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REACTIVE HYDROCARBON CONTROL COSTS FOR LOS ANGELES

Environmental Sciences Research Laboratory
Office of Research and Development
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REACTIVE HYDROCARBON CONTROL COSTS FOR LOS ANGELES

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ABSTRACT

This report documents the results of a study to determine the costs associated with controlling reactive organic emissions in the Metropolitan Los Angeles Air Quality Control Region. An inventory of organic emissions from 26 categories of stationary and mobile sources was developed for the calendar year 1975. The photochemical reactivity of the emissions from each category was determined in terms of a 3-class reactivity classification scheme. The costs associated with reducing the emissions from each category were estimated by assuming the application of the most cost effective combination of available control equipment. The costs associated with reducing the emissions from all sources were estimated by assuming the application of the most cost effective controls selected from those available for all source types. It was concluded that only approximately 53% of the total organic emissions could be eliminated using currently available control technology.

This report was submitted in fulfillment of EPA Contract No. 68-02-2445 by TRW under the sponsorship of the U.S. Environmental Protection Agency Work was completed as of 23 March 1977.

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SECTION 1

INTRODUCTION

This report documents the results of a study to estimate the costs associated with selectively controlling organic emissions from stationary and mobile sources on the basis of photochemical reactivity. The study area was the Metropolitan Los Angeles AQCR. There were four main objectives:

- Assemble an inventory of organic emissions from stationary and mobile sources in the Metropolitan Los Angeles AQCR.
- Calculate the reactivity index for each source type in terms of a 3-class reactivity scheme.
- Determine the costs associated with reducing the reactive emissions from each source type by applying the most cost effective combination of controls.
- Determine the costs associated with reducing total reactive emissions from all sources by applying the most cost-effective combination of controls from each source type.

The inventory was developed for the year 1975. That year was selected primarily because two major organic emission inventories of mobile and stationary sources were conducted for that time period. The availability of the data from these studies made it possible to make reliable emissions estimates for each of the 26 source categories.

In a previous study, reactivities were calculated in terms of a 5-class categorization scheme. For this study a 3-class scheme was used. The 5-class scheme has unitless reactivity indexes for each class. Since the 3-class scheme has qualitative indications of reactivity only, a procedure was developed for quantitatively estimating reactivity indices for each class.

The costs associated with reducing the reactive emissions from each category were calculated by applying one or more types of controls. The controls were applied in the order of their cost effectiveness. That is, the first reductions were obtained by using the most cost effective control and subsequent reductions by using increasingly less cost effective techniques.

The costs of controlling the aggregate reactive emissions from all sources in the AQCR were calculated in a similar manner. The most cost-effective control available from any source was applied first, with subsequent reductions being obtained by using the remaining control options in order of their cost effectiveness.

SECTION 2

INVENTORY OF TOTAL ORGANIC EMISSIONS

An updated inventory of organic emissions in the Metropolitan Los Angeles AQCR was developed. The inventory was based primarily on two programs funded by the California Air Resources Board (ARB). The first was an inventory of exhaust, evaporative and crankcase emissions from light duty gasoline powered vehicles conducted by TRW (1). The second was the preliminary version of a comprehensive inventory of organic emissions from stationary sources conducted by KVB Engineering (2). Information from these studies was supplemented with data produced by the ARB (3) and data contained in a previous TRW study of organic reactivity (4). The inventory is shown in Tables 1 and 2.

The assumptions used to obtain the total organic inventory are listed below for each source category.

Petroleum Production

Petroleum production refers to the removal of crude oil and gas from the ground. Organic emissions from petroleum production occur primarily from operations which separate water, gases, and oil at the drill site (4). The previous TRW reactivity study lists 56,200 kg/day (62.0 tons/day) (4). With little new information available, this value was used in this study.

Petroleum Refining

Organic emissions result from a variety of processes in petroleum refineries. The main processes include storage, pumping, compression, separation, cooling, leaks and spills. Organic emissions from boilers and heaters in refineries are included in the fuel combustion category of this inventory. The KVB study estimated emissions from five of the six counties which lie totally or partially in the Los Angeles AQCR (Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties) but excluded Santa Barbara County. Data from an inventory compiled by the California ARB was used to estimate emissions for that area (3). KVB and ARB data were combined to estimate emissions of 132,900 kg/day (146.5 tons/day) for this category.

Gasoline Marketing: Underground Service Station Tanks

Underground storage tanks at service stations emit organics as gasoline vapor is displaced into the atmosphere as the tanks are refilled. These tanks also emit organics through a "breathing" process caused by the diurnal cycle in ground temperature. The KVB study estimated combined emissions of 172,700 kg/day (190.4 tons/day) for both this category and auto tank filling

TABLE 1. 1975 TOTAL ORGANIC EMISSIONS INVENTORY FOR THE METROPOLITAN LOS ANGELES AQCR - METRIC UNITS

SOURCE CATEGORY	WEIGHT EMISSIONS		MOLAR EMISSIONS		AVERAGE MOLECULAR WEIGHT
	10^{-3} KG/DAY	WEIGHT % OF TOTAL	10^{-3} KG MOLES/DAY	MOLE % OF TOTAL	
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION					
Petroleum Production and Refining					
Petroleum Production	56.2	2.7	193.8	6.7	29
Petroleum Refining	132.9	6.4	142.9	4.9	93
Gasoline Marketing					
Underground Service Station Tanks	56.2	2.7	96.9	3.4	58
Auto Tank Filling	119.2	5.7	161.1	5.6	74
Fuel Combustion	21.9	1.1	87.6	3.0	25
Waste Burning & Fires	37.2	1.8	112.7	3.9	33
STATIONARY SOURCES: ORGANIC CHEMICALS					
Surface Coating					
Heat Treated	10.6	0.5	12.9	0.4	82
Air Dried	181.3	8.7	208.4	7.2	87
Dry Cleaning					
Petroleum Based Solvent	6.3	0.3	5.0	0.2	126
Synthetic Solvent (PCE)	22.8	1.1	13.7	0.5	166
Degreasing					
TCE Solvent	0.4	0.0	0.3	0.0	132
1,1,1-T Solvent	30.2	1.5	22.5	0.8	134
Printing					
Rotogravure	15.6	0.7	19.0	0.7	82
Flexigraphic	7.1	0.3	12.5	0.4	57
Industrial Process Sources					
Rubber & Plastic Manf.	0.7	0.0	1.0	0.0	73
Pharmaceutical Manf.	0.2	0.0	0.3	0.0	75
Miscellaneous Operations	46.1	2.2	57.6	2.0	80
MOBILE SOURCES					
Gasoline Powered Vehicles					
Light Duty Vehicles+					
Exhaust Emissions	575.4	27.7	833.9	28.9	69
Evaporative Emissions*	445.9	21.4	490.0	17.0	91
Heavy Duty Vehicles					
Exhaust Emissions	85.9	4.1	124.5	4.3	69
Evaporative Emissions*	66.8	3.2	73.4	2.5	91
Other Gasoline Powered Equipment					
Exhaust Emissions	99.8	4.8	144.6	5.0	69
Evaporative Emissions*	20.0	1.0	22.0	0.8	91
Diesel Powered Motor Vehicles	12.4	0.6	13.9	0.5	89
Aircraft					
Jet	15.5	0.7	12.8	0.4	121
Piston	14.1	0.7	25.2	0.9	56
TOTAL	2080.7	100	2886.5	100	

+ Includes light duty passenger cars and light duty trucks.
* Includes crankcase emissions.

TABLE 2. 1975 TOTAL ORGANIC EMISSIONS INVENTORY FOR THE METROPOLITAN LOS ANGELES AQCR - ENGLISH UNITS

SOURCE CATEGORY	WEIGHT EMISSIONS		MOLAR EMISSIONS		AVERAGE MOLECULAR WEIGHT
	TONS/DAY	WEIGHT % OF TOTAL	10^{-2} TON MOLES/DAY	MOLE % OF TOTAL	
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION					
Petroleum Production and Refining					
Petroleum Production	62.0	2.7	213.8	6.7	29
Petroleum Refining	146.5	6.4	157.5	4.9	93
Gasoline Marketing					
Underground Service Station Tanks	61.9	2.7	106.7	3.4	58
Auto Tank Filling	131.4	5.7	177.6	5.6	74
Fuel Combustion	24.1	1.1	96.4	3.0	25
Waste Burning & Fires	41.0	1.8	124.2	3.9	33
STATIONARY SOURCES: ORGANIC CHEMICALS					
Surface Coating					
Heat Treated	11.7	0.5	14.3	0.4	82
Air Dried	199.9	8.7	229.8	7.2	87
Dry Cleaning					
Petroleum Based Solvent	6.9	0.3	5.5	0.2	126
Synthetic Solvent (PCE)	25.1	1.1	15.1	0.5	166
Degreasing					
TCE Solvent	0.4	0.0	0.3	0.0	132
1,1,1-T Solvent	33.3	1.5	24.9	0.8	134
Printing					
Rotogravure	17.2	0.7	21.0	0.7	82
Flexigraphic	7.8	0.3	13.7	0.4	57
Industrial Process Sources					
Rubber & Plastic Manf.	0.8	0.0	1.1	0.0	73
Pharmaceutical Manf.	0.2	0.0	0.3	0.0	75
Miscellaneous Operations	50.8	2.2	63.5	2.0	80
MOBILE SOURCES					
Gasoline Powered Vehicles					
Light Duty Vehicles[+]					
Exhaust Emissions	634.3	27.7	919.3	28.9	69
Evaporative Emissions[•]	491.5	21.4	540.1	17.0	91
Heavy Duty Vehicles					
Exhaust Emissions	94.7	4.1	137.2	4.3	69
Evaporative Emissions[•]	73.6	3.2	80.9	2.5	91
Other Gasoline Powered Equipment					
Exhaust Emissions	110.0	4.8	159.4	5.0	69
Evaporative Emissions[•]	22.0	1.0	24.2	0.8	91
Diesel Powered Motor Vehicles	13.7	0.6	15.4	0.5	89
Aircraft					
Jet	17.1	0.7	14.1	0.4	121
Piston	15.5	0.7	27.7	0.9	56
TOTAL	2293.4	100	3184.0	100	

[+]Includes light duty passenger cars and light duty trucks

[•]Includes crankcase emissions

for the five-county area (2). The TRW study concluded that approximately 32% of these emissions are due to underground gasoline storage tanks (4). The total for this category, including the ARB estimated emissions in Santa Barbara County are 56,200 kg/day (61.9 tons/day) (3).

Gasoline Marketing: Automobile Tank Filling

During automobile tank filling, organic emissions occur as the gasoline vapor in the fuel tank is displaced by liquid gasoline. Some emissions (approximately a fifth of the total for this category) result from spilled gasoline (4). Sixty-eight percent (68%) of the KVB combined estimate for this category and underground service station tanks was combined with ARB data to arrive at 119,200 kg/day (131.4 tons/day) (2), (3), (4).

Fuel Combustion

This category includes organic emissions from combustion of all fuels, including that burned in refineries. The adjusted KVB estimate (adjusted for Santa Barbara County) of 21,900 kg/day (24.1 tons/day) was used (2), (3).

Waste Burning and Fires

The TRW study lists 37,200 kg/day (41.0 tons/day) for this category (4). That value was used for this study.

Surface Coating: Heat Treated

This category includes organic emissions from processes where the organic solvent either comes in contact with a flame or is baked, heat-cured or heat polymerized in the presence of oxygen (4). The adjusted KVB estimate of 10,600 kg/day (11.7 tons/day) was used (2), (3).

Surface Coating: Air Dried

Air dried surface coating emissions in the Metropolitan Los Angeles AQCR result mostly from industrial paint spray booths and architectural painting. The adjusted KVB estimate of 181,300 kg/day (199.9 tons/day) was used (2), (3).

Dry Cleaning: Petroleum Based Solvent

Two major dry cleaning solvents are used in the Los Angeles area. Emissions of petroleum based solvents were determined to be 6,300 kg/day (6.9 tons/day) from the adjusted KVB estimate (2), (3).

Dry Cleaning: Synthetic Solvent (PCE)

The adjusted KVB estimate of 22,800 kg/day (25.1 tons/day) for synthetic dry cleaning solvent (perchloroethylene) emissions was used (2), (3).

Degreasing: TCE Solvent

Two basic degreasing solvents are used in the Los Angeles area, trichloroethylene (TCE) and 1,1,1 trichloroethane (1,1,1-T). The adjusted KVB estimate of 400 kg/day (0.4 tons/day) for TCE solvent emissions was used for this study (2), (3).

Degreasing: 1,1,1-T Solvent

The adjusted KVB estimate of 30,200 kg/day (33.3 tons/day) for 1,1,1-T degreasing solvent emissions was used (2), (3).

Printing: Rotogravure

The adjusted KVB estimate of 15,600 kg/day (17.2 tons/day) for emissions from rotogravure printing operations was used (2), (3).

Printing: Flexigraphic

The adjusted KVB estimate of 7,100 kg/day (7.8 tons/day) for emissions from flexigraphic printing operations was used (2), (3).

Rubber, Plastic, Adhesive, and Putty Manufacturing

Data from several categories used in the KVB study and ARB data were compiled to arrive at the adjusted estimated emissions for this category of 700 kg/day (0.8 tons/day) (2), (3).

Pharmaceutical Manufacturing

The adjusted KVB estimate of 200 kg/day (0.2 tons/day) for this category was used (2), (3).

Miscellaneous Organic Solvent Operations

This category consists of miscellaneous chemical manufacturing (e.g. soaps, cleaners, insecticides, fertilizers, explosives, etc.) as well as miscellaneous solvent usage in industry (e.g. the potting of electrical and electronic equipment). Several categories used in the KVB study were combined and adjusted to arrive at the estimated emissions of 46,100 kg/day (50.8 tons/day) for this category (2), (3).

Light Duty Vehicle Exhaust

Organic emissions from light duty (under 6,000 pounds gross vehicle weight) passenger cars and trucks were determined in a study conducted by TRW. That study determined the emissions in a four-county area to be 546,100 kg/day (602 tons/day) (1). Using the same methodology, emissions for Ventura County were determined to be 22,900 kg/day (25.2 tons/day)(1). The ARB estimate for Santa Barbara County was 6,400 kg/day (7.1 tons/day) (3). The estimated total for light duty vehicle exhaust for the AQCR used in this study was 575,400 kg/day (634.3 tons/day).

Light Duty Vehicle Evaporative

Evaporative emissions, which for this study also include crankcase emissions, were calculated using the data sources listed above. Evaporative emissions for the four-county area, determined by the TRW study are 423,700 kg/day (467.1 tons/day). Using the TRW methodology, emission for Ventura County were estimated to be 17,900 kg/day (19.7 tons/day). ARB data indicates 3,700 kg/day (4.1 tons/day) for Santa Barbara County (3). The value for evaporative emissions for light duty vehicles was estimated to be 445,900 kg/day (491.5 tons/day).

Heavy Duty Vehicle Exhaust

Exhaust emissions from heavy duty gasoline powered vehicles were calculated from the ARB estimate of total vehicular evaporative and crankcase emissions (3). The emissions were estimated at 66,800 kg/day (73.6 gons/day).

Other Gasoline-Powered Equipment Exhaust

The original estimate of 99,800 kg/day (110.0 tons/day) was used (4).

Other Gasoline Powered Equipment - Evaporative

The original estimate of 20,000 kg/day (22.0 tons/day) was used for this study (4).

Diesel Powered Vehicles

The ARB estimate of 12,400 kg/day (13.7 tons/day) was used for this study (3).

Jet Aircraft Emissions

The ARB estimate of 15,500 kg/day (17.1 tons/day) was used for this study (3).

Piston Aircraft Emissions

The ARB estimate of 14,100 kg/day (15.5 tons/day) was used for this study (3).

SECTION 3

REACTIVITY RATINGS

A series of photochemical reactions are initiated when a mixture of organic chemical compounds and oxides of nitrogen (NO_x) are irradiated by sunlight in the atmosphere. These result in the formation of a complex mixture of secondary air pollutants. One of the most significant is ozone/oxidant. Although the chemistry of these reactions is not well understood, it has been shown in smog chamber studies that under similar conditions of radiation intensity, NO_x concentrations, and organic concentrations, the rate and amount of ozone formed is a function of the organic involved. Therefore, the measured photochemical reactivity of an organic is an index of its ozone forming potential.

The apparent reactivity of a large number of organics has been measured during several smog chamber studies. As measured by several researchers, the reactivity index of most compounds varied over a wide range. Since it could not be determined which smog chamber design and experimental conditions most accurately reflected actual conditions, reactivity ratings can be expressed only semi-quantitatively. In a previous study each compound was assigned to one of five (5) reactivity classes, each with an index of reactivity. Table 3 shows the reactivity scheme used.

For the current study, a reactivity scheme based on the same principles was employed. The new scheme, however, consists of only three (3) reactivity classes with qualitative instead of quantitative reactivity indices. Table 4 shows the 3-class scheme. Class I compounds are non-reactive; they do not result in ozone production above the allowable standard with multi-day exposure to sunlight. Class II compounds are moderately reactive; they result in ozone production above the standard, only after multi-day exposure to sunlifht. Class III compounds are highly reactive; they result in ozone production above the standard with less than one day exposure to sunlight.

To compare reactivity ratings for each source type quantitatively, a procedure for estimating a numerical reactivity rating for each source type had to be developed. This was done by employing the following technique. Since Class II compounds result in maximum ozone only after multi-day exposure, it is the concentration of these compounds on the second and third days after they are emitted that determines their contribution to the ambient ozone level. However, mechanical transport and diffusion would be expected to reduce the concentrations of these compounds by a significant amount. This dilution effect has been estimated at approximately 90% on an annual basis, and approximately 50% during a period of stagnation (5), (6). For purposes of calculating the reactivity indices, a worst case situation was used. That is, it was assumed that the dilution factor was 50%. For

TABLE 3. FIVE CLASS REACTIVITY CATEGORIZATION OF ORGANIC COMPOUNDS

CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V
C_1-C_3 paraffins	Mono-tert-alkyl benzenes	C_{4+}-paraffins	Prim-& sec-alkyl benzenes	Aliphatic olefins
Acetylene	Cyclic ketones	Cycloparaffins	Dialkyl benzenes	α-methyl styrene
Benzene	Tert-alkyl acetates	Alkyl acetylenes	Branched alkyl ketones	Aliphatic aldehydes
Benzaldehyde	2-nitropropane	Styrene	Prim-& sec-alkyl alcohols	Tri-& tetra-alkyl benzenes
Acetone		N-alkyl ketones	Cellosolve acetate	Unsaturated ketones
Tert-alkyl alcohols		Prim-& sec-alkyl acetates	Partially halogenated olefins	Diacetone alcohol
Phenyl acetate		N-methyl pyrrolidone		Ethers
Methyl benzoate		N,N-dimethyl acetamide		Cellosolves
Ethyl amines				
Dimethyl formamide				
Methanol				
Perhalogenated hydrocarbons				
Partially halogenated paraffins				

TABLE 4. THREE CLASS REACTIVITY CATEGORIZATION OF ORGANIC COMPOUNDS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I		Total Class II		Total Class III	

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

purposes of this study, it was assumed that all Class III compounds were either reacted to completion or had otherwise been removed from the atmosphere by the end of the day on which they were emitted.

The ozone producing ability of Class II organics was determined in the following manner:

1. Assuming no ozone formation on Day 1, 50% of the Class II organics remain in the air mass on Day 2.

2. Assuming half of the remaining Class II compounds form ozone on Day 2, 25% of the original emissions react. Half of the remaining emissions (12.5%) are carried over to Day 3.

3. It is assumed that on Day 3, all of the remaining Class II compounds (12.5%) form ozone.

4. Therefore, ozone is formed by 37.5% of the organics emitted on Day 1.

This procedure is shown schematically in Figure 1.

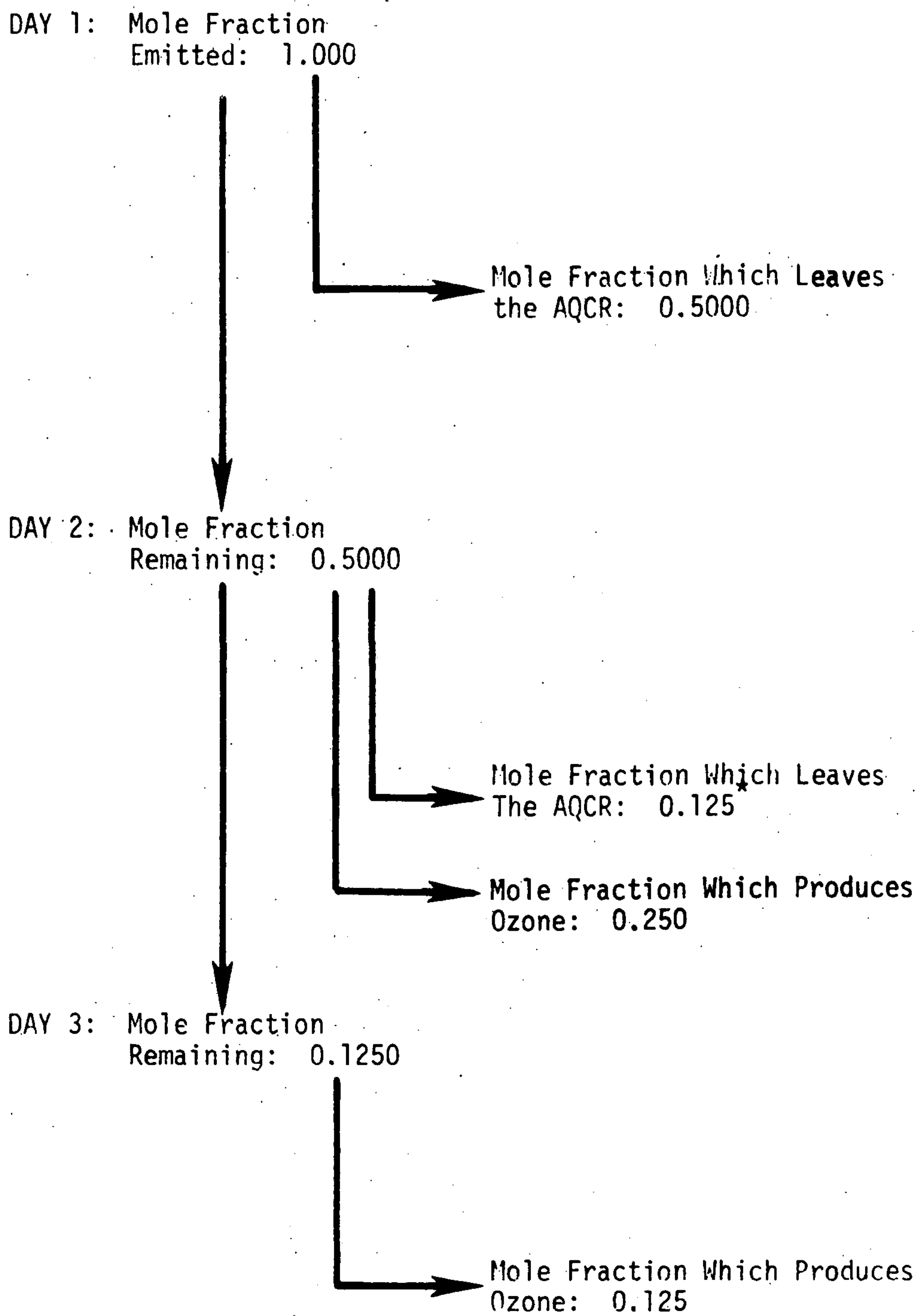
Since the reactivity indices are relative, the following indices were assigned:

Class I	0.00
Class II	0.38
Class III	1.00

It should be noted that these reactivity indices are different in nature from those used in the previous study (7). Since the Class II index is based partially on meteorological considerations, the calculated reactivity is AQCR specific. That is, the rate at which Class II compounds are removed from an AQCR will depend primarily on the meteorological conditions that normally prevail in that area.

This approach provided a working estimate of the relative reactivities of Class II and Class III compounds only. The hold-over approach is not universally accepted, and therefore any conclusions drawn from it should be used with caution. For example, the effects on air quality in areas downwind of the metropolitan Los Angeles AQCR are not considered. It was necessary to make some estimate of relative reactivities. This approach seems reasonable if not rigorous.

Another major component of this study is the organic emission composition data. To calculate the reactivity of emissions from each source type, it was necessary to know the detailed composition of these emissions. The same composition data developed for the previous study was used here (3). Although additional work on identifying the specific compounds emitted by various source types has been done since the initial report was written, these studies are either general in nature or do not apply to the special conditions in the Los Angeles area. Therefore, the best data appears to be that used in the previous study. The twenty-six (26) source categories were also retained so that direct comparisons between the 3-class and 5-class schemes can be made.



Total Moles Resulting in Ozone Formation: 0.375

*That is, half of the unreacted half, or one-quarter.

Figure 1. Ozone Formation From Class II Organics

Appendix A contains the estimated composition of the organics emitted from each of the categories in terms of the 5-class reactivity scheme. Table 5 is a summary of these data. In both cases the composition is expressed in mole percent, not weight percent. Table 6 shows the reactivity values calculated for each source type (5-class).

Tables 7 through 32 present the estimated composition of the organics emitted by each of the source categories in terms of the 3-class reactivity scheme. Table 33 summarizes these data. Percent composition by reactivity class is presented, and as with all tables in this report, percent composition means mole percent, unless otherwise indicated. Table 34 summarizes the source molar reactivity, source weight reactivities, and reactive emissions.

Source molar reactivities (SMR) are equal to the summation of the mole fraction (X_i) of each compound in each reactivity class multiplied by the reactivity rating (R_i) of that class, for n compounds, i = 1, 2, ..., n:

$$SMR \quad \sum_{i=1}^{n} \quad X_i R_i$$

Source weight reactivities (SWR) are equal to the source molar reactivities (SMR) divided by the average molecular weight (MW) for the corresponding source type category:

$$SWR = \frac{SMR}{MW}$$

Reactive emissions (RE) are calculated on a mass basis by multiplying the source weight reactivity (SWR) by the mass emission rate for each source.

The 3-class reactivities shown in Table 34 cannot be compared directly with the 5-class reactivities shown in Table. The 5-class reactivities contain arbitrary constants selected such that both the molar and weight reactivities of light-duty vehicle exhaust would be 0.72. The reasoning and justification for this are presented in the previous TRW report (3).

Table 35 showing the 3-class reactivities also incorporates a constant to adjust both the molar and weight reactivities of light-duty vehicle exhaust to 0.72. These reactivity values are the ones to be compared to the 5-class values presented in Table 6.

Reactive emissions are the true measure of the ozone producing potential of the aggregate emissions from a source type. This parameter incorporates both the mass emission rate and an index of the reactivity of those emissions. Reactive emissions can be reduced either by reducing the mass emission rates, or by reducing the reactivity of the organics emitted, or both.

It should be noted that reactivity considerations do not address the potential harm due to organics' toxicity, but only their ozone producing potential.

TABLE 5. SUMMARY OF COMPOSITION DATA IN TERMS OF THE FIVE-CLASS REACTIVITY SCHEME

SOURCE CATEGORY	MOLAR COMPOSITION (PERCENT)				
	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION					
Petroleum Production and Refining					
Petroleum Production	84	0	16	0	0
Petroleum Refining	11	0	67	8	14
Gasoline Marketing					
Underground Service Service Tanks	18	0	60	0	22
Auto Tank Filling	4	0	69	9	18
Fuel Combustion	90	0	3	1	6
Waste Burning & Fires	74	0	7	3	16
STATIONARY SOURCES-ORGANIC CHEMICALS					
Surface Coating					
Heat Treated	20	0	28	50	2
Air Dried	14	0	52	29	5
Dry Cleaning					
Petroleum Based Solvent	0	0	94	5	1
Synthetic Solvent (PCE)	100	0	0	0	0
Degreasing					
TCE Solvent	0	0	0	100	0
1,1,1-T Solvent	100	0	0	0	0
Printing					
Rotogravure	16	0	61	23	0
Flexigraphic	19	0	8	73	0
Industrial Process Sources					
Rubber & Plastic Manf.	16	1	24	7	52
Pharmaceutical Manf.	34	1	5	60	0
Miscellaneous Operations	44	0	29	18	9
MOBILE SOURCES					
Gasoline Powered Vehicles					
Light Duty Vehicles					
Exhaust Emissions	28	0	30	19	23
Evaporative Emissions	5	0	58	21	16
Heavy Duty Vehicles					
Exhaust Emissions	28	0	30	19	23
Evaporative Emissions	5	0	58	21	16
Other Gasoline Powered Equipment					
Exhaust Emissions	28	0	30	19	23
Evaporative Emissions	5	0	58	21	16
Diesel Powered Motor Vehicles	13	0	24	6	57
Aircraft					
Jet	9	4	38	16	33
Piston	34	0	23	10	33

TABLE 6. MOLAR REACTIVITIES AND WEIGHT REACTIVITIES FOR THE FIVE-CLASS SCHEME

SOURCE CATEGORY	SOURCE MOLAR REACTIVITIES	SOURCE WEIGHT REACTIVITIES
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION		
Petroleum Production and Refining		
Petroleum Production	.19	.45
Petroleum Refining	.71	.53
Gasoline Marketing		
Underground Service Station Tanks	.71	.84
Auto Tank Filling	.78	.73
Fuel Combustion	.20	.55
Waste Burning & Fires	.37	.77
STATIONARY SOURCES-ORGANIC CHEMICALS		
Surface Coating		
Heat Treated	.70	.59
Air Dried	.69	.55
Dry Cleaning		
Petroleum Based Solvent	.66	.36
Synthetic Solvent (PCE)	.10	.04
Degreasing		
TCE Solvent	.95	.50
1,1,1-T Solvent	.10	.05
Printing		
Rotogravure	.62	.52
Flexigraphic	.76	.92
Industrial Process Sources		
Rubber & Plastic Manf.	.97	.92
Pharmaceutical Manf.	.64	.59
Miscellaneous Onerations	.53	.46
MOBILE SOURCES		
Gasoline Powered Vehicles		
Light Duty Vehicles		
Exhaust Emissions	.72	.72
Evaporative Emissions	.80	.61
Heavy Duty Vehicles		
Exhaust Emissions	.72	.72
Evaporative Emissions	.80	.61
Other Gasoline Powered Equipment		
Exhaust Emissions	.72	.72
Evaporative Emissions	.80	.61
Diesel Powered Motor Vehicles	1.02	.79
Aircraft		
Jet	.88	.50
Piston	.74	.91

TABLE 7. ESTIMATED COMPOSITION OF ORGANICS EMITTED BY PETROLEUM PRODUCING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	84	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	13	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	3	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	84	Total Class II	16	Total Class III	0

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 8. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED FROM REFINERY OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	6	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	8
Benzene	3	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	14
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	67	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	2				
Total Class I	11	Total Class II	67	Total Class III	22

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 9 ESTIMATED COMPOSITION OF THE ORGANICS EMITTED FROM UNDERGROUND GASOLINE STORAGE TANKS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	18	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	22
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	59	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	18	Total Class II	60	Total Class III	22

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 10. ESTIMATED COMPOSITION OF ORGANICS EMITTED DURING AUTOMOBILE GASOLINE TANK FILLING

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	2	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	10
Benzene	2	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	17
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	68	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	4	Total Class II	69	Total Class III	27

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 11. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING THE COMBUSTION OF FUEL

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	85	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	1
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	3
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	3
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	3	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	5				
Total Class I	90	Total Class II	3	Total Class III	7

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 12. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED FROM WASTE BURNING AND OTHER FIRES

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	62	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	1
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	13
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	3
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol	4	C_3+ paraffins	3	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones	2	Primary & secondary C_2+ alcohols	2
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins			2	C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	8				
Total Class I	74	Total Class II	7	Total Class III	19

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 13. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING HEAT TREATING OF SURFACE COATINGS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	20	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	50
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	2
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	28	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	20	Total Class II	28	Total Class III	52

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 14. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING CURING OF AIR DRIED SURFACE COATINGS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	16
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates	3	Aliphatic aldehydes	
Acetone	10	2-Nitropropane		Branched alkyl ketones	2
Methanol	4	C_3+ paraffins	37	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	5	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones	6	Primary & secondary C_2+ alcohols	12
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	4
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins	1			C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	15	Total Class II	51	Total Class III	34

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 15. ESTIMATED COMPOSITION OF ORGANICS EMITTED FROM DRY CLEANING OPERATIONS USING PETROLEUM BASED SOLVENT

CLASS I (LOW REACTIVITY)		CLASS II (MODERATE REACTIVITY)		CLASS III (HIGH REACTIVITY)	
C_1-C_3 PARAFFINS		MONO-TERT-ALKYL-BENZENES		ALL OTHER AROMATIC HYDROCARBONS	6
BENZENE		CYCLIC KETONES		ALL OLEFINIC HYDROCARBONS (INCLUDING PARTIALLY HALOGENATED)	
BENZALDEHYDE		ALKYL ACETATES		ALIPHATIC ALDEHYDES	
ACETONE		2-NITROPROPANE		BRANCHED ALKYL KETONES	
METHANOL		C_3+ PARAFFINS	28	CELLOSOLVE ACETATE	
TERT-ALKYL ALCOHOLS		CYCLOPARAFFINS	66	UNSATURATED KETONES	
PHENYL ACETATE		N-ALKYL KETONES		PRIMARY & SECONDARY C_2+ ALCOHOLS	
METHYL BENZOATE		N-METHYL PYRROLIDONE		DIACETONE ALCOHOL	
ETHYL AMINES		N,N-DIMETHYL ACETAMIDE		ETHERS	
DIMETHYL FORMAMIDE		ALKYL PHENOLS*		CELLOSOLVES	
PREHALOGENATED HYDROCARBONS		METHYL PHTHALATES**		GLYCOLS*	
PARTIALLY HALOGENATED PARAFFINS				C_2+ ALKYL PHTHALATES**	
PHTHALIC ANHYDRIDE**				OTHER ESTERS**	
PHTHALIC ACIDS**				ALCOHOL AMINES**	
ACETONITRILE*				C_3+ ORGANIC ACIDS + DI-ACIDS**	
ACETIC ACID				FORMIN** (HEXA METHYLENE-TETRAMINE)	
AROMATIC AMINES				TERPENIC HYDROCARBONS	
HYDROXYL AMINES				OLEFIN OXIDES**	
NAPHTHALENE*				C_3 + DI-ACID ANHYDRIDES**	
CHLOROBENZENES*					
NITROBENZENES*					
PHENOL*					
ACETYLENE***					
TOTAL CLASS I	0	TOTAL CLASS II	94	TOTAL CLASS III	6

*REACTIVITY DATA ARE EITHER NON-EXISTENT OR INCONCLUSIVE, BUT CONCLUSIVE DATA FROM SIMILAR COMPOUNDS ARE AVAILABLE; THEREFORE, RATING IS UNCERTAIN BUT REASONABLE.

**REACTIVITY DATA ARE UNCERTAIN.

***ESTIMATED REACTIVITY; BASED ON POSITION IN 5-CLASS REACTIVITY SCHEME.

TABLE 16. COMPOSITION OF THE ORGANICS EMITTED FROM DRY CLEANING OPERATIONS USING SYNTHETIC SOLVENT (PCE)

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons	100	Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	100	Total Class II	0	Total Class III	0

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 17. COMPOSITION OF THE ORGANICS EMITTED DURING TRICHLOROETHYLENE (TCE) DEGREASING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	100
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	0	Total Class II	0	Total Class III	100

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 18. COMPOSITION OF THE ORGANICS EMITTED DURING 1,1,1,-TRICHLOROETHANE DEGREASING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins	100			C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	100	Total Class II	0	Total Class III	0

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 19. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY ROTOGRAVURE PRINTING OPERATIONS

Class I (Low Reactivity)	%	Class II (Moderate Reactivity)	%	Class III (High Reactivity)	%
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	10
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates	5	Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol	16	C_3+ paraffins	49	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	7	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	13
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	16	Total Class II	61	Total Class III	23

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 20. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY FLEXIGRAPHIC PRINTING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone	10	2-Nitropropane		Branched alkyl ketones	
Methanol	9	C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones	8	Primary & secondary C_2+ alcohols	73
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	19	Total Class II	8	Total Class III	73

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 21. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY RUBBER, PLASTIC, PUTTY AND ADHESIVE MANUFACTURING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	6
Benzene	7	Cyclic ketones	1	All olefinic hydrocarbons (including partially halogenated)	41
Benzaldehyde		Alkyl acetates	1	Aliphatic aldehydes	10
Acetone	4	2-Nitropropane		Branched alkyl ketones	2
Methanol		C_3+ paraffins	9	Cellosolve acetate	
Tert-alkyl alcohols	2	Cycloparaffins	7	Unsaturated ketones	
Phenyl acetate		n-alkyl ketones	3	Primary & secondary C_2+ alcohols	4
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins	3			C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	16	Total Class II	21	Total Class III	63

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 22. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING PHARMACEUTICAL MANUFACTURING

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	
Benzene		Cyclic ketones	1	All olefinic hydrocarbons (including partially halogenated)	
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone	7	2-Nitropropane		Branched alkyl ketones	3
Methanol	20	C_3+ paraffins		Cellosolve acetate	
Tert-alkyl alcohols	7	Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones	5	Primary & secondary C_2+ alcohols	57
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	34	Total Class II	6	Total Class III	60

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 23. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY MISCELLANEOUS SOLVENT USING OPERATIONS

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins		Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	11
Benzene	3	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	4
Benzaldehyde		Alkyl acetates	3	Aliphatic aldehydes	1
Acetone	19	2-Nitropropane		Branched alkyl ketones	4
Methanol	19	C_3+ paraffins	13	Cellosolve acetate	
Tert-alkyl alcohols	3	Cycloparaffins	4	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones	9	Primary & secondary C_2+ alcohols	4
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	3
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	44	Total Class II	29	Total Class III	27

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 24. ESTIMATED ORGANIC COMPOSITION OF THE EXHAUST EMISSIONS FROM LIGHT DUTY GASOLINE POWERED VEHICLES

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	14	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	22
Benzene	3	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	20
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	30	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		n-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	11				
Total Class I	28	Total Class II	30	Total Class III	42

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 25. ESTIMATED ORGANIC COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM LIGHT DUTY GASOLINE POWERED VEHICLES

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	1	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	24
Benzene	4	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	13
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ Paraffins	57	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	5	Total Class II	58	Total Class III	37

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 26. ESTIMATED ORGANIC COMPOSITION OF THE EXHAUST EMISSIONS FROM HEAVY DUTY GASOLINE POWERED VEHICLES

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	14	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	22
Benzene	3	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	20
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	30	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	11				
Total Class I	28	Total Class II	30	Total Class III	42

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 27 ESTIMATED ORGANIC COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM HEAVY DUTY GASOLINE POWERED VEHICLES

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	1	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	24
Benzene	4	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	13
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	57	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	5	Total Class II	58	Total Class III	37

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.
**Reactivity data are uncertain.
***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 28. ESTIMATED ORGANIC COMPOSITION OF THE EXHAUST EMISSIONS FROM OTHER GASOLINE POWERED EQUIPMENT

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	14	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	22
Benzene	3	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	20
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	30	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		n-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	11				
Total Class I	28	Total Class II	30	Total Class III	42

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 29. ESTIMATED ORGANIC COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM OTHER GASOLINE POWERED EQUIPMENT

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	1	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	24
Benzene	4	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	13
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	57	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***					
Total Class I	5	Total Class II	58	Total Class III	37

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 30. ESTIMATED COMPOSITION OF THE EXHAUST EMISSIONS FROM DIESEL POWERED VEHICLES.

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	11	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	6
Benzene		Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	27
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	30
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	24	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	2				
Total Class I	13	Total Class II	24	Total Class III	63

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 31. ESTIMATED COMPOSITION OF THE ORGANIC EMISSIONS FROM TURBINE POWERED AIRCRAFT

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 Paraffins	7	Mono-tert-alkyl-benzenes	4	All other aromatic hydrocarbons	20
Benzene	1	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	19
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	10
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	38	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins		Unsaturated ketones	
Phenyl acetate		n-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	1				
Total Class I	9	Total Class II	42	Total Class III	49

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 32. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY PISTON POWERED AIRCRAFT

Class I (Low Reactivity)		Class II (Moderate Reactivity)		Class III (High Reactivity)	
C_1-C_3 paraffins	20	Mono-tert-alkyl-benzenes		All other aromatic hydrocarbons	12
Benzene	2	Cyclic ketones		All olefinic hydrocarbons (including partially halogenated)	31
Benzaldehyde		Alkyl acetates		Aliphatic aldehydes	
Acetone		2-Nitropropane		Branched alkyl ketones	
Methanol		C_3+ paraffins	22	Cellosolve acetate	
Tert-alkyl alcohols		Cycloparaffins	1	Unsaturated ketones	
Phenyl acetate		N-alkyl ketones		Primary & secondary C_2+ alcohols	
Methyl benzoate		N-methyl pyrrolidone		Diacetone alcohol	
Ethyl amines		N,N-dimethyl acetamide		Ethers	
Dimethyl formamide		Alkyl phenols*		Cellosolves	
Prehalogenated hydrocarbons		Methyl phthalates**		Glycols*	
Partially halogenated paraffins				C_2+ Alkyl phthalates**	
Phthalic anhydride**				Other esters**	
Phthalic acids**				Alcohol amines**	
Acetonitrile*				C_3+ organic acids + di-acids**	
Acetic acid				Formin** (Hexa methylene-tetramine)	
Aromatic amines				Terpenic hydrocarbons	
Hydroxyl amines				Olefin oxides**	
Naphthalene*				C_3 + di-acid anhydrides**	
Chlorobenzenes*					
Nitrobenzenes*					
Phenol*					
Acetylene***	12				
Total Class I	34	Total Class II	23	Total Class III	43

*Reactivity data are either non-existent or inconclusive, but conclusive data from similar compounds are available; therefore, rating is uncertain but reasonable.

**Reactivity data are uncertain.

***Estimated reactivity; based on position in 5-class reactivity scheme.

TABLE 33. SUMMARY OF COMPOSITION DATA IN TERMS OF THE THREE-CLASS REACTIVITY SCHEME

SOURCE CATEGORY	MOLAR COMPOSITION (PERCENT)			AVERAGE MOLECULAR WEIGHT
	CLASS I	CLASS II	CLASS III	
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION				
Petroleum Production and Refining				
Petroleum Production	84	16	0	29
Petroleum Refining	11	67	22	93
Gasoline Marketing				
Underground Service Station Tanks	18	60	22	58
Auto Tank Filling	4	69	27	74
Fuel Combustion	90	3	7	25
Waste burning & Fires	74	7	19	33
STATIONARY SOURCES-ORGANIC CHEMICALS				
Surface Coating				
Heat Treated	20	28	52	82
Air Dried	15	51	34	87
Dry Cleaning				
Petroleum Based Solvent	0	94	6	126
Synthetic Solvent (PCE)	100	0	0	166
Degreasing				
TCE Solvent	0	0	100	132
1,1,1-T-Solvent	100	0	0	134
Printing				
Rotogravure	16	61	23	82
Flexigraphic	19	8	73	57
Industrial Process Sources				
Rubber & Plastic Manf.	16	21	63	73
Pharmaceutical Manf.	34	6	60	75
Miscellaneous Operations	44	29	27	80
MOBILE SOURCES				
Gasoline Powered Vehicles				
Light Duty Vehicles				
Exhaust Emissions	28	30	42	69
Evaporative Emissions	5	58	37	91
Heavy Duty Vehicles				
Exhaust Emissions	28	30	42	69
Evaporative Emissions	5	58	37	91
Other Gasoline Powered Equipment				
Exhaust Emissions	28	30	42	69
Evaporative Emissions	5	58	37	91
Diesel Powered Motor Vehicles	13	24	63	89
Aircraft				
Jet	9	42	49	121
Piston	34	23	43	56

TABLE 34. MOLAR REACTIVITIES AND WEIGHT REACTIVITIES FOR THE THREE-CLASS SCHEME

SOURCE CATEGORY	SOURCE MOLAR REACTIVITIES	SOURCE WEIGHT REACTIVITIES X 10^2	REACTIVE EMISSIONS		
			REACTIVE KG/DAY x 10^3	REACTIVE TONS/DAY	PERCENT OF TOTAL
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION					
Petroleum Production and Refining					
Petroleum Production	0.06	0.21	11.8	13.0	0.9
Petroleum Refining	0.47	0.51	67.8	74.7	5.0
Gasoline Marketing					
Underground Service Station Tanks	0.45	0.78	43.8	48.3	3.2
Auto Tank Filling	0.53	0.72	85.8	94.6	6.3
Fuel Combustion	0.08	0.32	7.0	7.7	0.5
Waste Burning & Fires	0.22	0.67	24.9	27.5	1.8
STATIONARY SOURCES: ORGANIC CHEMICALS					
Surface Coating					
Heat Treated	0.63	0.77	8.2	9.0	0.6
Air Dried	0.53	0.61	110.6	121.9	8.1
Dry Cleaning					
Petroleum Based Solvent	0.42	0.33	2.1	2.3	0.2
Synthetic Solvent (PCE)	0.00	0.00	0.0	0.0	0.0
Degreasing					
TCE Solvent	1.00	0.76	0.3	0.3	0.0
1,1,1-T Solvent	0.00	0.00	0.0	0.0	0.0
Printing					
Rotogravure	0.46	0.56	8.7	9.6	0.6
Flexigraphic	0.76	1.33	9.4	10.4	0.7
Industrial Process Sources					
Rubber & Plastic Manf.	0.71	0.97	0.7	0.8	0.1
Pharmaceutical Manf.	0.62	0.83	0.2	0.2	0.1
Miscellaneous Operations	0.38	0.48	22.1	24.4	1.6
MOBILE SOURCES					
Gasoline Powered Vehicles					
Light Duty Vehicles					
Exhaust Emissions	0.53	0.77	443.1	488.4	32.4
Evaporative Emissions	0.59	0.65	289.8	319.5	21.2
Heavy Duty Vehicles					
Exhaust Emissions	0.53	0.77	66.1	72.9	4.8
Evaporative Emissions	0.59	0.65	43.4	47.8	3.2
Other Gasoline Powered Equipment					
Exhaust Emissions	0.53	0.77	76.8	84.7	5.6
Evaporative Emissions	0.59	0.65	13.0	14.3	1.0
Diesel Powered Motor Vehicles	0.72	0.81	10.0	11.1	0.7
Aircraft					
Jet	0.65	0.54	8.4	9.2	0.6
Piston	0.52	0.93	13.1	14.4	1.0
TOTAL			1367.1	1507.0	100

TABLE 35. ADJUSTED MOLAR REACTIVITIES AND WEIGHT REACTIVITIES FOR THE THREE-CLASS SCHEME

SOURCE CATEGORY	SOURCE MOLAR REACTIVITIES	SOURCE WEIGHT REACTIVITIES
STATIONARY SOURCES: ORGANIC FUELS AND COMBUSTION		
Petroleum Production and Refining		
Petroleum Production	0.08	0.20
Petroleum Refining	0.64	0.48
Gasoline Marketing		
Underground Service Station Tanks	0.61	0.73
Auto Tank Filling	0.72	0.67
Fuel Combustion	0.11	0.30
Waste Burning & Fires	0.30	0.63
STATIONARY SOURCES: ORGANIC CHEMICALS		
Surface Coating		
Heat Treated	0.86	0.72
Air Dried	0.72	0.57
Dry Cleaning		
Petroleum Based Solvent	0.57	0.31
Synthetic Solvent (PCE)	0.00	0.00
Degreasing		
TCE Solvent	1.36	0.71
1,1,1-T Solvent	0.00	0.00
Printing		
Rotogravure	0.62	0.52
Flexigraphic	1.03	1.24
Industrial Process Sources		
Rubber & Plastic Manf.	0.96	0.91
Pharmaceutical Manf.	0.84	0.78
Miscellaneous	0.52	0.45
MOBILE SOURCES		
Gasoline Powered Vehicles		
Light Duty Vehicles		
Exhaust Emissions	0.72	0.72
Evaporative Emissions	0.80	0.61
Heavy Duty Vehicles		
Exhaust Emissions	0.72	0.72
Evaporative Emissions	0.80	0.61
Other Gasoline Powered Equipment		
Exhaust Emissions	0.72	0.72
Evaporative Emissions	0.80	0.61
Diesel Powered Motor Vehicles	0.98	0.76
Aircraft		
Jet	0.88	0.50
Piston	0.71	0.87

SECTION 4

CONTROL DEVICES

STATIONARY SOURCES

There are relatively few "off-the-shelf" technologies available for controlling organic emissions from stationary sources. For purposes of this study, only demonstrated technologies will be considered (8). For stationary sources there are seven (7) basic control techniques:

- Incineration
- Adsorption
- Absorption
- Condensation
- Substitution
- Floating roof tank seals
- Improved maintenance and control

The advantages, disadvantages, and applications of each technique are summarized in Table 36 and discussed in more detail in the following pages.

Incineration

Incineration processes control organic emissions by oxidation. When an emission stream contains a sufficient quantity of combustible organics, the pollutant itself is the fuel. An example of this is a refinery flame. Generally, supplementary fuel is employed to maintain stable combustion conditions. Two basic designs of incinerators use supplementary fuel, direct-flame and catalytic. Direct-flame incinerators consist of a burner and a refractory-lined incineration chamber. The incineration chamber is a plenum in which combustion occurs. In some situations the emission stream can be fed into an existing boiler or heater, eliminating the need for an incinerator. Catalytic incinerators are similar except that the combustion occurs on a catalyst bed. Less fuel is burned because catalytic oxidation occurs at lower temperatures. Lower fuel costs, however, are offset by the higher costs of the catalytic unit.

The advantages of this technique are:

- Possible heat recovery from the incineration process. If this can be done, both the heat from the supplementary fuel and the heat from what would otherwise be a pollutant can be utilized.

TABLE 36. SUMMARY OF MAJOR ORGANIC CONTROL TECHNIQUES FOR STATIONARY SOURCES

TYPE	ADVANTAGES	DISADVANTAGES	SOME APPLICATIONS
Incineration	1. Possible Heat Recovery 2. Control of Low Concentration Emissions	1. Consumes Fuel 2. Catalysts Can Be De-Activated 3. Cannot Be Used When the Organics Contain Halogens or Sulfur 4. No Solvent Recovery	1. Petroleum Refining 2. Chemical Processing 3. Baking Ovens
Adsorption	1. Solvent Recovery 2. Control of Low Concentration Emissions	1. Selective Control of Low Vapor Pressure Organics 2. Non-Continuous Process	1. Dry Cleaning 2. Degreasing 3. Paint Spraying 4. Solvent Extraction Processes 5. Metal Coating 6. Plastic, Chemical, Pharmaceutical and Rubber Manufacturing
Absorption	1. Applicable to Sources That Cannot Be Controlled By Other Techniques	1. Poor Economics 2. Relatively Low Control Efficiency (i.e. Relatively High Final Emissions Levels)	1. Petroleum Coking 2. Varnish and Resin Cookers
Condensation	1. Solvent Recovery 2. Applicable to Sources That Cannot Be Controlled By Other Techniques	1. Selective Control of Low Vapor Pressure Organics 2. Relatively Low Control Efficiency (i.e. Relatively High Final Emission Levels)	1. Gasoline Storage and Marketing Facilities 2. Petrochemical Manufacturing 3. Dry Cleaning 4. Degreasing Operations
Secondary Floating	1. Only Feasible Technique	1. Poor Economics	1. Petroleum and Chemical Storage
Substitution	1. Only Applicable Technique In Some Cases	1. Limited Applicability	1. Dry Cleaning 2. Surface Coatings 3. Degreasing Operation

- Control of very dilute concentrations of organics with catalytic incinerators; there is no lower concentration limit.

- Equal control of all types of organics. That is, regardless of the volatility, molecular weight or chemical structure of the organics, they are oxidized by the flame.

The disadvantages of this techniques are:

- Supplementary fuel is required.

- Some operations produce substances that poison (deactivate) the catalysts.

- If the organics contain halogens or sulfur, the combustion process can produce toxic or otherwise unacceptable emissions.

Incineration can be applied to the control of emissions from petroleum refining, chemical processing, baking ovens and others.

Adsorption (8)

Organic emissions can be controlled by using adsorption techniques. The adsorption process is one in which the molecules of a vapor adhere to the surface of a solid adsorbent. Two types of adsorption can occur: 1) physical adsorption - gas is attracted to the surface of the solid and 2) chemical adsorption - gas interacts chemically (and usually reversibly) with the solid. As an emission stream is passed through an adsorbent bed, the organics are selectively removed. When the bed becomes saturated it can either be replaced or regenerated.

The regeneration process consists of heating and/or stripping the collected organics with steam or an inert gas. Heating raises the temperature of the adsorbent to vaporize the organics. The organics, now more concentrated, can be disposed of or recovered. Stripping consists of passing an inert gas, usually steam, through a bed of adsorbent and condensing the stripped organics for disposal or recovery. In some cases, an adsorbent that is also an oxidation catalyst is used to destroy rather than recover the organics. The catalyst, inactive while adsorbing the organics, oxidizes them on heating.

Adsorbents do not remove all organics with equal efficiency. The components of an organic mixture usually are adsorbed at a rate roughly inverse to their vapor pressure. However, there are adsorbents which have greater affinities for some types of organics than others. Metal oxides, for example, tend to have an affinity for polar compounds.

In a newly regenerated adsorbent bed, this selectivity effect tends to be minimized with all components being adsorbed to nearly the same degree. As the adsorbent approaches saturation, higher boiling components begin to displace lower boiling ones. The point at which this begins to occur rapidly is called the "break point." As a general rule, organics with molecular weights less than 45 a.m.u. cannot be controlled efficiently by adsorption techniques. Methanol (Molecular weight 32) is an exception.

The advantages of this technique are:

- The organics can be totally or partially recovered. In some operations, solvent can be recovered which will partially or completely off-set the cost of the control equipment.

- It can be used to remove very low concentrations of organics.

- Adsorption may be the most economical method of controlling organic emissions in the concentration range of 100 to 200 ppm.

The disadvantages are:

- Low vapor pressure components are not controlled as well as high vapor pressure components.

- For smaller operations, the system is non-continuous.

Adsorption techniques are applicable to dry cleaning, degreasing, paint spraying, solvent extraction processes, metal coating, the manufacture of plastics, chemicals, pharmaceuticals and rubber, and others. Unless scrubbed to remove the substances that foul the adsorbents, emissions from paint and varnish manufacture cannot be controlled by this method.

Absorption (8)

In the absorption process some components of a gas mixture are retained by a liquid. Either the gas can dissolve in the liquid or can react chemically with it.

There are drawbacks to this technique. Absorption is best used in connection with other control techniques because it usually does not result in sufficiently low organic concentrations. The economics are often unfavorable unless the absorbent can be regenerated or the absorbing solution used as a process stream.

In general, solvents will have different affinities for different organics as the technique is somewhat selective. Since each constituent saturates the solvent at a different concentration, after a period of operation, some components will begin to pass through the solvent. (It is actually an absorption - desorption process but the result is the same).

The advantage of this process is:

- It can be used where the emission stream contains materials which would contaminate catalyst or adsorbent beds.

The disadvantages are:

- The method does not normally reduce emissions to sufficiently low levels.

- The economics are unfavorable under most circumstances.

Absorption techniques have been used to control organic emissions from petroleum coating units and varnish and resin coaters.

Condensation (8)

Organic emissions can also be controlled by condensation processes. The organics in an emission stream can, in principle, be condensed either by cooling the stream or by increasing its pressure. Refineries and oil producing operations use some condensing procedures. However, the cooling procedure is used almost exclusively.

Emission streams are cooled by two basic processes, surface and contact. In a surface condenser the gas stream passes over a heat exchanger and the hydrocarbons condense on its surface. Contact condensers cool the vapor by spraying a cold liquid, usually water, directly into the gas stream. The condensate can then either be disposed of or the organics can be separated and recovered. Contact condensers are usually less expensive and more efficient than the surface type.

Usually condensers are used only as a preliminary control device and therefore, must be followed by a secondary control system such as an incineration or adsorption unit. The lowest level to which a given organic can be reduced is limited primarily by its vapor pressure at the condenser operating temperature. That is, assuming organic vapor-liquid equilibrium, at each temperature a specific concentration of the organic will remain in the gas stream. For example, the vapor pressure of toluene at $0^{o}C$ ($32^{o}F$) is approximately 6mm Hg. At atmospheric pressure that corresponds to approximately 8000 ppm. In the contact type of condenser some organics may be soluble enough in the cold water for their concentration to be lowered to below the equilibrium level. In general, this type of control cannot reduce organic emissions to very low levels.

The vapor pressure limitation also results in selective control. If water solubility is ignored, the gas phase concentration of organics with higher vapor pressures (lower boiling points) will be higher than those with lower vapor pressure. The result is, low boiling components such as methane cannot be controlled as effectively as higher boiling compounds such as toluene.

Water solubility variations also contribute to selective control. 1-hexane (b.p. $63.4^{o}C$) for example, has a very low solubility in water while acetone (b.p. $56.2^{o}C$) is infinitely soluble. Even though the vapor pressure (as expressed by boiling points) of these two compounds are similar, because of the solubility differences, acetone would be expected to be controlled to a lower level.

The advantages of this system are:

- The organics can be totally or partially recovered.

- It can be used where the emission stream contains materials which would contaminate catalyst or adsorbent beds.

The disadvantages are:

- The process selectively controls emissions. Low boiling components, in general, are not controlled as effectively as high boiling compounds.
- Low emission levels cannot be achieved because of the vapor pressure limitation.

Condensers have been used to control emissions from gasoline storage and marketing facilities, petrochemical manufacturing, dry cleaning, and degreasing.

<u>Floating Roof Seals</u> (9), (10)

Many petroleum and chemical storage tanks have floating roofs. A floating roof, as the name implies, is a cover which floats on the liquid surface. Since the roof moves up and down as the volume of liquid changes, it is difficult to maintain a tight seal between the roof and the inside walls of the tank. Typically, a gap exists around the circumference of the roof. These emissions can be reduced by installing and properly maintaining a more efficient seal.

The advantage of this method is:

- It is frequently the only feasible method for controlling emissions from this source.

The disadvantages are:

- The seals are expensive to install.
- Seals are difficult to maintain.

This technique can be applied to petroleum and chemical storage facilities.

<u>Substitution</u> (8), (11)

In some circumstances, reactive organics can be controlled by substituting a less reactive solvent or solvent mixture in the process that results in the emissions. As mentioned in Section 3 with respect to reactivity, it is the reactive emissions, not the mass emissions that are significant. Therefore, substitution of less reactive components is considered to be a control technique.

In the Los Angeles area this technique has been applied to degreasing operations and, to a lesser extent, architectural and other types of coatings.

The advantage of the technique is:

- The potential for obtaining large reactive emission reductions at low cost.

The disadvantages are:

- It has limited applicability.
- It is not possible to attain very low levels of reactive emissions unless a non-reactive solvent can be used.

This technique has been applied to degreasing operations, dry cleaning and surface coatings.

Improved Maintenance and Control

In many industrial operations a substantial fraction of the total organic emissions are due to poor maintenance and poor process control. A large fraction of these emissions could be prevented by adequate maintenance. Improved maintenance has, in addition to the air pollution control benefits, additional benefits in terms of improved equipment reliability and safety. With many industrial facilities in Southern California being quite old, there is a tendency for the process monitoring and control instrumentation to be outdated. Since improved instrumentation can result in more efficient operation of many processes, it also qualifies as a control technique.

A study was conducted by the California Air Resources Board to determine the economic feasibility of requiring continuous monitoring of stack emissions from large combustion sources. It was concluded that in many cases, by using the required instrumentation to fine tune the boilers for lower emissions, the fuel savings would pay for the instruments, the maintenance, and data management that would be required (12).

The advantages of applying this technique are:

- It is possible that, in some cases, applying these techniques would result in a net savings to the plant operator.
- Little capital investment is required.

From an air pollution control point of view there are no disadvantages.

These techniques can be applied to most industrial operations, although they are more feasible in larger plants.

MOBILE SOURCES

Light Duty Vehicles, Heavy Duty Vehicles and Other Gasoline Powered Equipment

For these categories, there are three (3) types of emissions: exhaust, evaporative and crankcase.

Exhaust Emissions (11), (13), (14)

Exhaust emissions can be controlled by either modifying the combustion process or eliminating organics from the exhaust. Modifications of the spark advance, modifcation of the carburetor, or installation of exhaust gas recirculation (EGR) are examples of retro-fit combustion modifications. Catalytic or thermal reactors accomplish exhaust clean-up.

Evaporative Emissions (11), (13), (14)

Evaporative emissions occur at the carburetor and fuel tank. The applicable control technique for these emissions is vent modification. Emissions that occur as the engine is running are routed into the carburetor and burned. Those that occur when the engine is off are trapped until the engine is started and then routed into the carburetor. The trap is usually an activated carbon adsorption unit.

Crankcase Emissions (11), (13), (14)

Crankcase emissions are controlled by a connection of the crankcase vent to the carburetor or intake manifold. As with evaporative controls, the organics are then burned in the cylinders. The advantages to these techniques are:

- They can be applied to vehicles that are in use.
- They control emissions from the device type categories that, in aggregate, emit the largest quantities of organics.

The disadvantages are:

- Many of the vehicles now in use already have these or similar controls.
- The possible emission reductions are limited.

Diesel Powered Vehicles

Other than adequate maintenance, there are no feasible retro-fit control techniques for this source type (13), (14).

Jet Powered Aircraft

The only feasible control technique for reducing emissions from this source is redesign of the combustion chamber (13), (15).

Piston Powered Aircraft

Exhaust treatment with after-burners or reactors appears to be the only feasible control technique (13).

SECTION 5

COST DATA

CONTROL SELECTION

In considering which controls to apply to each category, three (3) factors were considered:

- Reactivity - If the reactivity of the emissions is zero, no controls are required.
- Controllability - Some emissions cannot feasibly be controlled.
- Cost Effectiveness - The most cost effective combination of controls for each source was selected.

In the following, the selection of controls for each category is discussed.

Petroleum Production

Local air pollution control district regulations have limited emissions from this source for several years (16). As a consequence, they are already strictly controlled. For purposes of this study it was assumed that no further controls could be applied.

Petroleum Refining

Local air pollution regulations limit emissions from this source also. For this study it was assumed that only fixed and floating roof tanks could be further controlled. The costs and techniques for controlling emissions from fixed roof tanks were assumed to be similar to those for gasoline marketing operations. Emissions from floating roof tanks were assumed to be controlled by the use of a secondary seal at the perimeter of the roof.

The following breakdown of refinery emissions was used (17):

Fixed Roof Tanks:	33,300 kg/day	(36.7 tons/day)
Floating Roof Tanks:	18,800 kg/day	(20.7 gons/day)
Other Sources:	80,800 kg/day	(89.1 tons/day)
TOTAL	132,900 kg/day	(146.5 tons/day)

Underground Service Station Tanks

Controls for this category of devices and Auto Tank Filling are usually applied together (18). For convenience, however, the costs were calculated separately. A combination of vapor recycle with adsorption or condensation units are the optimum control.

Auto Tank Filling

Controlled in conjunction with Underground Service Station Tanks.

Fuel Combustion

There are no feasible controls for this cateogry of emissions.

Waste Burning and Other Fires

Emissions from this category are already limited by local regulations. There are no further feasible controls.

Surface Coating - Heat Treated

Control requirements for this category of devices are similar to those for flexigraphic printing (18). Since catalytic incineration is the optimum method for that source, it was assumed to be the optimum method for this source also. The same cost effectiveness was assumed.

Surface Coating - Air Dried

This category includes emissions from two types of sources: architectural coatings and factory applied coatings. It was assumed the emissions from the first only could be controlled by solvent modifications. Also, it was assumed that the same controls that apply to emissions from heat treating coatings also apply to emissions from factory applied air dried surface coatings.

The following breakdown of air dried surface coating emissions was used (17):

Architectural Coatings:	93,100 kg/day (102.6 tons/day)
Factory Applied Coatings:	88,300 kg/day (97.3 tons/day)
TOTAL	181,300 kg/day*(199.9 tons/day)

Dry Cleaning - Petroleum Based Solvent

It was assumed that an adsorption system which allows recovery of the solvent was used.

Dry Cleaning - Synthetic Solvent (PCE)

Since the reactivity of PCE solvent is zero, the reactive emissions are zero. Therefore, no control is required.

* Rounding Error

Degreasing - TCE Solvent

Typical uncontrolled degreasing units emit approximately 0.5 to 1.0 lbs/hr-ft^2 of degreaser surface area (18). Inventory data show that emissions from a typical degreasing operation in the Los Angeles area are 24 kg/day (0.03 tons/day) (17). Therefore, emissions from this category already are controlled. This is consistent with local APCD regulations (16).

Degreasing - 1,1,1-T Solvent

Since the reactivity of 1,1,1-T solvent is zero, the reactive emissions are zero. Therefore, no control is required.

Printing - Rotogravure

It was assumed that an adsorption system which allows recovery of the solvent was used.

Printing - Flexigraph

It was assumed that a catalytic incineration system was used.

Rubber, Plastic, Adhesive, and Putty Manufacturing

Since this category includes a variety of operations, it was assumed that no one type of control would be applicable. Therefore, it was assumed that 50% of the emissions were controlled by catalytic incineration and 50% by adsorption.

Pharmaceutical Manufacturing

Same as above.

Miscellaneous Organic Solvent Operations

Same as above.

Light Duty Vehicle - Exhaust

Controls on organic exhaust emissions from light duty vehicles have been applied incrementally. That is, the controls required on new vehicles have become more stringent in later model years. As a result, the extent to which existing vehicles can be further controlled is dependent on model year.

Table 37 shows the existing emissions from several model year groups (19). The model year groupings were selected because the vehicles in each group have similar exhaust and evaporative emission controls.

Since there are no feasible retrofit controls for exhaust emissions on California vehicles for model years after 1969, the control potential for this source is limited. That is, only 46.9% of light duty vehicle exhaust emissions are controllable.

TABLE 37. LIGHT DUTY VEHICLE EXHAUST EMISSIONS SUMMARY (9)

MODEL YEAR GROUP	NUMBER OF VEHICLES	AGGREGATE EXHAUST EMISSIONS (TONS/DAY)	% OF EXHAUST EMISSIONS	AGGREGATE EVAPORATIVE EMISSIONS* (TONS/DAY)	% OF EVAPORATIVE EMISSIONS
Pre - 63	609,952	46.1	7.3	80.7	16.4
63 - 65	761,346	61.7	9.7	82.5	16.8
66 - 69	1,569,510	189.4	29.9	168.0	34.2
70	435,592	47.5	7.5	39.1	8.0
71	478,714	64.6	10.2	24.6	5.0
72 - 75	2,071,505	225.1	35.5	96.6	19.7

*Includes crankcase emissions

Light Duty Vehicles - Evaporative

The evaporative and crankcase emission controls on existing vehicles are also model year dependent. Evaporative emissions by model year group are presented in Table 37. As with exhaust emissions, the control potential for evaporative emissions is limited. Only 67.4% of these emissions are controllable.

Heavy Duty Vehicles - Exhaust

Table 38 shows a summary of emissions from heavy duty gasoline powered vehicles. As with light duty vehicles, the exhaust emission standards have become more restrictive in later model years. Heavy duty standards, however, are not as stringent as those for light duty vehicles and did not take effect until several years later. It was assumed that retrofit exhaust emission controls were applicable to 1972 and earlier vehicles.

Approximately 84.4% of the emissions are controllable.

Heavy Duty Vehicles - Evaporative

Evaporative and crankcase emissions from heavy duty vehicles are summarized in Table 38. Retrofit evaportive controls were assumed to be applicable to 1972 and earlier vehicles. Approximately 77.2% of the emissions are controllable.

Other Gasoline Powered Equipment - Exhaust

This category of devices was assumed to have emission characteristics similar to un-controlled automobiles. It was assumed further that the same controls are applicable.

Other Gasoline Powered Equipment - Evaporative

Same as above.

Diesel Power Vehicles

There are no feasible controls for this category of emissions.

Aircraft - Jet

Emissions from this category were assumed to be controllable only by retrofitting modified combustion cans.

Aircraft - Piston

Emissions from this category were assumed to be controllable only by retrofitting afterburners.

CONTROL COSTS

Figures 2 through 27 graphically present the costs associated with

TABLE 38. HEAVY DUTY VEHICLE EXHAUST EMISSIONS SUMMARY (19), (20), (21)

MODEL YEAR GROUP	NUMBER OF VEHICLES	AGGREGATE EXHAUST EMISSIONS (TONS/DAY)	% OF EXHAUST EMISSIONS	AGGREGATE EVAPORATIVE* EMISSIONS (TONS/DAY)	% OF EVAPORATIVE EMISSIONS
Pre - 61	41,922	18.8	19.9	19.0	25.8
61 - 63	19,932	8.9	9.4	7.6	10.3
64 - 68	50,705	29.0	30.6	18.5	25.1
69 - 71	41,680	17.1	18.1	15.2	20.7
72	15,901	6.1	6.4	6.0	8.2
73 - 74	36,468	13.7	14.5	5.5	7.5
75	12,419	1.3	1.4	1.8	2.4

*Includes crankcase emissions

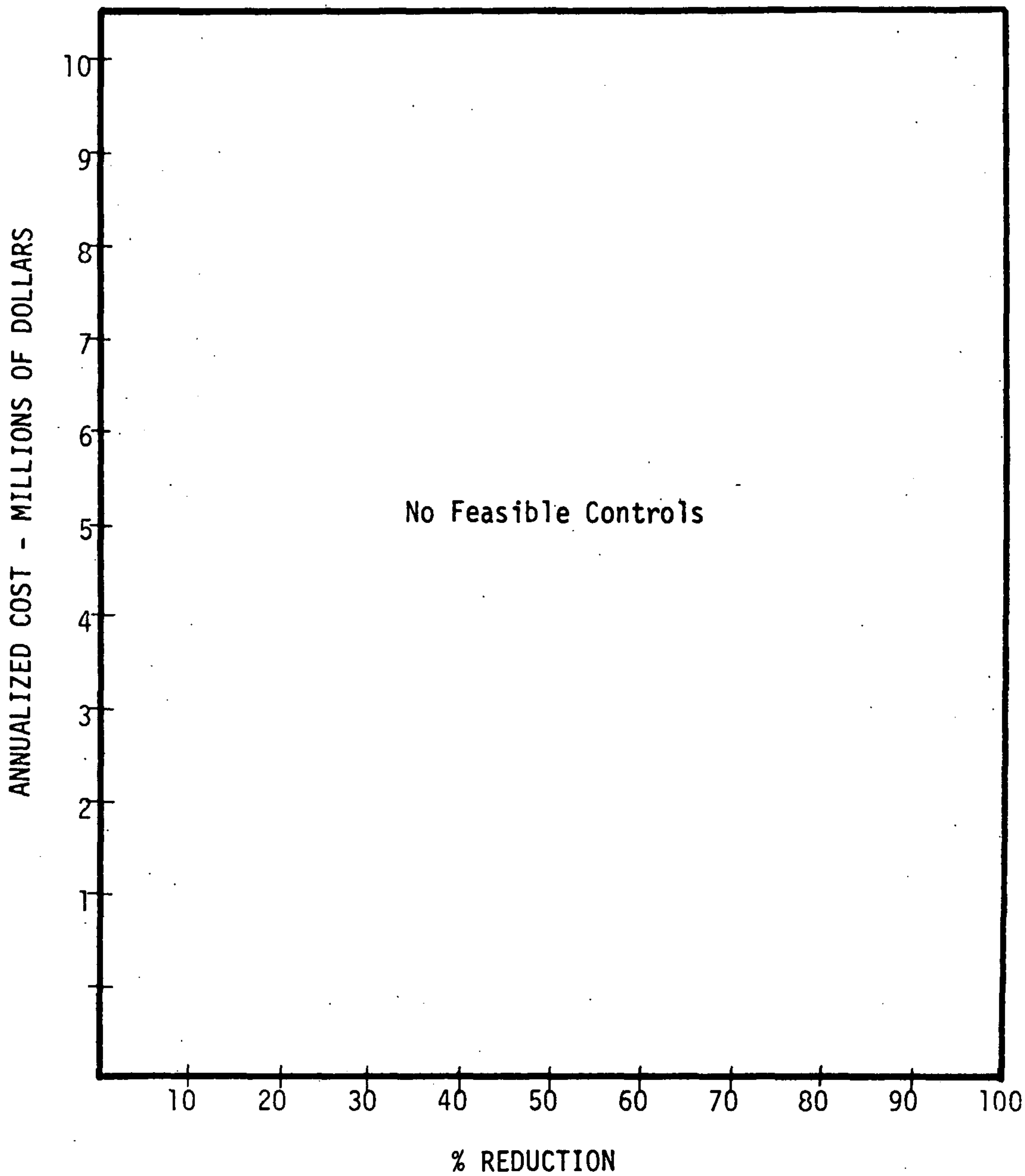


Figure 2. Petroleum Production

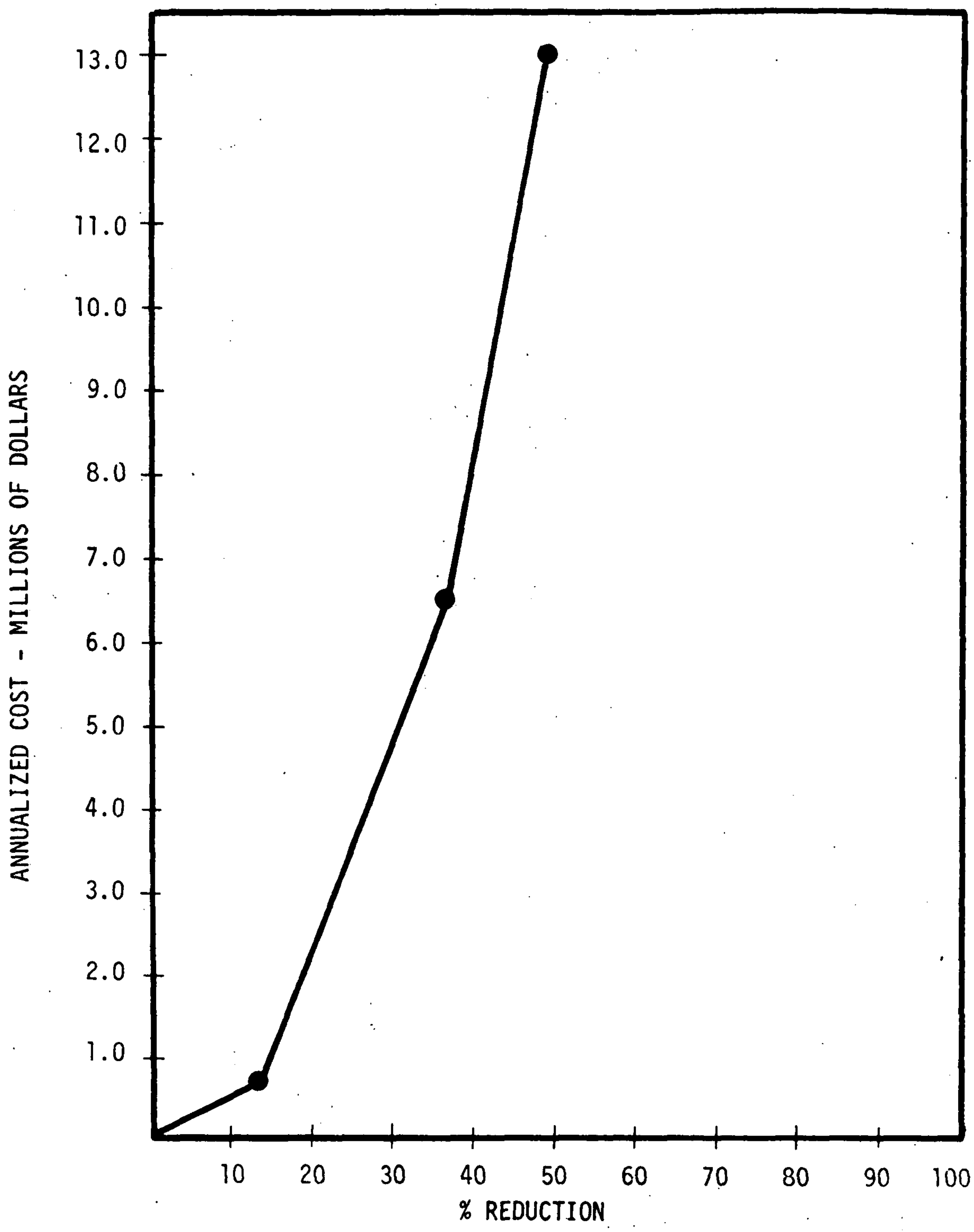


Figure 3. Petroleum Refining

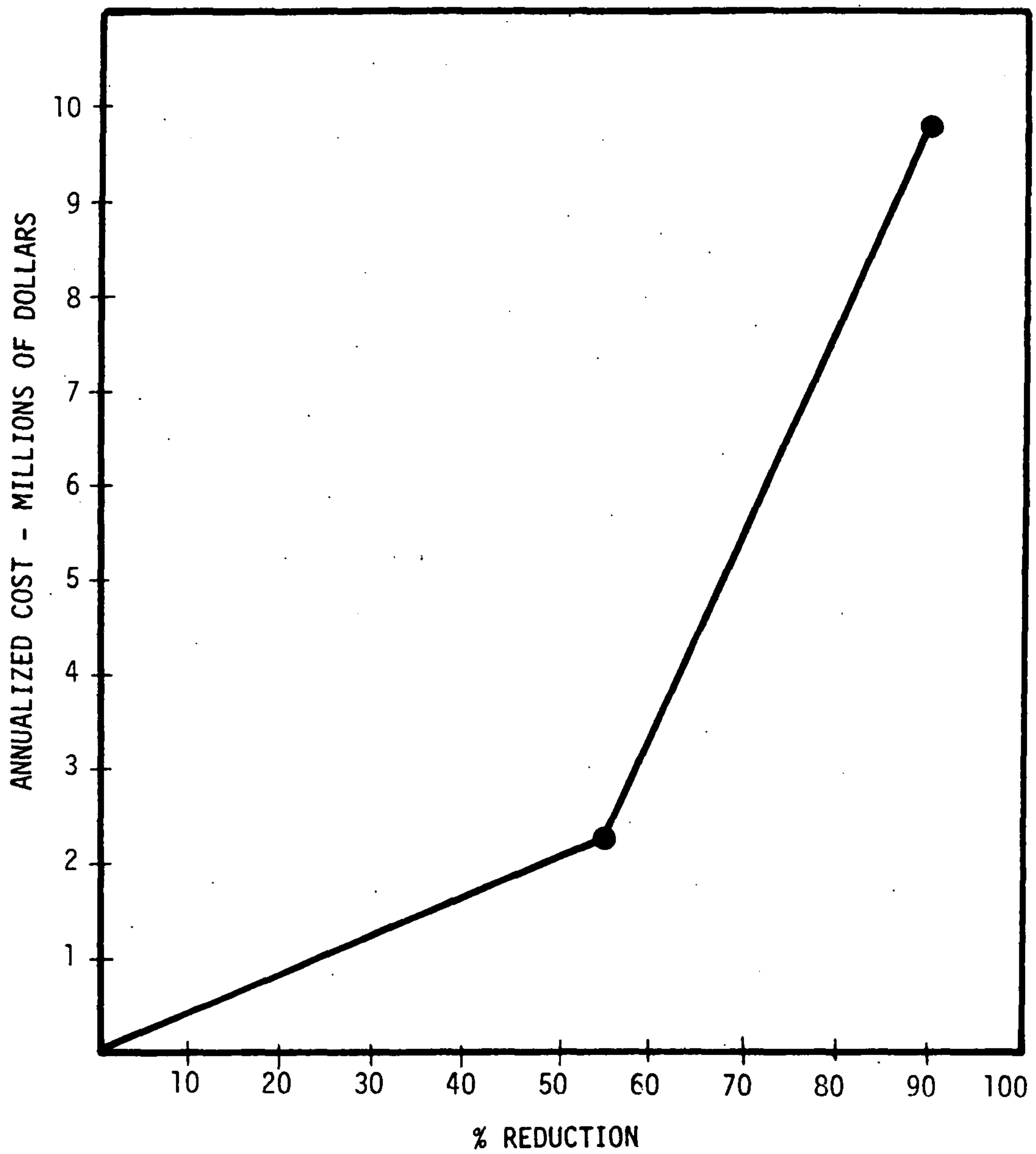


Figure 4. Underground Service Station Tanks

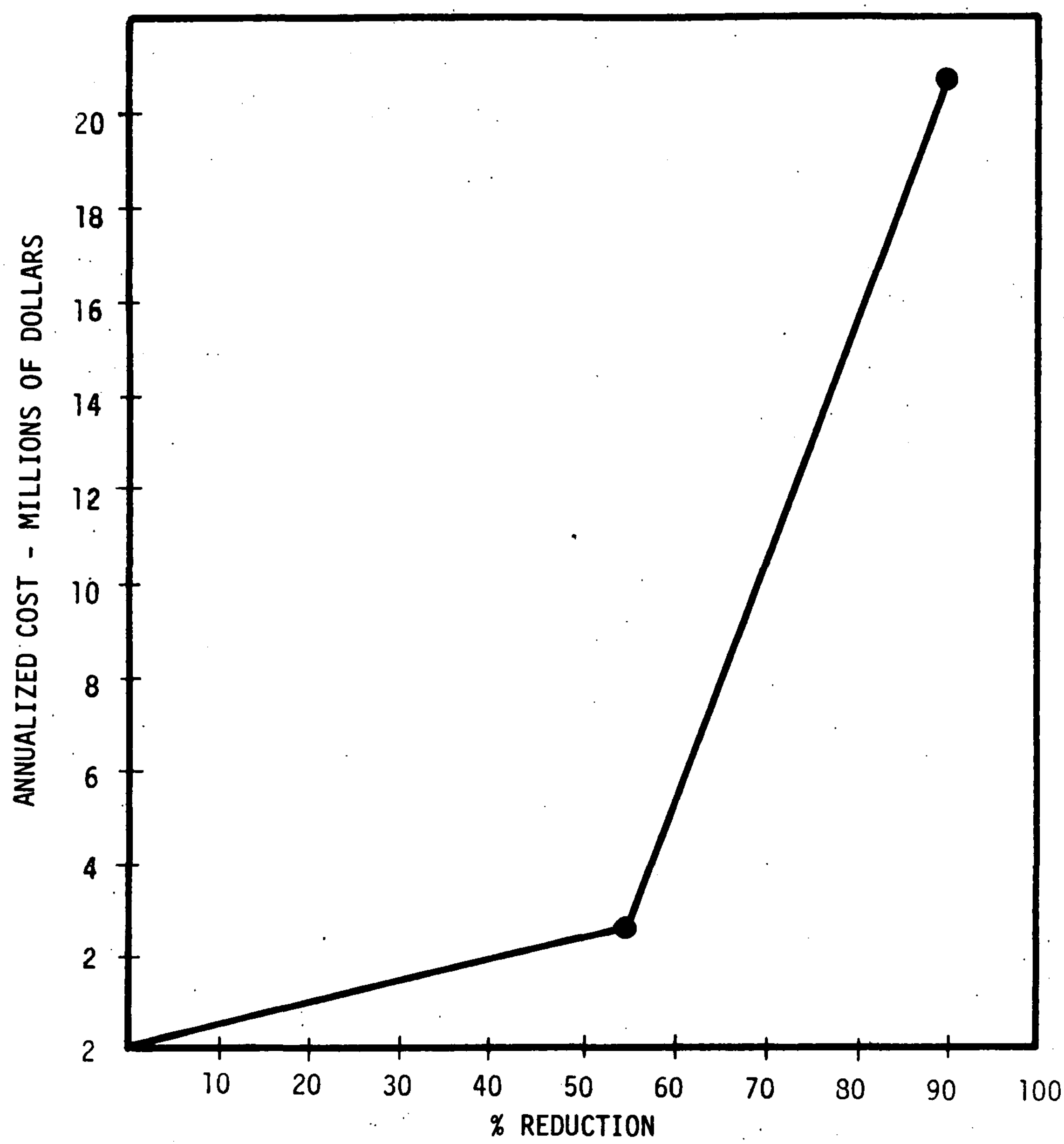


Figure 5. Auto Tank Filling

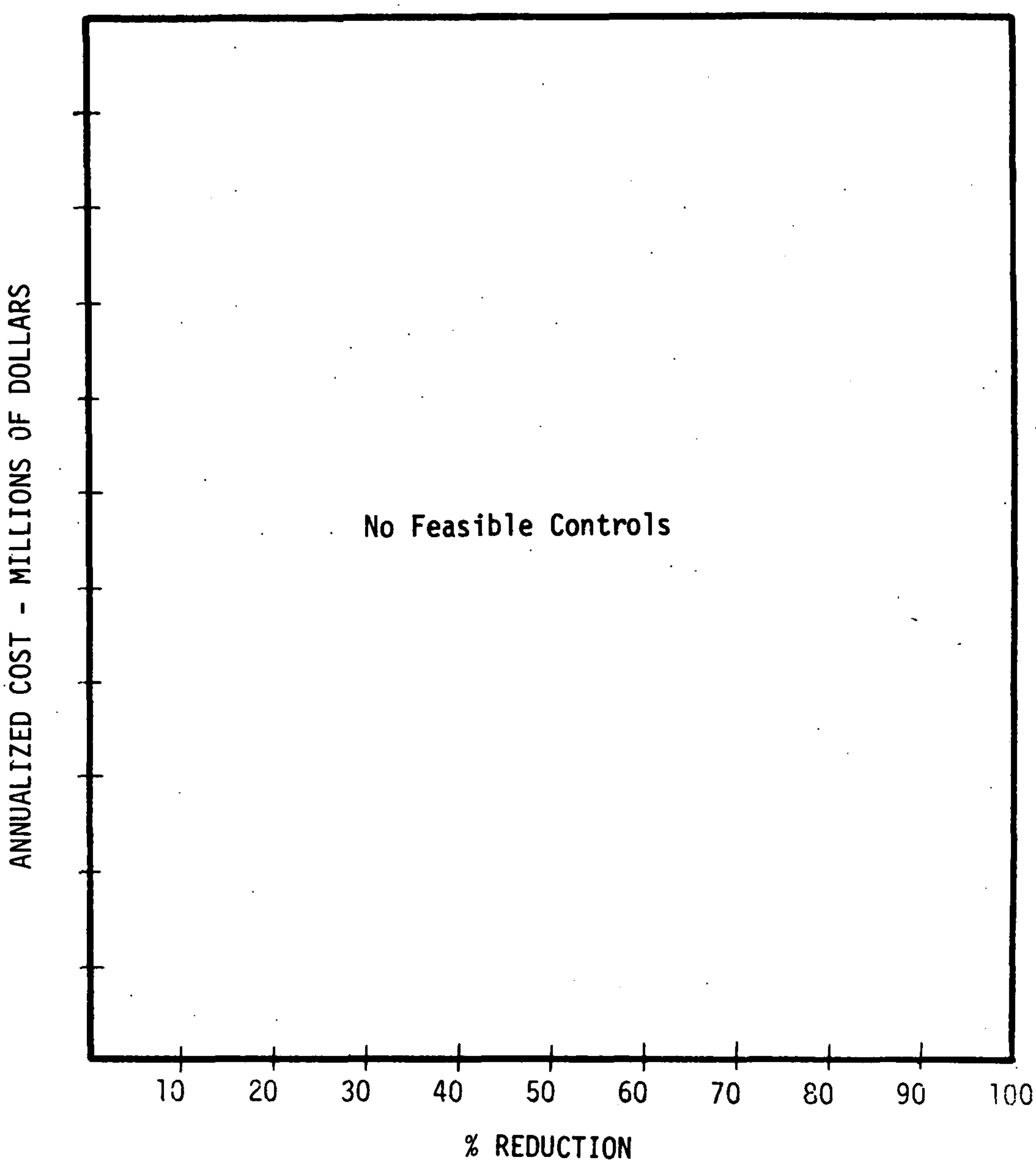


Figure 6. Fuel Combustion

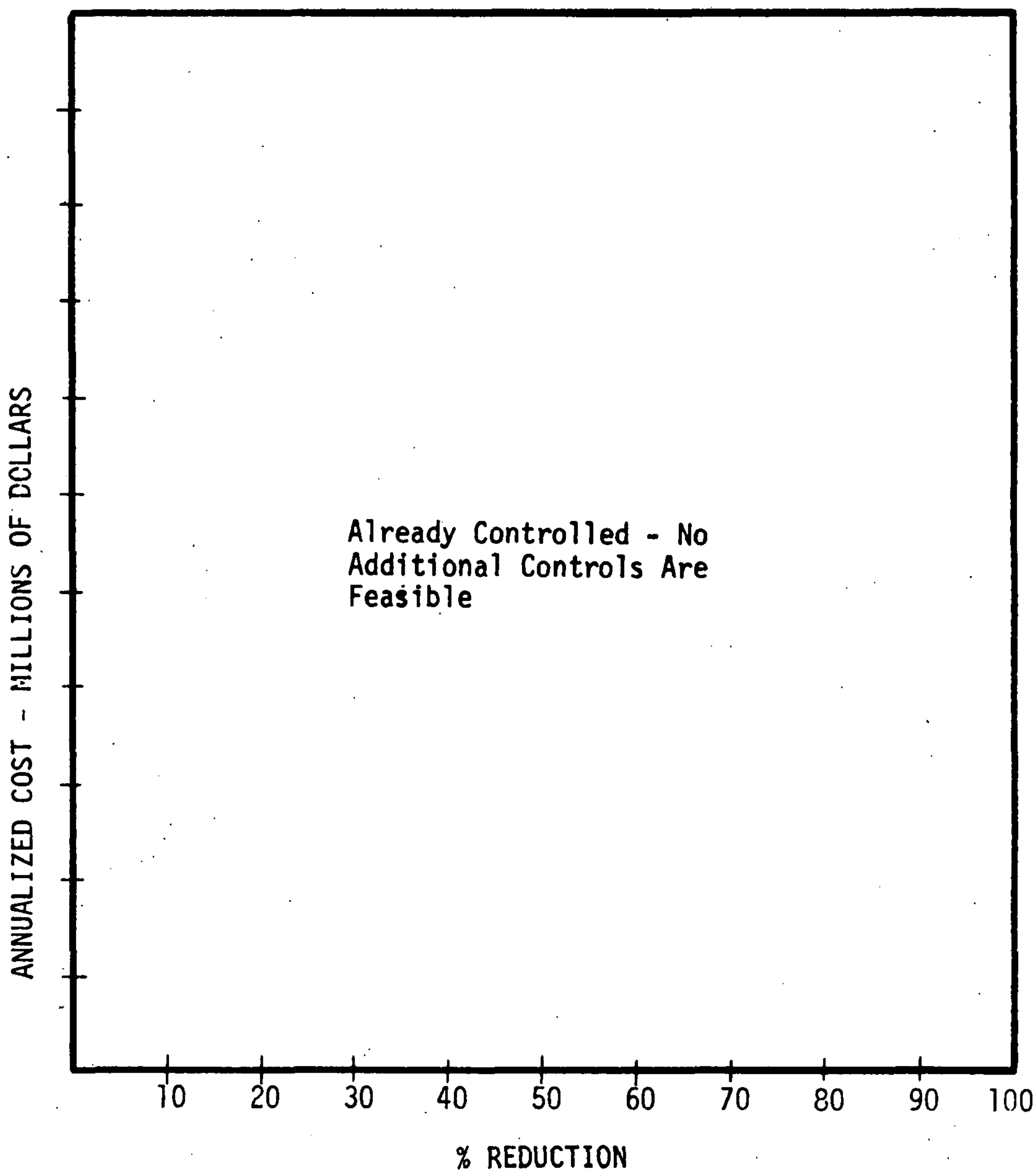


Figure 7. Waste Burning and Other Fires

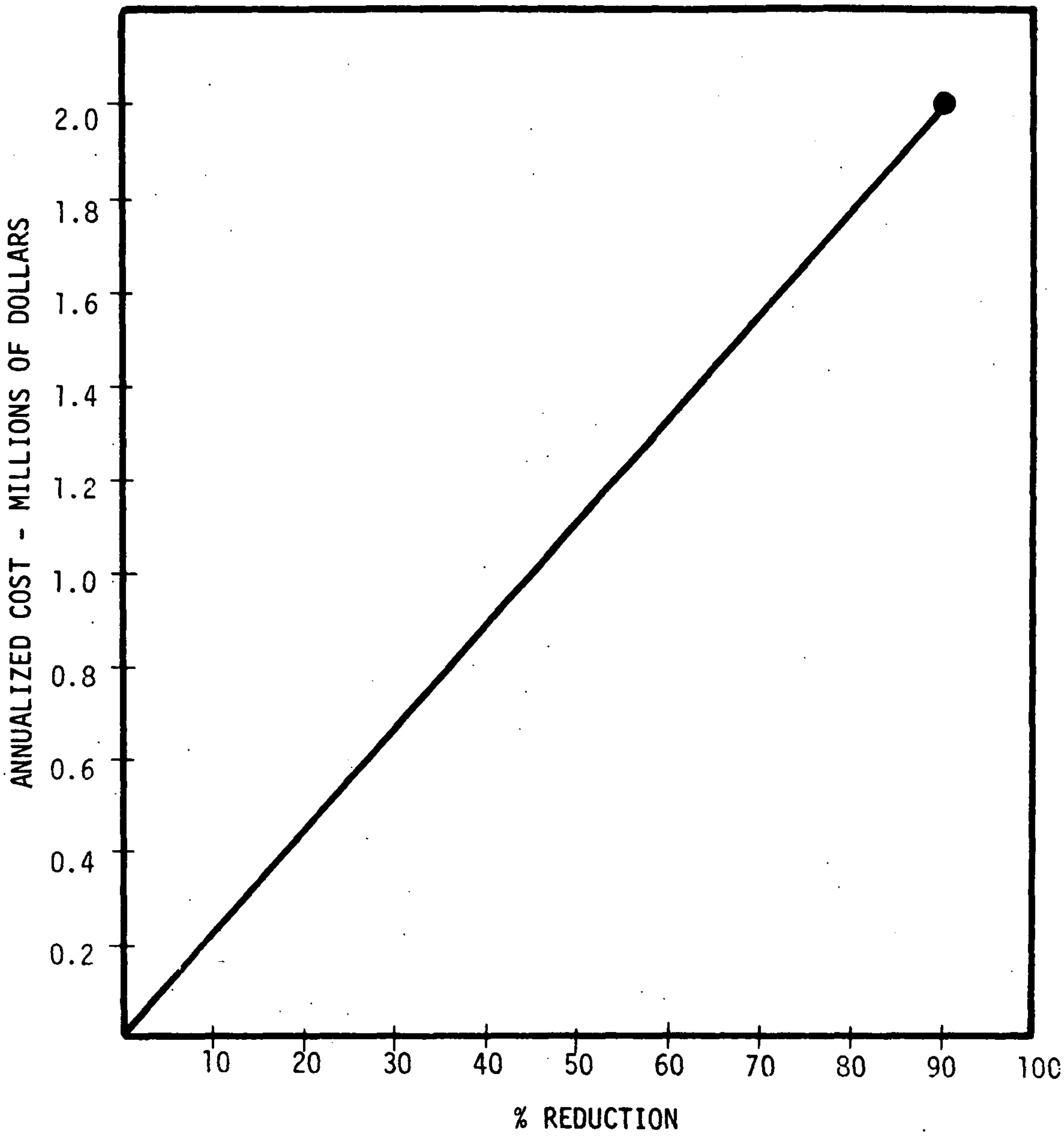


Figure 8. Surface Coating - Heat Treated

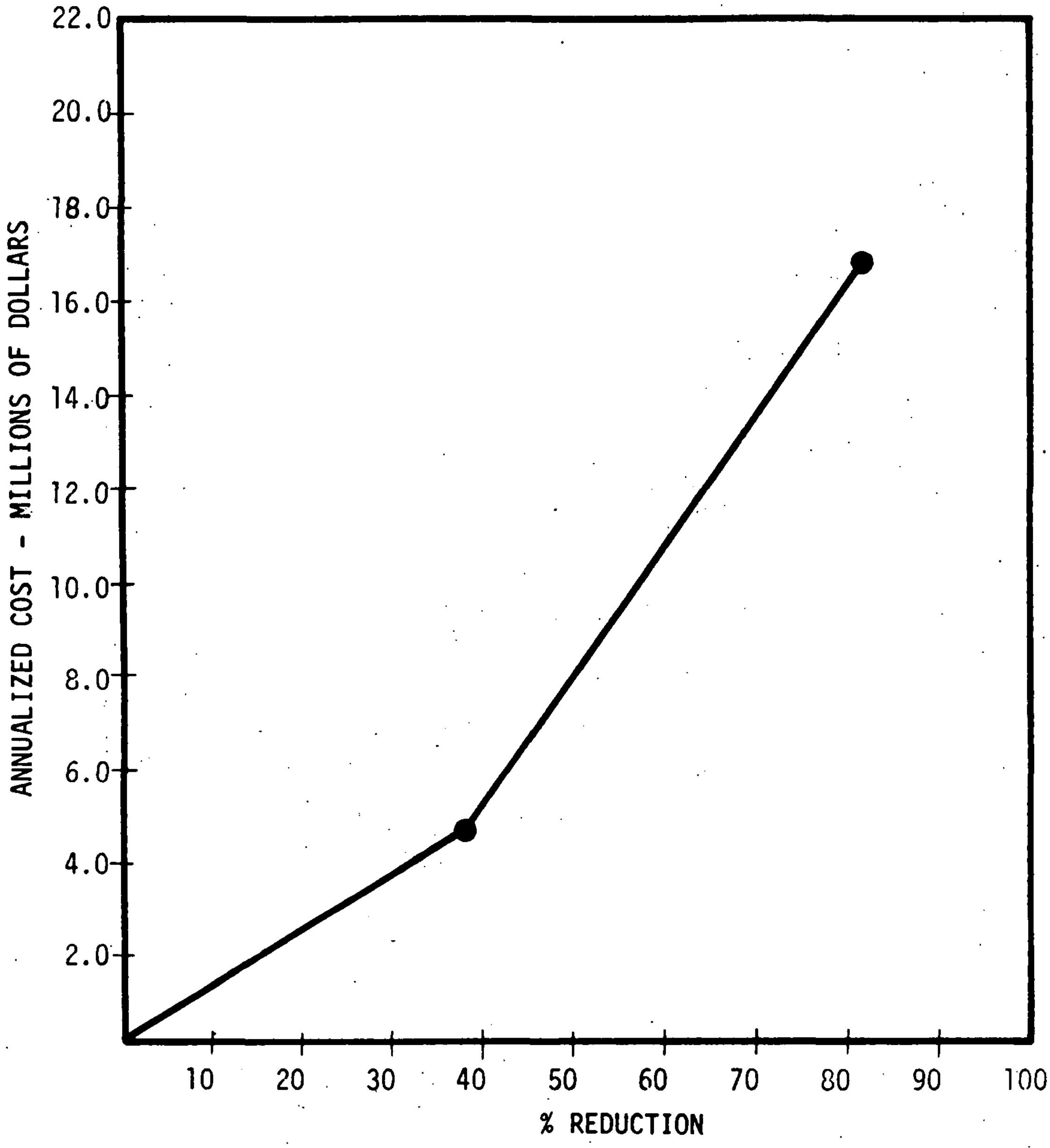


Figure 9. Surface Coating - Air Dried

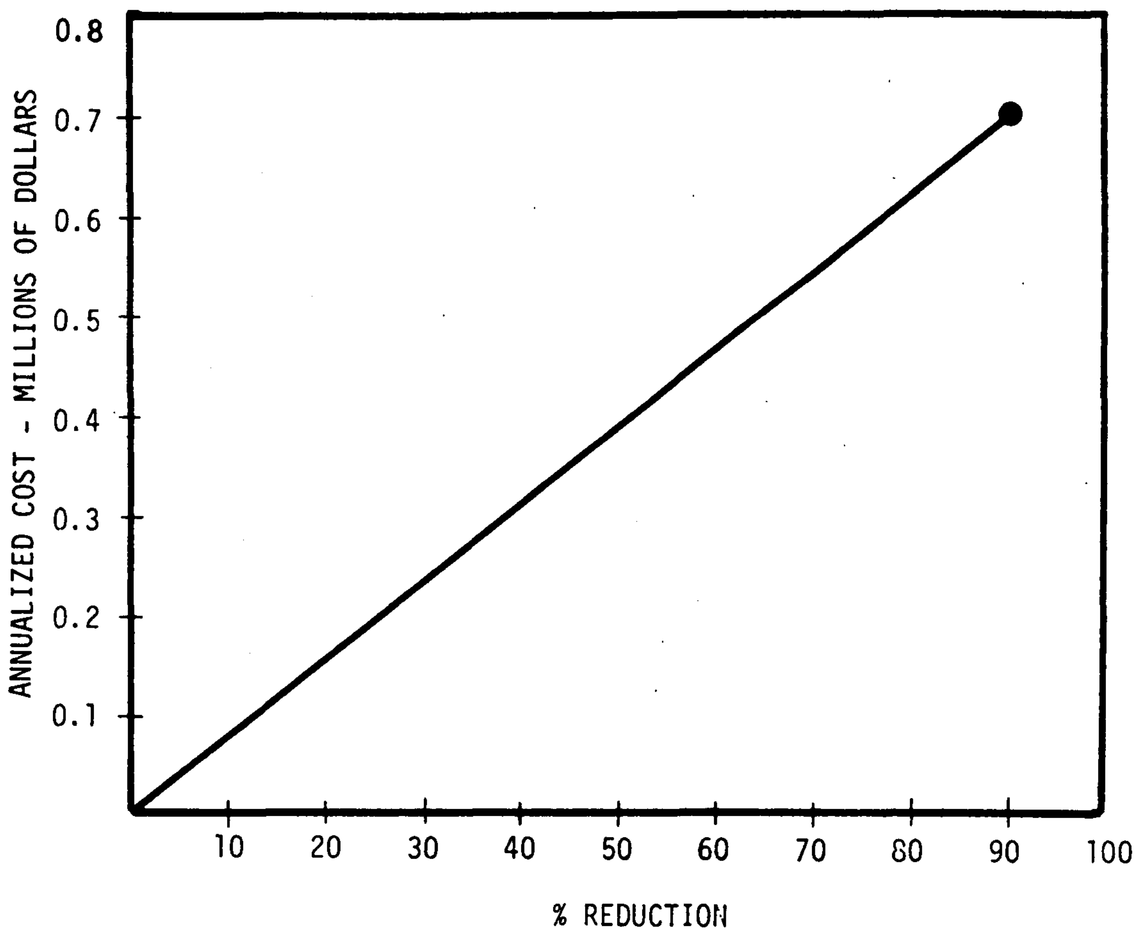


Figure 10. Dry Cleaning - Petroleum Based Solvent

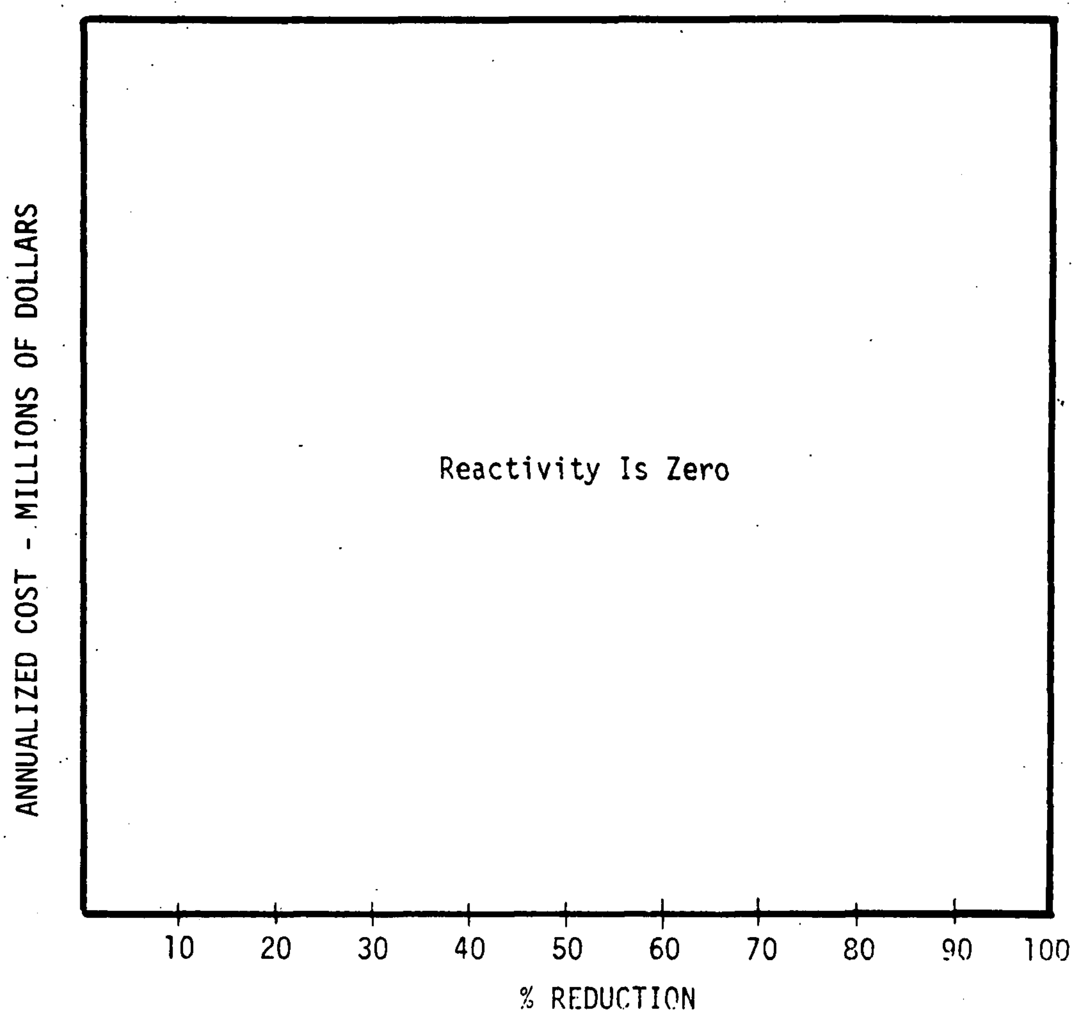


Figure 11. Dry Cleaning - Synthetic Solvent (PCE)

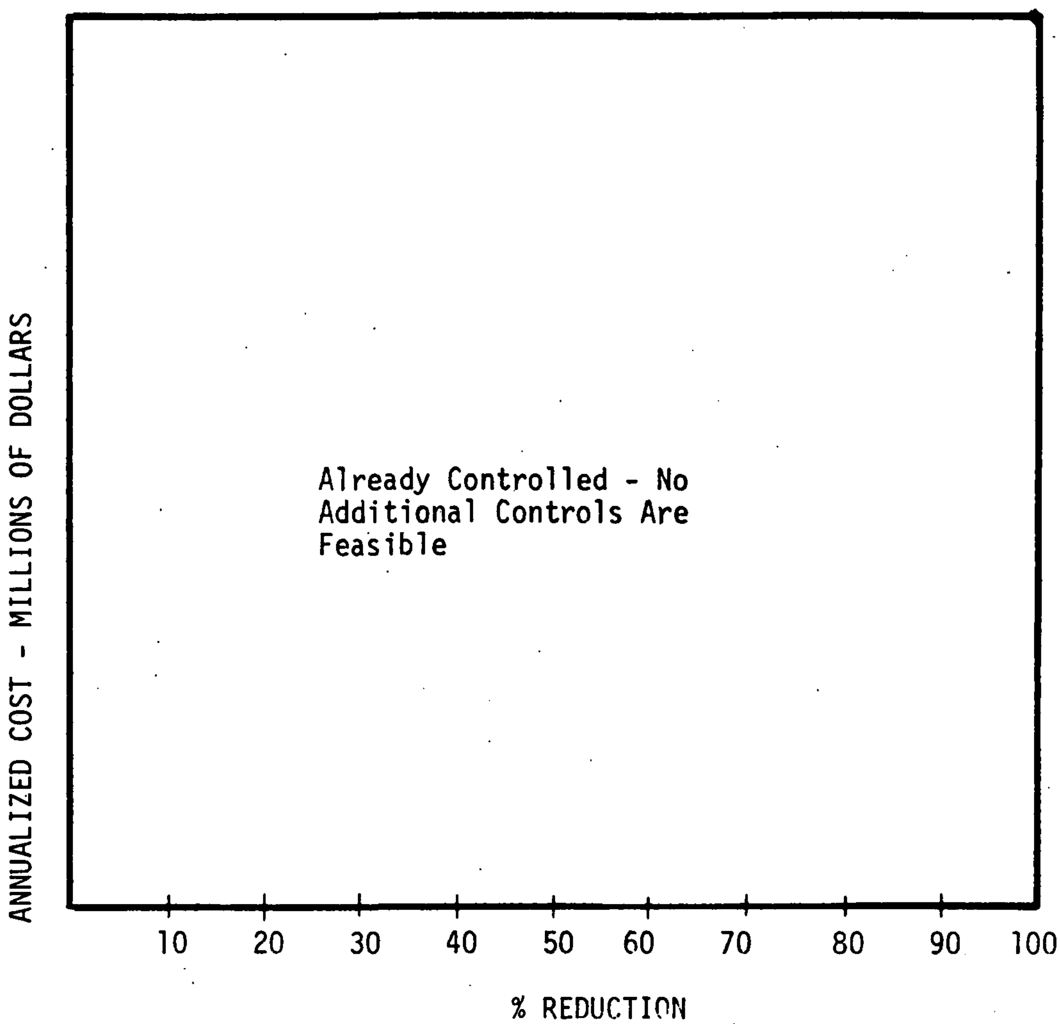


Figure 12. Degreasing - TCE Solvent

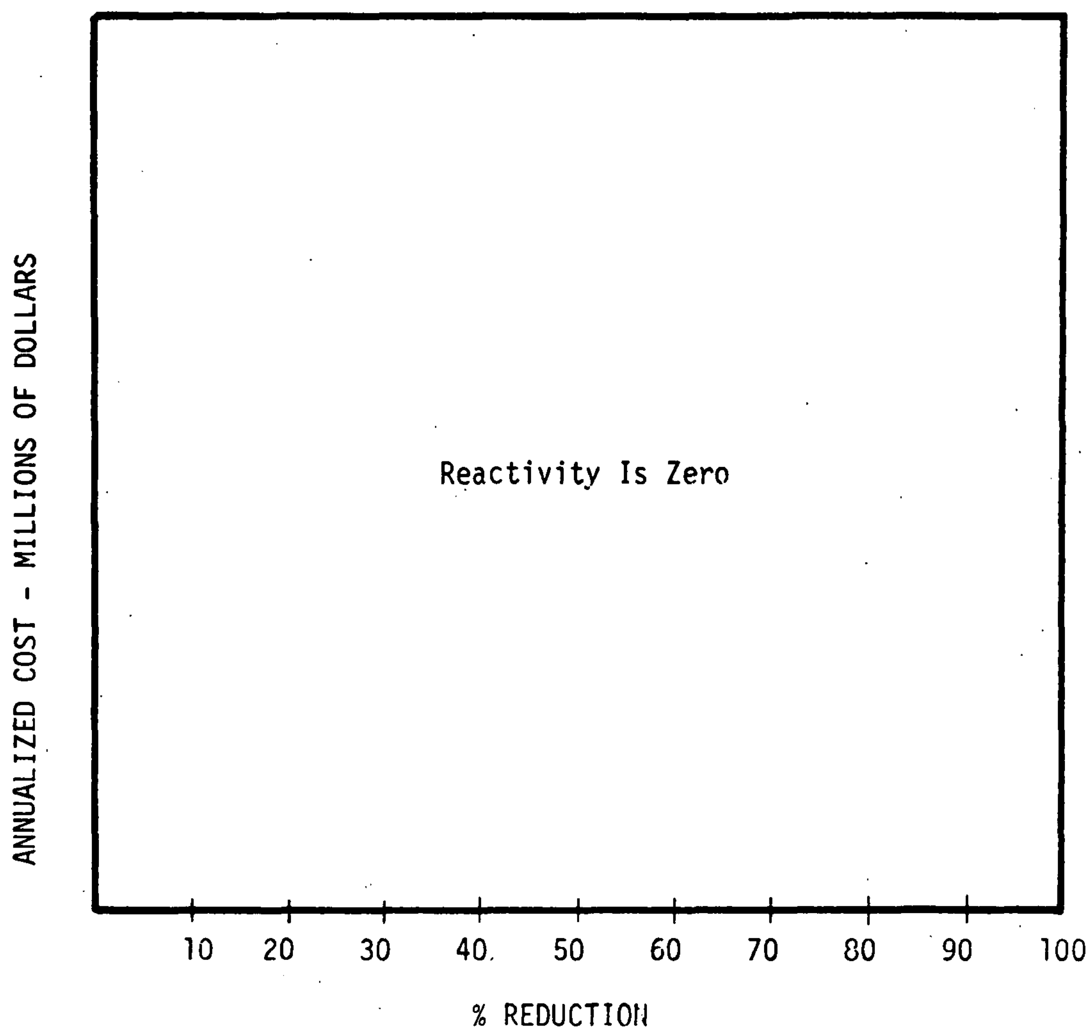


Figure 13. Degreasing - 1,1,1-T Solvent

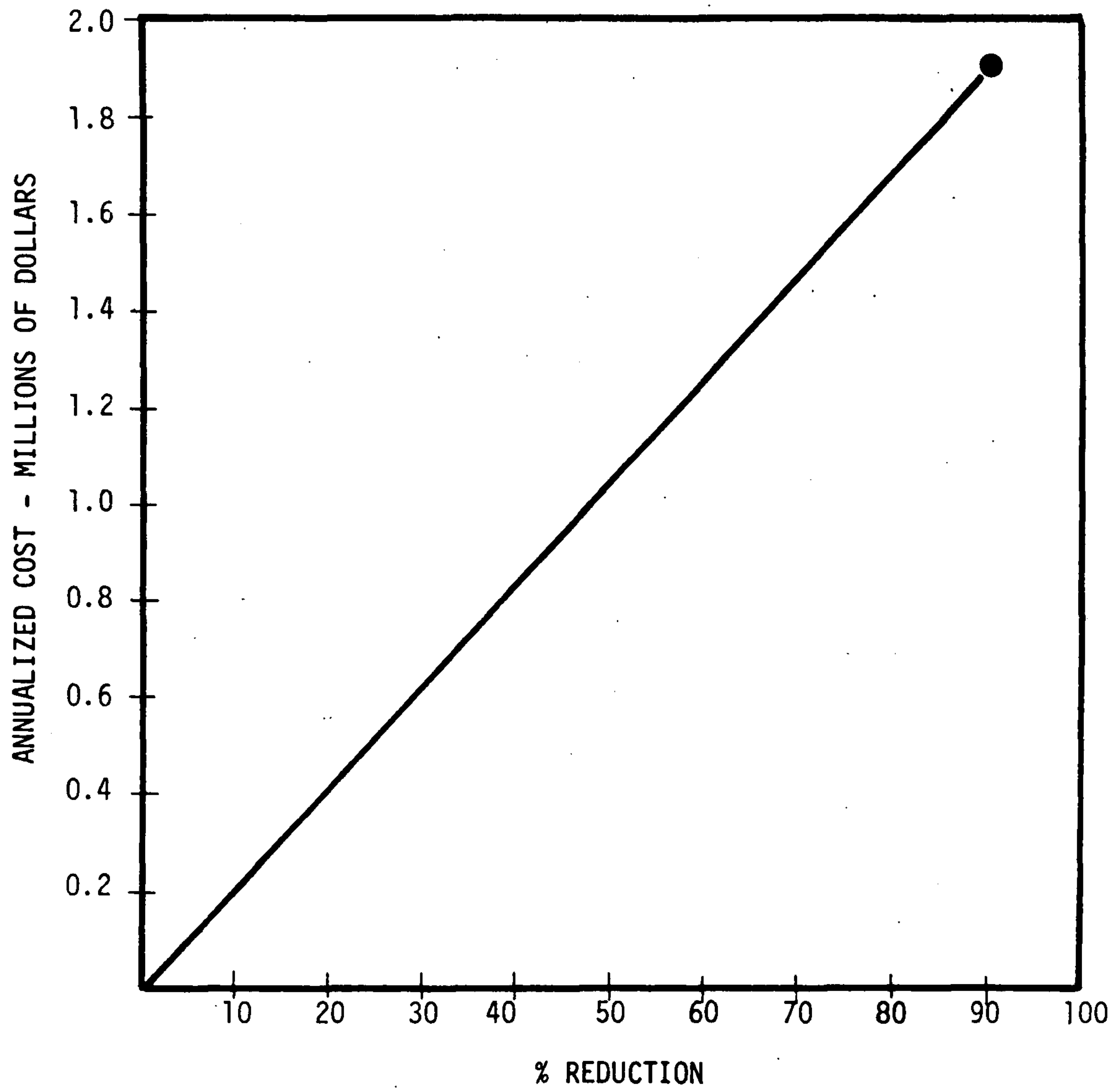


Figure 14. Printing - Rotogravure

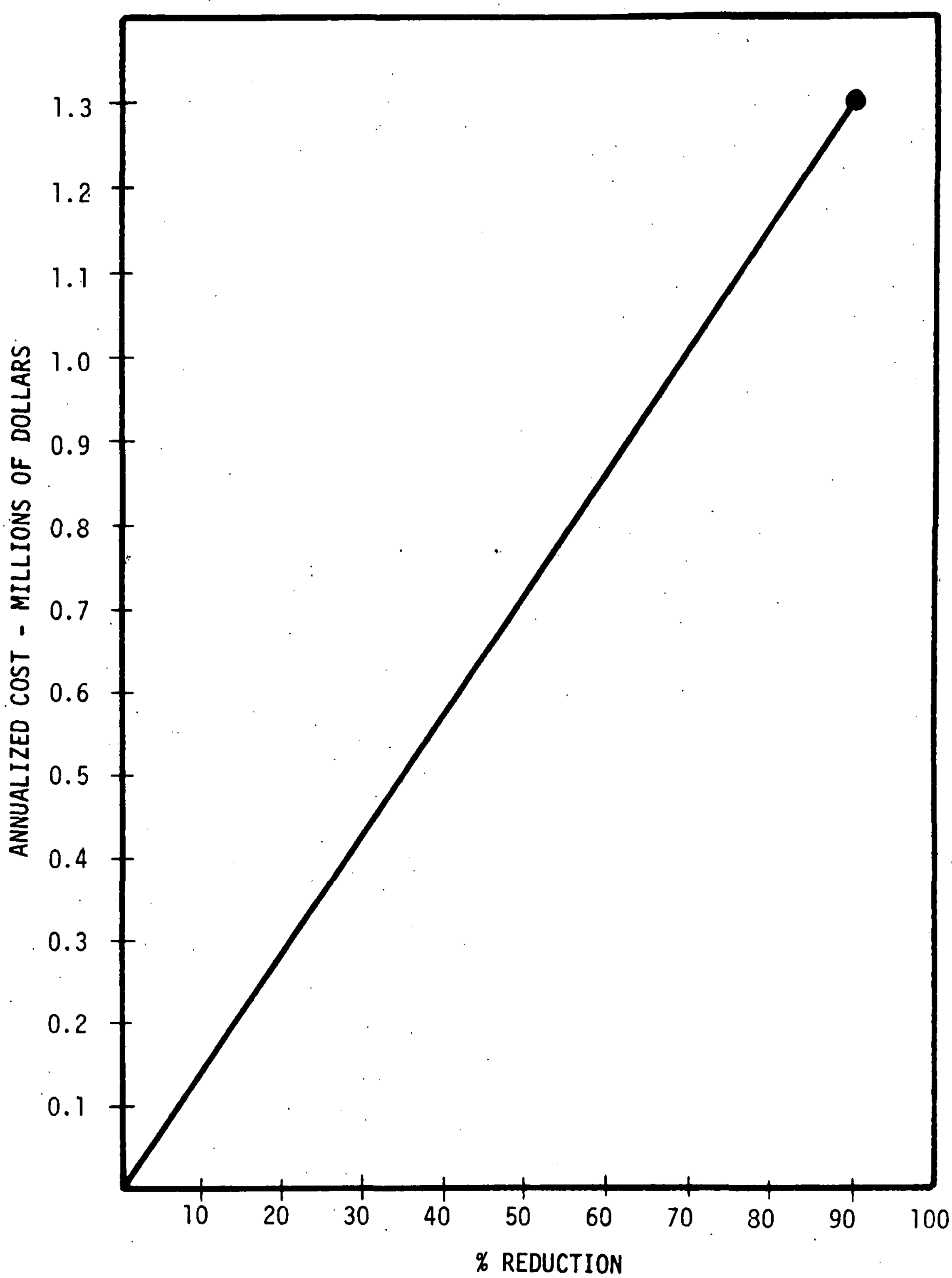


Figure 15. Printing - Flexigraphic

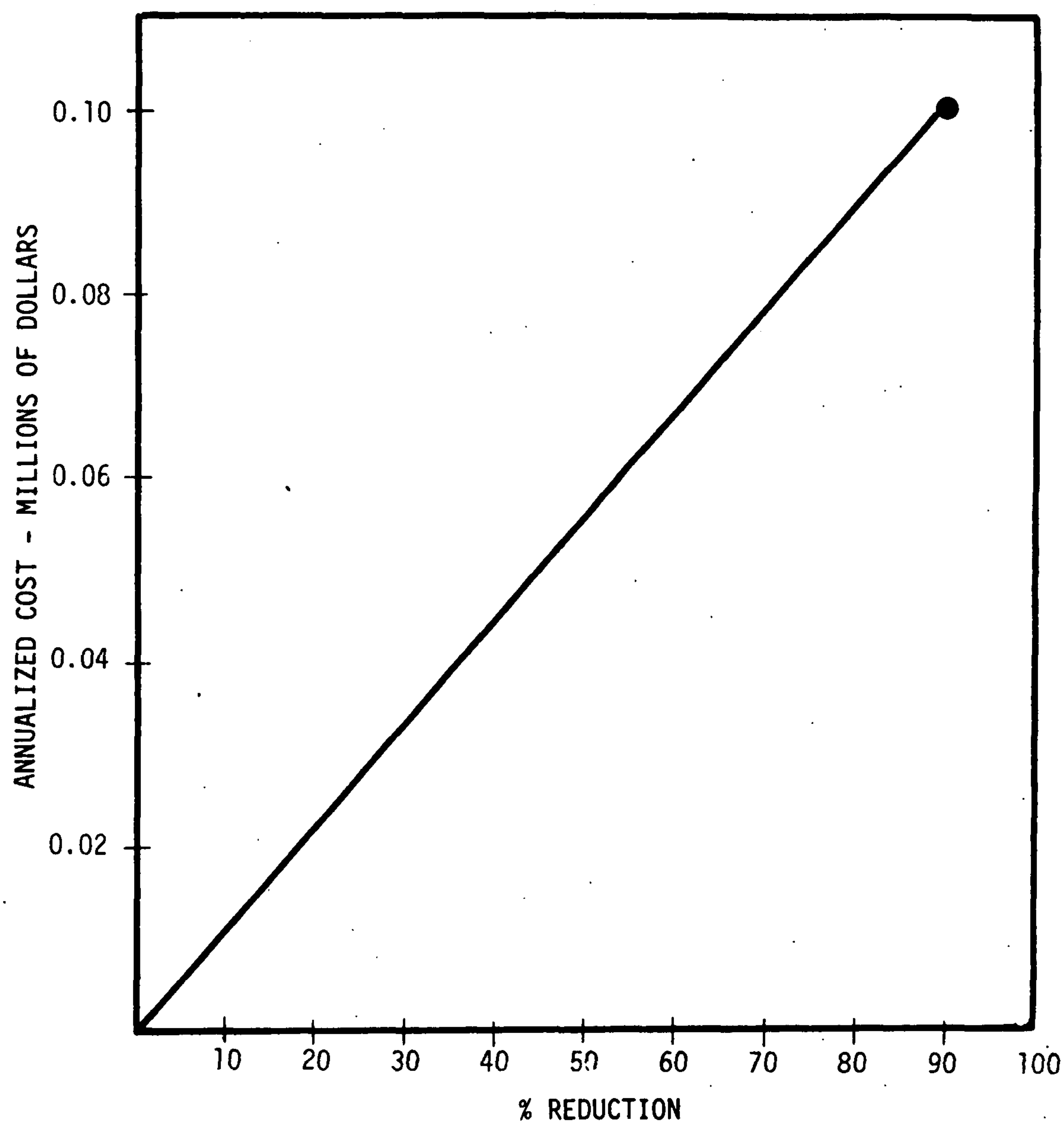


Figure 16. Rubber, Plastic, Adhesive and Putty Manufacturing

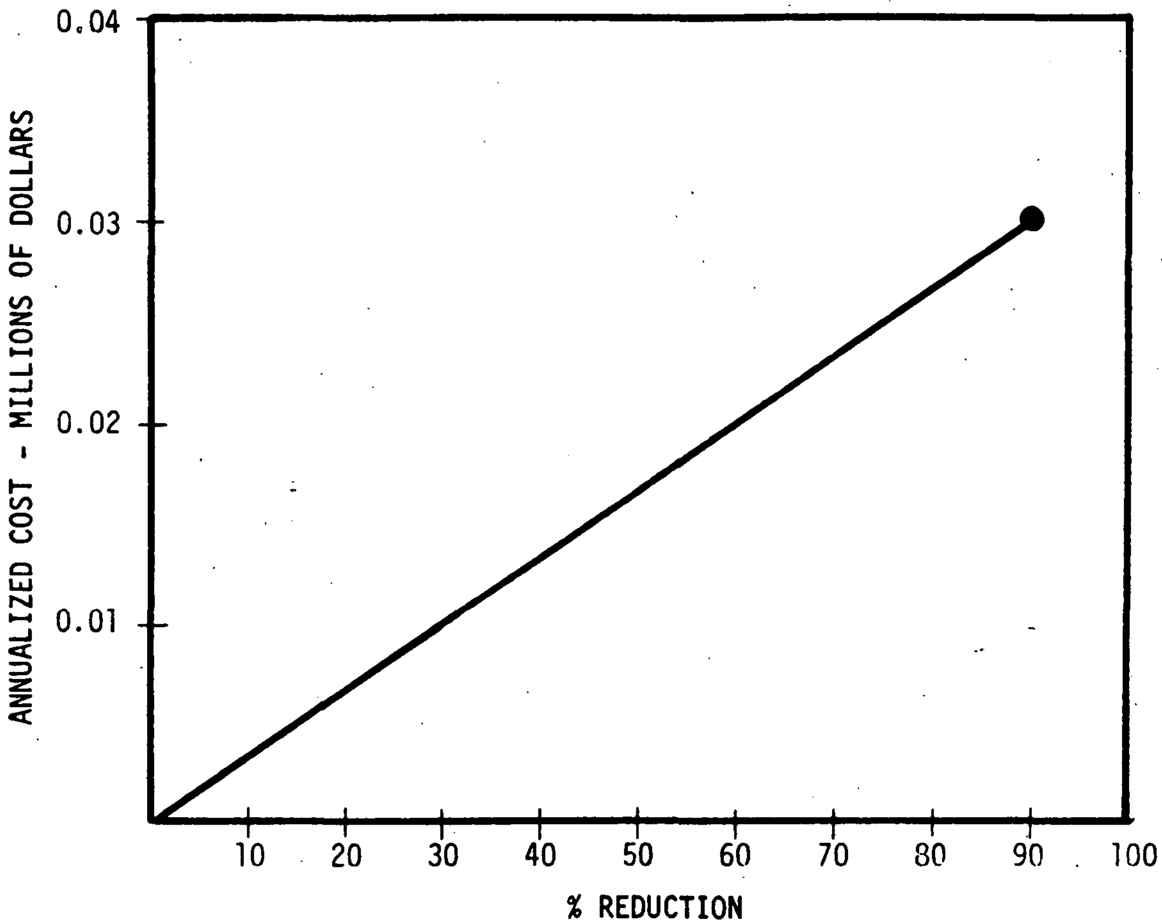


Figure 17. Pharmaceutical Manufacturing

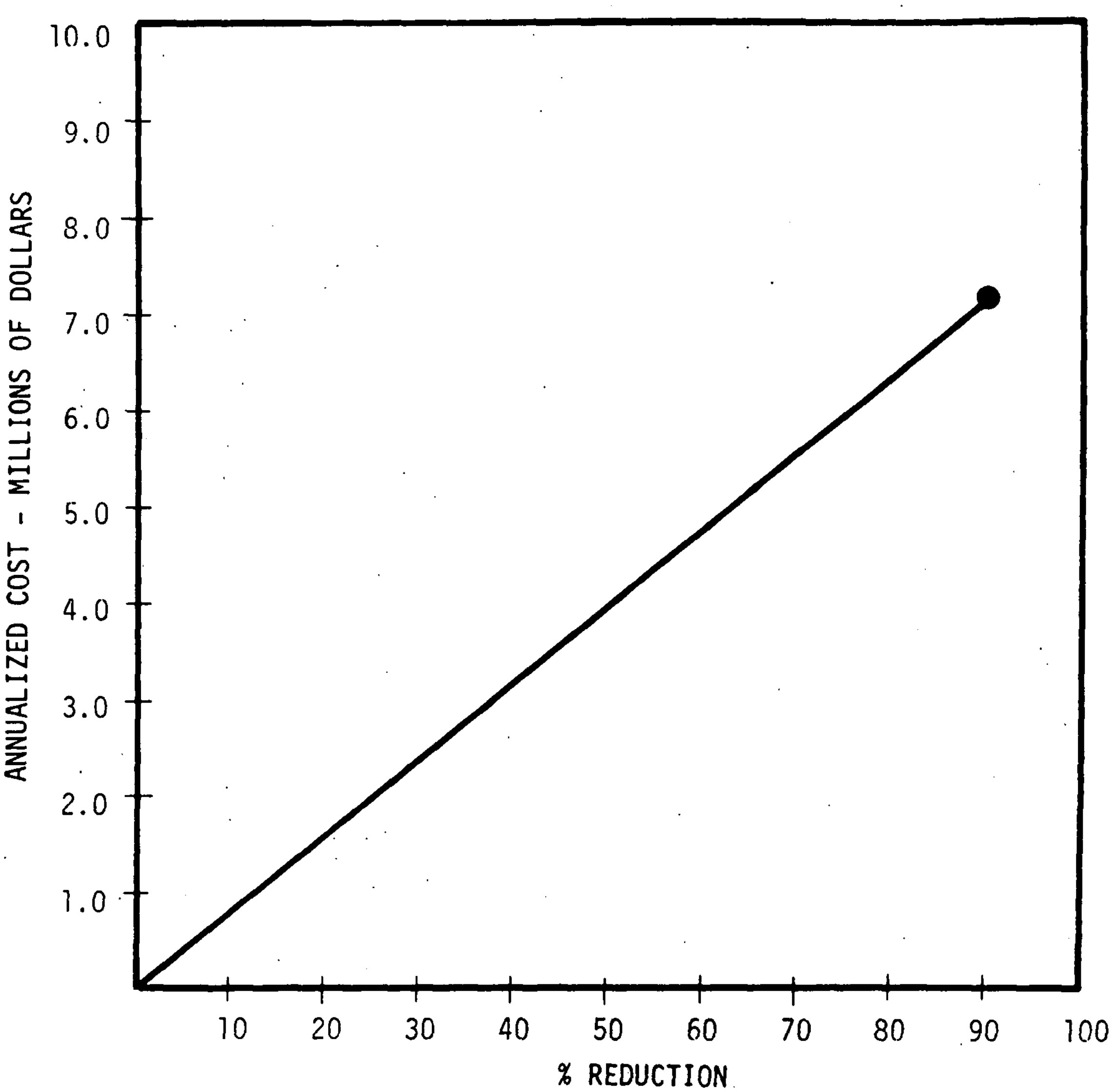


Figure 18. Miscellaneous Organic Solvent Operations

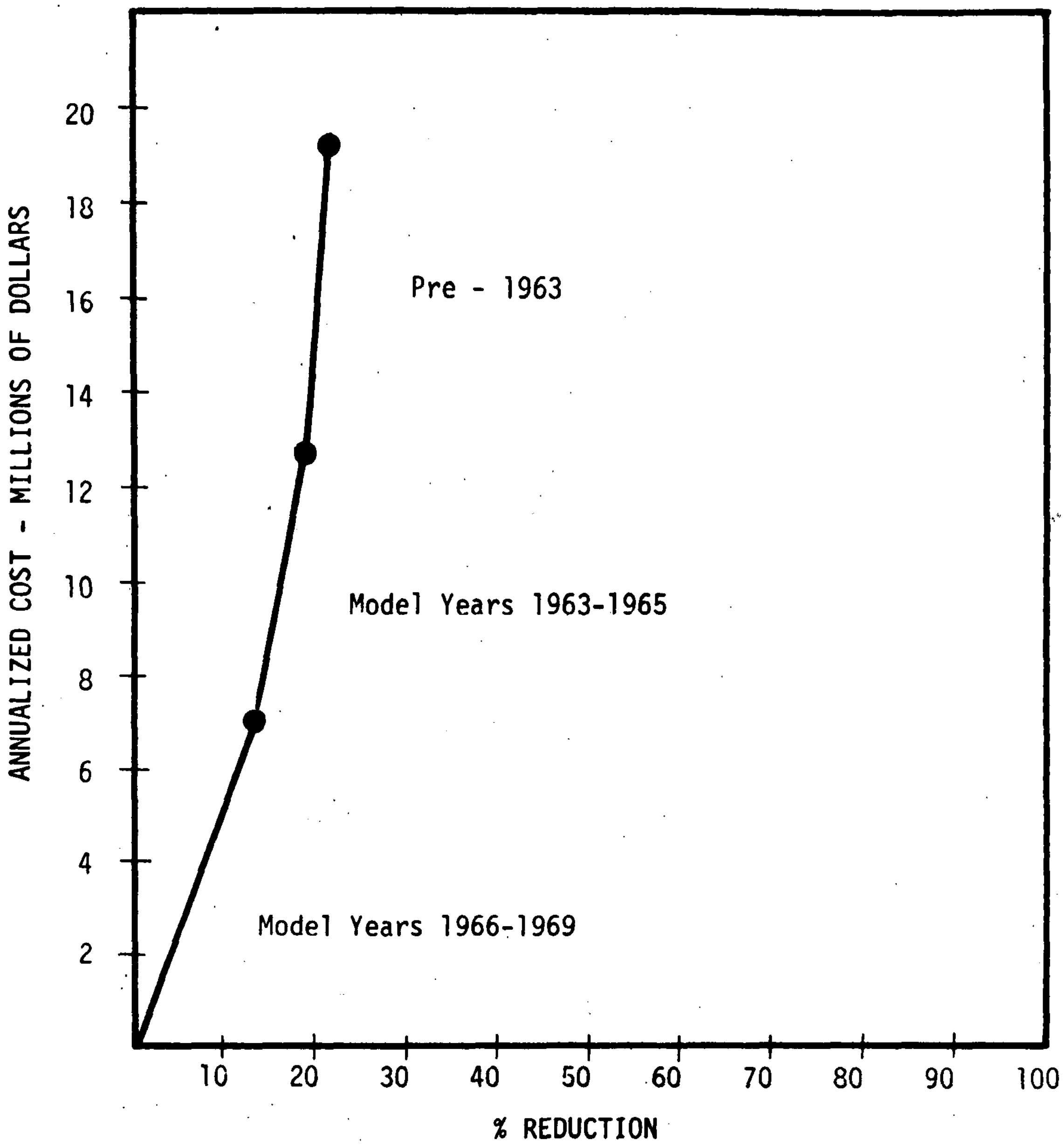


Figure 19. Light Duty Vehicle - Exhaust

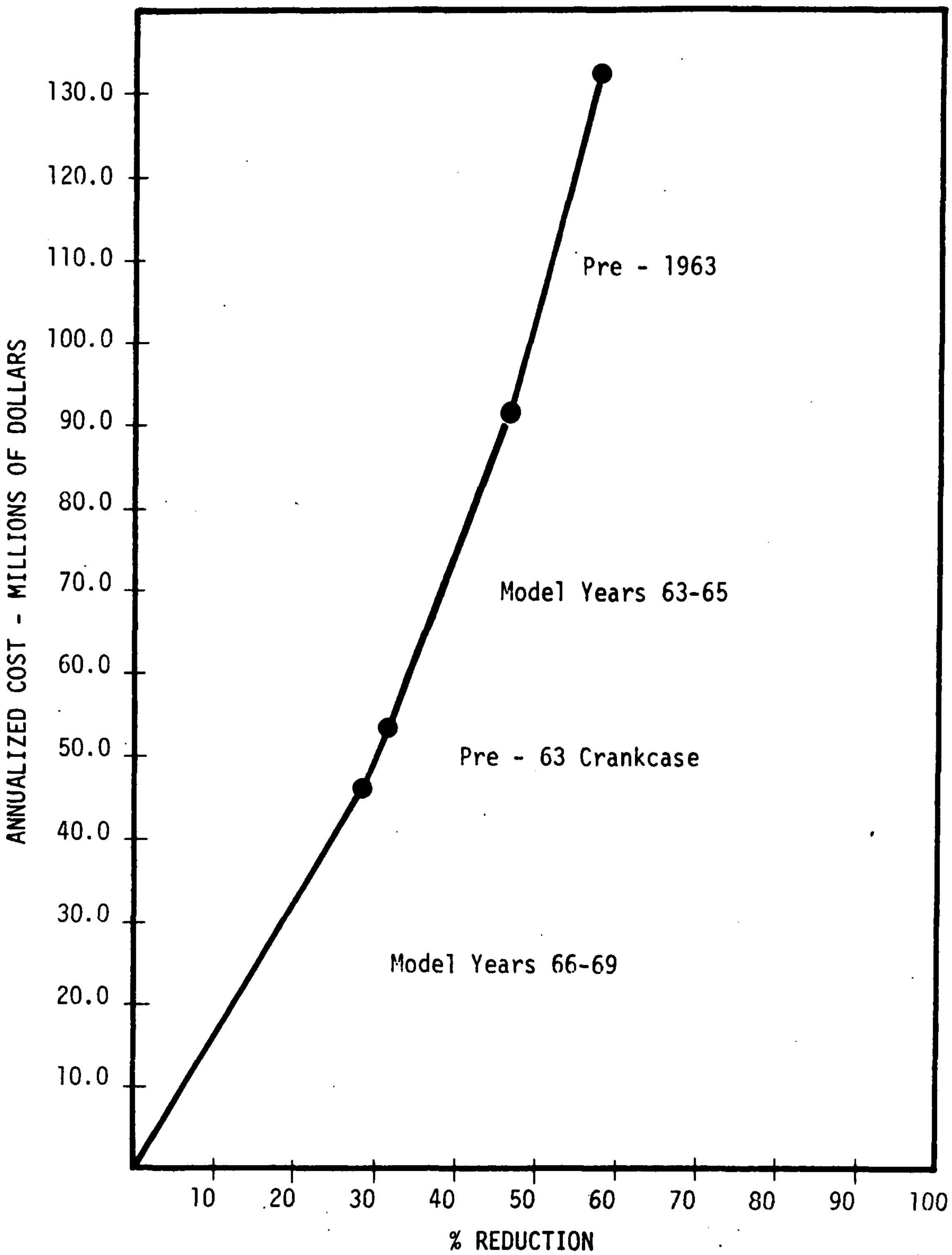


Figure 20. Light Duty Vehicle - Evaporative

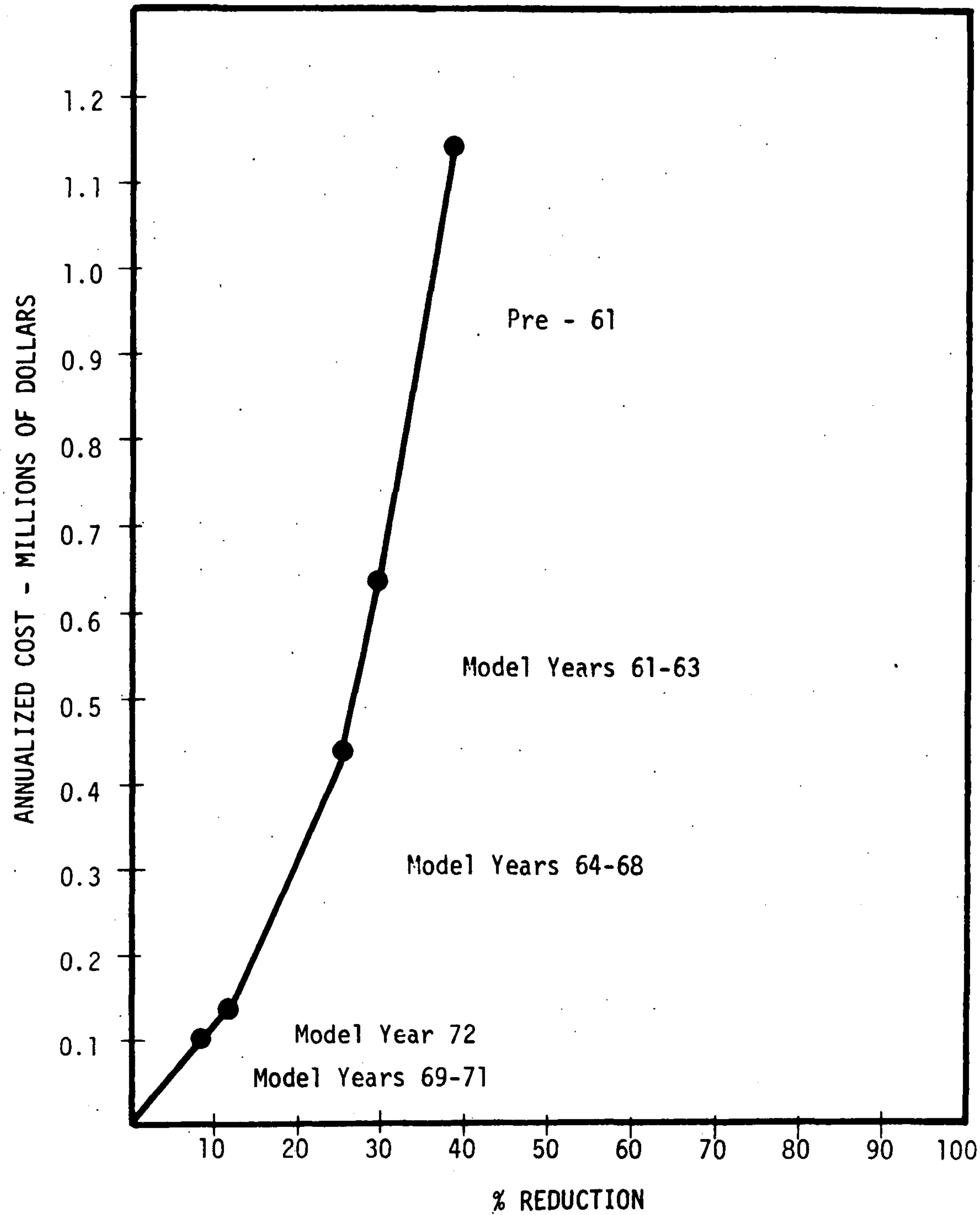


Figure 21. Heavy Duty Vehicles - Exhaust

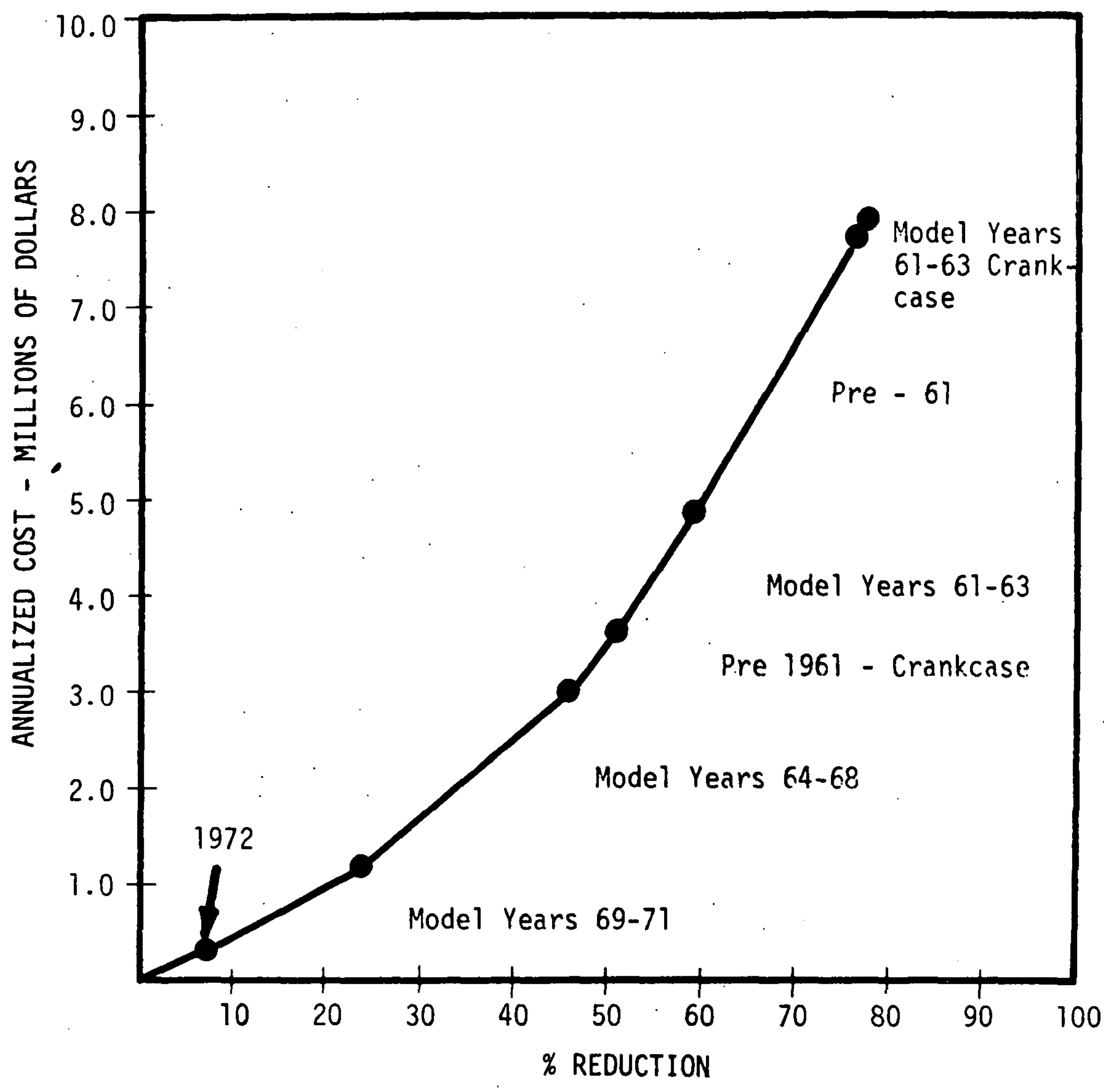


Figure 22. Heavy Duty Vehicles - Evaporative

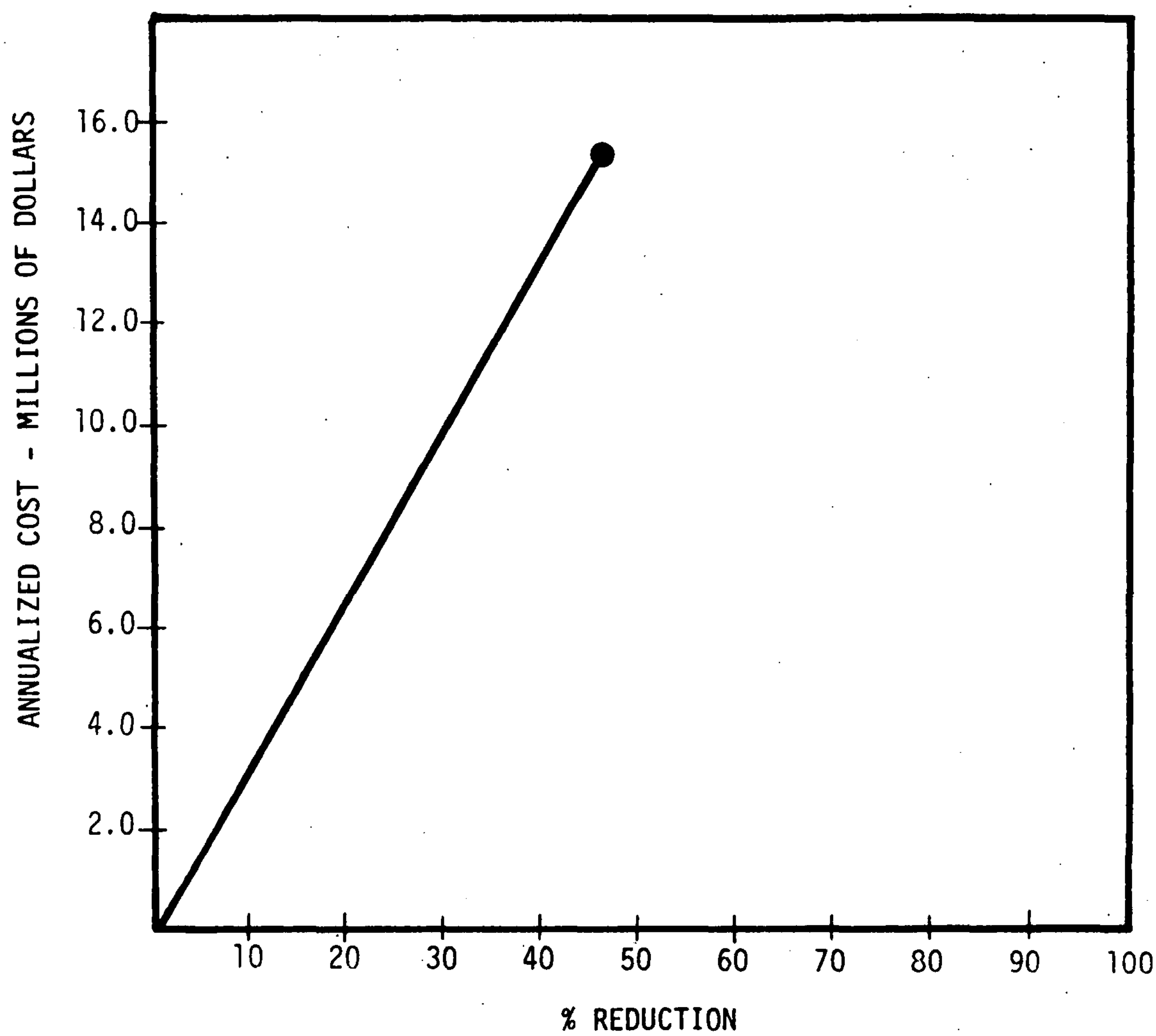


Figure 23. Other Gasoline Powered Equipment - Exhaust

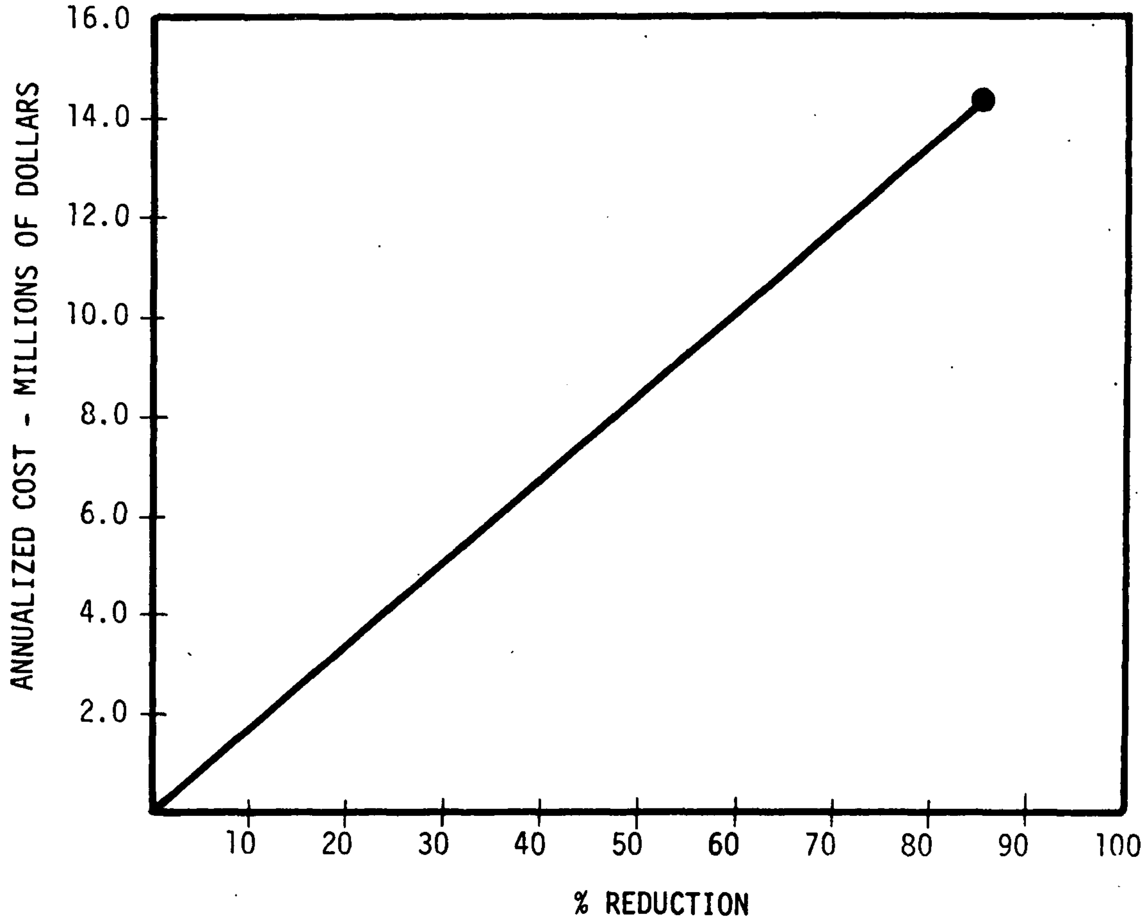


Figure 24. Other Gasoline Powered Equipment - Evaporative

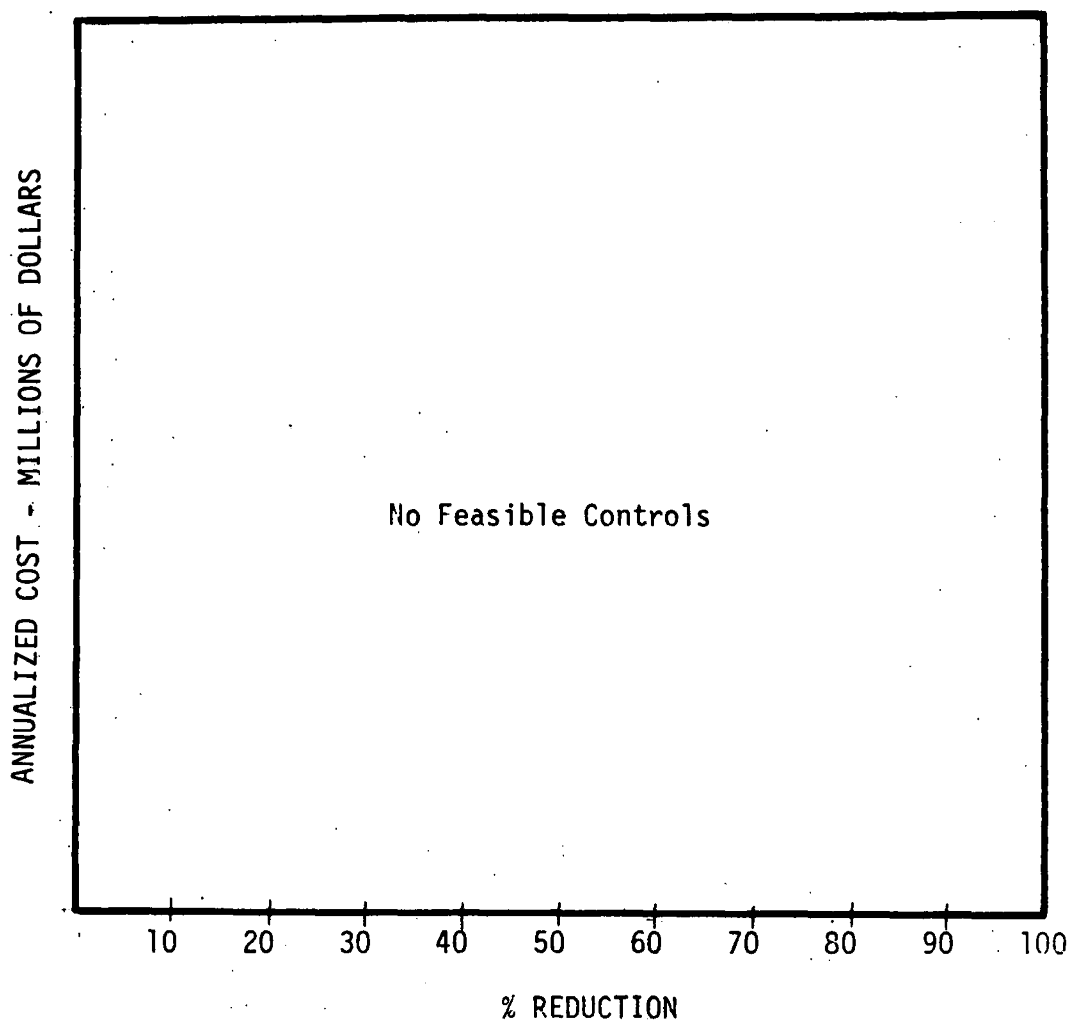


Figure 25. Diesel Powered Motor Vehicles

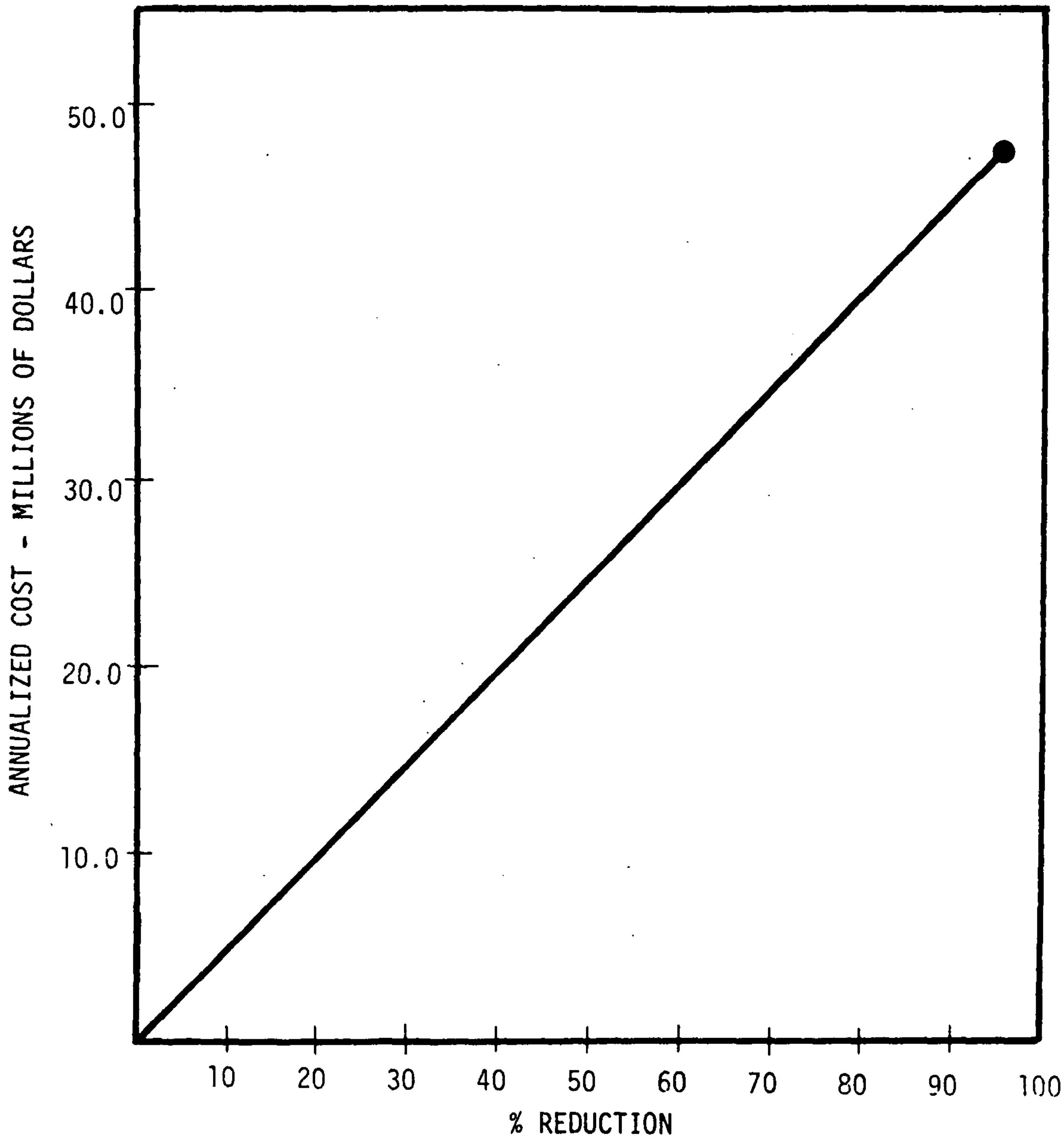


Figure 26. Aircraft - Jet.

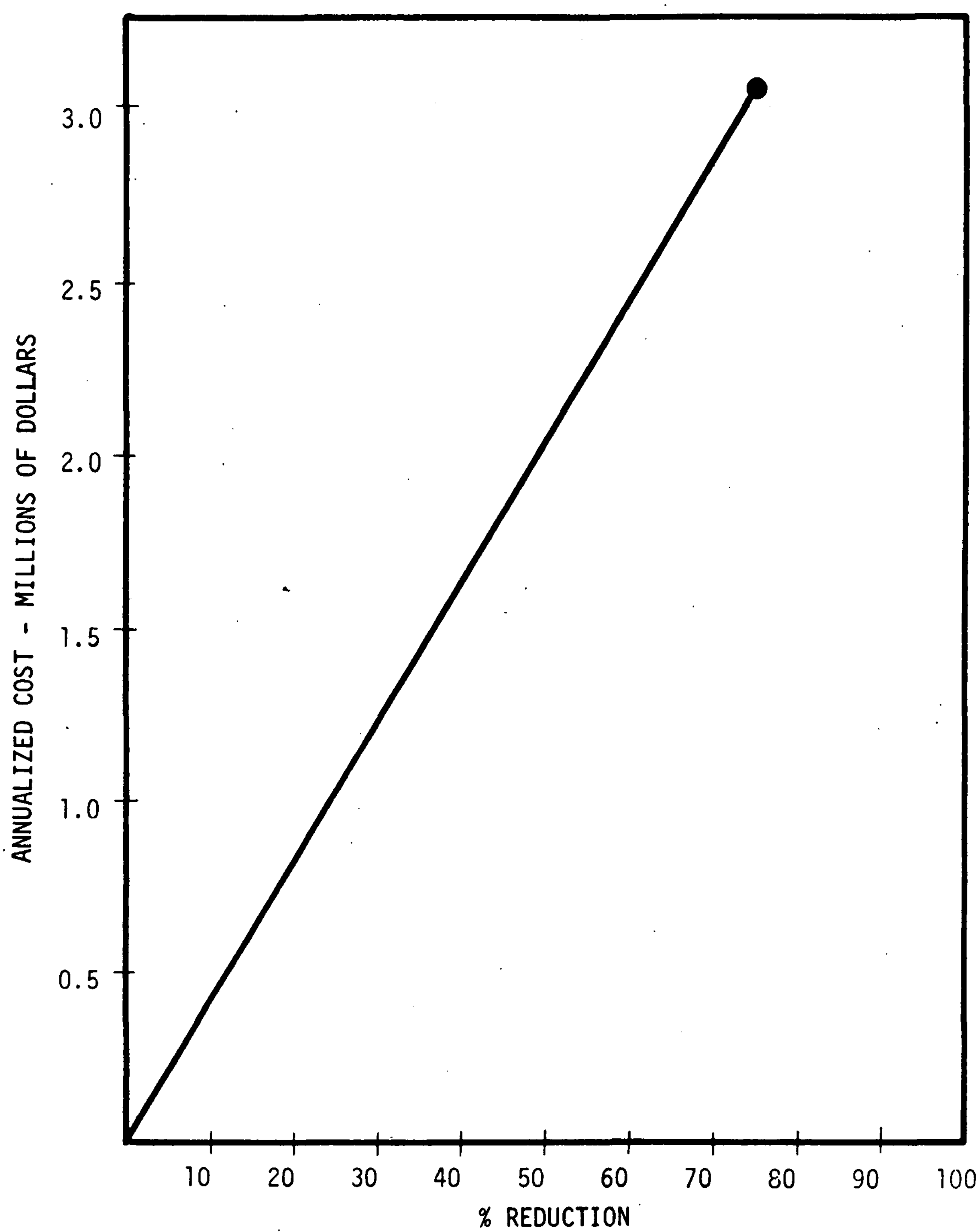


Figure 27. Aircraft - Piston

controlling emissions from each source type. Many of the curves consist of several segments, each of which represents a different control technique or control of a different segment of the category's emissions. The segments are placed in order of decreasing cost effectiveness. That is, the first emission reductions within each category were obtained by applying the most cost effective control.

The costs shown on the vertical axis are the total annualized costs of installing, operating and maintaining the control. The horizontal axis represents percent reduction of the emissions in that category.

Table 39 summarizes the same data in tabular form.

Table 39. SUMMARY OF ORGANIC CONTROL COSTS

$/TON REMOVED	% OF CATEGORY EMISSIONS REMOVED	CUMMULATIVE % OF CATEGORY EMISSIONS REMOVED	ANNUALIZED COST $\$ \times 10^{-6}$	CUMMULATIVE ANNUALIZED COST FOR CATEGORY $\$ \times 10^{-6}$	TECHNIQUE OR MODEL YEAR GROUP
Petroleum Production - No Feasible Controls					
Petroleum Refining					
100	14	14	0.7	0.7	Vapor Recycle
480	23	37	5.8	6.5	Vapor Adsorption
1000	12	49	6.5	13.0	Secondary Floating Roof Seals
Underground Service Station Tanks					
100	55	55	1.24	1.2	Vapor Recycle (3)
480	90	90	9.76	9.8	Vapor Adsorption or Condensation (3)
Automobile Tank Filling					
100	55	55	2.6	2.6	Vapor Recycle (3)
480	90	90	20.7	20.7	Vapor Adsorption or Condensation
Fuel Combustion - No Feasible Controls					
Waste Burning and Other Fires - No Feasible Controls					
Surface Coating - Heat Treated					
518	90	90	2.0	2.0	Catalytic Incineration (3)

Continued

TABLE 39. SUMMARY OF ORGANIC CONTROL COSTS (Continued)

$/TON REMOVED	% OF CATEGORY EMISSIONS REMOVED	CUMMULATIVE % OF CATEGORY EMISSIONS REMOVED	ANNUALIZED COST $ x 10^{-6}	CUMMULATIVE ANNUALIZED COST FOR CATEGORY $ x 10^{-6}	TECHNIQUE OR MODEL YEAR GROUP
Surface Coating - Air Dried					
160	38*	38	4.4	4.5	Solvent Modification (5)
518	44**	82	16.6	21.1	Catalytic Incineration (3)
Dry Cleaning - Petroleum Based Solvent					
330	90	90	0.7	0.7	Carbon Adsorption (3)
Degreasing - TCE Solvent - Already Controlled					
Degreasing - 1,1,1-T Solvent - Reactivity is Zero, No Control Required					
Printing - Rotogravure					
330	90	90	1.9	1.9	Adsorption (3)
Printing - Flexigraphic					
518	90	90	1.3	1.3	Catalytic Incineration (3)
Rubber and Plastic Manufacturing					
424	90	90	0.1	0.1	Catalytic Incineration and Adsorption (3)

*75% of architectural coating emissions **90% of non-architectural coating emissions

Continued

TABLE 39. SUMMARY OF ORGANIC CONTROL COSTS (Continued)

$/TON REMOVED	% OF CATEGORY EMISSIONS REMOVED	CUMMULATIVE % OF CATEGORY EMISSIONS REMOVED	ANNUALIZED COST $ x 10^{-6}	CUMMULATIVE ANNUALIZED COST FOR CATEGORY $ x 10^{-6}	TECHNIQUE OR MODEL YEAR
Pharmaceutical Manufacturing					
424	90	90	0.03	0.03	Catalytic Incineration and Adsorption (3)
Miscellaneous Solvent Operations					
424	90	90	7.1	7.1	Catalytic Incineration and Adsorption (3)
Light Duty Vehicle - Exhaust					
220	13.7	13.7	7.0	7.0	66 - 69 (6)
550	4.5	18.2	5.7	12.7	63 - 65 (6)
827	3.3	21.5	6.4	19.1	Pre - 63 (6)
Light Duty Vehicle - Evaporative					
877	29.1	29.1	45.7	45.7	66 - 69 (6)
1414	3.2	32.3	8.0	53.7	Pre - 63 Crankcase (6)
1477	14.1	46.4	37.3	91.0	63 - 65 (6)
2067	11.3	57.7	41.8	132.8	Pre - 63 (6)
Heavy Duty Vehicle - Exhaust					
35	8.3	8.3	0.1	0.1	69 - 71 (6)
39	3.0	11.3	0.04	0.14	72 (6)
62	14.0	25.3	0.3	0.44	64 - 68 (6)
134	4.3	29.6	0.2	0.64	61 - 63 (6)
159	9.1	38.7	0.5	1.14	Pre - 61 (6)

Continued

TABLE 39. SUMMARY OF ORGANIC CONTROL COSTS (Continued)

$/TON REMOVED	% OF CATEGORY EMISSIONS REMOVED	CUMMULATIVE % OF CATEGORY EMISSIONS REMOVED	ANNUALIZED COST $ x 10^{-6}	CUMMULATIVE ANNUALIZED COST FOR CATEGORY $ x 10^{-6}	TECHNIQUE OR MODEL YEAR
Heavy Duty Vehicle - Evaporative					
161	6.9	6.9	0.3	0.3	72 (6)
191	17.5	24.4	0.9	1.2	69 - 71 (6)
314	21.3	45.7	1.8	3.0	64 - 68 (6)
457	4.9	50.6	0.6	3.6	Pre - 61 Crankcase (6)
530	8.4	59.0	1.2	4.8	61 - 63 (6)
607	17.8	76.8	2.9	7.7	Pre - 61 (6)
1826	0.4	77.2	0.2	7.9	61 - 63 Crankcase (6)
Other Gasoline Power Equipment - Exhaust					
827	46	46	15.3	15.3	Pre - 1963 Automobile Controls (6)
Other Gasoline Powered Equipment - Evaporative					
2067	85	85	14.1	14.1	Pre - 1963 Automobile Controls (6)
Diesel Powered Vehicles - No Feasible Controls					
Aircraft - Jet					
8000	95	95	47.5	47.5	Combustion Modification (5)
Aircraft - Piston					
730	75	75	3.1	3.1	Afterburner (5)

SECTION 6

LEAST COST CALCULATIONS

Figure 28 graphically presents the cost versus percent control data for the combined emissions of all source categories. The vertical axis represents the total annualized cost of installing, operating and maintaining the combined controls for all categories. The horizontal axis represents the percent reduction in reactive emissions. It does not represent the percent reduction in mass emissions. The control techniques were applied in decreasing order of their cost effectiveness. That is, the first reductions were obtained with the most cost effective control. The same data are presented in tabular form in Table 40.

Table 41 shows the aggregate control costs for achieving various levels of control. Although approximately 95% control of organics would be required to assure that the ambient air quality standard was met (22), 53% is the maximum control that can be obtained using currently available control technology.

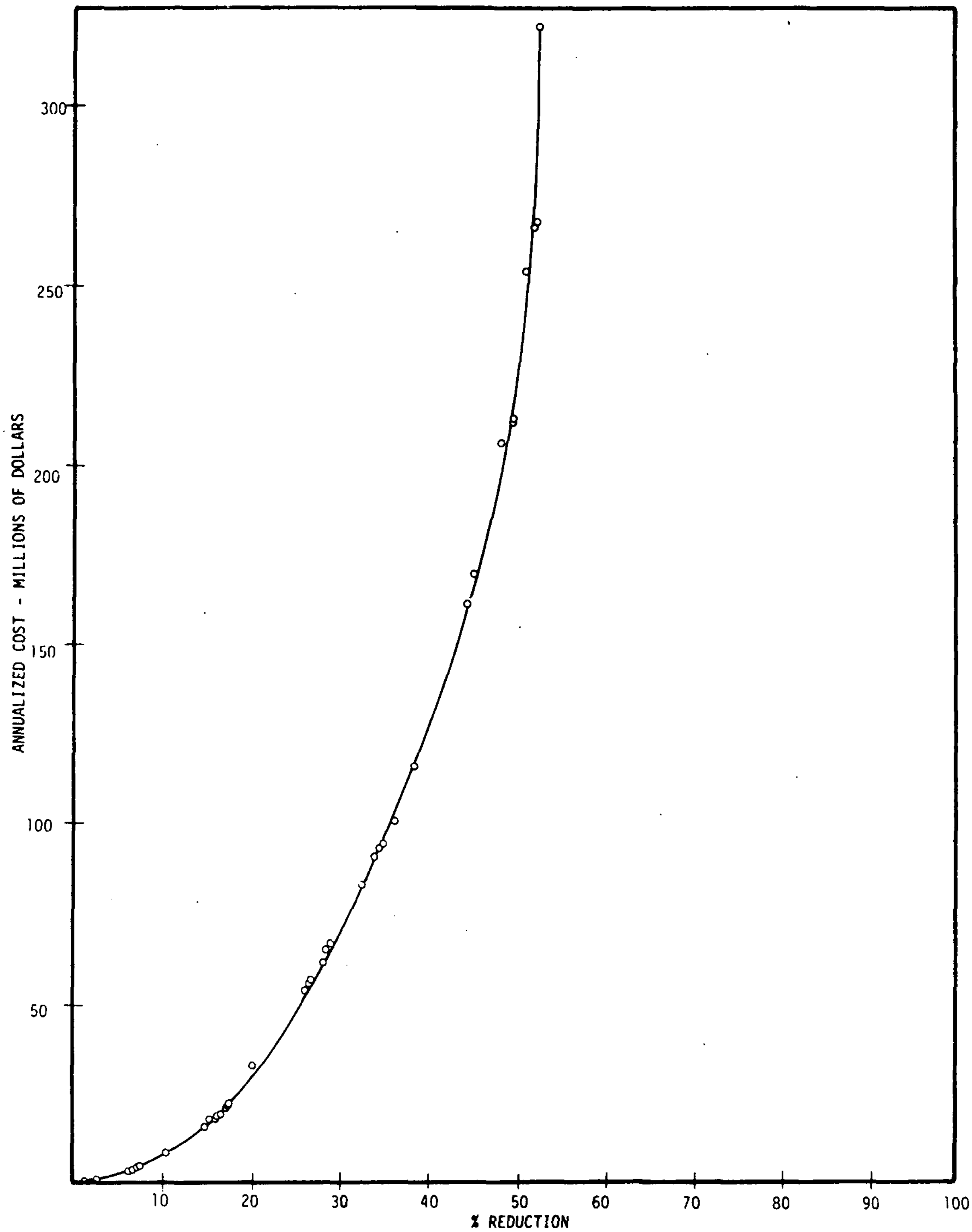


Figure 28. Cost of Achieving Various Levels of Control

TABLE 40. SUMMARY OF CONTROL COSTS

$ Per Reactive Ton Removed	Reactive Emissions Removed		Cumulative % of Reactive Emissions From All Sources	Cost for Maximum Control $\$ \times 10^{-6}$		Source Categories and Control Techniques Or Model Year Group
	kg/day $\times 10^{-3}$	(tons/day)		Industrial	Cumulative	
45	5.5	(6.1)	0.40	0.1	0.1	HDV - Exhaust; 69-71
51	2.0	(2.2)	0.55	0.04	0.1	HDV - Exhaust; 72
81	9.3	(10.2)	1.23	0.3	0.4	HDV - Exhaust; 64-68
128	24.0	(26.5)	2.99	1.2	1.6	Underground Service Station Tanks; Vapor Recycle
139	47.3	(52.1)	6.45	2.6	4.2	Auto Tank Filling; Vapor Recycle
174	2.9	(3.2)	6.66	0.2	4.4	HDV - Exhaust; 61-63
206	6.0	(6.6)	7.10	0.5	4.9	HDV - Exhaust; pre - 61
248	3.0	(3.3)	7.32	0.3	5.2	HDV - Evaporative; 72
262	42.6	(47.0)	10.44	4.5	9.7	Surface Coating - Air Dried Solvent Modification
286	60.9	(67.1)	14.89	7.0	16.7	LDV - Exhaust; 66-69

Continued

TABLE 40. SUMMARY OF CONTROL COSTS (Continued)

294	7.6	(8.4)	15.45	0.9	17.6	HDV - Evaporative; 69-71
389	8.4	(9.3)	16.07	1.3	18.9	Printing - Flexigraphic; Catalytic Incineration
437	0.6	(0.7)	16.12	0.1	19.0	Rubber and Plastic Manufacturing; Adsorption and Incineration
476	3.8	(4.2)	16.40	0.7	19.7	Petroleum Refining - Fixed Roof Tanks; Vapor Recycle
483	9.3	(10.2)	17.08	1.8	21.5	HDV - Evaporative; 74-68
511	0.2	(0.2)	17.09	0.03	21.6	Pharmaceutical Manufacturing; Adsorption and Incineration
589	7.9	(8.7)	17.67	1.9	23.5	Printing - Rotogravure; Adsorption
615	39.4	(43.4)	20.55	9.8	33.3	Underground Service Station Tanks; Vapor Adsorption or Condensation
667	77.3	(85.2)	26.20	20.7	54.0	Auto Tank Filling; Vapor Adsorption or Condensation
673	7.3	(8.1)	26.74	2.0	56.0	Surface Coating - Heat Treated; Catalytic Incineration
703	2.1	(2.3)	26.89	0.6	56.6	HDV - Evaporative; Pre-61 Crankcase
714	19.9	(21.9)	28.34	5.7	62.3	LDV - Exhaust; 63-65
785	9.8	(10.8)	29.06	3.1	65.4	Aircraft - Piston; Afterburner
815	3.6	(4.0)	29.33	1.2	66.6	HDV - Evaporative; 61-63

Continued

TABLE 40. SUMMARY OF CONTROL COSTS (Continued)

849	48.4	(53.4)	32.87	16.6	83.2	Surface Coating - Air Dried; Catalytic Incineration
883	19.9	(21.9)	34.32	7.1	90.3	Miscellaneous Operations; Adsorption and Incineration
934	7.7	(8.5)	34.88	2.9	93.2	HDV - Evaporative; Pre-61
1,000	1.8	(2.0)	35.01	0.7	93.9	Dry Cleaning - Petroleum Based Solvent; Adsorption
1,074	14.8	(16.3)	36.09	6.4	100.3	LDV - Exhaust; Pre-63
1,074	35.4	(39.0)	38.68	15.3	115.6	Other Gasoline Powered Equipment - Exhaust; Same as Pre-63 Auto
1,349	84.2	(92.8)	44.84	45.7	161.3	LDV - Evaporative; 66-69
2,175	9.2	(10.1)	45.51	8.0	169.3	LDV - Evaporative; Pre-63 crankcase
2,272	40.8	(45.0)	48.50	37.3	206.6	LDV - Evaporative; 63-65
2,286	6.3	(6.9)	48.96	5.8	212.4	Petroleum Refining - Fixed Roof Tanks; Adsorption or Condensation
2,809	0.2	(0.2)	48.97	0.2	212.6	HDV - Evaporative; 61-63 Crankcase
3,180	32.7	(36.0)	51.36	41.8	254.4	LDV - Evaporative; Pre-63
3,180	11.1	(12.2)	52.17	14.1	268.5	Other Gasoline Powered Equipment - Evaporative; Same as Pre-63 Auto
4,762	3.2	(3.5)	52.40	6.5	275.0	Petroleum Refining - Floating Roof Tanks; Secondary Seals
14,815	7.9	(8.7)	52.98	47.4	322.4	Aircraft - Jet; Combustor Can Redesign
	724.1	798.2		322.4		

TABLE 41. COST EFFECTIVENESS OF ACHIEVING VARIOUS LEVELS OF ORGANIC CONTROL

% Reduction In Reactive Emissions	Annualized Control Costs	Average Cost Effectiveness - Dollars Per Reactive Ton
10	$\$9.1 \times 10^6$	$312
20	$\$31.4 \times 10^6$	$539
30	$\$69.7 \times 10^6$	$797
40	$\$125.4 \times 10^6$	$861
50	$\$230.6 \times 10^6$	$1583
maximum 53	$\$322.4 \times 10^6$	$2088

REFERENCES

1. Goodman, H.S.; Abercrombie, G.E.; Arledge, K.W.; and Tan, R.L. "A Mobile Source Emissions Inventory System for Light Duty Vehicles in the South Coast Air Basin," California Air Resources Board Contract Number ARB-1236, TRW Environmental Engineering Division, February 1977.

2. Tabak, H., KVB Engineering, Tustin, California, Personal communication of data from a preliminary organic inventory conducted for the California Air Resources Board, February 1977.

3. Xavier, T., California Air Resources Board, Sacramento, California, Personal communication of 1975 organic inventory data.

4. Trijonis, J.C.; and Arledge, K.W., "Utility of Reactivity Criteria in Organic Emission Control Strategies for Los Angeles," EPA Contract Number 68-02-1735, TRW Environmental Services, December 1975.

5. Blumenthal, D., Private communication of data, MRI, Inc., Pasadena, California, March 1977.

6. Bonamassa, F., Private communication of data, California Air Resources Board, El Monte, California, March 1977.

7. Trijonis, J.C. and Arledge, K.W., "Utility of Reactivity Criteria in Organic Emission Control Strategies for Los Angeles," TRW Environmental Services, Redondo Beach, California, EPA Contract No. 68-02-1735, December, 1975.

8. National Air Pollution Control Administration, "Control Techniques for Hydrocarbon and Organic Solvent Emissions From Stationary Sources," March 1970.

9. Porter, W., Private communication, Standard Oil Company, El Segundo, California, March 1977.

10. Loop, J., Private communication, California Air Resources Board, Sacramento, California, March 1977.

11. Goodman, H., et al, "A Methodology for Determining Least Cost Air Pollution Control Strategies," TRW Transportation and Environmental Engineering Operations, EPA Contract No. 68-01-2629, June 1975.

12. Arledge, K.W., et al, "In-Stack Continuous Monitoring of Emissions From Stationary Sources," KVB Engineering, ARB Contract No. 3-733, January 1975.

13. Trijonis, J.C., An Economic Air Pollution Control Model - Application Photochemical Smog in Los Angeles County in 1975, Ph.D. Thesis, California Institute of Technology, Pasadena, California, May 1972.

14. National Air Pollution Control Administration, Control Techniques For Carbon Monoxide, Nitrogen Dioxide, and Hydrocarbon Emissions From Mobile Sources, March 1970.

15. Bastress, E.K., et al, "Assessment of Aircraft Emission Control Technology," Northern Research and Engineering, EPA Contract No. 68-04-0011, APTD 0805, NREC 1168 1, September 1971.

16. Danielson, J.A., Ed., "Air Pollution Engineering Manual," Los Angeles County Air Pollution Control District, AP-40, May 1973.

17. Tabak, H., Private communication of data from a preliminary organic inventory conducted for the California Air Resources Board, KVB Engineering, February 1977.

18. "Systems and Costs to Control Hydrocarbon Emissions From Stationary Sources," Office of Air Quality Planning and Standards, EPA, EPA 450/2 74 006, PB 236-921, September 1974.

19. Goodman, H.S., Abercrombie, G.E., Arledge, K.W. and Tan, R.L.; "A Mobile Source Emissions Inventory System for Light Duty Vehicles in the South Coast Air Basin," California Air Resources Board Contract Number ARB-1236, TRW Environmental Engineering Division, February 1977.

20. Trijonis, J.C., An Economic Air Pollution Control Model - Application: Photochemical Smog in Los Angeles County in 1975, Ph.D. Thesis, California Institute of Technology, Pasadena, California, May 1972.

21. Goodman, H., et al, "A Methodology for Determining Least Cost Air Pollution Control Strategies," TRW Transportation and Environmental Engineering Operations, EPA Contract No. 68-01-2629, June 1975.

22. Trijonis, J.C. and Arledge, K.W., "Utility of Reactivity Criteria in Organic Emission Control Strategies for Los Angeles," TRW Environmental Services, Redondo Beach, California, EPA Contract No. 68-02-1735, December, 1975.

APPENDIX A

ESTIMATED ORGANIC MOLAR COMPOSITION FOR 26 DEVICE CATEGORIES

This section presents the estimated molar composition of the organics emitted by each of the 26 categories of devices in terms of the five-class reactivity scheme.

TABLE A-1. ESTIMATED COMPOSITION OF ORGANICS EMITTED BY PETROLEUM PRODUCING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	84	Mono-tert-alkyl benzenes		C_{4+}-paraffins	13	Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins	3	Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	84	TOTAL CLASS II	0	TOTAL CLASS III	16	TOTAL CLASS IV	0	TOTAL CLASS V	0

TABLE A-2. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED FROM REFINERY OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	6	Mono-tert-alkyl benzenes		C_{4+}-paraffins	67	Prim-& sec-alkyl benzenes	3	Aliphatic olefins	14
Acetylene	2	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	5	α-methyl styrene	
Benzene	3	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	11	TOTAL CLASS II	0	TOTAL CLASS III	67	TOTAL CLASS IV	8	TOTAL CLASS V	14

TABLE A-3. ESTIMATED COMPOSITION OF ORGANICS EMITTED FROM UNDERGROUND GASOLINE STORAGE TANKS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	18	Mono-tert-alkyl benzenes		C_{4+}-paraffins	59	Prim-& sec-alkyl benzenes		Aliphatic olefins	22
Acetylene		Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	18	TOTAL CLASS II	0	TOTAL CLASS III	60	TOTAL CLASS IV	0	TOTAL CLASS V	22

*Weighed average of regular grade and premium grade storage tanks based on 1972 gasoline sales of 30 volume % regular grade and 70 volume % premium grade.

TABLE A-4. ESTIMATED COMPOSITION OF ORGANICS EMITTED DUE TO AUTOMOBILE GASOLINE TANK FILLING

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	2	Mono-tert-alkyl benzenes		C_{4+}-paraffins	68	Prim-& sec-alkyl benzenes	5	Aliphatic olefins	17
Acetylene		Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes	4	α-methyl styrene	
Benzene	2	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	1
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	4	TOTAL CLASS II	0	TOTAL CLASS III	69	TOTAL CLASS IV	9	TOTAL CLASS V	18

*Assuming 30 volume % regular and 70 volume % premium grade consumed, and 81 weight % emitted by vapor displacement and 19 weight % emitted due to spillage.

TABLE A-5. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING FUEL COMBUSTION

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	85	Mono-tert-alkyl benzenes		C_{4+}-paraffins	3	Prim-& sec-alkyl benzenes	1	Aliphatic olefins	3
Acetylene	5	Cyclic ketones		Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	3
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	90	TOTAL CLASS II	0	TOTAL CLASS III	3	TOTAL CLASS IV	1	TOTAL CLASS V	6

TABLE A-6. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY WASTE BURNING AND OTHER FIRES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	62	Mono-tert-alkyl benzenes		C_{4+}-paraffins	3	Prim-& sec-alkyl benzenes		Aliphatic olefins	13
Acetylene	8	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	1	α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes	2	Branched alkyl ketones		Aliphatic aldehydes	3
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols	2	Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones	2	Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol	4								
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	74	TOTAL CLASS II	0	TOTAL CLASS III	7	TOTAL CLASS IV	3	TOTAL CLASS V	16

TABLE A-7. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING HEAT TREATING OF SURFACE COATINGS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	20	Mono-tert-alkyl benzenes		C_{4+}-paraffins	28	Prim-& sec-alkyl benzenes	35	Aliphatic olefins	2
Acetylene		Cyclic ketones		Cycloparaffins		Dialkyl benzenes	15	α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	20	TOTAL CLASS II	0	TOTAL CLASS III	28	TOTAL CLASS IV	50	TOTAL CLASS V	2

TABLE A-8. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING CURING OF AIR DRIED SURFACE COATINGS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins	37	Prim-& sec-alkyl benzenes	9	Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins	5	Dialkyl benzenes	6	α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones	2	Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols	12	Tri-& tetra-alkyl benzenes	1
Acetone	10			N-alkyl ketones	6	Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates	3	Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	4
Ethyl amines									
Dimethyl formamide									
Methanol	4								
Perhalogenated hydrocarbons									
Partially halogenated paraffins	1								
TOTAL CLASS I	15	TOTAL CLASS II	0	TOTAL CLASS III	51	TOTAL CLASS IV	29	TOTAL CLASS V	5

TABLE A-9. ESTIMATED COMPOSITION OF ORGANICS EMITTED FROM DRY CLEANING OPERATIONS USING PETROLEUM BASED SOLVENTS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins	28	Prim-& sec-alkyl benzenes	5	Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins	66	Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	1
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	0	TOTAL CLASS II	0	TOTAL CLASS III	94	TOTAL CLASS IV	5	TOTAL CLASS V	1

TABLE A-10. COMPOSITION OF THE ORGANICS EMITTED FROM DRY CLEANING OPERATIONS USING SYNTHETIC SOLVENT (PCE)

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins		Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons	100								
Partially halogenated paraffins									
TOTAL CLASS I	100	TOTAL CLASS II	0	TOTAL CLASS III	0	TOTAL CLASS IV	0	TOTAL CLASS V	0

TABLE A-11. COMPOSITION OF THE ORGANICS EMITTED DURING TRICHLORETHYLENE (TCE) DEGREASING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins		Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins	100	Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	0	TOTAL CLASS II	0	TOTAL CLASS III	0	TOTAL CLASS IV	100	TOTAL CLASS V	0

TABLE A-12. COMPOSITION OF THE ORGANICS EMITTED DURING 1,1,1,-TRICHLOROETHANE DEGREASING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins		Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halo-genated paraffins	100								
TOTAL CLASS I	100	TOTAL CLASS II	0	TOTAL CLASS III	0	TOTAL CLASS IV	0	TOTAL CLASS V	0

TABLE A-13. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY ROTOGRAVURE PRINTING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins	49	Prim-& sec-alkyl benzenes	5	Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins	7	Dialkyl benzenes	5	α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols	13	Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates	5*	Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol	16								
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	16	TOTAL CLASS II	0	TOTAL CLASS III	61	TOTAL CLASS IV	23	TOTAL CLASS V	0

*Both saturated acetates and other esters are included in this category.

TABLE A-14. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY FLEXIGRAPHIC PRINTING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins		Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones		Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene				Tri-& tetra-alkyl benzenes	
Acetone	10			N-alkyl ketones	8	Prim-& sec-alkyl alcohols	73	Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Cellosolve acetate		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone		Partially halogenated olefins		Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol	9								
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	19	TOTAL CLASS II	0	TOTAL CLASS III	8	TOTAL CLASS IV	73	TOTAL CLASS V	0

TABLE A-15. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY RUBBER PLASTIC, PUTTY AND ADHESIVE MANUFACTURING OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins	9	Prim-& sec-alkyl benzenes		Aliphatic olefins	41
Acetylene		Cyclic ketones	1	Cycloparaffins	7	Dialkyl benzenes	1	α-methyl styrene	1
Benzene	7	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones	2	Aliphatic aldehydes	10
Benzaldehyde		2-nitropropane		Styrene	4	Prim-& sec-alkyl alcohols	4	Tri-& tetra-alkyl benzenes	
Acetone	4			N-alkyl ketones	3	Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols	2			Prim-& sec-alkyl acetates	1	Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins	3								
TOTAL CLASS I	16	TOTAL CLASS II	1	TOTAL CLASS III	24	TOTAL CLASS IV	7	TOTAL CLASS V	52

TABLE A-16. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED DURING PHARMACEUTICAL MANUFACTURING

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins		Prim-& sec-alkyl benzenes		Aliphatic olefins	
Acetylene		Cyclic ketones	1	Cycloparaffins		Dialkyl benzenes		α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones	3	Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols	57	Tri-& tetra-alkyl benzenes	
Acetone	7			N-alkyl ketones	5	Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols	7			Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol	20								
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	34	TOTAL CLASS II	1	TOTAL CLASS III	5	TOTAL CLASS IV	60	TOTAL CLASS V	0

TABLE A-17. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY MISCELLANEOUS ORGANIC SOLVENT OPERATIONS

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins		Mono-tert-alkyl benzenes		C_{4+}-paraffins	13	Prim-& sec-alkyl benzenes	4	Aliphatic olefins	4
Acetylene		Cyclic ketones		Cycloparaffins	4	Dialkyl benzenes	6	α-methyl styrene	
Benzene	3	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones	4	Aliphatic aldehydes	1
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols	4	Tri-& tetra-alkyl benzenes	1
Acetone	19			N-alkyl ketones	9	Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols	3			Prim-& sec-alkyl acetates	3	Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	3
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol	19								
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	44	TOTAL CLASS II	0	TOTAL CLASS III	29	TOTAL CLASS IV	18	TOTAL CLASS V	9

TABLE A-18. ORGANIC COMPOSITION OF THE EXHAUST FROM LIGHT DUTY GASOLINE POWERED MOTOR VEHICLES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	14	Mono-tert-alkyl benzenes		C_{4+}-paraffins	30	Prim-& sec-alkyl benzenes	6	Aliphatic olefins	20
Acetylene	11	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	13	α-methyl styrene	
Benzene	3	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	28	TOTAL CLASS II	0	TOTAL CLASS III	30	TOTAL CLASS IV	19	TOTAL CLASS V	23

TABLE A-19. ESTIMATED ORGANIC COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM LIGHT DUTY GASOLINE POWERED VEHICLES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	1	Mono-tert-alkyl benzenes		C_{4+}-paraffins	57	Prim-& sec-alkyl benzenes	9	Aliphatic olefins	13
Acetylene		Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes	12	α-methyl styrene	
Benzene	4	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halo-genated paraffins									
TOTAL CLASS I	5	TOTAL CLASS II	0	TOTAL CLASS III	58	TOTAL CLASS IV	21	TOTAL CLASS V	16

Weighted to represent: (1) 67% carburetor, 33% fuel tank emissions; (2) 30% regular, 70% premium grade gasolines.

TABLE A-20. ESTIMATED ORGANIC COMPOSITION OF THE EXHAUST EMISSIONS FROM HEAVY DUTY GASOLINE POWERED MOTOR VEHICLES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	14	Mono-tert-alkyl benzenes		C_{4+}-paraffins	30	Prim-& sec-alkyl benzenes	6	Aliphatic olefins	20
Acetylene	11	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	13	α-methyl styrene	
Benzene	3	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	28	TOTAL CLASS II	0	TOTAL CLASS III	30	TOTAL CLASS IV	19	TOTAL CLASS V	23

TABLE A-21. ESTIMATED ORGANIC COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM HEAVY DUTY GASOLINE POWERED VEHICLES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	1	Mono-tert-alkyl benzenes		C_{4+}-paraffins	57	Prim-& sec-alkyl benzenes	9	Aliphatic olefins	13
Acetylene		Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes	12	α-methyl styrene	
Benzene	4	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	5	TOTAL CLASS II	0	TOTAL CLASS III	58	TOTAL CLASS IV	21	TOTAL CLASS V	16

TABLE A-22. ESTIMATED ORGANIC COMPOSITION OF THE EXHAUST EMISSIONS FROM OTHER TYPES OF GASOLINE POWERED EQUIPMENT

Mole %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	14	Mono-tert-alkyl benzenes		C_{4+}-paraffins	30	Prim-& sec-alkyl benzenes	6	Aliphatic olefins	20
Acetylene	11	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	13	α-methyl styrene	
Benzene	3	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	28	TOTAL CLASS II	0	TOTAL CLASS III	30	TOTAL CLASS IV	19	TOTAL CLASS V	23

TABLE A-23. ESTIMATED COMPOSITION OF THE EVAPORATIVE EMISSIONS FROM OTHER GASOLINE POWERED EQUIPMENT

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	1	Mono-tert-alkyl benzenes		C_{4+}-paraffins	57	Prim-& sec-alkyl benzenes	9	Aliphatic olefins	13
Acetylene		Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes	12	α-methyl styrene	
Benzene	4	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	3
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	5	TOTAL CLASS II	0	TOTAL CLASS III	58	TOTAL CLASS IV	21	TOTAL CLASS V	16

TABLE A-24. ESTIMATED COMPOSITION OF THE EXHAUST EMISSIONS FROM DIESEL POWERED VEHICLES

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	11	Mono-tert-alkyl benzenes		C_{4+}-paraffins	24	Prim-& sec-alkyl benzenes	1	Aliphatic olefins	27
Acetylene	2	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	5	α-methyl styrene	
Benzene		Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	30
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	13	TOTAL CLASS II	0	TOTAL CLASS III	24	TOTAL CLASS IV	6	TOTAL CLASS V	57

TABLE A-25. ESTIMATED COMPOSITION OF THE ORGANIC EMISSIONS FROM TURBINE POWERED AIRCRAFT

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	7	Mono-tert-alkyl benzenes	4	C_{4+}-paraffins	38	Prim-& sec-alkyl benzenes	8	Aliphatic olefins	19
Acetylene	1	Cyclic ketones		Cycloparaffins		Dialkyl benzenes	8	α-methyl styrene	
Benzene	1	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	10
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	4
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	9	TOTAL CLASS II	4	TOTAL CLASS III	38	TOTAL CLASS IV	16	TOTAL CLASS V	33

For additional data see Tables B-16 through B-18.

TABLE A-26. ESTIMATED COMPOSITION OF THE ORGANICS EMITTED BY PISTON AIRCRAFT

MOLE %

CLASS I		CLASS II		CLASS III		CLASS IV		CLASS V	
C_1-C_3 paraffins	20	Mono-tert-alkyl benzenes		C_{4+}-paraffins	22	Prim-& sec-alkyl benzenes	6	Aliphatic olefins	31
Acetylene	12	Cyclic ketones		Cycloparaffins	1	Dialkyl benzenes	4	α-methyl styrene	
Benzene	2	Tert-alkyl acetates		Alkyl acetylenes		Branched alkyl ketones		Aliphatic aldehydes	
Benzaldehyde		2-nitropropane		Styrene		Prim-& sec-alkyl alcohols		Tri-& tetra-alkyl benzenes	2
Acetone				N-alkyl ketones		Cellosolve acetate		Unsaturated ketones	
Tert-alkyl alcohols				Prim-& sec-alkyl acetates		Partially halogenated olefins		Diacetone alcohol	
Phenyl acetate				N-methyl pyrrolidone				Ethers	
Methyl benzoate				N,N-dimethyl acetamide				Cellosolves	
Ethyl amines									
Dimethyl formamide									
Methanol									
Perhalogenated hydrocarbons									
Partially halogenated paraffins									
TOTAL CLASS I	34	TOTAL CLASS II	0	TOTAL CLASS III	23	TOTAL CLASS IV	10	TOTAL CLASS V	33

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report documents the results of a study to determine the costs associated with controlling reactive organic emissions in the Metropolitan Los Angeles Air Quality Control Region. An inventory of organic emissions from 26 categories of stationary and mobile sources was developed for the calendar year 1975. The photochemical reactivity of the emissions from each category was determined in terms of a 3-class reactivity classification scheme. The costs associated with reducing the emissions from each category were estimated by assuming the application of the most cost effective combination of available control equipment. The costs associated with reducing the emissions from all sources were estimated by assuming the application of the most cost effective controls selected from those available for all source types. It was concluded that only approximately 53% of the total organic emissions could be eliminated using currently available control technology.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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