Description

Wire coating is the process of insulating electrical wire by applying insulation varnish or enamel. Coated wire is used in a variety of electrical machinery such as motors and transformers.

During coating, the wire is unwound from a spool and passed through a bath of coating. The wire is then drawn through an orifice or die which scrapes off excess coating, leaving a layer of predetermined thickness. The wire is conveyed through an oven (around 800°F) where the solvent is driven off and the coating cured.

### Base Line Emissions

Annual solvent use for wire coating is 29,500 metric tons per year.<sup>1</sup> There is a high degree of control already in the industry, especially on newer coating lines. Estimates of current solvent emissions are 8,000 metric tons per year.

### Control Technology

Incineration, the only control technology commonly used, achieves 90 - 95 percent control and may be thermal or catalytic.<sup>2,3</sup> Most newer wire coating ovens are built with an internal catalytic incinerator which burns solvents inside the oven. Control is common because recovered heat can be used, and because it eliminates malodors and avoids the buildup of flammable resins in the stack. Some newer types of coatings

will poison catalysts. If coatings that poison catalysts are used, thermal incinerators are required.

Powder coatings and water-borne coatings have been developed for only a small number of wire products to date.

Cost of Control

A typical wire coating oven with an internal catalyst costs \$100,000 to \$200,000. The catalytic bed represents about \$20,000 of the total.

For internal incinerators, ten or more ovens are frequently vented to one incinerator. Costs for such an incinerator are given in Table 1.<sup>4</sup>

TABLE 1 INCINERATION COST FOR WIRE COATING  
(7 Mm<sup>3</sup>/s, 290°C, 15% of LEL)

Type of Incineration	Installed Cost\$	Annualized Operating Cost, \$/yr	Cost Effectiveness \$/metric ton of Solvent Removed
Non Catalytic Primary and Secondary Heat Recover-y	183,000	34,800	48
Catalytic Secondary Heat Recover-y	220,000	39,690	55

## References

1. "Sources and Consumption of Chemical Raw Materials in Paints and Coatings - By Type and End Use", Stanford Research Institute, October 1974, page 210.
2. Ruff, R. J., "Catalytic Combustion in Wire Enameling", Wire, October 1951, pages 936-940.
3. Kloppenburg, W. B., DeBell and Richardson Trip Report No. 106, April 6, 1976.
4. Combustion Engineering, Inc., Wellsville, N.Y., "Report of Fuel Requirements, Capital Cost and Operating Expense for Catalytic and Thermal Afterburners". Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, N.C. under Contract No. 68-02-1473, (Task No. 13), Publication No. 450/3076/031.

## FLAT WOOD PRODUCTS

### Process Description

Flat wood products include plywood, particle board, hardboard, cedar siding, and softwood molding. Not all such products are factory coated. When they are factory coated, VOC emissions occur from: reverse-roll-coating of filler; direct roll-coating of sealer; direct roll-coating of topcoats; curtain coating; printing of wood-grain patterns and drying in an infrared or steam-heated oven after one or more of the above coating operations.

### Base Line Emissions

At present, approximately 54,000 metric tons of VOC are emitted yearly by sources in this category.'

### Control Technology

The control technology available for flat wood products includes low-solvent ultraviolet (UV) curable coatings, water-borne coatings, and incinerators.<sup>2</sup> UV curable coatings are sensitive to UV radiation, under which rapid polymerization takes place to form the coating film. UV fillers are frequently employed but only a few lines use UV cured topcoats. UV curable inks from the paper coating industry would seem to be applicable for grain printing as well. Opaque base coats curable with UV radiation are not now available though they are expected to be available soon. Where UV coatings are applicable, they produce

essentially zero VOC emissions. Use of water-borne coatings usually results in about an 80 percent VOC emission reduction. Water-borne coatings are available for filling and base coating but few water-borne graining inks or topcoats are marketed.

Afterburners can be used to control VOC emissions from baking ovens with **control** efficiencies of greater than 90 percent.<sup>2</sup> Although no flatboard coating facility is now known to use carbon adsorption as an air pollution control device, it is technically feasible.

Limitations to the use of UV coatings are lack of suitable opaque basecoats and the difficulties associated with curing irregular shapes. Water-borne coatings have problems with "blocking" (i.e., the sticking of the paper sheets used to separate boards), poor adhesion or staining. Also, high gloss water-borne topcoats are not generally available at present.

#### Cost of Control

Accurate cost estimates are not yet available, but there probably would be increased costs associated with water-borne coatings. First, the coatings themselves may cost more. Also, there may be higher maintenance and utility costs with these coatings. Utility costs for UV curing are less than the costs for curing conventional coatings.

#### Environmental Considerations

UV cure coatings do not have any adverse impact on the environment. Water-borne coatings may result in slightly increased cost for water pollution control since clean-up residue is **sewered**.

## Energy Requirements

Energy requirements for UV curing are less than for conventional curing. For water-borne coatings, energy requirements may be slightly greater than for conventional coatings though some plants are able to operate at the same fuel usage. At afterburner equipped plants, there would seem to be ample opportunity to make use of recovered heat in the baking oven.

## References

1. "Sources and Consumption of Chemical Raw Materials in Paints and Coatings - By Type and End Use," Stanford Research Institute, October 1974, page 210.
2. Emission Test Reports from Metropolitan Office of Southern California Air Pollution Control District, No. C-2133, C-2292.

## INDUSTRIAL SURFACE COATING

### Process Description

There are many surface coating operations for which emission limitations have not been recommended in specific EPA guidelines (Control Technology Documents) or Standards Support and Environmental Impact Statements. While each product has to meet usage and possibly substrate specifications which may be unique, nevertheless, generalizations can be made as to the applicability of the low solvent coatings, i.e. powder, water-borne and high solids coatings. These coatings are adaptable to many metal and plastic products. Particularly where the coating is hand sprayed or air dried, low solvent coating may represent the most cost effective means of VOC control.

### Base Line Emissions

Base line emissions are shown below.

<u>Industry</u>	<u>Solvents Used , (metric tons per year)</u>
Transportation equipment (other than auto and light trucks)	15,400
Marine equipment	27,300
Factory finished building products (other than flat wood products)	6,800
Exterior industrial maintenance	68,600
Interior industrial maintenance	38,600
Other products finishes	84,100
Thinness used	<u>114,500</u>
Total	335,300

### Control Technology

Metal and plastic can be coated with enamels or other coatings containing at least 33 percent solids by volume. With average percent solids

now around 20 percent, there will be about a 50 percent emission reduction achieved by going to the higher solids coating. Coating with 33 percent solids have already been used in many products, so no new technology should be involved for most industries to use this technology. The coatings are also applicable to wood products with opaque coatings.

The 33 percent solids coatings are not feasible for wood furniture and other wood products with clear coatings which show the wood grain. Neither do they apply to "trade sales", that is shelf goods or stock type coatings sold through retail or wholesale outlets to jobbers, dealers, painters, contractors, builders, automobile refinishers, or jobbers for maintenance of residences, institutions, and office buildings. These types of coatings can't usually be employed in industrial maintenance finishes which are specifically formulated for a particular performance requirement in the industrial environment.

There are many small metal products that are coated in only a few colors. Such products include lawn and garden machinery, light fixtures, bicycles, tools, playground equipment, small parts, metal furniture, and innumerable other fabricated metal products. These products usually can be primed by electrodeposition (EDP) and topcoated with powder coatings, resulting in significantly less volatile organic compound (VOC) emissions. EDP and powder coatings have been used by numerous sources in these industries for both new and retrofit installations. Organic solvent emissions when using these coating technologies are almost zero, so efficiency of control approaches 100 percent. A realistic number limit is 0.04 kilogram of VOC per liter of coating used. Water-borne dip and spray and high-solids



coatings also are applicable to these sources but emission are greater, about 0.37 kilograms per liter of coating used. This is an 80-90 percent VOC reduction over typical organic solvent-borne coatings. If EDP or powder cannot be used, the latter should be evaluated. The key factor governing applicability is whether the product meets normal use specifications when coated with powder or by EDP. This is not usually a problem since EDP and powder almost always give superior finish. Many colors, frequent color change, large size, or the presence of heat-sensitive materials may affect the feasibility of these options.

#### Cost of Control

The cost for metal coaters to switch to 33 percent solids enamels usually is not great. There should be no development costs since such coatings are already marketed. Conventional application techniques and equipment frequently can be used but some capital investment may be necessary.

#### References

1. Stanford Research Institute, "Sources and Consumption of Chemical Raw Materials in Paints and Coatings - By Type and End Use", October 1974, page 210.

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