EMISSIONS CONTROL OPTIONS FOR THE SYNTHETIC ORGANIC CHEMICALS MANUFACTURING INDUSTRY

Ethylene Dichloride Product Report

November 1978

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EPA Contract No. 68-02-2577

Ethylene Dichloride Product Report

F. D. Hobbs and J. A. Key

Prepared for
Emission Standards and Engineering Division
Office of Air Quality Planning and Standards
ENVIRONMENTAL PROTECTION AGENCY
Research Triangle Park, North Carolina

November 1978

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ABBREVIATIONS AND CONVERSION FACTORS

EPA policy is to express all measurements in agency documents in metric units. Listed below are the International System of Units (SI) abbreviations and conversion factors for this report.

To Convert From	To	Multiply By
Pascal (Pa)	Atmosphere (760 mm Hg)	9.870×10^{-6}
Joule (J)	British thermal unit (Btu)	9.480×10^{-4}
Degree Celsius (°C)	Degree Fahrenheit (°F)	(°C X 9/5) + 32
Meter (m)	Feet (ft)	3.28
Cubic meter (m^3)	Cubic feet (ft^3)	3.531×10^{1}
Cubic meter (m^3)	Barrel (oil) (bbl)	6.290
Cubic meter (m^3)	Gallon (U.S. liquid) (gal)	2.643×10^{2}
Cubic meter/second (m^3/s)	Gallon (U.S. liquid/min) (gpm)	1.585×10^{4}
Watt (W)	Horsepower (electric) (hp)	1.340×10^{-3}
Meter (m)	Inch (in.)	3.937×10^{1}
Pascal (Pa)	Pound-force/$inch^2$ (psi)	1.450×10^{-4}
Kilogram (kg)	Pound-mass (lb)	2.205
Joule (J)	Watt-hour (W-h)	2.778×10^{-4}

Standard Conditions

68°F = 20°C

1 atmosphere (Torr) = 101,325 Pascals

PREFIXES

Prefix	Symbol	Multiplication Factor	Example
T	tera	10^{12}	1 Tg = 1 X 10^{12} grams
G	giga	10^{9}	1 Gg = 1 X 10^{9} grams
M	mega	10^{6}	1 MW = 1 X 10^{6} grams
k	kilo	10^{3}	1 km = 1 X 10^{3} meters
m	milli	10^{-3}	1 mV = 1 X 10^{-3} volt
μ	micro	10^{-6}	1 μg = 1 X 10^{-6} gram

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I. PREFATORY AND INTRODUCTORY MATERIAL

(This section to be supplied by EPA.)

II. INDUSTRY DESCRIPTION

A. INTRODUCTION

Ethylene dichloride (EDC) was selected for consideration because the large amounts produced and its moderate volatility (see Appendix A for pertinent physical properties) result in high emissions of volatile organic compounds (VOC).[1] Ethylene dichloride constitutes a major portion of emissions from both direct chlorination and oxychlorination of ethylene,[1] the two commercial processes for its manufacture. Recently it was recommended that ethylene dichloride be treated as a carcinogen because it has been found to cause statistically significant increases of cancer in laboratory animals.[2]

B. USAGE AND GROWTH

The end uses and expected growth rates for ethylene dichloride are given in Table II-1. The predominant use is as an intermediate in the production of vinyl chloride monomer (VCM); approximately 93% of the VCM produced in 1974 was made from ethylene dichloride. A large portion of the remaining ethylene dichloride is used in production of chlorinated solvents.[3]

The domestic ethylene dichloride capacity for 1977 is reported to be about 6,726,000 Mg/yr.[4] Production was reported to be about 4,679,000 Mg in 1977,[5] or about 70% of capacity. Based on a projected growth rate of 4 to 5%,[3] production will utilize 85 to 89% of the 1977 capacity by 1982. There are indications that the growth may exceed the projected rate. Several companies are either completing construction and startup of new VCM plants or are planning new VCM capacity,[6] which usually must include additional ethylene dichloride capacity. Ethylene dichloride for sale must come from direct chlorination of ethylene unless a supply of hydrogen chloride (HCl) is available as feed for the oxychlorination process. Conversely, unless the HCl produced as a by-product during the cracking of ethylene dichloride to VCM has another use, it is used as feed for the oxychlorination process.[3]

C. DOMESTIC PRODUCERS

There were 12 producers operating 18 ethylene dichloride plants in the United States in 1977. Table II-2 lists the producers, locations, and capacities;[3,4,7--9] Fig. II-1 shows plant locations.

Table II-1. Ethylene Dichloride Usage and Growth*

End Use	Production for 1974 (%)	Average Growth for 1974--1979 (%/yr)
Vinyl chloride	81	4
1,1,1-Trichloroethane	3	5.5
Trichloroethylene	3	-1
Perchloroethylene	3	5.5
Ethyleneamines	3	5
Vinylidene chloride	2	7
Lead scavanger	2	0
Exports	3	Not available

*See ref. 3.

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Table II-2. Ethylene Dichloride Capacity[a]

Plant	Capacity as of 1977 (Mg/yr)
ICI ~~Allied~~, Baton Rouge, LA	315,000
Borden, Geismar, LA	225,000[b]
Conoco, Lake Charles, LA	524,000[c]
Diamond Shamrock, Deer Park, TX	145,000[d]
Dow, Freeport, TX	726,000
Dow, Oyster Creek, TX	499,000
Dow, Plaquemine, LA	952,000[e]
Ethyl, Baton Rouge, LA	317,000
Ethyl, Houston, TX	118,000
Goodrich, Calvert City, KY	454,000[f]
PPG, Lake Charles, La	544,000
PPG, Guayanilla, PR	379,000
Shell, Deer Park, TX	544,000
Shell, Norco, LA	544,000
Stauffer, Long Beach, CA	154,000
Union Carbide, Taft, LA	68,000[g]
Union Carbide, Texas City, TX	68,000[g]
Vulcan, Geismar, LA	150,000[h]
Total	6,726,000

[a] See ref. 4.

[b] Plant started up in 1977 (see ref. 7).

[c] Conoco plans to double production by 1980 (see ref. 8).

[d] Diamond Shamrock reported plans to expand capacity with a 794,000-Mg/yr plant at San Jacinto, TX, by mid-1978 (see ref. 8).

[e] Includes a recently completed expansion (see ref. 8).

[f] Goodrich and Bechtel have announced a joint venture including a 363,000-Mg/yr ethylene dichloride facility near Houston, TX (see ref. 9).

[g] Union Carbide is the only producer making ethylene dichloride exclusively by the direct chlorination of ethylene process; all other producers use both the direct-chlorination and the oxychlorination processes (see ref. 3).

[h] Vulcan recently added a purification unit at the Geismar, LA, facilities (see ref. 8).

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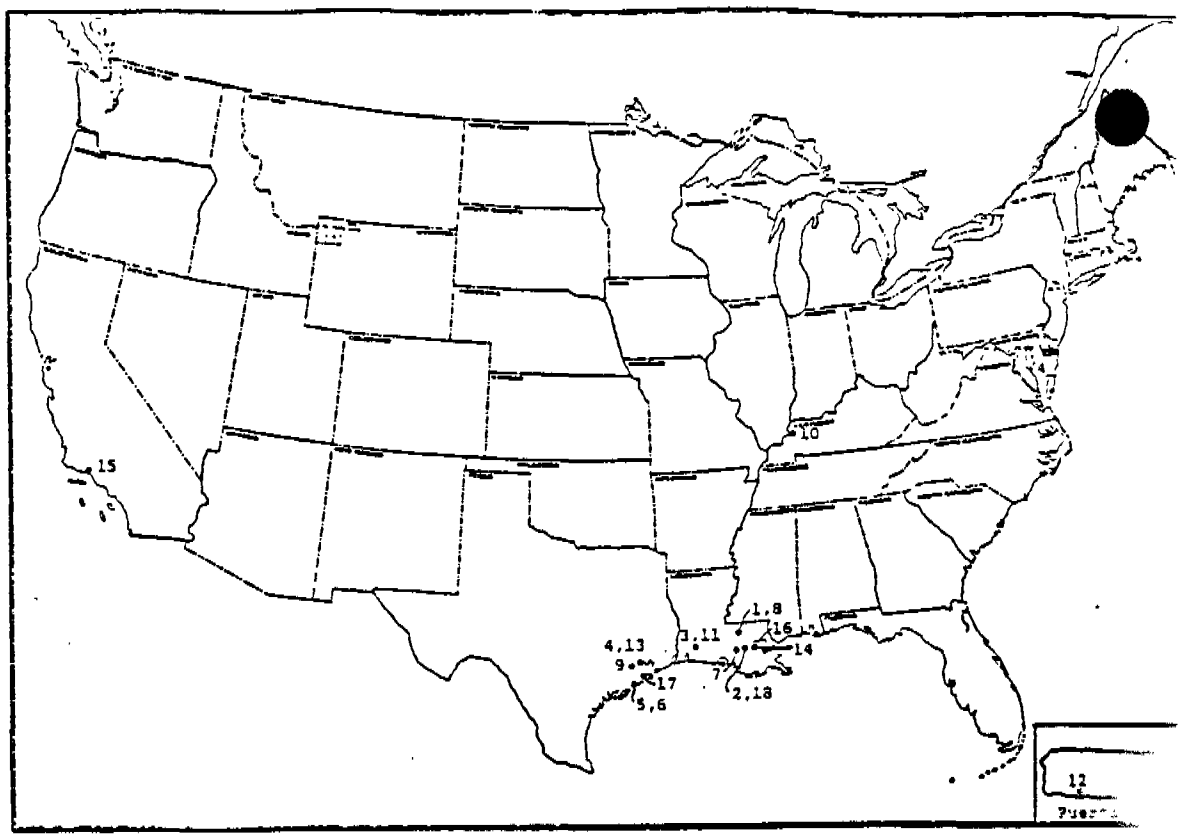

(1) Allied Chemical Co., Baton Rouge, LA
(2) Borden Chemical Co., Geismar, LA
(3) Conoco Chemicals, Lake Charles, LA
(4) Diamond Shamrock Corp., Deer Park, TX
(5) Dow Chemical Co., Freeport, TX
(6) Dow Chemical Co., Oyster Creek, TX
(7) Dow Chemical Co., Plaquemine, LA
(8) Ethyl Corp., Baton Rouge, LA
(9) Ethyl Corp., Houston, TX
(10) B.F. Goodrich Co., Calvert City, KY
(11) PPG Industries, Inc., Lake Charles, LA
(12) PPG Industries, Inc., Guayanilla, P.R.
(13) Shell Chemical Co., Deer Park, TX
(14) Shell Chemical Co., Norco, LA
(15) Stauffer Chemical Co., Long Beach, CA
(16) Union Carbide Corp., Taft, LA
(17) Union Carbide Corp., Texas City, TX
(18) Vulcan Materials Co., Geismar, LA

Fig. II-1. Locations of Plants Manufacturing Ethylene Dichloride

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Producing Companies

1. Allied

   About 70% of the ethylene dichloride capacity is required to operate the VCM facilities at capacity. The remainder is sold.[3] ICI America has reported plans to purchase this facility.[6]

2. Borden

   All ethylene dichloride is captively consumed in the manufacture of VCM. The facilities were started up in 1977.[7]

3. Conoco

   All ethylene dichloride is captively consumed in the manufacture of VCM.[3] The plans are to double their capacity by 1980.[8]

4. Diamond Shamrock

   About 38% of the ethylene dichloride capacity is required for the trichloroethylene and perchloroethylene facilities at their full capacity; the remainder is sold.[3] Plans have been reported to expand the capacity with a 794,000-Mg/yr plant at San Jacinto, TX, by mid-1978.[8]

5. Dow

   Approximately 75% of the ethylene dichloride capacity is used as an intermediate for capacity production of numerous end products; the remaining ethylene dichloride is sold.[3] The capacity at the Plaquemine, LA, location was recently expanded by about 453,000 Mg/yr.[8]

6. Ethyl

   Nearly all the ethylene dichloride capacity is required as an intermediate for the manufacture of various end products.[3]

7. Goodrich

   All ethylene dichloride is captively consumed in VCM production.[3] Goodrich and Bechtel have agreed on a joint venture to manufacture ethylene dichloride at a facility near Houston, TX.[9]

8. PPG

Nearly all ethylene dichloride is captively consumed in the manufacture of VCM and other chlorinated hydrocarbons.[3] Plans have been announced to increase the vinyl chloride capacity by 227,000 Mg/yr at the Lake Charles, LA, facility by late 1980.[6]

9. Shell

Ethylene dichloride is captively consumed in VCM manufacture.[3]

10. Stauffer

About 85% of the ethylene dichloride is consumed in VCM production; the remainder is sold.[3]

11. Union Carbide

Union Carbide is the only producer making all ethylene dichloride exclusively by the direct-chlorination process. About 85% of the ethylene dichloride capacity is required for operation of ethylenediamine plants at capacity.[3]

12. Vulcan

A small amount of the ethylene dichloride is consumed in the manufacture perchloroethylene; most of it is sold.[3] It was announced that a purifica unit would be installed by late 1977.[8]

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9. "Business Newsletter," Chemical Week 123(5), 7 (1978).

*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

III. PROCESS DESCRIPTION

A. INTRODUCTION

Most of the ethylene dichloride (EDC) produced domestically is used in the production of vinyl chloride monomer (VCM). Three principal steps are involved in producing VCM: (1) the direct chlorination of ethylene to yield EDC, (2) which is then cracked to yield VCM plus hydrogen chloride (HCl), and (3) the use of HCl with oxygen, which may be in the form of air, to oxychlorinate ethylene to produce additional EDC plus water. These steps constitute the "balance" process, so-called because all the HCl is recycled.

This report is concerned with only the direct-chlorination process and the two variations of the oxychlorination process for producing ethylene dichloride. Also, in the model plants discussed the ratio of EDC produced by these processes is fixed because no net HCl is produced. In other plants, however, such as one in which HCl is available as a by-product from other processes, the ratio will be different. One ethylene dichloride producer uses only the direct-chlorination process. Previously, ethylene dichloride was produced as a by-product of ethylene oxide manufacture by the chlorohydrin process; however, the last domestic producer using that process converted to propylene oxide manufacture in 1970.[1]

B. DIRECT-CHLORINATION AND OXYCHLORINATION (AIR) PROCESSES

Ethylene dichloride is produced by direct chlorination of ethylene by the catalytic reaction

$$\underset{\text{(ethylene)}}{CH_2{=}CH_2} + \underset{\text{(chlorine)}}{Cl_2} \longrightarrow \underset{\text{(ethylene dichloride)}}{ClCH_2CH_2Cl}$$

Almost all commercial plants now use a ferric chloride catalyst in a liquid-phase process.

Ethylene dichloride is also produced by oxychlorination of ethylene with hydrogen chloride and air or oxygen by the following catalytic reaction:

$$\underset{\text{(ethylene)}}{2CH_2{=}CH_2} + \underset{\text{(oxygen)}}{O_2} + \underset{\text{(hydrogen chloride)}}{4HCl} \longrightarrow \underset{\text{(ethylene dichloride)}}{2ClCH_2CH_2Cl} + \underset{\text{(water)}}{2H_2O}$$

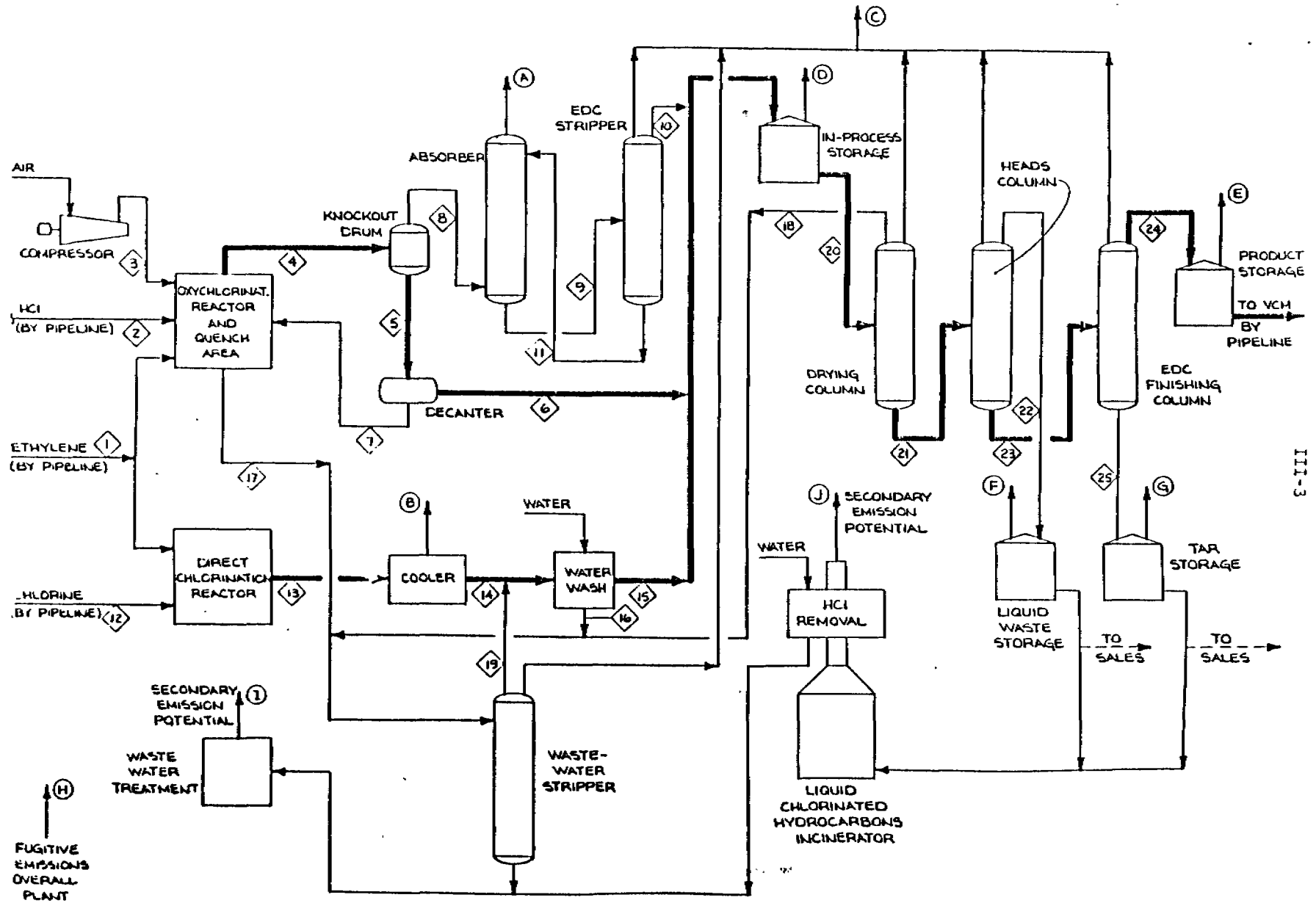
The catalyst is a mixture of copper chloride and other chlorides and the react is carried out in the vapor phase in either a fixed- or fluid-bed reactor.

The typical ethylene dichloride process shown in Fig. III-1 begins with ethylene (Stream 1) being fed by pipeline to both the oxychlorination reactor and the direct-chlorination reactor. In the oxychlorination reactor the ethylene is mixed with approximately stoichiometric proportions of anhydrous hydrogen chloride (Stream 2) and air (Stream 3) at pressures of 140--520 kPa and temperatures of 200--315°C. The conversion of ethylene to ethylene dichloride is virtually completed in the reactor. The reaction is exothermic, generating more than 230 kJ of heat per mole of ethylene dichloride produced, and requires efficient heat removal for adequate temperature control.[2]

The products of reaction from the oxychlorination reaction are quenched and cooled (Stream 4) and then go to a knockout drum. The condensed crude ethylene dichloride and water (Stream 5) separated by the knockout drum enter a decanter, where the crude ethylene dichloride is separated from the aqueous phase. The crude ethylene dichloride (Stream 6) goes to in-process storage, and the aqueous phase (Stream 7) is recycled to the quench step. Noncondensed material (Stream 8) from the knockout drum is fed to an absorber, where ethylene dichloride is recovered from the nitrogen and other inert gases, which are released to the atmosphere (Vent A). Absorbed ethylene dichloride and the absorbent (Stream 9) enter a stripper that removes ethylene dichloride overhead (Stream 10), which then goes to crude ethylene dichloride storage. The stripped absorbent (Stream 11) from the stripper is recycled to the absorber.

In the direct-chlorination step of the balanced process ethylene (Stream 1) and a stoichiometric amount of chlorine (Stream 12) are reacted at a temperature of 38--49°C and at pressures of 69--138 kPa. This process produces 218 kJ/mole (of EDC) of heat that must be removed for proper temperature control.[2]

Products (Stream 13) of reaction from the direct-chlorination reactor are cooled, and the crude ethylene dichloride (Stream 14) is washed with water to remove dissolved hydrogen chloride before being transferred (Stream 15) to the in-process storage. Any inerts fed with the ethylene or chlorine is released to the atmosphere from the cooler (Vent B). The waste wash water (Stream 16) is sent to the wastewater stripper along with the wastewater (Stream 17) from the oxychlorination



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III-3

Fig. III-1. Ethylene Dichloride from a Balanced Process

quench area and the wastewater (Stream 18) from the drying column. The overhe (Stream 19) from the wastewater stripper, which consist of recovered ethylene dichloride, other chlorinated hydrocarbons, and water, are returned to the process by adding them to the crude ethylene dichloride (Stream 14) going to the water wash.

Crude ethylene dichloride (Stream 20) from in-process storage goes to the drying column, where water (Stream 18) is distilled overhead and sent to the wastewater stripper. The dry crude ethylene dichloride (Stream 21) goes to the heads column, which removes light ends (Stream 22) for storage and disposal or sale. Bottoms (Stream 23) from the heads column enter the ethylene dichloride finishing column, where ethylene dichloride (Stream 24) goes overhead to product storage. The tars from the ethylene dichloride finishing column (Stream 25) are taken to tar storage for disposal or sales.

The largest amount of emission is the oxychlorination gas from vent A, because all the nitrogen from the air (Stream 3) fed to the reactor exits the process there. This vent also contains all the ethane from the ethylene feed to the oxychlorination reactor, carbon dioxide and carbon monoxide formed by side reactions, some ethylene dichloride and other chlorinated hydrocarbons not recovered by the absorber, and a small amount of the absorbent. Other process emissions are the vent gases f the direct-chlorination cooler (Vent B) and from the various distillation colum (Vents C).

Storage emission sources (Vents D through G) include in-process storage, product storage, liquid waste storage, and tar storage. Because ethylene dichloride is fed by pipeline to the cracking section of a VCM plant and the light ends and tars are piped to the incinerator, there are no handling emissions from this process as shown. They will occur, however, when ethylene dichloride or the light ends or the tars are loaded into tank trucks, tank cars, or barges for shipping to other sites.

Fugitive emissions (H) occur when leaks develop in valves or in pump or compressor seals. When the process pressures are higher than the cooling-water pressure, ethylene dichloride and other VOC can leak into the cooling water and escape as a fugitive emissions from the cooling tower.

Secondary emissions can occur when wastewater containing VOC is sent to a wastewater treatment system or lagoon and the VOC are desorbed (I). Another source of secondary emissions is from the incineration of liquid-waste streams, where VOC are emitted with the flue gases (Vent J).

C. DIRECT-CHLORINATION AND OXYCHLORINATION (OXYGEN) PROCESSES

Only two domestic EDC producers use oxygen as the oxidant in the oxychlorination reactor. The process details are considered to be confidential by both producers. Although conceptual descriptions of such processes are given in the literature, it is not known how the processes actually used compare with those described. One producer has released data showing that the plant is not truly balanced; i.e., the ratio of ethylene dichloride from oxychlorination and direct chlorination differs from that of a balanced plant. However, both producers have direct chlorination, ethylene dichloride purification and cracking, and VCM purification steps at the same site, which probably constitute an integrated process.[3--6]

Figure III-2 shows a typical oxygen-based oxychlorination process as given in the literature. For a balanced process plant the direct chlorination and purification steps are the same as those shown in Fig. III-1 and therefore are not shown again in Fig. III-2. Ethylene (Stream 1) is fed in large excess of stoichiometric requirements, e.g., 2 to 3 times the amount needed to fully consume the hydrogen chloride (HCl) feed (Stream 2). Oyxgen (Stream 3) is also fed to the reactor, which may be either a fixed bed or a fluid bed. After passing through the oxychlorination reactor and quench area, the reaction products (Stream 4) go to a knockout drum, where the condensed crude ethylene dichloride and water (Stream 5) produced by the oxychlorination reaction are separated from the unreacted ethylene and the inert gases (Stream 6), e.g., carbon dioxide, carbon monoxide, nitrogen, argon, and nonreactive hydrocarbons, which enter the reactor as impurities with the feed streams or are formed during the oxychlorination reaction itself. From the knockout drums the crude ethylene dichloride and water (Stream 5) go to a decanter, where wastewater (Stream 7) is separated from the crude ethylene dichloride (Stream 8), which goes to in-process storage as in the air-based process. The wastewater (Stream 7) is sent to the steam stripper in the direct-chlorination step for recovery of dissolved organics.[3,4]

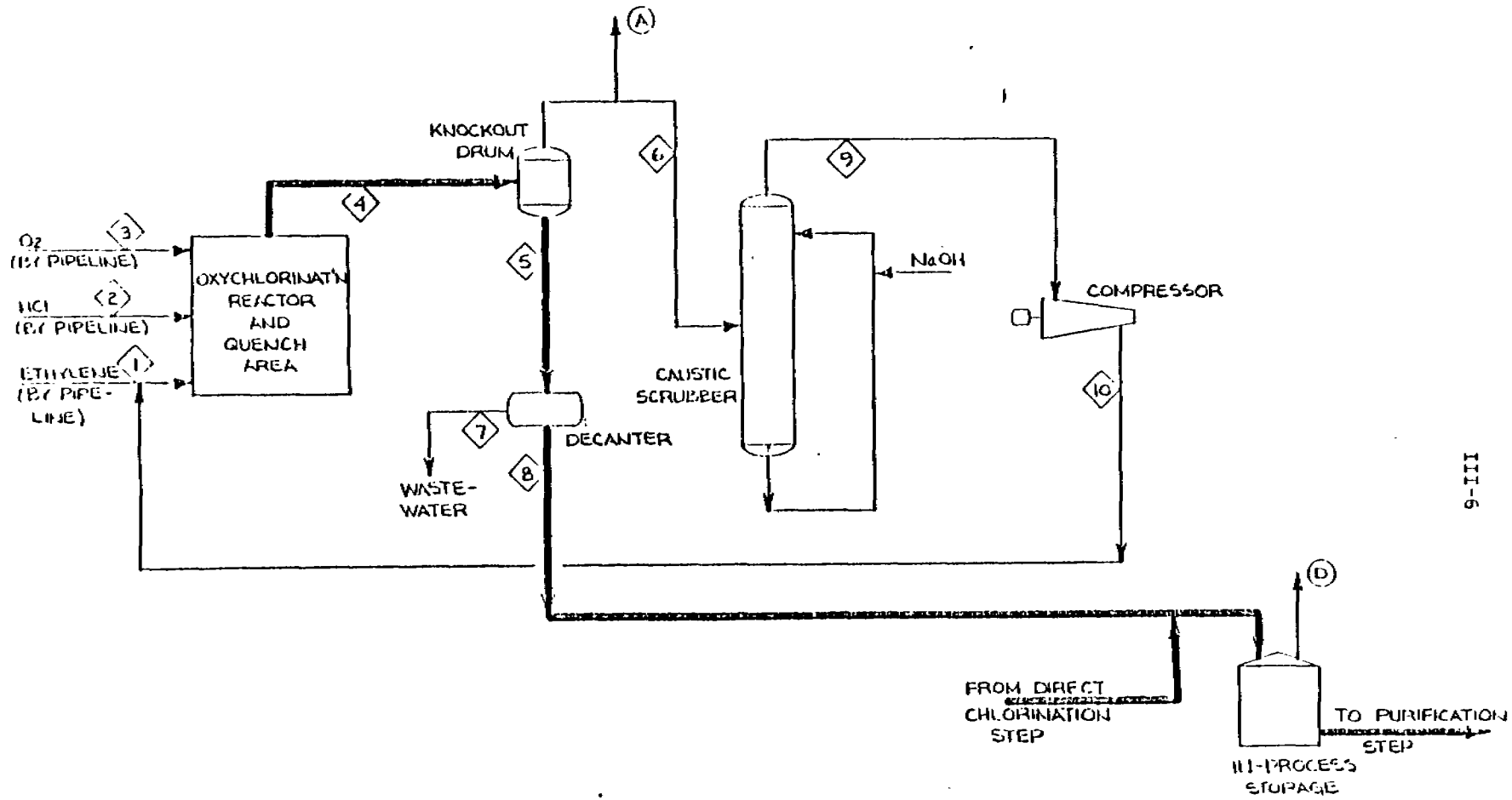

Fig. III-2. Ethylene Dichloride by Oxygen Process, Oxychlorination Step

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The vent gases (Stream 6) from the knockout drum go to a caustic scrubber for removal of hydrogen chloride and carbon dioxide. The purified vent gases (Stream 9) are then compressed and recycled (Stream 10) to the oxychlorination reactor as part of the ethylene feed.[3,4]

A small amount of the vent gas (Vent A) from the knockout drum is purged to prevent buildup of the inert gases entering with the feed streams or formed during the reaction.[3,4]

D. PROCESS VARIATIONS

Although all ethylene dichloride is produced either by direct chlorination of ethylene or by oxychlorination of ethylene, there are many variations in the reactors, recovery methods, and purification trains. However, while the general differences are well known and documented,[2--4,7,8] the details are considered to be trade secrets and confidential by the various manufacturers of ethylene dichloride.

The oxychlorination reactor may be either a tubular fixed-bed type with the catalyst inside the tubes and the coolant in the shell or a fluid-bed type with internal cooling coils. The reactor effluent may be cooled by indirect heat exchange to condense the ethylene dichloride. In one process chlorine is added to the vent gases, which are then passed through one or more catalytic reactors for removal of unreacted ethylene by conversion to ethylene dichloride. When absorption/stripping is used for recovery of ethylene dichloride from the vent gases, the absorbent may be either water or an aromatic solvent. Refrigerated vent condensers may be used to cool the oxychlorination vent gases to as low as -23°C for recovery of chlorinated hydrocarbons.[2--5,7,8]

The direct chlorination of ethylene with chlorine may be carried out either in the vapor phase or in the liquid phase. The reaction usually takes place in the liquid phase with a considerable excess of reaction product. The catalyst may be a metallic chloride such as ferric, aluminum, copper, or antimony chloride; ferric chloride in a liquid-phase reactor is used by almost all commercial plants. The vapors may be condensed by water-cooled and/or refrigerated condensers or they may be absorbed in water or dilute caustic.[1,2,8]

The crude ethylene dichloride from the oxychlorination step may be combined wi that from the direct chlorination and washed with water or caustic or both. The crude ethylene dichloride may be used wthout purification in many applications; in other applications it may be purified and may include recycled EDC from the VCM purification step.[5,7,8]

Production of other chlorinated hydrocarbons, such as 1,1,1-trichloroethane and 1,1,2-trichloroethane, may be integrated with ethylene dichloride--vinyl chloride plants.[9] Vent gas streams from the direct-chlorination step or other processing units may be recycled to the oxychlorination reactor as part of the feed to utilize the raw materials contained in the streams.[7,10] These recycle streams or the ethylene, hydrogen chloride, and chlorine feeds may contain impurities, such as methane,[7] that will exit the process in the vent gases. The light chlorinated hydrocarbons recovered in the purification step may be used as feed to perchloroethylene and carbon tetrachloride plants or may be further purified for recovery of specific chlorinated hydrocarbons. The heavy chlorinated hydrocarbons may also be processed for recovery of some of the chlorinated hydrocarbons.[5,7]

E. REFERENCES*

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*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

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IV. EMISSIONS

A. DIRECT-CHLORINATION AND OXYCHLORINATION (AIR) PROCESSES

1. Model Plant

The model plant for the balanced process (Fig. III-1) has an ethylene dichloride (EDC) capacity of 400,000 Mg/yr, based on 8760 hr of operation annually; 215,000 Mg/yr is produced by direct chlorination and 185,000 Mg/yr by oxychlorination with air. A small quantity (8000 Mg/yr) of liquid-waste chlorinated hydrocarbons is produced and then burned in a liquid-waste incinerator. These liquid wastes could be used or sold. If there is no demand, they would be burned. The model plant is typical of several existing ethylene dichloride plants.[1]

Typical in-process, product, and waste by-product storage-tank capacities are estimated for the 400,000-Mg/yr plant. The storage-tank parameters are given in Sect. IV.A.2.d, and estimates of potential fugitive emission sources are given in Sect. IV.A.2.e. Characteristics of the model plant that are important in air-dispersion modeling are given in Table B-1 in Appendix B.

2. Sources and Emissions

Emission rates and sources for the balanced process based on air are summarized in Table IV-1.

a. Oxychlorination Vent -- The oxychlorination vent gas (Vent A, Fig. III-1) contains nitrogen and unreacted oxygen from the air fed to the reactor; ethane and unreacted ethylene from the ethylene feed; and the ethylene dichloride product, other chlorinated hydrocarbons, and carbon oxides produced in the reactor and not removed from the vent gases in the absorber. Table IV-2 gives the composition of this stream based on an average of data from several sources[1] but is not representative of actual data from any specific plant or process. The data points show such wide scatter that no composition can be found that is typical for either fluid-bed or fixed-bed reactors. It appears that operating conditions may influence the vent gas composition more than reactor configuration. Although there are more inert gases (nitrogen, oxygen, and carbon oxides) in the fluid-bed vent gas and more total vent gas per kg of ethylene dichloride produced than for the fixed-bed case, for both reactors the values of the ratios of total VOC and EDC emitted

Table IV-1. Uncontrolled Emissions of EDC and Total VOC from Model Plants[a]

Emission Source	Vent or Source Designation (Figs. III-1,2)	Emissions: Ratio[b] (g/kg) EDC	Emissions: Ratio[b] (g/kg) Total VOC	Emissions: Rate kg/hr EDC	Emissions: Rate kg/hr Total VOC
Oxychlorination vent					
Air process	A	3.24	7.17	148	327
Oxygen process	A[c]	0.462	9.39	21.1	429
Direct-chlorination vent	B	1.08	2.84	49.1	130
Column vents	C	3.00	13.0	137	594
Storage vents					
In-process	D	0.0340	0.0340	1.55	1.55
Product	E	0.124	0.124	5.65	5.65
Liquid waste	F		0.0654		2.98
Tar	G		0.00229		0.105
Fugitive	H	0.0830	0.166	3.79	7.58
Secondary					
Wastewater treatment	I	0.0181	0.0272	0.829	1.24
Incinerator	J		0.190		8.68
Total for air process		7.6	24	350	1100
Total for oxygen process		4.8	26	220	1200

[a]All emissions are based on 8760 hr of operation per year.

[b]g of emission per kg of EDC produced by balanced process.

[c]See Fig. III-2 for this vent source; see Fig. III-1 for all others.

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Table IV-2. Composition of Model-Plant Oxychlorination (Air) Vent Gas

Component	Composition (wt %)	Emission Ratio[a] (g/kg)
Ethylene dichloride	0.81	7.0
Ethylene	0.61	5.3
Ethane	0.03	0.3
Other VOC[b]	0.34	2.9
Nitrogen	89.24	770.1
Oxygen	5.33	46.0
Carbon dioxide	2.79	24.1
Carbon monoxide	0.85	7.3
Total	100.00	863.0

[a] g of emission per kg of ethylene dichloride produced by oxychlorination.

[b] Ethyl chloride, VCM, and other chlorinated hydrocarbons. VCM concentration meets current EPA emission standards.

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per kg of EDC produced have the same ranges and averages. The ethane content of the vent gas from the model plant is calculated based on ethylene containing 0.1% ethane and on ethane being neither consumed nor produced in the oxychlorination reactor. Only inert gases are contained in the hydrogen chloride feed used in the model plant; therefore methane does not appea. in the oxychlorination vent gas.

b. Direct-Chlorination Vent -- The vent gases from the direct-chlorination step (Vent B, Fig. III-1) are primarily the inert gases from the ethylene and hydrogen chloride feeds, unreacted ethylene, and ethylene dichloride not condensed in the cooler. The ethylene dichloride in the vent gases is estimated to be 2 g/kg of the ethylene dichloride produced from the direct-chlorination step. The ethylene feed to the model plant contains 0.1% ethane, which exits with the vent gases along with the unreacted ethylene, estimated to be 3 g/kg of the ethylene dichloride produced by direct chlorination. The chlorine to the model-plant reactor consists 0.5% inert gases, or 3.65 g/kg of direct-chlorination product, which is a significant portion of the vent emissions.

c. Column Vents -- The vent gases from the EDC stripper, the wastewater stripper, the drying column, the heads column, and the EDC finishing column (Vents C, Fig. III-1) are the noncondensables that are dissolved in the feed to the columns, the VOC that are not condensed, and, for the columns operated under vacuum, the air that leaks into the column and is removed by the vacuum jet systems. An estimate was made of the quantity of these emissions, since the available data are scarce and vary widely.[1,2]

d. Storage and Handling Emissions -- Emissions result from the storage of ethylene dichloride, in-process, and liquid-waste streams. Sources for the model plant are shown in Fig. III-1 (Sources D through G). Storage tank parameters for the model plant are given in Table IV-3. The calculated emissions in Table IV-1 are based on fixed-roof tanks, half full, an 11°C diurnal temperature variation, and the use of the emission equations from AP-42.[3]

No handling emissions occur in the model plant, as all raw materials, product, and waste by-products are transported by pipeline. This may not be the case in existing plants, where loading and unloading operations could result in additional emissions.

Table IV-3. Model-Plant Storage Tank Data

Storage Tank	Contents	No. of Tanks Required	Tank Size (m^3)	Turnovers (Per Year)	Bulk Temperature (°C)
In-process storage	Crude EDC	1	1140	6*	27
Liquid waste storage	Light ends	1	380	8	27
Tar storage	Heavy ends	1	380	8	27
Product	EDC	1	3800	12*	27

*These tanks operate at approximately constant level, and the number of turnovers indicated is an attempt to account for slight level variations.

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e. Fugitive Emissions -- Process pumps, process valves, and pressure relief devices are potential sources of fugitive emissions (Source H). The model plant is estimated to have 42 pumps handling VOC, 21 of which handle ethylene dichloride. There are an estimated 1100 valves and 40 pressure relief devices in VOC service, with 550 valves and 20 pressure relief devices in ethylene dichloride service. The fugitive-emission factors from Appendix C were applied to these estimates, and the totals are shown in Table IV-1 as fugitive emissions.

f. Secondary Emissions -- Secondary emissions can result from the handling and disposal of process waste-liquid streams. Two potential sources (I and J) are indicated in Fig. III-1 for the model plant.

The secondary emissions from wastewater treatment (Source I) were estimated by procedures that will be discussed in a future EPA report on secondary emissions. An estimate of wastewater composition and flow rate was made, based on data received from ethylene dichloride producers.[1] A Henry's-law constant was then calculated for the vapor-liquid system under consideration, and the emission rate was estimated by comparison with information given in existing literature, such as an article by Thibodeaux.[4] This emission rate is shown in Table IV-1.

The secondary emissions of total VOC in the flue gases from the liquid chlorinated hydrocarbon incinerator (Source J) were estimated as 1% of feed. Information on these emissions is not presently available, and so the estimate was based on 99% destruction of the liquid feed. Higher than normal temperatures and residence times are required to destroy 99% or more of a liquid chlorinated hydrocarbon feed that contains no salts or solids except for a small amount of finely divided carbon. Before the flue gases are vented to the atmosphere, they are normally sent first to absorbers for recovery of HCl and then to a dilute caustic scrubber to remove unrecovered HCl and any chlorine formed in the incineration. The dilute recovered HCl may be concentrated to anhydrous HCl, which can be used as feed to the oxychlorination reactor.[2]

B. DIRECT-CHLORINATION AND OXYCHLORINATION (OXYGEN) PROCESSES

1. Model Plant

In the model-plant oxychlorination (oxygen) process (Fig. III-2) for producing ethylene dichloride, oxygen is fed to the reactor instead of air. All the capacities for both model plants are identical, i.e., 400,000 Mg/yr of ethylene dichloride from the plant, with 185,000 Mg/yr being produced by the oxychlorination step, etc. Figure III-2 shows only the oxychlorination step. Storage tank requirements and estimates of potential fugitive emission sources and secondary emission sources are also the same as for the air process. Characteristics of the model plant that are important in air dispersion modeling are given in Table B-2 in Appendix B.

2. Sources and Emissions

Emission rates and sources for the balanced ethylene dichloride process based on oxygen are summarized in Table IV-1.

a. Oxychlorination Vent -- The oxychlorination vent gas (Vent A, Fig. III-2) acts as a purge stream to prevent buildup of impurities in the recycle stream (Stream 6, Fig. III-2). These impurities are the carbon oxides, nitrogen, argon, or nonreactive hydrocarbons that enter the reactor with the feed streams or that are formed during the oxychorination reaction itself. Table IV-4 gives the composition of this stream based on an average of data from oxygen based processes[1] but is not representative of actual data from any specific process. The ethane content of the vent gas from the oxygen-based model plant is calculated based on ethylene containing 0.1% ethane and on no ethane being consumed or produced in the oxychlorination reactor. Since the ethylene and hydrogen chloride feed to the model plant contains no methane, no methane is present in these vent gases.

b. Other Emissions -- All other emissions from the the oxygen process are identical to those from the process based on air and are discussed in Sect. IV.A.2.

C. CURRENT EMISSIONS

An estimate of the 1978 emissions from the industry is 11,000 Mg/yr of ethylene dichloride and 35,000 Mg/yr of total VOC, based on an estimated 1978 level of ethylene dichloride production of 4,900,000 Mg/yr obtained by applying a 5% growth

Table IV-4. Composition o odel-Plant Oxychlorination (Oxygen Vent Gas

Component	Composition (wt %)	Emission Ratio[a] (g/kg)
Ethylene dichloride	1.5	1
Ethylene	27.6	18
Ethane	0.5	0.3
Other VOC[b]	1.5	1
Nitrogen	15.3	10
Oxygen	3.1	2
Carbon dioxide	45.9	30
Carbon monoxide	4.6	3
Total	100.0	65.3

[a] g of emission per kg of ethylene dichloride produced by oxychlorination.

[b] Ethyl chloride, VCM, and other chlorinated hydrocarbons.

rate to the reported 1977 production of 4,679,000 Mg/yr.[5] These emission estimates are based on engineering judgement and data from individual ethylene dichloride producers, state and local emission control agencies, and the open literature. The following individual estimated projections were made:

Source	1978 Emissions (Mg/yr) EDC	Total VOC
Process	10,600	33,200
Storage and handling	500	700
Fugitive	60	110
Secondary	90	600
Total (rounded)	11,000	35,000

D. REFERENCES*

1. Responses to EPA requests for information on ethylene dichloride emissions; see Appendix E.

2. W. A. Schwartz et al., Houdry Div., Air Products and Chemicals, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 3: Ethylene Dichloride Manufacture by Oxychlorination, EPA-450/3-73-006-c, Research Triangle Park, NC (November 1974).

3. C. C. Masser, "Storage of Petroleum Liquids," Sect. 4.3 in Supplement No. 7 for Compilation of Air Pollutant Emission Factors, AP-42, 2d ed., EPA, Research Triangle Park, NC (April 1977).

4. L. J. Thibodeaux, "Air Stripping of Organics from Wastewater. A Compendium," pp. 358--378 in The Proceedings of the Second National Conference on Complete Watereuse. Water's Interface with Energy, Air and Solids, Chicago, IL, May 4--8, 1975, sponsored by AIChE and EPA Technology Transfer.

5. "Manual of Current Indicators--Supplemental Data," p. 219 in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (June 1978).

*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

V. APPLICABLE CONTROL SYSTEMS

A. DIRECT-CHLORINATION AND OXYCHLORINATION (AIR) PROCESSES

1. Oxychlorination Vent

The gases from the oxychlorination vent can be thermally oxidized to effectively control the ethylene dichloride (EDC) and VOC in them. Because of the large percentage of nitrogen and carbon dioxide in the vent gases, they must be supplemented by additional fuel for the necessary temperature to be reached. The flue gases from the thermal oxidation of chlorine containing compounds will contain hydrogen chloride (HCl) and a small amount of chlorine, depending on operating temperature,[1] that must be removed before the flue gases are discharged to the atmosphere. The model-plant thermal oxidizer operates at 1100°C and a residence time of 1 sec and has a quench chamber with water sprays to remove the HCl and a tail-gas scrubber to remove any remaining HCl and any chlorine before the flue gases are discharged from the stack. The acid water from the quench chamber and tail-gas scrubber is neutralized with 20% caustic soda and then recycled. A purge stream to waste treatment is required to prevent a buildup of dissolved solids.

With a properly designed and operated thermal oxidizer having a residence time of 1 sec at 1100°C, a reduction of 99% or greater can be achieved in ethylene dichloride and total VOC emissions. This reduction was used for calculation of the controlled emissions from the thermal oxidizer that originated in the oxychlorination vent (see Table V-1). Data and documentation to support these operating conditions will be presented in a future EPA report on emission control systems.

Heat recovery from the thermal oxidizer flue gases can be used to produce steam to provide a credit. Experience with thermal oxidation and heat recovery of vent gases containing chlorinated hydrocarbons is limited but has revealed several problems. The flue gases are corrosive at some temperature conditions. The thermal oxidizer and heat recovery equipment must be operated carefully to prevent the occurrence of the corrosive conditions, especially on startup and shutdown of the unit.[1] One indication of the severity of these problems is the installation by Diamond Shamrock of two parallel, full-capacity, thermal oxidizer systems

Table V-1. EDC and Total VOC Controlled Emissions for Model Plants[a]

Emission Source	Vent or Source Designation (Figs. III-1,2)	Control Device or Technique	Emission Reduction (%)	Emissions			
				Ratio[b] (g/kg)		Rate (kg/hr)	
				EDC	Total VOC	EDC	Total VOC
Oxychlorination vent							
Air process	A	Thermal oxidizer	99 (or greater)	0.0324	0.0717	1.48	3.27
Oxygen process	A[c]	Thermal oxidizer	99 (or greater)	0.00462	0.0939	0.211	4.29
Direct-chlorination vent	B	Thermal oxidizer	99 (or greater)	0.0108	0.0294	0.491	1.30
Column vents	C	Thermal oxidizer	99 (or greater)	0.0300	0.130	1.37	5.94
Storage vents							
In-process	D	Internal floating roof	93	0.00252	0.00252	0.115	0.115
Product	E	Internal floating roof	96	0.00530	0.00530	0.242	0.242
Liquid waste	F	Internal floating roof	91		0.00562		0.256
Tar	G	None			0.00229		0.105
Fugitive	H	Detection and repair of major leaks	92	0.00790	0.0158	0.361	0.721
Secondary							
Wastewater treatment	I	None		0.0181	0.0272	0.829	1.24
Incinerator	J	Change operating conditions	100		Not detectable		
Total for air process				0.11	0.29	4.9	13
Total for oxygen process				0.08	0.31	3.6	14

[a]All emissions are based on 8760 hr of operation per year.

[b]kg of emission per kg of EDC produced by balanced process.

[c]See Fig. III-2 for this source; see Fig. III-1 for other sources.

with heat recovery in their new VCM plant to ensure an on-stream factor of greater than 98%.[2] No thermal oxidizers have been retrofitted to air process oxychlorination vents;[3] however, Borden's recently constructed plant at Geismar has a thermal oxidizer with heat recovery that is fed the vent gases from their oxychlorination (air) step and several other vent gas streams. When visited, their unit had been out of service for modifications to correct design problems and so no actual operating data are yet available.[4]

Two alternatives for the thermal oxidizer for the direct-chlorination and oxychlorination (air) model plant were studied: one with heat recovery to produce steam and one without heat recovery. Both cases have the same emission reduction efficiency, but differ in the size of the quench chamber, caustic scrubber, fan, and pumps because of the different temperatures of the flue gas to the quench chamber that result in different flue gas volumes to be quenched and scrubbed and in different amounts of water that are evaporated.

Several other alternative thermal oxidizer configurations are possible, both with and without heat recovery. An acid scrubber may be used instead of a water quench to recover dilute hydrochloric acid, which may be used in other processes for its acidity or may be neutralized with a cheaper base than caustic soda. Other systems may be used to recover hydrochloric acid at higher concentrations, as well as anhydrous hydrogen chloride.[1,5,6] The thermal oxidizer may be designed to burn both vent gases and liquid chlorinated by-products.[4]

Diamond Shamrock has retrofitted a commercial-sized catalytic oxidizer to their older oxychlorination facility. The unit reportedly does remove carbon monoxide and ethylene with better than 99.7% reduction; however, it removes less than 75% of the ethylene dichloride and less than 60% of the VCM, with 100 ppm of ethylene dichloride and 8 ppm of VCM remaining in the stack gases.[7] For this reason a catalytic oxidizer at its present state of development is not judged to be an adequate control device for the oxychlorination (air) process.

Another device that reduces the ethylene in the oxychlorination vent gases is a "post" reactor, where chlorine is added to chlorinate the residual ethylene to ethylene dichloride. Conoco, Shell, and Stuaffer have installed this type of control.[3] Reportedly complete ethylene conversion is obtained, with the residual

concentration in the vent gas being as low as 10 ppm of ethylene.[8] Data from plant using this technology show only 0.02 wt % of ethylene but 0.75 wt % of ethylene dichloride and 2 wt % of total VOC in the vent gas after it has been refrigerated to subzero temperature and then scrubbed with water.[3]

Other devices, such as refrigerated vent condensers and hydrocarbon or chilled water absorbers, do remove some ethylene dichloride and total VOC from the vent gas; however, they leave significant quantities to go to the atmosphere.[1,3] These types of controls are used by Allied, Conoco, Goodrich, Ethyl, Shell, and Vulcan. Conoco and Shell also have a post reactor, as previously mentioned.[3]

2. Direct-Chlorination Vent

The emissions from the direct-chlorination vent can be controlled by piping them to the thermal oxidizer used for controlling the oxychlorination vent gas as discussed in Sect. A.1 or to a vapor and liquid thermal oxidizer serving other processing units.[3] A reduction of 99% was used in the calculations of the controlled emissions from the thermal oxidizer that originate in the direct-chlorination vent (see Table V-1). Borden, Dow, PPG, and Shell burn the vent gases from their direct-chlorination reactors in thermal oxidizers. Union Carbide sends them to a flare after scrubbing.[3]

Other devices that may be used to control the emissions from the direct-chlorination vent are refrigerated vent condensers, scrubbers, and flares, or a combination of these, depending on the composition of the vent gases. If properly designed, a refrigerated vent condenser is effective for removal of ethylene dichloride (approximately 96% if the vent gases are cooled from 35°C to -26°C at 240 kPa), although the unreacted ethylene and ethane will remain. Scrubbers may absorb some ethylene dichloride depending on the operating conditions, but are primarily installed for removal of hydrogen chloride and unreacted chlorine.[1]

Conoco plans to install a vent gas incinerator to burn all the vent gases from their ethylene dichloride facility except for those from the oxychlorination vent. At present all gases are sent to a water scrubber and then vented to the atmosphere. The direct-chlorination vent gas also passes through a refrigerated vent condenser. At Diamond Shamrock's older plant the direct-chlorination vent gas is sent through a refrigerated vent condenser and then a water scrubber,

but at their newer facility the vent gas is burned in a thermal oxidizer. Goodrich uses a refrigerated vent condenser to minimize their direct-chlorination vent emissions. Allied Chemical has piped the gas from the direct-chlorination vent into the oxychlorination reactor. The removal efficiency for ethylene dichloride or total VOC was not reported.[3]

3. Column Vents

The emissions from the column vents can also be effectively controlled by piping them to the thermal oxidizer used for controlling the emissions from the oxychlorination and direct-chlorination vents or to a vapor and liquid thermal oxidizer serving other processing units.[1,3] A reduction of 99% was used in the calculations of the controlled emissions from the thermal oxidizer that originated in the column vents (see Table V-1).

The same devices discussed above for the direct-chlorination vent are used to control the gases from the column vents and the same conditions apply to their use and effectiveness. Borden, Conoco (future plans), Diamond Shamrock's new facility, Dow, PPG, and Shell send their column vent gases to their thermal oxidizer. Allied, Goodrich, and Vulcan have vent condensers on their column vents, and Allied plans to recycle their column vent gases to various parts of the process. The inert gases are dissolved in the column feeds and leak into the vacuum columns, with the quantity varying widely.[3] The amount of these inert gases can have a considerable impact on the reduction efficiency of a refrigerated vent condenser, as discussed above.

4. Storage Vents

The emissions from the model-plant storage tanks are controlled by use of internal-floating-roof tanks.* Because the stored materials are chlorinated and may contain dissolved hydrogen chloride, the construction materials for the floating roof and seals must be carefully selected. Options for control of storage emissions are covered in a recent EPA report.[9] Guidelines for storage-emission control techniques will be given in a future EPA document.

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*Consist of internal floating covers or covered floating roofs as defined in API 25-19, 2d ed., 1976 (fixed-roof tanks with internal floating device to reduce vapor loss.

According to information received from companies producing ethylene dichloride, the crude ethylene dichloride, the product ethylene dichloride, the lights, and the heavies are stored in fixed-roof tanks. Often the crude ethylene dichloride is stored under a water layer, which will reduce the emissions somewhat. A nitrogen blanket is sometimes employed to keep the product ethylene dichloride dry. Emissions can also be controlled by using refrigerated vent condensers and by piping the storage tank vents to a thermal oxidizer.[3]

The controlled storage emissions given in Table V-1 were calculated with equations from AP-42[10] modified to reduce the calculated floating-roof-tank withdrawal loss as indicated in the recent EPA report on storage and handling.[9]

Refrigerated vent condensers are used by Diamond Shamrock and Dow to control tank emissions, while the gases from the tank vent condensers in Diamond Shamrock's new plant and from some of Shell's ethylene dichloride storage tanks go to their thermal oxidizers. Allied, Diamond Shamrock, Conoco, and Goodrich maintain a water layer on their crude ethylene dichloride. Conoco, PPG, and Shell use scrubbers on some of their storage tank vents.[3]

5. Fugitive Emissions

Controls for fugitive emissions from the synthetic organic chemicals manufacturing industry will be discussed in a future EPA document. Emissions from pumps, process valves, and pressure relief devices can be controlled by an appropriate leak-detection system and with repair and maintenance as needed. Controlled fugitive emissions were calculated with the appropriate factors given in Appendix C and are included in Table V-1.

6. Secondary Emissions

a. Wastewater Treatment -- Calculations based on estimated wastewater flow rates and compositions for the model plant indicate that the emissions from the wastewater treatment are relatively small. No control system has been identified for the model plant.

b. Liquid Chlorinated Hydrocarbon Incinerator -- Control of the secondary emissions from the liquid chlorinated hydrocarbon incinerator consists of changing the incinerator operating conditions. Data on the relationship of emissions to

operating conditions are not available at this time. Some information indicates that higher temperatures and longer residence times are probably helpful in reducing these secondary emissions.[5,11--13] Levels of organic chlorides in the flue gases from the liquid chlorinated hydrocarbon incinerators have been reported to be none and 30 ppm by weight.[14,15] The controlled secondary emissions from the model-plant liquid chlorinated hydrocarbon incinerator are estimated to be nondetectable, as indicated in Table V-1.

B. DIRECT-CHLORINATION AND OXYCHLORINATION (OXYGEN) PROCESSES

1. Oxychlorination Vent

The vent gases from the oxychlorination vent when oxygen is used as the feed contain much less nitrogen than when air is used and can support combustion with little or no supplemental fuel required. A thermal oxidizer is used by Dow and PPG to control emissions from their oxygen-based oxychlorination process.[3] An emission reduction of 99% was used to calculate the controlled emissions from the thermal oxidizer that originated in the model-plant oxychlorination vent (see Table V-1). With a properly designed and operated thermal oxidizer having a residence time of 1 sec at 1100°C a reduction of 99% or greater can be achieved in ethylene dichloride and total VOC emissions. Data and documentation to support these operating conditions will be presented in a future EPA report on emission control systems.

Heat recovery from the thermal oxidizer flue gases can be used to produce steam. The same problems discussed in Sect. A.1 will apply to this case. Both PPG and Dow have indicated plans to incorporate heat recovery in their thermal oxidizers.[3]

2. Other Vents

The control systems and controlled emissions for the model-plant direct-chlorination vent, column vents, storage vents, fugitive sources, and secondary sources are the same as for the air process model plant (see Table V-1).

C. REFERENCES*

1. W. A. Schwartz et al., Houdry Div., Air Products and Chemicals, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 3: Ethylene Dichloride Manufacture by Oxychlorination, EPA-450/3-73-006-c, Research Triangle Park, NC (November 1974).

2. Texas Air Control Board, A Construction Permit...to Diamond Shamrock Chemical Company Authorizing Construction of Vinyl Chloride Plant...at La Porte, Harris County, Texas, Permit No. C-3855 (Nov. 2, 1976).

3. Responses to EPA requests for information on ethylene dichloride emissions; see Appendix E.

4. J. A. Key, Hydroscience, Inc., Trip Report for Visit to Borden Chemical, Geismar, Louisiana, March 2, 1978 (data on file at EPA, ESED, Research Triangle Park, NC).

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7. W. R. Taylor, letter to EPA from Diamond Shamrock Corporation, Deer Park, TX. Oct. 3, 1977, in response to EPA request for information on the catalytic oxidation unit.

8. P. Reich, "Air or Oxygen for VCM?" Hydrocarbon Processing 55(3), 85-89 (1976).

9. D. G. Erikson, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry -- Storage and Handling Report (draft report on file at EPA, ESED, Research Triangle Park, NC) (October 1978).

10. C. C. Masser, "Storage of Petroleum Liquids," Sect. 4.3 in Supplement No. 7 for Compilation of Air Pollutant Emission Factors, AP-42, 2d ed., EPA, Research Triangle Park, NC (April 1977).

11. S. B. Farbstein and J. Elder, Energy Conservation in the Chemical Industry Through New Process Development -- The B. F. Goodrich Catoxid Process, paper presented before the Federal Energy Administration Project Independence Hearing, San Francisco, CA, Oct. 7, 1974.

12. R. E. Van Ingen, letter to EPA from Shell Oil Company, Norco, LA, Dec. 6, 1974, in response to EPA request for information on vinyl chloride monomer operations.

13. T. T. Shen et al., "Incineration of Toxic Chemical Wastes," Pollution Engineering 10(10), 45--50 (1978).

14. J. A. Mullins, letter to EPA from Shell Oil Company, Deer Park, TX, June 22, 1978, in response to EPA request for information on ethylene dichloride manufacture.

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15. J. A. Key, Hydroscience, Inc., Trip Report for Visit to Dow Chemical, U.S.A. Oyster Creek Division, Freeport, TX, September 20, 1977 (data on file at EPA, ESED, Research Triangle Park, NC).

*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

VI. IMPACT ANALYSIS

A. ENVIRONMENTAL AND ENERGY IMPACTS

1. Direct-Chlorination and Oxychlorination (Air) Processes

Table VI-1 shows the environmental impact of reducing the ethylene dichloride (EDC) and VOC emissions by application of the indicated control systems to the air process model plant. Use of these control devices or techniques results in the reduction of EDC emissions by 3000 Mg/yr and total VOC emissions by 9400 Mg/yr for the model plant.

a. Process Vents -- The thermal oxidizer used for control of emissions from vents A [oxychlorination (air)], B (direct chlorination), and C (column vents) (Fig. III-1) reduces the air process model plant EDC emissions by 2900 Mg/yr and total VOC emissions by 9100 Mg/yr.

The thermal oxidizer uses natural gas as supplemental fuel and electric power for the blowers, pumps, lighting, and instruments. The total energy required to operate the thermal oxidizer for the air process model plant is approximately 26 GJ/hr. If heat recovery equipment is installed and approximately 70% of the available energy from the combustion gases is recovered as steam, the amount of steam produced will be about 37 GJ/hr. Since a balanced VCM plant consumes a substantial quantity of steam above that produced in the oxychlorination reactor system, this steam can usually be utilized on-site.[1,2]

The combustion of chlorinated compounds in the thermal oxidizer produces hydrogen chloride (HCl) and free chlorine, which leave in the flue gases. In the removal and neutralization of these acid gases by the model plant's quench chamber, tail gas scrubber, and neutralization sump, 7600 Mg of salt in dilute solution is produced annually. Plants located near the ocean can dispose of this salt solution without major problems.[3] Others may find it more economical to use alternative systems for removal of HCl and chlorine that produce a dilute hydrochloric acid solution as discussed in Sect. V.

b. Other Emissions (Storage, Fugitive, and Secondary -- Control methods described for these sources for the model plants are internal-floating-roof storage tanks,

Table VI-1. Environmental Impact of Controlled Ethylene Dichloride for Model Plants

Emission Source	Vent or Source Designation (Figs. III-1,2)	Control Device or Technique	Emission Reduction (%)	Emission Reduction[a] (Mg/yr) EDC	Emission Reduction[a] (Mg/yr) Total VOC
Oxychlorination vent					
Air process	A	Thermal oxidizer	99	1280	2840
Oxygen process	A[b]	Thermal oxidizer	99	183	3720
Direct chlorination vent	B	Thermal oxidizer	99	425	1130
Column vents	C	Thermal oxidizer	99	1190	5150
Storage vents					
In-process	D	Internal floating roof	93	12.6	12.6
Product	E	Internal floating roof	96	47.4	47.4
Liquid waste	F	Internal floating roof	91		23.9
Tar	G	None			
Fugitive	H	Detection and repair of major leaks	92	35.0	70.0
Secondary					
Wastewater treatment	I	None			
Incinerator	J		100		76.0
Total for air process				3000	9400
Total for oxygen process				1900	10,200

[a]Annual reduction is based on 8760 hr of operation.

[b]See Fig. III-2 for this vent source; see Fig. III-1 for all other sources.

leak repair for fugitive emissions, and change of operating conditions for the liquid waste incinerator.

Application of these systems results in an EDC emission reduction of 95 Mg/yr and a VOC emission reduction of 230 Mg/yr for the model plants. Internal-floating-roof tanks for emission control neither consume energy nor have adverse environmental or energy impacts.

2. Direct-Chlorination and Oxychlorination (Oxygen) Processes

Table VI-1 shows the environmental impact of reducing the EDC and VOC emissions by application of the indicated control systems to the oxygen-process model plant. Application of these control devices or techniques results in the reduction of EDC emissions by 1900 Mg/yr and total VOC emissions by 10,200 Mg/yr for the model plant.

a. Process Vents -- The thermal oxidizer used for control of emissions from vent A (Fig. III-2) and vents B and C (Fig. III-1) reduces the model-plant EDC emission by 1800 Mg/yr and total VOC emissions by 10,000 Mg/yr.

The thermal oxidizer for the model plant does not require supplemental fuel, because the vent gases from the process vents are self-combustible. The energy required as electric power for the blowers, pumps, lighting, and instruments is approximately 0.25 GJ/hr. If heat recovery equipment is installed and approximately 70% of the available energy from the combustion gases is recovered as steam, about 27 GJ of steam will be produced per hour.

The removal and neutralization of the acid gases from the thermal oxidizer flue gases will produce about 5900 Mg/yr of salt from the model plant.

b. Other Emissions (Storage, Fugitive, and Secondary) -- The control methods and environmental and energy impacts for these sources in the oxygen-process model plant are identical to those of the air-process model plant; see Sect. VI.A.1.b.

B. CONTROL COST IMPACT

This section gives estimated costs and cost-effectiveness data for control of ethylene dichloride and total VOC emissions resulting from the production of

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ethylene dichloride. Details of the model plant (Figs. III-1 and III-2) are given in Sects. III and IV. Cost estimate calculations are included in Appendix D.

Capital cost estimates represent the total investment required for purchase and installation of all equipment and material needed for a complete emission control system performing as defined for a new plant at a typical location. These estimates do not include the cost of ethylene dichloride production lost during installation or startup, research and development, or land acquisition. Costs for retrofitting these systems in existing plants may be greater than for a new installation. The primary difficulty in retrofitting may be in finding space to fit the system into the existing plant layout.

Bases for the annual cost estimates for the control alternatives include utilities, waste disposal, chemicals, operating labor, maintenance supplies and labor, recovery credits, capital charges, and miscellaneous recurring costs such as taxes, insurance and administrative overhead. The cost factors used are itemized in Table VI-2. The capital recovery factor of 0.1628 is based on an assumed 10-year life and a 10% annual interest rate. Recovery credits are based on the market value for the material being recovered. Annual costs are for a 1-year period beginning in mid-1978.

1. Direct-Chlorination and Oxychlorination (Air) Processes

a. Process Vents -- The estimated installed capital cost of a thermal oxidizer designed to reduce by 99% or greater the ethylene dichloride and total VOC from the process vents in the model plant is $1.305 million (see Table VI-3). If waste heat recovery is included to reduce the operating cost, the estimated installed capital cost is $1.234 million. These costs are based on a thermal oxidizer designed for a residence time of 1 sec at 1100°C, completely installed, and includes a quench chamber, tail gas scrubber, sump, pumps, blower, and stack. The use of heat recovery reduces the temperature, and therefore the volume, of the flue gases to the quench and scrubber, which consequently will be smaller. Because of the large mass flow of flue gases the reduction in cost of the quench and scrubber more than compensates for the cost of the heat recovery equipment, and the total cost of a thermal oxidizer with heat recovery is less than one without heat recovery.

Table VI-2. Cost Factors Used in Computing Annual Costs

Utilities	
Natural gas	$1.90/GJ
Electricity	$8.33/GJ ($0.03/kWh)
Cooling water	$0.026/$m^3$
Liquid waste disposal	$3.00/$m^3$
Maintenance material and labor	0.05 X capital cost
Capital charges	
Capital recovery	0.1628 X capital cost
Miscellaneous (taxes, insurance, administration)	0.04 X capital cost
Recovery credit* (energy)	$1.90/GJ
Chemical cost* (50% caustic soda solution)	$0.11/kg

*See Appendix D.

Table VI-3. Cost Estimates for Control of Emissions from Process Vents for Ethylene Dichloride Model Plants

Control	Total Installed Capital Cost	Annual Operating Costs								(B) Emission Reduction			(C)[a] Cost Effectiveness	
		Utilities	Chemicals	Manpower	Maintenance	Capital Recovery	Misc. Capital	Waste Disposal	Recovery Credits	(A) Net Annual	EDC (Mg/yr)	Total VOC (Mg/yr)	(%)	EDC	Total VOC
Direct-Chlorination and Oxychlorination (Air) Processes															
Thermal oxidizer															
With heat recovery	$1,234,000	$458,000	$1,139,000	$35,000		$312,000		$2,050,000	$622,000	$3,372,000	2,900	9,100	99	$1,163	$371
Without heat recovery	1,305,000	463,000	1,139,000	35,000		330,000		2,050,000	None	4,017,000	2,900	9,100	99	1,385	441
Direct-Chlorination and Oxychlorination (Oxygen) Processes															
Thermal oxidizer															
With heat recovery	$1,117,000	$ 36,000	$ 894,000	$35,000		$282,000		$1,629,000	$451,000	$2,423,000	1,800	10,000	99	$1,346	$242
Without heat recovery	1,083,000	36,000	894,000	35,000		274,000		1,629,000	None	2,866,000	1,800	10,000	99	1,592	287

[a](C) = (A) ÷ (B).

The process-vent-gas rate varies directly with the production rate; therefore the capacity of the thermal oxidizer will depend on the capacity of the plant. Figure VI-1 was plotted to show the variation of installed capital cost of a thermal oxidizer, with and without heat recovery, versus plant capacity.

To determine the cost effectiveness of a thermal oxidizer, estimates were made of the direct operating cost, the capital recovery cost, and miscellaneous capital costs, both with and without heat recovery. The recovery credit was calculated for the heat recovery case based on recovery of approximately 70% of the energy in the flue gases valued as equivalent to natural gas at $1.90/GJ and not for the steam that may be generated. The net annual cost for each case was then calculated (see Table VI-3) and plotted in Fig. VI-2 to show the variation with plant capacity for both cases. The cost effectiveness for each case for controlling both ethylene dichloride and total VOC was calculated from the net annual cost and the emission reduction (see Table VI-3).

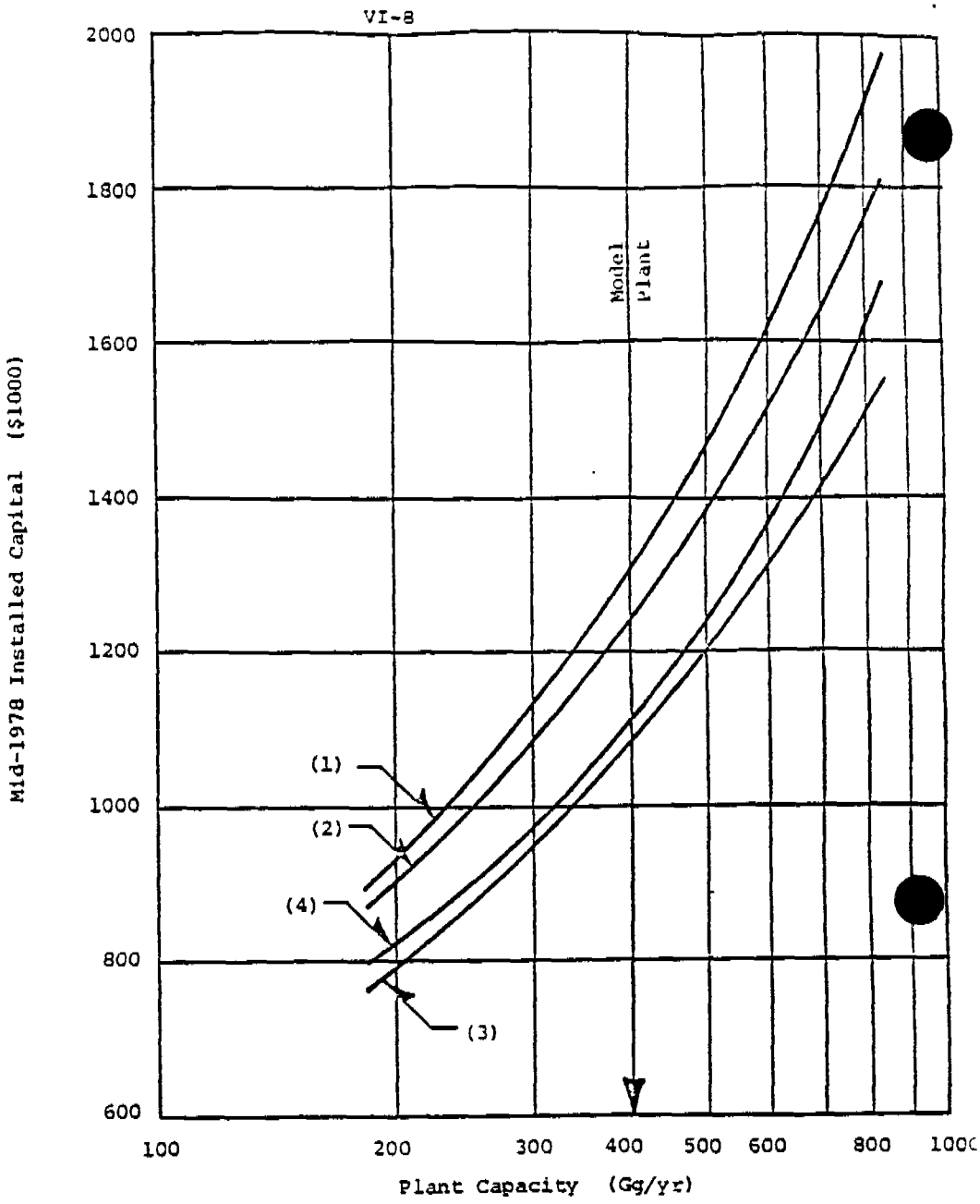
b. Storage Sources -- The control system for storage sources is use of floating-roof tanks. Another EPA report covers storage and handling emissions and their applicable controls for all the synthetic organic chemicals manufacturing industry.[4]

c. Fugitive Sources -- A control system for fugitive sources is defined in Appendix C. A future document will cover fugitive emissions and their applicable controls for all the synthetic organic chemicals manufacturing industry.

d. Secondary Sources -- No control system has been identified for controlling the secondary emissions from wastewater treatment. The secondary emissions from the incinerator can be controlled by changing operating conditions. A future EPA document will cover secondary emissions and their applicable controls for all the synthetic organic chemicals manufacturing industry.

2. Direct-Chlorination and Oxychlorination (Oxygen) Processes

a. Process Vents -- The estimated installed capital cost of a thermal oxidizer designed to reduce by 99% or greater the ethylene dichloride and total VOC from the process vents in the oxygen-process model plant is $1.117 million with heat



(1) Thermal oxidation without heat recovery, air process
(2) Thermal oxidation with heat recovery, air process
(3) Thermal oxidation without hear recovery, oxygen process
(4) Thermal oxidation with heat recovery, oxygen process

Fig. VI-1. Installed Capital Cost vs Plant Capacity for Emission Control by Thermal Oxidation

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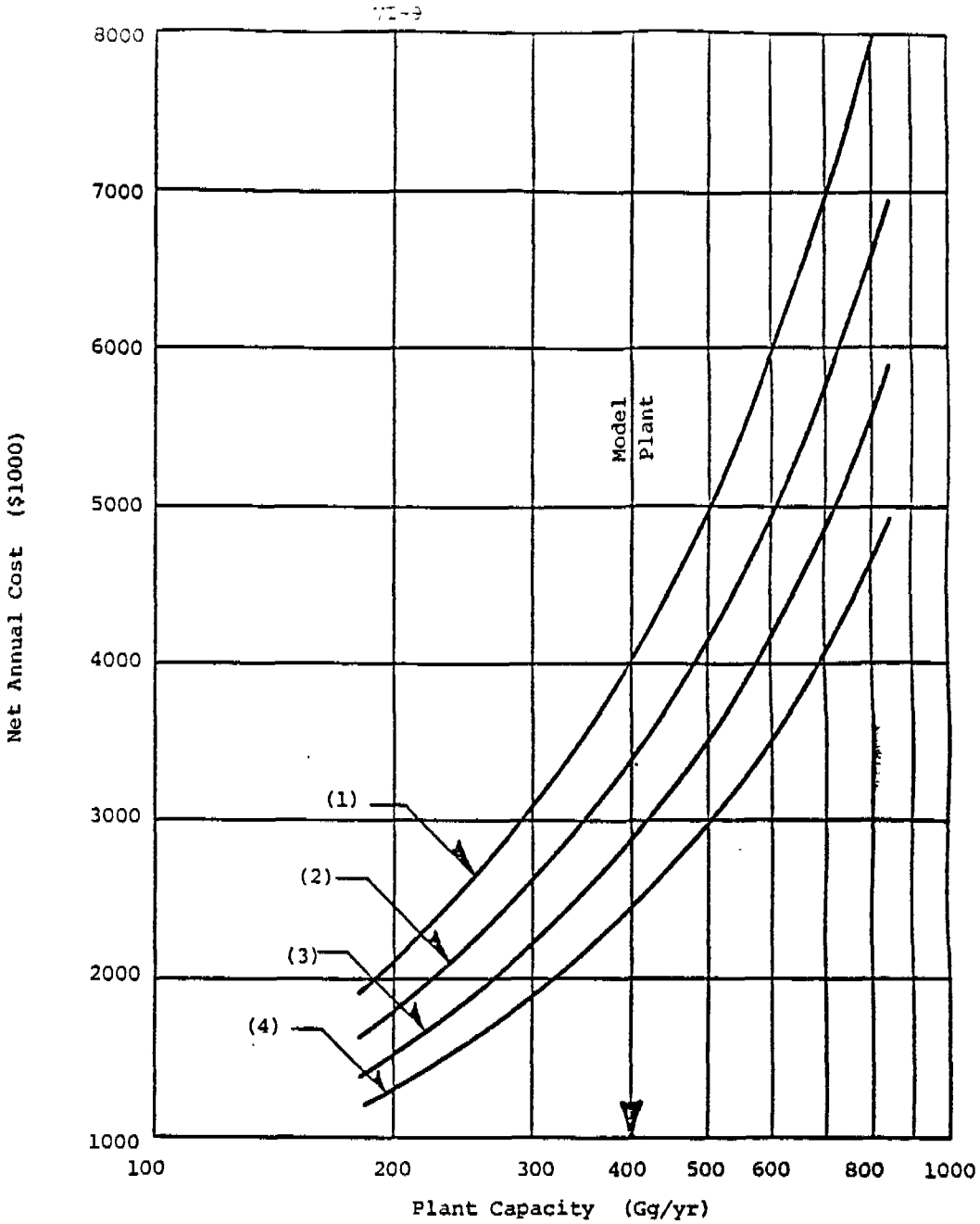

(1) Thermal oxidation without heat recovery, air process
(2) Thermal oxidation with heat recovery, air process
(3) Thermal oxidation without heat recovery, oxygen process
(4) Thermal oxidation with heat recovery, oxygen process

Fig. VI-2. Net Annual Cost vs Plant Capacity for Emission Control by Thermal Oxidation

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recovery and $1.083 without heat recovery (see Table VI-3). These costs are based on a thermal oxidizer designed for a residence time of 1 sec at 1100°C, completely installed, and includes a quench chamber, tail gas scrubber, sump, pumps, blower, and stack.

Figure VI-1 shows the variation of installed capital cost of a thermal oxidizer, with and without heat recovery, versus plant capacity.

The cost effectiveness was calculated as described above for the air-process thermal oxidizer (see Table VI-3). The net annual costs for oxygen-process thermal oxidizers with and without heat recovery are given in Table VI-3 and the variations with plant capacity are shown in Fig. VI-2.

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C. REFERENCES*

1. W. A. Schwartz et al., Houdry Div., Air Products and Chemicals, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 3: Ethylene Dichloride Manufacture by Oxychlorination, EPA-450/3-73-006-c, Research Triangle Park, NC (November 1974).

2. P. Reich, "Air or Oxygen for VCM?" Hydrocarbon Processing 55(3), 85--89 (1976).

3. C. G. Bertram, "Minimizing Emissions from Vinyl Chloride Plants," Environmental Science and Technology 11(9), 864--868 (1977).

4. D. G. Erikson, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry--Storage and Handling Report (draft report on file at EPA, ESED, Research Triangle Park, NC) (October 1978).

*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

VII. PRODUCT ASSESSMENT

A. SUMMARY

Ethylene dichloride (EDC) is produced by the direct chlorination of ethylene and by the oxychlorination of ethylene with hydrogen chloride (HCl) and oxygen or air, often in a balanced plant, where the EDC is used to make vinyl chloride monomer (VCM) and with hydrogen chloride (HCl) produced as by-product. The HCl is recycled and the ethylene dichloride product is about evenly split between the direct-chlorination step and the oxychlorination step.[1--3]

The annual growth rate of ethylene dichloride production is estimated to be 4 to 5%,[1] and production is projected to utilize 85 to 89% of 1977 capacity by 1982.

Emission sources and uncontrolled and controlled emission rates for the direct-chlorination and the oxychlorination (air and oxygen) processes are given in Table VII-1. The current emissions projected for the domestic ethylene dichloride industry based on the estimated degree of control existing in 1978 are 11,000 Mg of ethylene dichloride per year and 35,000 Mg of total VOC per year. Control devices for operating plants include thermal oxidizers, catalytic oxidizers, vent condensers, scrubbers, and vent-gas post reactors. Emission reduction of 99% or greater may be realized in a thermal oxidizer. The installed capital cost of a thermal oxidizer for the air-based-process model plant is $1.234 million with heat recovery and $1.305 without heat recovery; for the oxygen-based-process model plant it is $1.117 million with heat recovery and $1.083 million without heat recovery. Supplemental fuel is required for the combustion of the gases from the direct-chlorination, oxychlorination (air), and column vents but not for the oxygen-process vents because those gases contain much less nitrogen and are self-combustible.

For the thermal oxidizer on the direct-chlorination and oxychlorination (air) model-plant[2] vents the cost effectiveness for ethylene dichloride is $1163/Mg if heat is recovered and $1385/Mg if it is not. The cost effectiveness for total VOC is $371/Mg with heat recovery and $441/Mg without heat recovery. The cost effectiveness of the thermal oxidizer on the direct-chlorination and oxychlorination (oxygen) model-plant vents is $1346/Mg of ethylene dichloride and $242/Mg

Table VII-1. Emission Summary for Model Plants[a]

Emission Source	Vent or Source Designation (Figs. III-1,2)	Emission Rate (kg/hr) Uncontrolled EDC	Uncontrolled Total VOC	Controlled EDC	Controlled Total
Oxychlorination vent					
For air process	A	148	327	1.48	3.27
For oxygen process	A[b]	21.1	429	0.211	4.29
Direct-chlorination vent	B	49.1	130	0.491	1.30
Column vents	C	137	594	1.37	5.94
Storage vents					
In-process	D	1.55	1.55	0.115	0.115
Product	E	5.65	5.65	0.242	0.242
Liquid waste	F		2.98		0.256
Tar	G		0.105		0.105
Fugitive	H	4.36	8.72	0.361	0.721
Secondary					
Wastewater treatment	I	0.829	1.24	0.829	1.24
Incinerator	J		8.68		
Total for air process		350	1100	4.9	13
Total for oxygen process		220	1200	3.6	14

[a]All emissions are based on 8760 hr of operation per year.

[b]See Fig. III-2 for this source; see Fig. III-1 for all other sources.

of total VOC if heat is recovered or $1592/Mg of ethylene dichloride and $287/Mg of total VOC without heat recovery. Approximately 37 GJ of steam per hour is produced from the air-process thermal oxidizer flue gases at approximately 70% recovery and about 27 GJ/hr from the oxygen-process gases at the same recovery.

B. SUPPLEMENTAL INFORMATION

Process emissions from the model plants are based on emission data included in trip reports, responses to EPA letters requesting information from sites not visited, and the Houdry reports.[4--6] Nonconfidential information from emission inventory questionnaires submitted to the Texas Air Control Board and the Louisiana Air Control Commission was also used as an emission data source. Literature sources, such as the SRI Chemical Economics Handbook and the Kirk-Othmer Encyclopedia of Chemical Technology, were utilized to gain a better understanding of process unit operations and process chemistry. The data on emissions from individual distillation columns were generally not available and the small amount of data on distillation emissions that was given showed wide variations.[4]

The operating costs for the thermal oxidizers include the cost of neutralizing the HCl produced. If HCl recovery is included as part of the thermal oxidizer system, the costs may be more favorable.

C. REFERENCES*

1. J. L. Blackford, "Ethylene Dichloride," pp. 651.5031A--651.5033I in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (November 1975).

2. P. Reich, "Air or Oxygen for VCM?" Hydrocarbon Processing 55(3), 85--89 (1976).

3. W. E. Wimer and R. E. Feathers, "Oxygen Gives Low Cost VCM," Hydrocarbon Processing 55(3), 81--84 (1976).

4. R. G. Bellamy and W. A. Schwartz, Houdry Div., Air Products and Chemicals, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 8: Vinyl Chloride Manufacture by the Balanced Process, EPA-450/3-73-006-h, Research Triangle Park, NC (July 1975).

5. W. A. Schwartz, et al, Houdry Div., Air Products and Chemicals, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 3: Ethylene Dichloride Manufacture by Oxychlorination, EPA-450/3-73-006-c, Research Triangle Park, NC (November 1974).

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*A reference located at the end of a paragraph usually refers to the entire paragraph. If another reference relates to certain portions of the paragraph, the reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

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APPENDIX A

PHYSICAL PROPERTIES OF EDC

APPENDIX B
AIR-DISPERSION PARAMETERS

Table B-1. Atmospheric-Dispersion Parameters for Ethylene Dichloride Model Plants (Air) (Capacity, 400,000 Mg/yr), Controlled and Uncontrolled

Source	Emission Rate (g/sec) EDC	Emission Rate (g/sec) Total VOC	Tank Height (m)	Tank Diameter (m)	Stack Height (m)	Stack Diameter (m)	Discharge Temperature (K)	Flow Rate (m^3/sec)	Discharge Velocity (m/sec)
Uncontrolled Emissions									
Oxychlorination vent	41.1	90.9			50	0.6	300	4.34	15.4
Direct-chlorination vent	13.6	36.1			30	0.1	300	0.0419	5.34
Column vents	38.1	165			20	0.2	300	0.218	6.94
Storage vents									
In process	0.43	0.43	9.8	12.2			300		
Product	1.57	1.57	12.2	19.9			300		
Liquid waste		0.83	9.8	7.0			300		
Tar		0.029[b]	9.8	7.0			300		
Fugitive	1.21[a]	2.42							
Secondary									
Wastewater treatment	0.23[b]	1.24[b]							
Incinerator		2.41			30	0.6	340	1.45	5.12
Controlled Emissions									
Thermal oxidizer with heat recovery	0.929	2.92			30	1.0	330	10.4	13.2
Thermal oxidizer without heat recovery	0.929	2.92			30	1.2	350	15.6	13.8
Storage vents									
In-process	0.032	0.032	9.8	12.2			300		
Product	0.067	0.067	12.2	19.9			300		
Liquid waste		0.071	9.8	7.0			300		
Fugitive	0.10[b]	0.20[b]							
Secondary									
Incinerator		N.D.[c]			30	0.6	340	1.45	5.12

[a] Distributed over an area of 100 m by 200 m.

[b] No control specified.

[c] None detectable.

Table B-2. Atmospheric-Dispersion Parameters for Ethylene Dichloride Model Plant (Oxygen) (Capacity, 400,000 Mg/yr), Controlled and Uncontrolled

Source	Emission Rate (g/sec) EDC	Emission Rate (g/sec) Total VOC	Tank Height (m)	Tank Diameter (m)	Stack Height (m)	Stack Diameter (m)	Discharge Temperature (K)	Flow Rate (m^3/sec)	Discharge Velocity (m/sec)
Uncontrolled Emissions									
Oxychlorination vent	5.87	119			50	0.2	300	0.272	8.7
Direct-chlorination vent	13.6	36.1			30	0.1	300	0.0419	5.34
Column vents	38.1	165			20	0.2	300	0.218	6.94
Storage vents									
In-process	0.41	0.43	9.8	12.2			300		
Product	1.57	1.57	12.2	19.9			300		
Liquid waste		0.83	9.8	7.0			300		
Tar		0.029[b]	9.8	7.0			300		
Fugitive	1.21[a]	2.42							
Secondary									
Wastewater treatment	0.23[b]	1.24[b]							
Incinerator		2.41			30	0.6	340	1.45	
Controlled Emissions									
Thermal oxidizer with heat recovery	0.576	3.20			30	0.9	330	7.16	11.6
Thermal oxidizer without heat recovery	0.576	3.20			30	1.0	350	11.0	14.0
Storage vents									
In-process	0.032	0.032	9.8	12.2			300		
Product	0.067	0.067	12.2	19.9			300		
Liquid waste		0.071	9.8	7.0			300		
Fugitive	0.10[b]	0.20[b]							
Secondary									
Incinerator		N.D.[c]			30	0.6	340	1.45	5.12

[a] Distributed over an area of 100 m by 200 m.

[b] No control specified.

FUGITIVE EMISSION FACTORS

Fugitive emission factors established for petroleum refinery operation and published in AP-42 are based on emission quantities per unit throughput and therefore are unsatisfactory for use here.[1] The emission factors for each equipment component used in this report are based on the orginal emission studies[2--4] used to establish the AP-42 factors with assumptions as follows:

1. Pump Seals (including standby pumps)
   a. "Uncontrolled" is the average loss measured for mechanical seals.
   b. "Controlled" is the average loss for mechanical seals, with major leaks assumed to be fixed.

	Uncontrolled	Controlled
Pump seals (kg/day/seal)	1.5	0.16

2. Compressor Seals
   a. "Uncontrolled" is the average loss measured for all seals venting to atmosphere.
   b. "Controlled" is the average loss based on the large leaks being fixed.

	Uncontrolled	Controlled
Compressor seals (kg/day/seal)	3.9	1.0

3. Valves
   a. "Uncontrolled" is the average loss measured for all valves.
   b. "Controlled" is the average loss, with the large leaks assumed to be fixed.

	Uncontrolled	Controlled
Pipeline valves (kg/day/valve)	0.068	0.006

4. Pressure Relief Devices

   a. "Uncontrolled" is the average loss meas for all valves.

   b. "Controlled" is the average loss based on the assumption that the large leaks are fixed.

	Uncontrolled	Controlled
Pressure relief devices (kg/day/valve)	1.1	0.1

* * * * *

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[1]W. M. Vatavak, "Petroleum Industry," pp. 9.1-1 to 9.1-8 in Compilation of Air Pollutant Emission Factors, 2d ed., AP-42, EPA, Research Triangle Park, NC (March 1975).

[2]R. K. Palmer, Hydrocarbon Losses from Valves and Flanges. Report No. 2, PB-216-682, Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, CA (March 1957).

[3]B. J. Steigerwald, Emissions of Hydrocarbons to the Atmosphere from Seals on Pumps and Compressors. Report No. 6, PR-216-582, Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, CA (April 1958).

[4]B. J. Steigerwald, Hydrocarbon Leakage from Pressure Relief Valves. Report No. 3, PB-216-715, Joint District, Federal and State Project for the Evaluation of Refinery Emissions. Air Pollution Control District, County of Los Angeles, CA (May 1957).

*Usually, when a reference is located at the end of a paragraph, it refers to the entire paragraph. If another reference relates to certain portions of that paragraph, that reference number is indicated on the material involved. When the reference appears on a heading, it refers to all the text covered by that heading.

APPENDIX C

FUGITIVE-EMISSION FACTORS

Vapor pressure	
Melting point	
Boiling point	
Density	
Physical state	
Vapor density	
Water solubility	

*From: J. Dorigan et al., "Ethylene Dichloride," p. AII-270 in Appendix II, Rev 1, Scoring of Organic Pollutants. Chemistry, Production and Toxicity of Selected Organic Chemicals (Chemicals D--E), MTR-7248, MITRE Corp. (September 1976).

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36. D. E. Gilbert, Vulcan Materials Company, letter to EPA with information on oxychlorination process at Geismar, Louisiana, Apr. 23, 1974.

37. G. A. Vlacos, Louisiana Air Control Commission Emission Inventory Questionnaire for Vulcan Materials Company Geismar, Louisiana Plant, Aug. 16, 1976.

38. W. W. Duke, EPA Questionnaire for Vulcan Materials Company Geismar, Louisiana Plant, Oct. 12, 1972.

LIST OF EPA INFORMATION SOURCES

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2. J. A. DeBernardi, Conoco Chemicals, letter to EPA with information on VCM plant in Lake Charles, Louisiana, May 16, 1978.

3. K. D. Konter, B. F. Goodrich Chemical Company, letter to EPA with information on EDC manufacturing at Calvert City, Kentucky, June 15, 1978.

4. J. A. Mullins, Shell Oil Company, letter to EPA with information on Deer Park, TX, EDC plant, June 22, 1978.

5. R. E. Van Ingen, Shell Oil Company, letter to EPA with information on Deer Park, TX, EDC oxychlorination process, Apr. 10, 1975.

6. R. J. Samelson, PPG Industries, Inc., letter to EPA with information on EDC emissions at Lake Charles, Louisiana, June 2, 1978.

7. F. C. Dhen, PPG Industries, Inc., letter to EPA with information on EDC oxychlorination process, at Lake Charles, Louisiana and at Guayanilla, Puerto Rico, Apr. 15, 1975.

8. W. R. Taylor, Diamond Shamrock Corporation, letter to EPA with information on catalytic oxidation of the oxychlorination vent, at Deer Park, Texas, October 3, 1977 (nonconfidential portion only).

9. W. M. Reiter, Allied Chemical Corporation, letters to EPA with information on EDC oxychlorination process, at Baton Rouge, Louisiana, Apr. 18, 1975, and June 18, 1975.

10. P. B. Cornell, Louisiana Air Control Commission Emission Inventory Questionnaire for Allied Chemical Corporaiton North Works, Baton Rouge, LA (nd).

11. R. M. Teets, Sr., EPA Questionnaire for Allied Chemical Corporation, Baton Rouge, Louisiana, October 18, 1972.

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13. J. A. DeBernardi, Conoco Chemicals, letters to EPA with information on oxychlorination process, in Lake Charles, Louisiana, Apr. 14, 1975, and Nov. 21, 1974.

14. J. A. DeBernardi, Louisiana Air Control Commission Emission Inventory Questionnaire for Conoco Chemicals, May 31, 1961.

15. D. O. Popovac, EPA Questionnaire for Conoco Chemicals Lake Charles, Louisiana, VCM Plant, Sept. 1, 1972.

16. Texas Air Control Board, A Construction Permit···to Diamond Shamrock Chemical Company Authorizing Construction of Vinyl Chloride Plant...at La Porte, Harris County, Texas, Permit No. C-3855 (Nov. 2, 1976).

17. W. C. Hutton, Texas Air Control Board Emissions Inventory Questionnaire for Diamond Shamrock Corporation, Sept. 15, 19[illegible] and Dec. 29, 1972.

18. R. D. Hall, EPA Questionnaires for Diamond Shamrock Corporation, Sept. 15, 1972, and Dec. 29, 1972.

19. H. W. Johnson, Jr., Texas Air Control Board Emissions Inventory Questionnaires for Dow Chemical Co., Texas Division, Feb. 6, 1976.

20. M. H. Siemens, Dow Chemical USA, letters to EPA with information on oxychlorination vent, at Oyster Creek Division, Nov. 14, 1974, and Feb. 25, 1975 (nonconfidential portions only).

21. M. H. Siemens, Texas Air Control Board 1975 Emissions Inventory Questionnaire for Dow Chemical USA, Oyster Creek Div., Mar. 19, 1976.

22. C. A. Christian, EPA Questionnaire for Dow Chemical USA, Oyster Creek Division, Aug. 4, 1972.

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24. R. H. Marshall, Texas Air Control Board 1975 Emissions Inventory Questionnaire for Ethyl Corp., Pasadena, Texas, March 21, 1976.

25. J. H. Huguet, EPA Questionnaires for Ethyl Corporation, Baton Rouge, Louisiana, Sept. 8, 1972, and Oct. 19, 1972.

26. W. C. Holbrook, B. F. Goodrich Chemical Company, letter to EPA with information on oxychlorination process at Calvert City, Kentucky, Apr. 7, 1975.

27. C. L. Woods, EPA Questionnaire for B. F. Goodrich Chemical Company Calvert City Kentucky, June 26, 1972.

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30. R. E. Van Ingen, Shell Oil Company, letters to EPA with information on oxychlorination and direct chlorination vents at Deer Park, Texas, June 14, 1974, July 5, 1974, and Dec. 6, 1974.

31. R. J. Trautner, Louisiana Air Control Commission Emission Inventory Questionnaire for Shell Chemical Company-Norco Plant, Jan. 31, 1977.

32. R. Gliuard, Texas Air Control Board 1975 Emissions Inventory Questionnaire for Shell Chemical Co. Deer Park Manufacturing Complex, Mar. 19, 1976.

33. A. L. de Vries, EPA Questionnaire for Stauffer Chemical Company Long Beach, California, Jan. 10, 1973.

APPENDIX E

LIST OF EPA INFORMATION SOURCES

PROJECT: EDC-CASE II THERMAL OXIDIZER FOR O_2 PROCESS (WITH HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
PRE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		300,000 Mg/YR (EDC) CAP.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 Mid-1978
6.	30% NaOH Storage Tank, API 10,000 Gal, Steel 1.22 sg.		101.9
7	Piping (x-Items 1-6) Water Lines approx 8" ϕ x 300' Sewer Line " 4" ϕ x 200'		14.9
8	Instruments (x-Items 1-6).		41.9
9	Scrubber (caustic)		373.5
	SUBTOTAL =		1265
	TOTAL WITH ALLOWANCES + 26 % =		1612

PRELIMINARY CAPITAL

PROJECT: EDC - CASE T - THERMAL OXIDIZER FOR O. PROCESS (WITH H_2P)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
PRE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 M.C. 1978
6.	30% NaOH Storage Tank API 100m Gal, Steel 1.22 s.g.		101.9
7	Piping (X-Items 1-6) Waterlines 2m x 2"ϕ x 200' Sewerline " 4"ϕ x 2m'		18.9
8	Instruments (X-Items 1-6)		41.9
9	Scrubber (Caustic Quench)		143.4
	SUBTOTAL =		644.6
	TOTAL WITH ALLOWANCES + 25% =		821

SL 101130

PRELIMINARY CAPITAL D-36

PROJECT: EDC - Case II Thermal Oxidizer + O2 Process (W/o HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pre-I		J. Fearnside	10-19-78	2106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg(EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 M&C-15
1.	Thermal Oxidizer Waste Gas + Air 80 SCFM, ~1.6 MM Btu/Hr, 2000°F out, Steel + refractory, Includes equipment, support struct, burners controls platforms, instruments, blowers, ductwork, stack, With ~~Without~~ Heat Recovery		424.
2.	Quench Chamber, with brick & FRP lining-sprays (carbon)		212.
3.	Circulating Water Sump 6300 gal In-ground type, FRP		34
4.	(2) Circulating Water Pumps, FRP 1240 GPM 60 HP		56
5.	50% NaOH Unload Pump Nickel 50 GPM, 40 PSI, 3 HP T&C		17.

SL 101131

PRELIMINARY CAPITAL D-33

PROJECT				
EDC-Case II-Thermal Oxidizer For O_2 Process (With H.P.)				
PHASE	E.F. NUMBER	BY	DATE	JOB NUMBER
Pre-1		J. Fordyce	10-18-78	3106
CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME		
		400,000 Mg/yr (EDC) Cap.		

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-1978
6.	20% NaOH Storage Tank, API, 10000 Gal., Steel 1.22 s.g.		101.9
7	Piping (X-Items 1-6)		14.9
	Water Lines 2000 ea 2"ϕ x 200'		
	Sewer Lines " 4"ϕ x 200'		
8	Instruments (X-Items 1-6).		41.9
9	Scrubber 8'-3" x 32 ft. lined.		233.6
	SUBTOTAL =		882.
	TOTAL WITH ALLOWANCES 25% =		1,117.

SL 101132

PRELIMINARY CAPITAL D-34

PROJECT: EDC - CASE II - THERMAL OXIDIZER FOR O2 PROCESS (With HP)

PAGE	E P NUMBER	BY	DATE	JOB NUMBER
Page-1		J. FORBYCE	10-19-78	9105-

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200 000 M# (EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.	$ 1000 Mid-19
1.	Thermal Oxidizer, Waste Gas + Air 6500 SCFM, 17.9 MM Btu/Hr, 2 comb'n out, Steel + refractory, Includes equipment, support struct, burners, controls, platforms, stack, instruments, blowers, ductwork, With Waste Heat Recovery	199.6
2.	Quench Chamber, with brick & FRP lining, sprays (scale down)	80.
		15.
3.	Circulating Water Sump 1500 gal In-ground type, FRP	
4.	(2) Circulating Water Pumps, FRP 210 GPM 15 HP	29
5.	50% NaOH Unload Pump Nickel 50 GPM, 40 PSI, 3 HP, T&C	17.

SL 101133

PROJECT: EDC-Case II Thermal Oxidizer For O₂ Process (Less HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
Pre-1		S. Fordyce	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		800 000 Mg/yr (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 Mid-1978
6.	30% NaOH Storage Tank, API 100 000 Gal, Steel 1.22 sg		101.9
7	Piping (X-Items 1-6) Water-lines approx 8" ϕ x 200' Sewer lines " 4" ϕ x 200'		14.9
8	Instruments (X-Items 1-6)		41.9
9	Scrubber (scale up)		331.1
	SUBTOTAL =		1203.9
	TOTAL WITH ALLOWANCES + 25 % =		1,517

PROJECT: EDC - Case I - Thermal Oxidizer For O. Exc. (With HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pase - 1		J. Forbyce	10-19-78	9106 -

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		400 000 Mg (EDC)/Y - Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid - 1
1.	Thermal Oxidizer Waste Gas + Air 15000 SCFM, 35.8 MM Btu/Hr, 2000°F out, Steel + refractory lined, equipment support struct burners controls platforms, instruments blower stack, ductwork With Waste Heat Recovery		378.
2.	Quench Chamber, 6.5' ϕ x 20' high with brick & Firing-sprays		131.
3.	Circulating Water Sump 3100 gal In-ground type, FRP		22.
4.	(2) Circulating Water Pumps, FRP 630 GPM 30 HP		4.
5.	50% NaOH Unload Pump Nickel 50 GPM, 40 PSI, 3 HP T&C		17.

SL 101135

PRELIMINARY CAPITAL

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR O2 PROCESS (LESS HP)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
PDE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 MID-1978
6.	20% NaOH Storage Tank, API 10000 Gal, Steel 1.22 s.g.		101.9
7	Piping (% - Items 1-6) Water Lines approx 3" ϕ x 200' Sewer Line " 4" ϕ x 200'		14.9
8	Instruments (% - Items 1-6)		41.9
9.	Scrubber (caustic)		125.4
	SUBTOTAL =		617.0
	TOTAL W/ 4 ALLOWANCES 27.5 % =		787

SL 101136

PRELIMINARY CAPITAL D-30

PROJECT: EDC - CASE T - THERMAL OXIDIZER FOR O_2 PROCESS (LESS HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
Case-1		J. FOSDYCK	10-19-72	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		8 CO 000 Mg(EDC)/Y - Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-19
1.	Thermal Oxidizer, Waste Gas + Air 26000 SCFM, 71.6 M Btu/Hr, Incinerator, Steel + refractory, Includes equipment, support structure, burners, controls, platforms, stack, instruments, blowers, ductwork, ☒ Without ☒ Heat Recovery		212.
2.	Quench Chamber, with brick & acid lining, spray (scrubber)		662.
3.	Circulating Water Sump 8500 gal In-ground type, FRP		38.
4.	(2) Circulating Water Pumps, FRP 1900 GPM 100 HP		83.
5.	50% NaOH Unload Pump Nickel, 50 GPM, 40 PSI, 3 HP, T&C		17.5

SL 101137

PROJECT: EDC-CASE II THERMAL OXIDIZER FOR O₂ PROCESS (LESS HP)

PHASE	E / NUMBER	BY	DATE	JOB NUMBER
P2E-1		S.A. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		400,000 Mg/YR (EDC) CAP.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 MID-1978
6.	20% NaOH Storage Tank API 10000 Gal, Steel 1.22 s.g.		101.9
7	Piping (X-Items 1-6) Water Lines approx 3"ϕ x 200' Sewer Line " 4"ϕ x 200'		14.9
8	Instruments (X-Items 1-6).		41.9
9	Scrubber 9.3'ϕ x 32' HI LINED.		203.8
	SUBTOTAL =		856.3
	TOTAL WITH ALLOWANCES 26.5% =		1,082

SL 101138

PRELIMINARY CAPITAL

PROJECT				
EDC - Case II - Thermal Oxidizer For O2 Process (Less HP)				
PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pse-1		J. Forbyce	10-19-78	9105
CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME		
		200,000 Mg (EDC)/Yr Cap.		

	NAME OF FACILITY DESCRIPTION QUANT.	$ 1000 Mid-19
1.	Thermal Oxidizer Waste Gas + Air 6250 SCFM, 17.9 MM Btu/Hr, 2000°F out, Steel + refractory lined, has equipment support struct, burners controls platforms, instruments blowers ductwork stack, ☒ Without ☐ Heat Recovery	121.6
2.	Quench Chamber, with brick & FRP lining, sprays Carbon steel	137.
2.	Circulating Water Sump 2120 gal. In-ground type, FRP	12.
4.	(2) Circulating Water Pumps, FRP 450 GPM 25 HP	37.4
5.	50% NaOH Unload Pump Nickel 50GPM, 40PSI, 2 HP T&C	17.8

SL 101139

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (WITH HP)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
PRE-1		J. FORDYCE	10-18-78	5106
CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME		
		500 000 Mg/YR (EDC) CAP.		

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 M.I.=1978
6.	30% NaOH Storage Tank, API 100000 Gal, Steel 1.22 sg		101.9
7	Piping (X-Items 1-6) Water Lines approx 8" ϕ x 300' Sewer Line " 4" ϕ x 200'		14.9
8	Instruments (X-Items 1-6)		41.9
9	Scrubber complete		402.1
	SUBTOTAL =		1392.
	TOTAL WITH ALLOWANCES 25.5 % =		1747

SL 101140

PROJECT: EDC - CASE II - THERMAL OXIDIZER FOR O₂ PROCESS (LESS HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pre-I		J. FORDYCE	10-19-78	9105

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		400 000 Mg (EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 MID-19
1.	Thermal Oxidizer Waste Gas + Air 13000 SCFM, 35.8 MM Btu/Hr, 200°F out Steel + refractory, Includes equipment, support struct burners controls platforms instruments Heavers ductwork, stack, ~~With~~ Without ~~Heat~~ Heat Recovery		160.
2.	Quench Chamber 9'-8" ϕ x 26' high with brick & FRP lining-sprays		225
3.	Circulating Water Sump 4200 gal In-ground type, FRP		23.
4.	(2) Circulating Water Pumps, FRP 900 GPM 50 HP		63.
5.	50% NaOH Unload Pump Nickel 500 GPM, 40 PSI, 5 HP T+C		17.

SL 101141

PRELIMINARY CAPITAL

D-23

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (WITH HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
PRE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 MID-1978
6.	20% NaOH Storage Tank, API 100000 Gal, Steel 1.22 s.g.		101.9
7	Piping (X-Items 1-6) Water Lines approx 3" ϕ x 200' Sewer Line " 4" ϕ x 200'		14.9
8	Instruments (X-Items 1-6).		41.9
9	Scrubber ~~scale down~~		153.4
	SUBTOTAL =		712.7
	TOTAL WITH ALLOWANCES 27 % =		905

SL 101142

PRELIMINARY CAPITAL

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (WITH HR)

PHASE	C F NUMBER	BY	DATE	JOB NUMBER
Pre-1		J. FORDYCE	10-19-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		800000 Mg (EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-19
1.	Thermal Oxidizer, Waste Gas + Air		457.
	35000 SCFM ≅ 100 M̄ Btu/Hr,		
	2000°F out, Steel + refractory,		
	Includes equipment, support struct,		
	burners, controls, platforms,		
	instruments, blowers, ductwork, stack,		
	With ~~Without~~ Heat Recovery		
2.	Quench Chamber		246
	with brick & FRP lining-sprays		
	make up.		
3.	Circulating Water Sump 8000 gal		41.
	In-ground type, FRP		
4.	(2) Circulating Water Pumps, FRP		69.
	1600 GPM 75 HP		
5.	50% NaOH Unload Pump		17.5
	Nickel 50GPM, 40PSI, 3HP, T&C		

SL 101143

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (WITH HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
PRE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		400,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 MID-1978
6.	20% NaOH Storage Tank, API 100m Gal, Steel 1.22 sg.		101.9
7	Piping (x-Items 1-6) Waterlines approx 3"ϕ x 200' Sewerline " 4"ϕ x 200'		14.9
8	Instruments (x-Items 1-6).		41.9
9	Scrubber 9.7'ϕ x 32 H. lined		247.3
	SUBTOTAL =		979.3
	TOTAL WITH ALLOWANCES + 26 % =		1 234

SL 101144

PRELIMINARY CAPITAL D-22

PROJECT: EDC - Case I - Thermal Oxidizer For Air Process (With HR)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pre-I		J. Fordyce	10-19-79	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg(EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-19
1.	Thermal Oxidizer Waste Gas + Air 6,000 SCFM @ 25 MM Btu/Hr, 2 combust Steel + refractory, Includes equipment support struct burners controls platforms stack, instruments blowers ductwork with ~~Waste Heat~~ Heat Recovery		332.
2.	Quench Chamber, with brick & ~~SS~~ lining - spray area is above		93.
3.	Circulating Water Sump 2000 gal In-ground type, ERP		19.
4.	(2) Circulating Water Pumps, ERP 330 GPM 50 HP		23.
5.	50% NaOH Unload Pump Nickel 500 GPM, 40 PSI, 3 HP T&C		17.

SL 101145

PROJECT: EDC-CASE I THERMAL OXIDIZER FOR AIR PROCESS (LESS HP)

PHASE	E.P. NUMBER	BY	DATE	JOB NUMBER
PRE-1		S. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.	$1000 MID-1978
6.	20% NaOH Storage Tank API 100000 Gal, Steel 1.22 s.g.	101.9
7	Piping (% - Items 1-6) Water Lines approx 8" ϕ x 200' Sewer Line " 4" ϕ x 200'	14.9
8	Instruments (% - Items 1-6)	41.9
9.	Scrubber (caustic)	473.0
	SUBTOTAL =	1519.8
	TOTAL WITH ALLOWANCES 25.5 % =	1907.

PRELIMINARY CAPITAL D-20

PROJECT	EDC - Case I - Thermal Oxidizer For Air Process (With HR)
PHASE	Case - I
BY	J. Forsyce
DATE	10-19-79
JOB NUMBER	9106
SECTOR NUMBER & NAME	600,000 Mg (EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-1
1.	Thermal Oxidizer, Waste Gas + Air		327
	18,000 SCFM, ≅ 50 M̄ Btu/Hr,		
	200°F out, Steel + refractory,		
	Includes equipment, support struct		
	burners, controls, platforms,		
	instruments, blowers, ductwork, stack,		
	With Heat Recovery		
2.	Quench Chamber, 8.2' φ x 22' high		151
	with brick lining - spray		
3.	Circulating Water Sump 4000 gal		27.
	In-ground type, FRP		
4.	(2) Circulating Water Pumps, FRP		46.
	720 GPM 40 HP		
5.	50% NaOH Unload Pump		17.
	Nickel, 50GPM, 40PSI, 3HP T&C		

SL 101147

PROJECT: EDC - Case I - Thermal Oxidizer For Air Process (Less HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
P2=1		S.L. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		*1000 Mid-1978
6.	20% NaOH Storage Tank, API 100m Gal, Steel 1.22 eg.		101.9
7	Piping (X-Items 1-6) Water Lines approx 2"ϕ x 200' Sewer Line " 11"ϕ x 200'		14.9
8	Instruments (X-Items 1-6).		41.9
9.	Scrubber (caustic dupl.)		179.3
	SUBTOTAL =		728.5
	TOTAL WITH ALLOWANCES 27 % =		925

PRELIMINARY CAPITAL D-18

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (LESS UP)

PHASE	E P NUMBER	BY	DATE	JOB NUMBER
Pgz-1		J. FOSDYCK	10-19-78	9105
CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME		
		500,000 Mg(EDC)/Yr Cap.		

	NAME OF FACILITY DESCRIPTION QUANT.		$ 1000 Mid-1Q
1.	Thermal Oxidizer Waste Gas + Air 36,000 SCFM, ≅ 100 MM Btu/Hr, 2000°F out Steel + refractory, Includes equipment, support struct, burners controls platforms instruments blowers ductwork, stack, ~~With~~ Without Heat Recovery		261.
2.	Quench Chamber, with brick & ~~FRP~~ lining - spray tank up		463.
3.	Circulating Water Sump 1600 gal In-ground type, FRP		51.
4.	(2) Circulating Water Pumps, FRP 2400 GPM 125 HP		92.
5.	50% NaOH Unload Pump Nickel 50 GPM, 40 PSI, 3 HP T&C		17.

SL 101149

PROJECT: EDC-Case Thermal Oxidizer For Air Process (Less HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
PRE-1		S.L. FORDYCE	10-18-78	9106

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		400,000 Mg/YR (EDC) Cap.

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 Mid-1978
6.	30% NaOH Storage Tank, API 100m Gal, Steel 1.22 s.g.		101.9
7	Piping (x-Items 1-6) Water Lines approx 2"ϕ x 200' Sewer Line " 4"ϕ x 20'		14.9
8	Instruments (x-Items 1-6)		41.9
9.	Scrubber 10'-8"ϕ x 32' Ht, Lined		291.2
	SUBTOTAL =		1035.9
	TOTAL With ALLOWANCES 26 % =		1305

PRELIMINARY CAPITAL D-16

PROJECT: EDC - CASE I - THERMAL OXIDIZER FOR AIR PROCESS (LESS HR)

PHASE	E F NUMBER	BY	DATE	JOB NUMBER
Ecs-1		J. FOSDYCE	10-19-72	9105

CASE NUMBER	SECTION NUMBER	SECTOR NUMBER & NAME
		200,000 Mg (EDC)/Yr Cap

	NAME OF FACILITY DESCRIPTION QUANT.	$ 1000 MID-15
1.	Thermal Oxidizer, Waste Gas + Air 900K SCFM, ? as M Btu/Hr, 2000°F out, Steel + refractory, Includes equipment, support struct, burners, controls, platforms, stack, instruments, Hot gas ductwork, ~~With~~ Without Heat Recovery	1,31
2.	Quench Chamber, with brick & FRP lining, spray (~~included~~)	176
3.	Circulating Water Sump 2000 gal In-ground type, FRP	22
4.	(2) Circulating Water Pumps, FRP 300 GPM 30 HP	42.3
5.	50% NaOH Unload Pump Nickel, 50GPM, 40 PSI, 2 HP, T&C	17.5

SL 101151

SUBJECT: EDC - THERMAL OXIDIZERS & SYSTEMS

JOB NO. 9106-7 | SHEET | FILE | BY J. R. FORDYCE | DATE OCT. 19, 1978

E. RAW MATERIALS DATA: (400,000 Mg/Yr EDC Plt).

(1) 2.1 CASE I - AIR PROCESS (Without and With Heat Recovery)

Ref. { Chemical Marketing Reporter; Sep. 4, 1978. Caustic Soda $140 - $175 /ton 100% basis. }

For 50% NaOH Solution use $.05/lb.

(USE $/RATE). for 50% cost for 50%

1200 #/hr (100%) x 2 x 8760 hr/yr x $.05/# = $1,136,800/yr

Caustic

2.2 CASE II - O_2 PROCESS (With, or Without Heat Recovery)

1000 #/hr (100%) x 2 x 8760 hr/yr x $.05/# = $693,500/yr

Caustic

(1) 4. Waste Disposal Data: (400,000 Mg/Yr EDC Plt)

4.1 Case I - Air Process (With, or Without Heat Recovery)

300 gpm purge x 525600 min/yr x $.01/gal = $2,049,800/yr

4.2 Case II - O_2 Process (With, or Without Heat Recovery)

310 gpm purge x 525600 min/yr x $.01/gal = $1,629,400/yr

(1) 5. Credit: (400,000 Mg/Yr EDC Plt)

5.1 Case I - Air Process (Heat Recovery)

35.3 MBtu/Hr x 8760 Hr/Yr x $2/MBtu = $622,000/yr

5.2 Case II - O_2 Process (Heat Recovery)

25.72 MBtu/Hr x 8760 Hr/Yr x $2/MBtu = $450,600/yr

(1) Directly proportion for 200,000 & 800,000 Mg/Yr Plants.

PRELIMINARY CAPITAL D-14

PROJECT				
EDC - Case I - Thermal Oxidizer For Air Process (Less HR)				
PHASE: Pre-I	E.F. NUMBER:	BY: J. Forry	DATE: 10-19-79	JOB NUMBER: 9105
CASE NUMBER:	SECTION NUMBER:	SECTOR NUMBER & NAME: 400,000 Mg (EDC)/Yr Cap		

	NAME OF FACILITY DESCRIPTION QUANT.		$1000 Mid-19
1.	Thermal Oxidizer, Waste Gas + Air 18,000 SCFM ≅ 50 M Btu/Hr, 2000°F out, Steel + refractory, Includes equipment, support struct, burners, controls, platforms, instruments, blowers, ductwork, stack, Without Heat Recovery		135.
2.	Quench Chamber, 11' ϕ x 37' high with brick lining - spray		256.
3.	Circulating Water Sump 5800 gal In-ground type, FRP		34.
4.	(2) Circulating Water Pumps, FRP 1200 GPM 60 HP		61.
5.	50% NaOH Unload Pump Nickel, 50 GPM, 40 PSI, 3 HP, T&C		17.5

SL 101153

EDC - THERMAL OXIDIZERS & SYSTEMS

JOB NO. 9106-7 | SHEET 2 OF | FILE | BY J.R. FORDYCE | DATE OCT. 19, 1978.

2. UTILITIES DATA.

2.1 Case I - Air Process.

2.1.1 400,000 Mg/Yr EDC Plt Capacity (With Heat Recovery).

Power

Fans = 22,000 CFM x 8" H_2O x .00015/72% E = 37 HP
Pumps = approx. = .4 "
Yard Light ~ Instruments = 5 "
Consider always running = 85

85 HP x .746 Kw/HP x 8760 Hr/Yr x $.03/Kwh = $16,700/yr

$457,700/yr UTILITIES (1)

Cooling Water

350 GPM x 525600 Min/Yr x $.10/1000 gal = $20,500/yr

Natl. Gas

24 MM Btu/hr x 8760 Hr/Yr x $2/MM Btu. = $420,500/yr

2.1.2 400,000 Mg/Yr EDC Plt. Capacity (Less Heat Recovery)

Power 22000 x 5' x .00015/72%E..
Fans @ 33 HP, Pumps @ 63 HP, Yard Lights + Instr = 101 HP
101 HP x .746 x 8760 x $.03/Kwh = $19,800/yr

Cool Water
430 gpm x $2.56 = $22600/yr

Natl. Gas same as above = $420500/yr

$462,900/yr UTILITIES (1)

(1) Directly proportion for 200,000 & 800,000 Mg/Yr Plants.

SUBJECT EDC - Thermal Oxidizers & Systems

JOB NO. 9106.7 SHEET 4 OF FILE BY J.R Fordyce DATE Oct. 19, 1978

2.2 Case II — O_2 Process

2.2.1 400,000 Mg/Yr EDC Plt. Cap. (With Heat Recovery)

Power

Fans; 15600 CFM x 8" x .00015/72 % — 26 HP

Pumps: — 63 "

Yard Lights: Instruments. — 5"

94

94 HP x .746 x 8760 x $.03/Kw — $15,400/yr

(1) 34,200 hr/yr Utilities

Cool H_2O — $

300 gpm x 52.56 — $15,800/yr

Natl Gas. none regd.

2.2.2. 400,000 Mg/Yr EDC Plt. Cap. (Less Heat Recovery)

Fans: 23300 x 8" x .00015 ÷ 72% — 23 HP

Pumps — 53 "

Yd Lts - Insts — 5 "

81 "

81 HP x .746 x 8760 x $.03/Kw — $15,900/yr

(1) 33,500 hr/yr Utilities

Cool H_2O

335 GPM x $52.56 — $17,600/yr

Natl. Gas — none regd.

(1) Directly proportion for 300,000 & 200,000 Mg/Yr Plts.

EDC - THERMAL OXIDIZERS & SYSTEMS

JOB NO. 9106-1 | SHEET 1 of | FILE | BY J. R. FORDYCE | DATE OCT. 18, '78.

1. CAPITAL COSTS OF OXIDIZERS & H.R. UNITS:

1.1 Ref: Booz, Allen & Hamilton Inc. "Final Report - Cost of Hydrocarbon Emission Control to the U.S. Chemical Industry" pps. IV-7, IV-8, IV-9, & Fig IV-1.

Factors used are (frm pp. IV-9 @ 2.81 - .22 for contingency) + .25 for 2000°F burning x 1.15 escalatic from 1976 to mid-1978. = 3.266 factor.

1.2 Case I - Air Process:

1.2.1 400,000 Mg/Yr EDC Plt Capacity.. 49.9 MM Btu/Hr.

Per J.K. calc. SCFM prior to combustion = 18000 @ 60°F.

Fig. IV-1
With Heat Recovery; 100 M$ x 3.266 = 327 M$
Without " " ; 57 " x " = 186 " "

1.2.2 200,000 Mg/Yr Capacity,
≅ 9,000 SCFM.
With Heat Recovery; 73 M$ x 3.266 = 238 M$
Without " " ; 40 " x " = 131 "

1.2.3 800,000 Mg/Yr. Capacity
≅ 36,000 SCFM
With Heat Recovery; 140 M$ x 3.266 = 457 M$
Without " " ; 80 " x " = 261 "

SL 101156

PROJECT
EDC - THERMAL OXIDIZERS & SYSTEMS

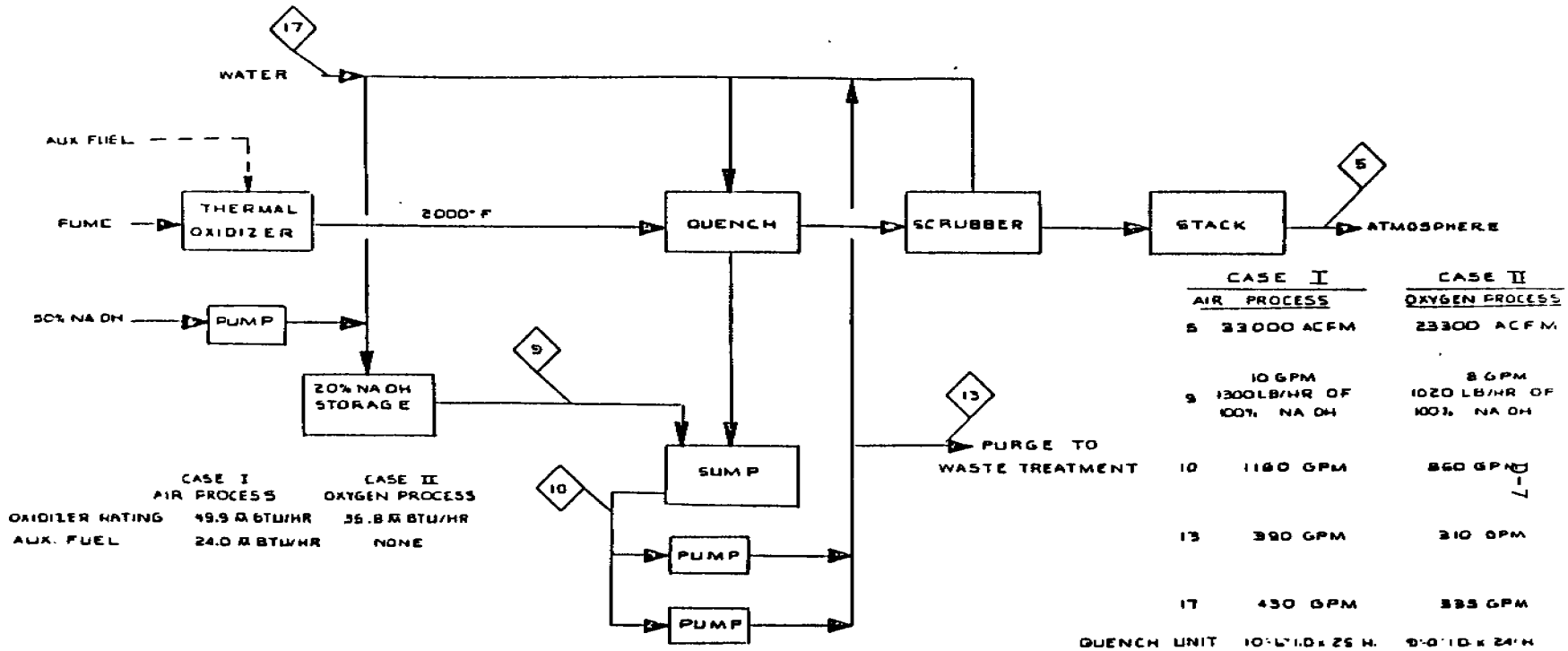
JOB NO. SHEET TITLE BY DATE
5103-I J.R. FORDYCE OCT. 18, 78

1.3 Case III - O₂ Process :

1.3.1 Per J.K. Calc. SCFM prior to combustion = 13000 SCFM
for 400,000 Mg/Yr EDC Plt Capacity. 25.8 M Btu/H.
Fig. IV-1
With Heat Recovery ; 85 M$ x 3.266 = 278 M$
Without " " ; 49 " x " = 160 "

1.3.2 200,000 Mg/Yr Capacity
≅ 6500 SCFM
With Heat Recovery : 61 M$ x 3.266 = 199 M$
Without " " ; 37 " x " = 121 "

1.3.3 800,000 Mg/Yr. Capacity
≅ 26,000 SCFM
With Heat Recovery ; 130 M$ x 3.266 = 424 M$
Without " " ; 65 " x " = 212 "



	CASE I AIR PROCESS	CASE II OXYGEN PROCESS
OXIDIZER RATING	49.9 M BTU/HR	36.8 M BTU/HR
AUX. FUEL	24.0 M BTU/HR	NONE

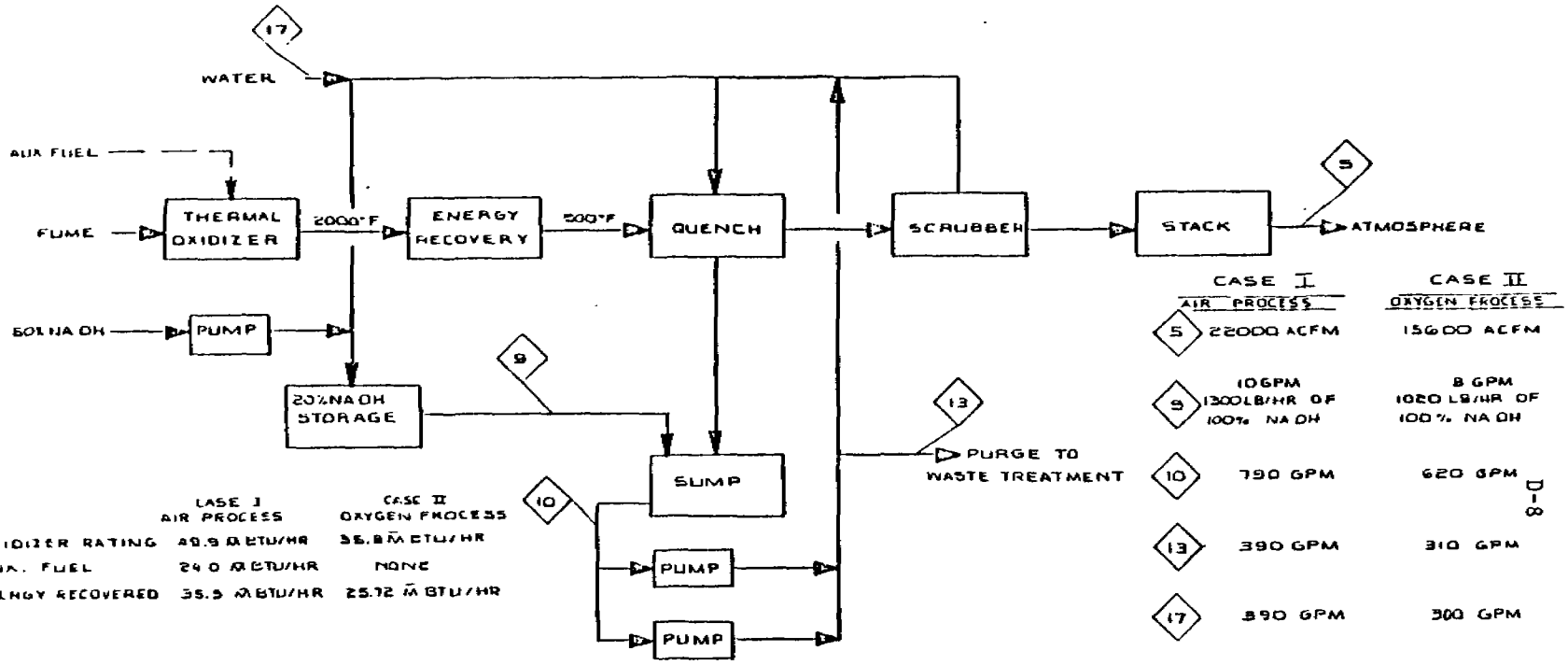
	CASE I AIR PROCESS	CASE II OXYGEN PROCESS
5	23000 ACFM	23300 ACFM
9	10 GPM 1300 LB/HR OF 100% NA OH	8 GPM 1020 LB/HR OF 100% NA OH
10	1160 GPM	860 GPM
13	390 GPM	310 GPM
17	450 GPM	335 GPM
QUENCH UNIT	10'-6" I.D. x 25 H.	8'-0" I.D. x 24' H.
SCRUBBER UNIT	10'-0" I.D. x 26' H.	8'-6" I.D. x 26 H.

THERMAL OXIDIZER FOR CHLORINATED VENT GASES --- WITHOUT HEAT RECOVERY --- 400 000 Mg/Yr. CAPACITY

EDC PROCESS
FUME CONTROL

9106-7
J.R. FORDYCE
OCT. 31, 1978

SL 101158



THERMAL OXIDIZER FOR CHLORINATED VENT GASES — WITH HEAT RECOVERY — 400 000 Mg/yr PLT CAPACITY

EDC PROCESS
FUME CONTROL
9106 - 1
J R FORDYCE
OCT. 31 1978

D-8

SL 101159

CASE I. AIR PROCESS — CHARG 5-5 — 9106.7 — BY: JRF — DATE 10-20-78 PG.

INCINERATION	UNITS	200 Gg/Yr PLT.CAP [1]	200 Gg/Yr PLT.CAP [2]	BASE CASE 400 Gg/Yr PLTCAP [1]	BASE CASE 400 Gg/Yr PLTCAP [2]	800 Gg/Yr PLT.CAP [1]	800 Gg/Yr PLT.CAP [2]	[1]	[2]
WASTE EMISSIONS REDUCTION (VOC)	Mg/Yr	4600	4600	9100	9100	18000	18000		
" " " (EDC)	" "	1500	1500	2900	2900	5800	5800		
MID 1978 INSTALLED CAPITAL	$ 1000	925	905	1305	1234	1907	1747		
UTILITIES POWER									
COOLING WATER	$ 1000/yr	232	229	463	458	926	916		
NATL. GAS									
RAW MATERIALS EDC & NaCl	$ 1000/yr	569	569	1139	1139	2278	2278		
MANPOWER	$ 1000/yr	35	35	35	35	35	35		
MAINTENANCE 5.0 % CAP.									
CAPITAL RECOVERY 16.28 % CAP	$ 1000/yr	234	229	330	312	482	442		
MISC. CAPITAL COSTS 4.0 % CAP									
WASTE DISPOSAL	$ 1000/yr	1025	1025	2050	2050	4100	4100		
RECOVERY CREDITS	$ 1000/yr	0	311	0	622	0	1244		
NET ANNUALIZED COST	$ 1000/yr	2095	1776	4017	3372	7821	6527		
COST EFFECTIVENESS (VOC)	$/Mg	455	386	441	371	435	363		
(EDC)	" "	1397	1184	1385	1163	1348	1125		
[1] WITHOUT HEAT RECOVERY									
[2] WITH "	"								

SL 101160

CASE II-OXYGEN PROCESS CHARGE NO. 7 BY: JRF DATE 10-78 PG.

INCINERATION	UNITS	200G /Yr. PLT. CAP [1]	200G /Yr. PLT. CAP [2]	BASE CASE 400G /Yr PLT CAP [1]	400G /Yr PLT CAP [2]	800G /Yr. PLT. CAP. [1]	800G /Yr. PLT. CAP. [2]	[1]	[2]
WASTE EMISSIONS REDUCTION (VOC)	Mg/Yr	5000	5000	10000	10000	20000	20000		
" " (EDC)	" "	900	900	1800	1800	3600	3600		
MID 1978 INSTALLED CAPITAL	$/1000	787	821	1083	1117	1517	1619		
UTILITIES Power									
Cooling Water	$/1000/yr	17	17	34	34	68	68		
RAW MATERIALS 50% NaOH	$/1000/yr	447	447	894	894	1788	1788		
MANPOWER	$/1000/yr	35	35	35	35	35	35		
MAINTENANCE 5.0 % CAP									
CAPITAL RECOVERY 16.28 % CAP	$/1000/yr	199	207	274	282	383	409		
MISC CAPITAL COSTS 4.0 % CAP									
WASTE DISPOSAL	$/1000/yr	814	814	1629	1629	3258	3258		
RECOVERY CREDITS	$/1000/yr	0	225	0	451	0	901		
NET ANNUALIZED COST	$/1000/yr	1512	1295	2866	2423	5592	4657		
COST EFFECTIVENESS (VOC)	$/Mg	302	259	287	242	277	233		
" (EDC)	" "	1680	1439	1592	1346	1537	1294		
[1] WITHOUT HEAT RECOVERY									
[2] WITH "	"								

SL 101161

COST ESTIMATE DETAILS

This appendix contains the details of the estimated costs presented in this report.

The accuracy of an estimate is a function of the degree of data available when the estimate was made. Figure D-1 illustrates this relationship. A contingency allowance as indicated on this chart has been included in the estimated costs to cover the undefined scope of the project.

Capital costs given in this report are based on a screening study, as indicated by Fig. D-1, based on general design criteria, block flowsheets, approximate material balances, and data on general equipment requirements. These costs have an accuracy range of +30% to -23%, depending on the reliability of the data, and provide an acceptable basis to determine the most cost-effective alternate within the limits of accuracy indicated.

Figure D-2 shows the installed capital costs for tanks and was prepared primarily from data presented in the EPA, OAQPS report Evaluation of Hydrocarbon Emissions from Petroleum Liquid Storage, which was prepared by Pacific Environmental Services under Contract 68-02-2606. The curves plotted are judgmental averages of the data presented. Additional retrofit cost information was obtained by telephone from Chicago Bridge and Iron, Ultraflote, and Grover Tank Co. The highest retrofit cost quoted by these companies was used as a base. The retrofit curve was then increased to compensate for freight, taxes, engineering, and estimated allowances.

In all capital calculations, allowances of 13 to 20% were added for magnitude, hazard, and definition contingencies.

Cost-effectiveness data for open-top floating roof tanks were not developed because the available data indicate the cost to be approximately the same as that for internal floating roofs for most tank sizes. Open-top floating roofs are not as efficient for emission reduction as internal floating roofs.

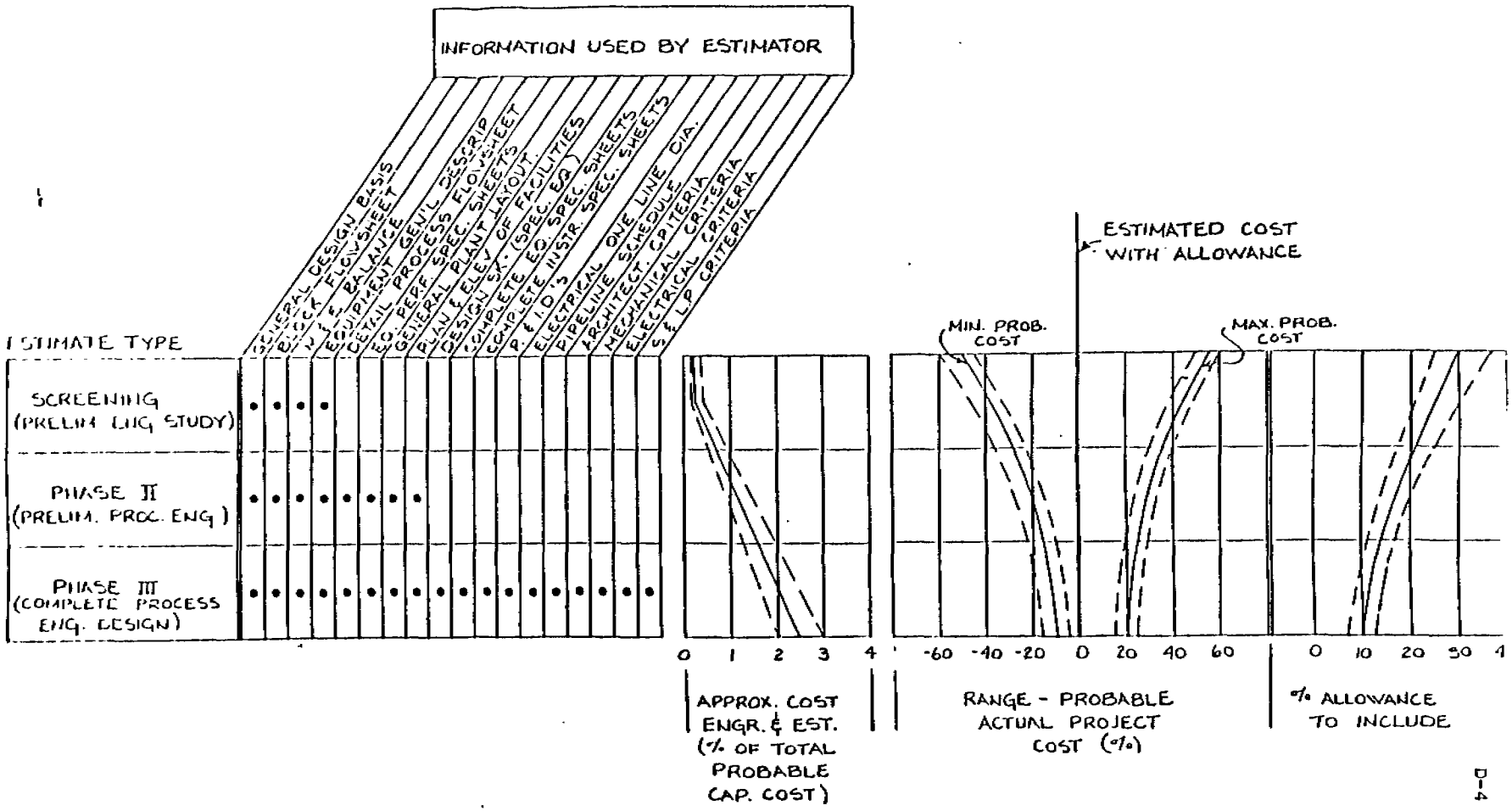


Fig. D-1. Precision of Capital Cost Estimates

LATEST REVISION - 5/2/77

D-4

SL 101163

APPENDIX D

COST ESTIMATE DETAILS FOR MODEL-PLANT EMISSION CONTROLS

sulfhydryl groups of cysteine in vitro, but that in vivo, total sulfhydryl concentration in rat liver and kidney was decreased at the LD90 doses. Brain and heart sulfhydryl values were not affected. Signs of toxicity included clonic and tonic convulsions, respiratory depression, and thirst.

No information on metabolism of ethylene dichloride by humans was found in the literature. The similarity of the human responses to exposure to ethylene dichloride and 2-chloroethanol and the pathologic findings after such exposures are not proof that ethylene dichloride is metabolized to 2-chloroethanol. With both compounds, the delay in onset of symptoms (Table XII-2) is indicative of metabolism to more toxic compounds. [128-130] Ethylene dichloride and 2-chloroethanol could share a common metabolic pathway to monochloroacetic acid with chloroacetaldehyde as an intermediate metabolite. (RA Van Dyke, written communication, February 1975)

McCann et al [135] tested the mutagenicity of ethylene dichloride, its metabolite chloroeacetic acid, and its possible metabolic intermediates, chloroethanol and chloroacetaldehyde, by their ability to revert a bacterial tester strain. Ethylene dichloride and 2-chloroethanol were described as weakly mutagenic compared to chloroacetaldehyde, which was hundreds of times more effective in causing reversions. Monochloroacetic acid showed no activity in the testing.

Correlation of Exposure and Effect

Ethylene dichloride has anesthetic properties but it was found to be too toxic to be used for this purpose. [32-35] Guinea pigs developed a state of unconciousness in 0.5 hour with exposures of 4,000 and 4,500 ppm. [42] A monkey exposed at 4,500 ppm for 10 minutes became unable to

maintain itself on the perch of the cage. [42]

During a 7-hour exposure at 3,000 ppm, guinea pigs, rats, mice, and rabbits showed varying degrees of narcosis according to Heppel et al. [106] Spencer et al [108] considered that the inactivity or stupor and slowness of response to handling of rats exposed for up to 8 hours to a series of concentrations in the range of 300 to 3,000 ppm may have been due to toxic injury other than central nervous system depression.

Workers acutely poisoned by occupational exposure to ethylene dichloride developed symptoms indicative of central nervous system effects including headache, dizziness, feelings of drunkenness, and sometimes unconciousness. [74-77,80-82,86] In some cases workers who were not overcome during exposure became unconscious later. [81,86]

Because of the profound effects of other chlorinated hydrocarbons on the liver and kidneys, many of the clinical and epidemiologic studies with ethylene dichloride have been directed toward the detection of dysfunction and degeneration of these organs. Evidence of liver and kidney injuries have been noted following both ingestion and occupational exposure, as evidenced by increased serum bilirubin, [9,86] decreased blood glucose, [82] positive Takata-Ara tests, [9,86] tender and palpable liver, [9] and the presence in the urine of albumin, blood cells, and hyaline and granular casts. [86,102]

However, even repeated exposures at high concentrations in animals and accidental poisonings in humans produced only slight to moderate fatty degeneration in the liver and kidneys. [75,107,108] What was much more evident in these and other organs at autopsy was the hyperemia and

hemorrhaging into the tissues. [44,46,47,50,52,54,56,57,60,61,62,65, 66,68,75,76,77,81]

The effects of ethylene dichloride ingestion, vapor inhalation, and absorption through the skin were similar. Early signs of circulatory damage included bleeding into the visceral organs, [46,50,51,54,56,62,70], cyanosis, [46,50,52,54,55,57,59 60,65,75,81,84,86] and rapid and weak pulse. [46,50,52,56,59,74,81,84] Acute exposures, both by ingestion and inhalation, were often fatal. Death resulted from respiratory and circulatory failure, following a period of nausea, vomiting, and unconsciousness. Autopsies revealed hyperemia and hemorrhagic lesions in the stomach, intestines, heart, brain, liver, and kidneys. [46,47,49-52,54,56,57,59,61-62,64-66,70,72,73,75,76,81]

Disseminated intravascular coagulopathy (DIC) and hyperfibrinolysis were reported in 1969 by Martin et al [64] in a patient who had ingested ethylene dichloride. They first noticed prolonged bleeding from venipunctures 24 hours after the ingestion and then studied the clotting factors, finding a reduction in factors II, V, VII, and VIII and complete defibrination. Platelet count was low (14,300/cu mm), fibrinolysis was markedly increased, and proactivator levels were below 10% of normal. Autopsy examination revealed thrombi in the pulmonary arterioles and capillaries, and hemorrhages into the mucosa of the esophagus, stump of the stomach, rectum, subepicardial, subendocardial, and myocardial tissues.

A decrease in clotting factors II and V was also found by Schonborn et al [65] 5.5 hours after a person ingested ethylene dichloride. Yodaiken and Babcock [66] noted that 2 hours after a patient ingested ethylene dichloride the prothrombin time was increased and the clotting

ability of the blood continued to decrease. On the 4th day, all clotting factors except VIII were markedly decreased.

An absence of clots and intensely red, thick blood were among the autopsy findings in 2 workers following an acute occupational exposure. [75] Extensive subepicardial, subendocardial, and a few subpleural hemorrhages were also found.

Chronic occupational exposures have also resulted in ethylene dichloride intoxication. Repeated exposures have resulted in neurological changes, anorexia, nausea, vomiting, epigastric pain, irritation of the mucous membranes, possible liver and kidney dysfunction, and death. [88,90-98,105]

Cetnarowicz [9] investigated the possibility of ethylene dichloride poisoning in an oil refinery in Poland where the concentrations were in the range of 10-200 ppm. Ten workers employed in the centrifuge room, where 3 concentration measurements were 62, 64, and 200 ppm, complained of a burning sensation of the eyes and lacrimation. Six of the workers had dryness of the mouth, an unpleasant sweet aftertaste, dizziness, lassitude, sleepiness, nausea, vomiting, constipation, and loss of appetite. Three workers also complained of pain in the epigastrium. Of 6 workers employed in other sections of the plant, where concentrations ranged from 10 to 37 ppm, one worker complained of the above-mentioned symptoms.

Further clinical investigations showed liver tenderness upon palpation in 4 workers, epigastric pain in 7 persons, elevated urobilinogen levels in the majority of individuals, abnormal percentile distribution of white blood cells in 8 persons. Other abnormal findings included high serum bilirubin levels, elevated nonprotein nitrogen levels, diminished

amounts of albumin in the serum, elevated globulin levels, positive Takata-Ara tests, and delayed return to normal values in the glucose tolerance test.

Two reports [88,91] of years of experience with ethylene dichloride in Russia indicated that acute effects were found after exposure at 75-125 ppm. The symptoms of these acute effects included general weakness, headache, dizziness, vomiting (usually producing a trace of bile), and irritation of the skin and mucous membranes. When some workers experienced these signs and symptoms 2 or more times in a period of 2 to 3 weeks, fatalities resulted. However, there was no mention of the method of air sampling, of the number of people exposed, or the duration of exposure.

Byers [93] reported that delayed effects of ethylene dichloride, such as lassitude, nausea, vomiting, and abdominal pain were experienced in the evening by workers exposed at 100 ppm or slightly higher for 7.5 hours daily. These effects were not completely alleviated when ventilation procedures reduced the ethylene dichloride concentration to 70 ppm.

Exposure conditions were more extensively described for the 2 cases of neurological involvement reported by Guerdjikoff. [97] These workers used a gas mask for the operation where higher ethylene dichloride concentrations were expected for 2-3 minutes about 10 times/day. In this operation, there was opportunity for occasional exposure if the mask was not worn properly. In another operation, the workers were exposed 3-4 times/day for 10 minutes each time at a concentration of about 120 ppm, and in another operation, they were exposed at a higher concentration for 10-15 minutes once/day. An estimate of the daily TWA for these workers was not made.

The workers developed sensory and motor problems during 6-9 months of exposure. [97] Anorexia, epigastric pains, fatigue, irritability, and nervousness appeared first after 3 weeks of exposure. Eventually each worker developed a difficulty in walking, trembling hands, and hyperhidrosis.

Heightened lability of the autonomic nervous system, diffuse red dermographism, increased hidrosis, fatigability, irritability, and insomnia were among the responses reported by Rosenbaum [88] in a group of 100 workers exposed to ethylene dichloride at less than 25 ppm for 6 months to 5 years.

Impairment of the central nervous system and increased morbidity, especially diseases of the liver and bile ducts, were found in workers chronically exposed to ethylene dichloride at concentrations below 40 ppm and averaging 10-15 ppm. [105]

An analysis of the data presented by the author indicated a TWA concentration of about 15 ppm (see Table XII-3 and Figures XI-1 and XI-2). There are reasons to suspect that this may be an overestimate of most of the workers' exposures. The author pointed out that an insignificant number of the workers were employed in disassembling the metal molds, washing the tanks, etc. During disassembly of the metal forms, the workers were inside the tanks where ethylene dichloride concentrations of about 45-52 ppm were found. These concentrations were included by the author in the array associated with gluing. The measurements were apparently not breathing zone measurements and the ventilation system was designed with the exhaust ducts on the floor. As a consequence, the author [105] found an average concentration of about 27 ppm near the gluing table, about 40

ppm at 1 meter from the floor, and about 6 ppm at 2 meters from the floor. From these considerations it would appear that a more realistic appraisal of the TWA exposures of the majority of workers is 10-15 ppm.

Ethylene dichloride was found in the milk of nursing women occupationally exposed at approximately 15.5 ppm for an unspecified time. [99] The concentrations of ethylene dichloride in the milk ranged from 0.54 to 0.64 mg %. Concentrations of about 14.5 ppm ethylene dichloride were found in the women's breath. Eighteen hours after exposure, the concentrations of ethylene dichloride in milk samples and breath were found to be 0.195-0.63 mg % and 2-4 ppm, respectively. This one report of ethylene dichloride concentrations in the milk of female workers is supported by one study of ethylene dichloride concentrations in the milk of cows fed 1.75 to 17.5 mg/kg (based on body weights of about 400 kg). Additional research on this subject is needed.

Brzozowski et al [104] considered that absorption of ethylene dichloride through the skin was primarily responsible for producing such symptoms as nausea, weakness, abdominal pain, irritation of the mucous membranes, and weakness in the agricultural workers they studied. The workers were exposed in the field at atmospheric concentrations of about 15 ppm. Exposures to about 60 ppm occurred during transfer of ethylene dichloride into buckets. The workers were exposed to direct contact with the liquid that was spilled in large quantities on their skin and clothes while carrying it to the field in open buckets and they used it to wash their skin.

Medical examinations were performed on 118 workers. Ninety of them had some positive findings, including conjunctival congestion, weakness,

reddening of the pharynx, bronchial symptoms, metallic taste in the mouth, headache, dermatographism, nausea, cough, liver pain, burning sensation of the conjunctiva, hastened pulse, and dyspnea after effort. The "hippuric acid Quick test" was used to measure liver dysfunction and was reported to be positive in 40 of 56 workers investigated. [104]

A mixture of 25% ethylene dichloride and 75% carbon tetrachloride is used for grain fumigation in the United States. There are no reports in the literature of poisoning from the use of this fumigant mixture. However, in Italy, where the proportions of ethylene dichloride and carbon tetrachloride are approximately reversed, there are many reports of fumigant intoxication. [78-80,85,102]

Experimental studies performed by Borisova [4,101] resulted in effects on the vascular and respiratory systems with short-term exposure at very low concentrations of ethylene dichloride. A 30-second exposure of 4 subjects at 1.5 ppm resulted in a temporary stenosis of the blood vessels in all 4 subjects. This reaction was generally more pronounced especially in the vessels of the fingers when the exposure was at 3 ppm.

Borisova [4,101] found that a 1-minute exposure at 1.5 ppm produced a change in the depth of breathing as indicated by an increase in the height of the wave of the spirogram.

Experimental exposures to animals have resulted in circulatory effects similar to those found in humans, including pulmonary congestion and edema with focal extravasation of blood, generalized congestion throughout the visceral organs, hyperemia, and hemorrhage into the lungs, stomach, intestines, liver, and adrenals. [42,106-109]

Guinea pigs were exposed at concentrations from 600 to 60,000 ppm ethylene dichloride for periods up to 8 hours by Sayers et al. [42] Congestion and edema of the lungs and generalized passive congestion of the visceral organs were found in animals that died during exposure at 30,000 or 60,000 ppm for 30-40 minutes. Pulmonary congestion and edema and renal hyperemia were found in animals exposed at concentrations greater than 1,200 ppm. No deaths or apparent symptoms resulted from 8-hour exposures at 1,200 ppm.

Pulmonary congestion and hemorrhage, generalized visceral congestion, hepatic necrosis, and slight fatty degeneration of the renal tubular epithelium were found by Heppel et al [106] in rabbits, rats, and mice that died from exposure at 3,000 ppm ethylene dichloride. Guinea pigs exposed at the same concentrations developed focal necrosis of the adrenal cortex, sometimes with hemorrhage, and fatty degeneration of the myocardium was found in 7 of 8 guinea pigs. Repeated 7-hour exposures at 1,500 ppm resulted in hemorrhage in the lungs, stomach, intestines, and adrenals, fatty degeneration of the myocardium, and congestion in the liver and intestines of rats, guinea pigs, rabbits, and dogs. [106]

Degenerative changes in the renal tubular epithelium, pulmonary congestion with focal extravasation of blood, congestion, hemorrhage and fatty changes in the liver, and focal myocarditis were among the effects noted by Heppel et al [107] after exposing various animals at 1,000 ppm for 7 hours/day, 5 days/week for up to 177 days. When the exposure concentration was lowered to 200 ppm, mortality remained high but only occasional pathological findings, varying from animal to animal, were observed. These included pulmonary congestion, fatty degeneration of the

renal convoluted tubules, necrosis and hemorrhage in the liver, necrosis of the adrenal cortex, and fine fat droplets in the liver and myocardium. [107]

Spencer et al [108] exposed a variety of animals at 400 ppm ethylene dichloride for 7 hours/day. One of 2 exposed monkeys died after 8 exposures and the other died after 12 exposures. Prothrombin time was increased and microscopic findings included fatty degeneration of the liver and kidneys.

No abnormal findings were observed grossly or microscopically in 2 male monkeys subjected to 148 7-hour exposures at 100 ppm ethylene dichloride in 212 days. [108]

Both male and female guinea pigs exposed at 100 ppm ethylene dichloride for as many as 162 7-hour exposures in 226 days had reduced growth rates and increased liver to body weight ratios compared to controls. Lung, heart, kidney, spleen, and testes organ weight to body weight ratios were normal. [108] Cats similarly exposed also had reduced growth rates. [109]

A summary of findings from animal exposures is presented in Table XII-4.

Ethylene dichloride was shown to be metabolized to monochloroacetic acid through 2-chloroethanol in mice. [126] Both thzse compounds are more toxic than ethylene dichloride. [131,134] The signs of poisoning by 2-chloroethanol from both accidental and occupational exposures of humans and experimental exposures of animals is very similar to those resulting from ethylene dichloride poisoning. [127-131] This similarity of signs, symptoms, and microscopic findings provides evidence that the mechanism of

human poisoning from ethylene dichloride resides at least in part in its metabolic products. [124,131,133]

There were no reports found in the literature dealing directly with carcinogenic or teratogenic effects of ethylene dichloride.

A feeding study conducted by the National Cancer Institute (EK Weisburger, written communication, January 1976) showed that some female rats developed mammary tissue masses after receiving 50 and 100 mg/kg ethylene dichloride in their diet for 78 weeks. No statistical or histopathologic data were given concerning the tumors.

Ethylene dichloride and its known metabolic product, chloroacetic acid, showed low mutagenicity when tested by McCann et al [135] on a tester strain of bacteria. However, by comparison, the possible intermediate metabolites, chloroethanol and chloroacetaldehyde, were extremely potent mutagens.

LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT / JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	EC-VCM-HCL UNIT							
	PROCESS OPERATOR	STEL	N/A	2	0.830 TO 1.240	1.014	.	15PPM
		TWA	N/A	14	0.100 TO 2.100	0.317	0.03	5PPM
	VC AUX.OPERATOR	STEL	4	9	0.100 TO 8.500	0.361	1.79	15PPM
		TWA	4	13	0.100 TO 1.750	0.269	0.05	5PPM
	WELDER	TWA	N/A	2	0.070 TO 35.900	1.585	.	5PPM
	EDC LIQ PHASE							
	EDC OPERATOR	TWA	N/A	19	0.010 TO 20.300	3.235	38.21	5PPM
	EDC-MC UNIT							
	AREA	TWA	AREA SAMPLES	10	0.050 TO 1.490	0.232	0.26	5PPM
	EDC OPERATOR	STEL	N/A	4	0.500 TO 27.400	2.369	15.87	15PPM
		TWA	N/A	14	0.010 TO 12.100	0.968	15.87	5PPM
	GENERAL WORKER	STEL	N/A	2	0.500 TO 0.560	0.529	.	15PPM
	INSTRUMENTATION MAN	TWA	N/A	5	0.760 TO 1.500	0.895	0.03	5PPM
	TRI-ETHANE LEAD OPER	TWA	*	15	0.190 TO 11.000	1.002	6.68	5PPM
	TRI ETHANE OPERATOR	TWA	*	11	0.370 TO 8.900	1.033	5.48	5PPM
	T.E.2 STABILIZER OPR	TWA	N/A	1	0.590 TO 0.590	0.590	.	5PPM
	TRI-ETHANE AUX.OPER.	STEL	*	3	0.010 TO 37.200	1.426	30.85	15PPM
		TWA	*	16	0.740 TO 19.600	3.130	30.85	5PPM
	VDC OPERATOR	TWA	N/A	6	0.200 TO 4.040	0.992	9.68	5PPM
	WELDER	STEL	N/A	1	0.100 TO 0.100	0.100	.	15PPM
		TWA	N/A	4	0.640 TO 3.870	1.584	6.68	5PPM
	EDC-VDC							
	AREA	TWA	AREA SAMPLES	4	1.870 TO 9.890	3.551	30.85	5PPM
	AREA SUPERVISOR	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	EDC OPERATOR	STEL	4	18	0.100 TO 74.300	5.935	30.85	15PPM
		TWA	4	33	0.370 TO 33.600	2.706	24.20	5PPM
	EDC LEAD OPERATOR	STEL	N/A	3	0.100 TO 1.630	0.434	0.62	15PPM
		TWA	N/A	5	0.100 TO 0.590	0.295	0.03	5PPM
	EDC-VDC AUX.OPERATOR	STEL	4	2	0.100 TO 9.260	0.962	.	15PPM
		TWA	4	12	0.370 TO 10.400	4.206	42.07	5PPM
	EDC-VDC OPERATOR	STEL	4	60	0.100 TO 36.700	2.248	9.68	15PPM
		TWA	4	68	0.250 TO 35.600	1.592	8.08	5PPM
	FOREMAN	TWA	N/A	25	0.100 TO 8.030	0.388	1.39	5PPM
	INSTRUMENTATION MAN	TWA	N/A	9	0.100 TO 1.710	0.511	0.47	5PPM
	LEAD OPERATOR	STEL	4	7	0.500 TO 1.480	0.584	0.03	15PPM
		TWA	4	31	0.100 TO 3.620	0.361	0.35	5PPM
	LOGBOOK INSTRUM.MAN	TWA	1	11	0.340 TO 4.720	1.233	4.46	5PPM
	LOGBOOK MECHANIC	TWA	1	11	0.220 TO 49.200	0.689	11.51	5PPM
	LOADER LABORER	TWA	N/A	1	1.860 TO 1.860	1.860	.	5PPM
	MACHINIST	TWA	N/A	7	0.450 TO 8.100	2.271	21.19	5PPM
	PIPEFITTERS	TWA	N/A	2	0.240 TO 0.560	0.367	.	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT / JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	EDC-VDC							
	SUPERVISOR	STEL	N/A	1	4.000 TO 4.000	4.000	.	15PPM
	VDC OPERATOR	STEL	*	3	0.170 TO 7.350	1.148	8.08	15PPM
		TWA	*	4	1.080 TO 13.480	2.691	30.85	5PPM
	ETHYL CHLORIDE							
	EC HCL OPERATOR	TWA	N/A	15	0.010 TO 2.500	0.112	4.46	5PPM
	LABORATORY							
	AREA	TWA	AREA SAMPLES	7	0.320 TO 7.960	1.082	9.68	5PPM
	CHEMIST	STEL	N/A	2	0.500 TO 0.600	0.548	.	15PPM
		TWA	N/A	40	0.100 TO 6.830	0.155	0.03	5PPM
	LABORATORY ANALYST	TWA	N/A	78	0.010 TO 6.390	0.536	1.79	5PPM
	LAB SENIOR ANALYST	STEL	N/A	1	7.880 TO 7.880	7.880	.	15PPM
		TWA	N/A	42	0.140 TO 2.900	0.419	0.05	5PPM
	LAB ASSOCIATE	TWA	N/A	11	0.100 TO 0.880	0.166	0.03	5PPM
	LAB. ASSISTANT	STEL	N/A	1	5.900 TO 5.900	5.900	.	15PPM
		TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	LAB JUNIOR ANALYST	TWA	N/A	19	0.160 TO 5.700	0.803	3.59	5PPM
	LAB SENIOR ASSOCIATE	TWA	N/A	14	0.100 TO 2.260	0.331	0.26	5PPM
	RESEARCH SCIENTIST	TWA	N/A	2	0.130 TO 0.400	0.228	.	5PPM
	SUPERVISOR	TWA	N/A	4	0.190 TO 0.690	0.446	0.03	5PPM
	LIQUEFACTION							
	AREA	TWA	AREA SAMPLES	3	0.110 TO 0.180	0.130	0.03	5PPM
	MAINTENANCE							
	AREA	STEL	AREA SAMPLES	1	0.590 TO 0.590	0.590	.	15PPM
	ELECTRICIAN	TWA	N/A	1	0.470 TO 0.470	0.470	.	5PPM
	GENERAL WORKER	TWA	N/A	4	0.010 TO 0.950	0.083	4.46	5PPM
	INSTRUMENTATION MAN	TWA	N/A	7	0.100 TO 0.920	0.299	0.07	5PPM
	INSULATOR	TWA	N/A	12	0.100 TO 14.200	0.507	5.48	5PPM
	LOGBOOK INSTRUM.MAN	TWA	N/A	7	0.220 TO 1.340	0.423	0.10	5PPM
	LOGBOOK MECHANIC	TWA	N/A	5	0.150 TO 2.030	0.348	0.82	5PPM
	MACHINIST	STEL	N/A	2	3.140 TO 5.810	4.271	.	15PPM
		TWA	N/A	26	0.100 TO 60.900	0.574	6.68	5PPM
	PAINTER	STEL	N/A	2	0.410 TO 0.600	0.496	.	15PPM
		TWA	N/A	2	0.100 TO 0.630	0.251	.	5PPM
	PIPEFITTERS	TWA	N/A	50	0.100 TO 47.000	0.496	4.46	5PPM
	SERVICE HELPER	TWA	N/A	1	0.420 TO 0.420	0.420	.	5PPM
	UTILITY CREW	TWA	N/A	2	0.420 TO 0.430	0.425	.	5PPM
	UTILITY MECHANIC	TWA	N/A	1	0.860 TO 0.860	0.860	.	5PPM
	WELDER	STEL	N/A	1	0.300 TO 0.300	0.300	.	15PPM
		TWA	N/A	29	0.100 TO 8.200	0.436	2.28	5PPM
	YARDCREW	STEL	N/A	2	0.500 TO 0.500	0.500	.	15PPM
		TWA	N/A	25	0.100 TO 13.800	0.634	5.48	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	MAJOR MAINTEN.							
	LOGBOOK INSTRUM.MAN	TWA	N/A	1	0.370 TO 0.370	0.370	.	5PPM
	OHC-EDC							
	AREA	TWA	AREA SAMPLES	1	2.300 TO 2.300	2.300	.	5PPM
	MACHINIST	TWA	N/A	1	0.010 TO 0.010	0.010	.	5PPM
	OHC AUXILIARY OPERAT	TWA	N/A	8	1.000 TO 5.890	3.657	30.85	5PPM
	OHC OPERATOR	TWA	N/A	8	0.710 TO 49.200	2.321	27.43	5PPM
	TETRA OPERATOR	TWA	N/A	9	0.010 TO 2.200	0.469	8.08	5PPM
	OHC-TETRA							
	AUXILIARY OPERATOR	STEL	4	4	1.400 TO 17.100	5.318	21.19	15PPM
		TWA	4	12	1.400 TO 22.000	4.515	46.02	5PPM
	LOGBOOK INSTRUM.MAN	TWA	1	15	0.290 TO 2.360	0.719	0.03	5PPM
	OHC OPERATOR	STEL	4	1	2.600 TO 2.600	2.600	.	15PPM
		TWA	4	7	0.190 TO 2.000	0.816	2.87	5PPM
	OHC-TETRA LEAD OPER.	TWA	4	1	34.500 TO 34.500	34.500	.	5PPM
	TETRA OPERATOR	TWA	4	15	0.480 TO 11.900	1.874	15.87	5PPM
	W.T.U. OPERATOR	TWA	N/A	1	0.250 TO 0.250	0.250	.	5PPM
	OHC-TETRA-WTU							
	AREA	STEL	AREA SAMPLES	2	0.230 TO 1.380	0.563	.	15PPM
		TWA	AREA SAMPLES	89	0.010 TO 673.000	0.910	18.41	5PPM
	BFI CONTRACTOR	STEL	N/A	2	6.400 TO 13.700	9.364	.	15PPM
		TWA	N/A	6	0.370 TO 4.460	1.381	6.68	5PPM
	HYDROTECH CONT.	STEL	N/A	11	0.010 TO 13.700	0.414	8.08	15PPM
		TWA	N/A	23	0.320 TO 15.000	2.257	24.20	5PPM
	INCINERATOR OPERATOR	STEL	*	5	0.100 TO 7.700	1.557	9.68	15PPM
		TWA	*	7	0.150 TO 1.540	0.464	0.13	5PPM
	INSTRUMENTATION MAN	TWA	N/A	10	0.160 TO 7.550	0.545	4.46	5PPM
	LEAD OPERATOR	TWA	*	18	0.010 TO 2.450	0.408	6.68	5PPM
	OHC AUXILIARY OPERAT	STEL	*	8	0.100 TO 30.300	3.710	21.19	15PPM
		TWA	*	20	0.150 TO 53.000	5.188	50.00	5PPM
	OHC OPERATOR	TWA	*	21	0.140 TO 13.700	1.065	11.51	5PPM
	TCE OPERATOR	STEL	*	6	0.050 TO 61.200	3.323	27.43	15PPM
		TWA	*	22	0.010 TO 13.300	1.379	21.19	5PPM
	VACUUM TRUCK OPER.	TWA	N/A	2	10.700 TO 10.800	10.750	.	5PPM
	W.T.U. LEAD OPER.	TWA	*	7	0.090 TO 2.520	0.396	0.82	5PPM
	W.T.U. OPERATOR	TWA	*	24	0.010 TO 3.500	0.624	5.48	5PPM
	PER/TRI UNIT							
	AREA	TWA	AREA SAMPLES	27	0.010 TO 120.000	0.497	18.41	5PPM
	AREA SUPERVISOR	TWA	N/A	8	0.100 TO 0.250	0.152	0.03	5PPM
	AUXILIARY OPERATOR	STEL	N/A	3	0.100 TO 0.530	0.298	0.03	15PPM
		TWA	N/A	11	0.060 TO 0.830	0.237	0.03	5PPM
	FOREMAN	TWA	N/A	22	0.100 TO 0.350	0.164	0.03	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT / JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	PER/TRI UNIT							
	INSTRUMENTATION MAN	TWA	N/A	14	0.010 TO 1.480	0.186	0.62	5PPM
	LEAD OPERATOR	TWA	N/A	6	0.100 TO 0.210	0.113	0.03	5PPM
	LOGBOOK INSTRUM.MAN	TWA	1	15	0.100 TO 1.450	0.481	0.07	5PPM
	LOGBOOK MECHANIC	TWA	1	15	0.210 TO 1.680	0.516	0.03	5PPM
	MACHINIST	TWA	N/A	12	0.060 TO 0.900	0.236	0.05	5PPM
	PIPEFITTERS	TWA	N/A	3	0.090 TO 0.600	0.181	0.07	5PPM
	PER/TRI AUX OPERATOR	STEL	4	10	0.100 TO 2.280	0.228	0.03	15PPM
		TWA	4	64	0.010 TO 2.270	0.266	0.62	5PPM
	P/T C OPERATOR	STEL	4	5	0.100 TO 1.680	0.298	0.47	15PPM
		TWA	4	33	0.090 TO 1.580	0.344	0.07	5PPM
	P/T LEAD OPERATOR	STEL	4	1	0.100 TO 0.100	0.100	.	15PPM
		TWA	4	21	0.010 TO 6.050	0.204	2.28	5PPM
	P/T REACT OPERATOR	TWA	4	61	0.010 TO 1.730	0.168	0.26	5PPM
	P/T STILL OPERATOR	STEL	4	1	0.010 TO 0.010	0.010	.	15PPM
		TWA	4	50	0.010 TO 3.390	0.203	0.62	5PPM
	WELDER	STEL	N/A	1	8.280 TO 8.280	8.280	.	15PPM
	YARDCREW	TWA	N/A	8	0.050 TO 0.200	0.102	0.03	5PPM
	PER/TRI-TETRA							
	AREA	STEL	AREA SAMPLES	1	0.010 TO 0.010	0.010	.	15PPM
		TWA	AREA SAMPLES	14	0.010 TO 2.400	0.100	5.48	5PPM
	GENERAL WORKER	TWA	N/A	3	0.540 TO 13.700	2.093	30.85	5PPM
	PIPEFITTERS	TWA	N/A	2	1.200 TO 1.700	1.428	.	5PPM
	PER/TRI AUX OPERATOR	TWA	N/A	17	0.010 TO 2.000	0.096	2.87	5PPM
	P/T LEAD OPERATOR	TWA	N/A	5	0.010 TO 0.580	0.083	1.79	5PPM
	P/T REACT OPERATOR	TWA	N/A	12	0.010 TO 1.700	0.121	2.87	5PPM
	P/T STILL OPERATOR	TWA	N/A	13	0.010 TO 2.800	0.233	8.08	5PPM
	SHIFT REPAIRMAN	TWA	N/A	1	0.010 TO 0.010	0.010	.	5PPM
	WELDER	TWA	N/A	1	0.010 TO 0.010	0.010	.	5PPM
	PLNT B N. MAINT							
	CARPENTER	TWA	N/A	9	0.100 TO 0.420	0.124	0.03	5PPM
	ELECTRICIAN	TWA	N/A	11	0.100 TO 0.170	0.114	0.03	5PPM
	FOREMAN	TWA	N/A	8	0.100 TO 0.170	0.116	0.03	5PPM
	INSPECTOR REPAIRER	TWA	N/A	4	0.100 TO 0.100	0.100	0.03	5PPM
	INSTRUMENTATION MAN	TWA	N/A	10	0.100 TO 5.710	0.207	0.62	5PPM
	INSULATOR	TWA	N/A	3	0.290 TO 0.950	0.471	0.03	5PPM
	JANITOR	TWA	N/A	11	0.100 TO 0.440	0.159	0.03	5PPM
	LOGBOOK INSTRUM.MAN	TWA	N/A	12	0.090 TO 6.910	0.259	0.82	5PPM
	LOGBOOK MECHANIC	TWA	N/A	12	0.060 TO 0.720	0.126	0.03	5PPM
	MACHINIST	TWA	N/A	25	0.100 TO 3.720	0.238	0.26	5PPM
	MAINTENANCE FOREMAN	TWA	N/A	2	0.100 TO 0.100	0.100	.	5PPM
	PAINTER	TWA	N/A	2	0.100 TO 0.100	0.100	.	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	PLNT B N. MAINT							
	PIPEFITTERS	TWA	N/A	35	0.100 TO 42.800	0.252	2.87	5PPM
	RIGGERS	TWA	N/A	1	0.140 TO 0.140	0.140	.	5PPM
	SHIFT REPAIRMAN	TWA	N/A	2	0.100 TO 0.100	0.100	.	5PPM
	UTILITY CREW	TWA	N/A	3	0.100 TO 0.390	0.157	0.03	5PPM
	UTILITY MECHANIC	TWA	N/A	21	0.100 TO 0.700	0.140	0.03	5PPM
	WELDER	TWA	N/A	65	0.100 TO 39.000	0.210	0.82	5PPM
	YARDCREW	STEL	N/A	10	0.740 TO 75.700	6.217	30.85	15PPM
		TWA	N/A	57	0.100 TO 78.900	0.273	3.59	5PPM
	ZONE PLANNER	TWA	N/A	6	0.100 TO 0.180	0.110	0.03	5PPM
	PLNT B S. MAINT							
	ELECTRICIAN	TWA	N/A	1	0.250 TO 0.250	0.250	.	5PPM
	FOREMAN	TWA	N/A	7	0.100 TO 0.500	0.279	0.03	5PPM
	INSTRUMENTATION MAN	TWA	N/A	14	0.110 TO 0.910	0.225	0.03	5PPM
	JANITOR	TWA	N/A	10	0.100 TO 0.340	0.148	0.03	5PPM
	LOGBOOK INSTRUM.MAN	TWA	N/A	8	0.100 TO 0.440	0.164	0.03	5PPM
	LOGBOOK MECHANIC	TWA	N/A	6	0.100 TO 1.740	0.305	2.28	5PPM
	MACHINIST	TWA	N/A	19	0.100 TO 1.650	0.229	0.03	5PPM
	PAINTER	TWA	N/A	7	0.100 TO 0.310	0.163	0.03	5PPM
	PIPEFITTERS	TWA	N/A	45	0.100 TO 1.600	0.222	0.03	5PPM
	SHIFT REPAIRMAN	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	UTILITY CREW	TWA	N/A	2	0.120 TO 0.540	0.255	.	5PPM
	UTILITY MECHANIC	TWA	N/A	11	0.100 TO 1.990	0.370	0.47	5PPM
	WELDER	TWA	N/A	48	0.100 TO 1.530	0.192	0.03	5PPM
	YARDCREW	TWA	N/A	29	0.100 TO 1.420	0.232	0.03	5PPM
	ZONE PLANNER	TWA	N/A	4	0.100 TO 0.350	0.191	0.03	5PPM
	PLT C ELEC SHOP							
	AREA	TWA	AREA SAMPLES	1	0.940 TO 0.940	0.940	.	5PPM
	WELDER	TWA	N/A	1	0.760 TO 0.760	0.760	.	5PPM
	SHIPPING							
	AREA	STEL	AREA SAMPLES	1	2.520 TO 2.520	2.520	.	15PPM
	FOREMAN	TWA	N/A	4	0.110 TO 0.460	0.187	0.03	5PPM
	LEAD TANKER MAN	TWA	6	1	0.220 TO 0.220	0.220	.	5PPM
	LEADLOADER	TWA	*	2	0.250 TO 1.840	0.678	.	5PPM
	LOADER	STEL	*	5	0.300 TO 19.000	2.915	15.87	15PPM
		TWA	*	38	0.010 TO 11.200	0.185	5.48	5PPM
	LOADER HELPER	STEL	*	6	0.140 TO 17.000	1.374	9.68	15PPM
		TWA	*	34	0.010 TO 20.100	0.247	8.08	5PPM
	TANKER MAN HELPER	STEL	22	4	0.500 TO 19.400	1.665	9.68	15PPM
		TWA	22	34	0.070 TO 7.980	0.480	3.59	5PPM
	TANKER MAN	STEL	28	7	0.520 TO 15.200	1.893	2.28	15PPM
		TWA	28	37	0.100 TO 14.200	0.489	4.46	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT / JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	TECHNICAL							
	AREA	TWA	AREA SAMPLES	1	0.370 TO 0.370	0.370	.	5PPM
	LABORATORY ANALYST	TWA	N/A	7	0.100 TO 3.000	0.460	1.39	5PPM
	LAB SENIOR ANALYST	TWA	N/A	2	0.100 TO 0.100	0.100	.	5PPM
	LAB ASSOCIATE	STEL	N/A	1	0.010 TO 0.010	0.010	.	15PPM
		TWA	N/A	1	0.160 TO 0.160	0.160	.	5PPM
	TRI-ETHANE II UNIT							
	AREA	STEL	AREA SAMPLES	3	1.700 TO 38.500	4.991	27.43	15PPM
		TWA	AREA SAMPLES	41	0.050 TO 197.000	1.152	27.43	5PPM
	AREA SUPERVISOR	TWA	N/A	15	0.160 TO 1.010	0.413	0.03	5PPM
	AUXILIARY OPERATOR	STEL	N/A	9	0.500 TO 27.300	2.204	6.68	15PPM
		TWA	N/A	3	0.390 TO 8.220	1.915	27.43	5PPM
	FOREMAN	TWA	N/A	15	0.220 TO 0.870	0.446	0.03	5PPM
	FURNACE OPERATOR	TWA	N/A	8	0.180 TO 4.720	1.082	9.68	5PPM
	GENERAL WORKER	STEL	N/A	8	0.100 TO 23.000	1.361	9.68	15PPM
	INSTRUMENTATION MAN	TWA	N/A	13	0.010 TO 4.800	0.241	2.28	5PPM
	INSULATOR	TWA	N/A	1	0.260 TO 0.260	0.260	.	5PPM
	LEAD OPERATOR	TWA	N/A	9	0.440 TO 2.180	0.815	0.10	5PPM
	LOGBOOK INSTRUM.MAN	TWA	1	20	0.130 TO 8.990	0.528	0.82	5PPM
	LOGBOOK MECHANIC	TWA	1	20	0.100 TO 5.560	0.592	2.87	5PPM
	MACHINIST	TWA	N/A	5	0.110 TO 0.350	0.202	0.03	5PPM
	MC-DCE OPERATOR	STEL	4	21	0.100 TO 0.500	0.393	0.03	15PPM
		TWA	4	30	0.100 TO 2.910	0.329	0.05	5PPM
	OHC OPERATOR	TWA	4	41	0.150 TO 6.200	1.005	2.87	5PPM
	STORAGE OPERATOR	TWA	N/A	1	0.350 TO 0.350	0.350	.	5PPM
	SUPERVISOR	TWA	N/A	2	0.210 TO 0.310	0.255	.	5PPM
	T.E.2 AUX. OPERATOR	STEL	4	44	0.050 TO 75.500	1.639	11.51	15PPM
		TWA	4	57	0.100 TO 8.810	1.971	21.19	5PPM
	T.E.2 FURNACE OPER.	TWA	4	43	0.100 TO 9.060	1.331	9.68	5PPM
	T.E.2 LEAD OPERATOR	TWA	4	22	0.060 TO 3.240	0.373	0.10	5PPM
	T.E.2 MC OPERATOR	TWA	*	15	0.010 TO 1.030	0.244	0.62	5PPM
	T.E.2 STABILIZER OPR	TWA	4	39	0.010 TO 1.940	0.373	0.47	5PPM
	TRI-ETHANE AUX.OPER.	STEL	N/A	3	0.500 TO 0.500	0.500	0.03	15PPM
		TWA	N/A	2	0.730 TO 0.870	0.797	.	5PPM
	WELDER	TWA	N/A	6	0.010 TO 1.510	0.175	2.87	5PPM
	YARDCREW	TWA	N/A	1	0.280 TO 0.280	0.280	.	5PPM
	TRIETH-VDCM-MC							
	AREA	TWA	AREA SAMPLES	13	0.010 TO 5.000	0.106	5.48	5PPM
	EDC OPERATOR	STEL	N/A	2	23.400 TO 59.400	37.282	.	15PPM
		TWA	N/A	3	0.860 TO 4.600	2.255	18.41	5PPM
	TRI-ETHANE LEAD OPER	STEL	N/A	3	0.010 TO 0.010	0.010	0.03	15PPM
		TWA	N/A	8	0.010 TO 2.000	0.309	9.68	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT / JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	TRIETH-VDCM-MC							
	TRI ETHANE OPERATOR	STEL	N/A	4	0.010 TO 7.100	0.052	4.46	15PPM
		TWA	N/A	25	0.010 TO 15.500	0.270	11.51	5PPM
	TRI-ETHANE AUX.OPER.	STEL	N/A	9	0.010 TO 27.500	0.118	9.68	15PPM
		TWA	N/A	28	0.010 TO 26.100	2.502	38.21	5PPM
	VCM II							
	AREA	TWA	AREA SAMPLES	1	0.820 TO 0.820	0.820	.	5PPM
	AREA SUPERVISOR	TWA	N/A	12	0.100 TO 0.800	0.166	0.03	5PPM
	AUXILIARY OPERATOR	STEL	4	4	0.100 TO 13.900	1.871	15.87	15PPM
		TWA	4	20	0.430 TO 98.600	3.772	42.07	5PPM
	EDC OPERATOR	STEL	4	36	0.100 TO 775.000	1.430	9.68	15PPM
		TWA	4	38	0.100 TO 4.770	0.619	2.28	5PPM
	EDC LEAD OPERATOR	TWA	4	9	0.050 TO 1.610	0.163	0.07	5PPM
	FOREMAN	TWA	N/A	25	0.100 TO 1.130	0.124	0.03	5PPM
	FURNACE OPERATOR	STEL	4	10	0.100 TO 1.620	0.385	0.03	15PPM
		TWA	4	29	0.100 TO 7.330	0.340	1.39	5PPM
	LEAD OPERATOR	TWA	N/A	12	0.080 TO 1.200	0.181	0.03	5PPM
	OHC OPERATOR	STEL	4	11	0.100 TO 8.830	0.470	0.35	15PPM
		TWA	4	40	0.100 TO 3.420	0.229	0.03	5PPM
	OPERATOR-VCM-FURN	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	OPERATOR-VCM-PROC	TWA	N/A	1	0.410 TO 0.410	0.410	.	5PPM
	PROCESS OPERATOR	STEL	4	15	0.100 TO 5.030	0.375	0.07	15PPM
		TWA	4	61	0.100 TO 6.030	0.221	0.19	5PPM
	STORAGE OPERATOR	STEL	4	6	0.100 TO 0.500	0.283	0.03	15PPM
		TWA	4	36	0.050 TO 0.500	0.134	0.03	5PPM
	SUPERVISOR	TWA	N/A	4	0.100 TO 0.130	0.107	0.03	5PPM
	VC AUX.OPERATOR	STEL	N/A	34	0.500 TO 35.900	5.836	13.57	15PPM
		TWA	N/A	26	0.100 TO 7.880	1.878	15.87	5PPM
	VCM LEAD OPERATOR	TWA	4	19	0.100 TO 2.260	0.148	0.03	5PPM
	VINYL CHLORIDE							
	EC HCL OPERATOR	TWA	N/A	3	0.010 TO 1.400	0.115	6.68	5PPM
	LEAD OPERATOR	TWA	N/A	1	0.010 TO 0.010	0.010	.	5PPM
	OPERATOR-VCM-FURN	TWA	N/A	22	0.010 TO 3.300	0.201	6.68	5PPM
	OPERATOR-VCM-PROC	TWA	N/A	24	0.010 TO 3.900	0.178	5.48	5PPM
	WTU-INCINERATOR							
	AREA	STEL	AREA SAMPLES	5	0.290 TO 100.300	3.534	30.85	15PPM
		TWA	AREA SAMPLES	15	0.160 TO 4.970	0.774	4.46	5PPM
	AREA SUPERVISOR	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	AUXILIARY OPERATOR	STEL	4	17	0.100 TO 11.600	1.557	2.87	15PPM
		TWA	4	56	0.100 TO 7.090	0.745	4.46	5PPM
	FOREMAN	TWA	N/A	20	0.100 TO 5.310	0.282	2.28	5PPM
	INCINERATOR OPERATOR	TWA	4	29	0.100 TO 8.570	0.398	0.82	5PPM

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LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	WTU-INCINERATOR							
	LOGBOOK INSTRUM.MAN	TWA	N/A	3	0.210 TO 1.340	0.546	0.82	5PPM
	PIPEFITTERS	TWA	N/A	1	0.230 TO 0.230	0.230	.	5PPM
	SUPERVISOR	TWA	N/A	4	0.100 TO 0.100	0.100	0.03	5PPM
	TCE OPERATOR	TWA	N/A	15	0.100 TO 8.710	1.005	5.48	5PPM
	TETRA OPERATOR	STEL	N/A	1	0.500 TO 0.500	0.500	.	15PPM
		TWA	N/A	14	0.320 TO 2.840	1.157	3.59	5PPM
	WTU-INCINER.LEAD OP.	TWA	4	8	0.100 TO 0.530	0.243	0.03	5PPM
	W.T.U. OPERATOR	TWA	4	49	0.100 TO 6.420	0.560	3.59	5PPM

SL 101183

LAKE CHARLES
LEIDEL-BUSCH STATISTICS
ALL RECORDS ON FILE
REPORTED: 06/23/88

CHEM	DEPARTMENT JOB TITLE	SAMP TYPE	NUM EMP JOB TITLE	NUMBER OF SAMPLES	RANGE	GEOM AVERAGE	PERCENT OVERSTANDARDS	PPG IPEL
EDC	COMP MACHN SHOP							
	ELECTRICIAN	TWA	N/A	1	0.250 TO 0.250	0.250	.	5PPM
	INSTRUMENTATION MAN	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	SHIFT REPAIRMAN	TWA	N/A	1	0.100 TO 0.100	0.100	.	5PPM
	CONTRACTOR							
	AREA	TWA	AREA SAMPLES	6	0.100 TO 39.900	0.680	21.19	5PPM
	BFI CONTRACTOR	TWA	N/A	4	0.390 TO 23.400	4.295	46.02	5PPM
	CONTRACT LABORER	STEL	N/A	3	0.100 TO 28.100	~~1.992~~	21.19	15PPM
		TWA	N/A	12	0.070 TO 89.800	~~1.895~~ 8.195	30.85	5PPM
	FOREMAN	TWA	N/A	1	0.050 TO 0.050	0.050	.	5PPM
	HEAVY EQUIP.OPERATOR	STEL	N/A	1	204.200 TO 204.200	204.200	.	15PPM
		TWA	N/A	5	0.410 TO 9.200	3.529	38.21	5PPM
	HYDROTECH CONT.	TWA	N/A	2	1.200 TO 2.200	1.625	.	5PPM
	TRUCK DRIVER	TWA	N/A	2	13.000 TO 14.000	13.491	.	5PPM
	VACUUM TRUCK OPER.	STEL	N/A	2	3.600 TO 6.400	4.800	.	15PPM
		TWA	N/A	78	0.100 TO 201.000	6.406	57.93	5PPM
	DERIV.-GENERAL							
	ENVIRON. FOREMAN	TWA	N/A	4	0.110 TO 0.300	0.167	0.03	5PPM
	SAFETY SUPERVISOR	TWA	N/A	4	0.100 TO 0.100	0.100	0.03	5PPM
	SHIFT SUPERVISOR	TWA	N/A	8	0.140 TO 0.580	0.235	0.03	5PPM
	EC-VCM-HCL UNIT							
	AREA	TWA	AREA SAMPLES	16	0.050 TO 3.870	0.369	1.07	5PPM
	AREA SUPERVISOR	TWA	N/A	4	0.100 TO 0.130	0.112	0.03	5PPM
	EC HCL OPERATOR	STEL	4	1	0.010 TO 0.010	0.010	.	15PPM
		TWA	4	46	0.010 TO 3.920	0.200	0.35	5PPM
	FOREMAN	TWA	N/A	6	0.100 TO 0.610	0.153	0.03	5PPM
	FURNACE OPERATOR	STEL	N/A	1	64.500 TO 64.500	64.500	.	15PPM
		TWA	N/A	9	0.100 TO 7.240	0.650	6.68	5PPM
	GENERAL WORKER	STEL	N/A	5	0.100 TO 32.200	1.771	21.19	15PPM
		TWA	N/A	7	0.010 TO 1.120	0.263	3.59	5PPM
	INSTRUMENTATION MAN	TWA	N/A	11	0.110 TO 1.040	0.253	0.03	5PPM
	LEAD OPERATOR	STEL	4	1	0.100 TO 0.100	0.100	.	15PPM
		TWA	4	31	0.010 TO 1.960	0.183	0.19	5PPM
	LOGBOOK INSTRUM.MAN	TWA	1	10	0.080 TO 0.850	0.386	0.03	5PPM
	LOGBOOK MECHANIC	TWA	1	9	0.090 TO 0.490	0.214	0.03	5PPM
	MACHINIST	TWA	N/A	4	0.060 TO 0.260	0.122	0.03	5PPM
	OPERATOR-VCM-FURN	STEL	4	11	0.360 TO 64.700	3.421	21.19	15PPM
		TWA	4	30	0.010 TO 6.470	0.458	9.68	5PPM
	OPERATOR-VCM-PROC	STEL	4	6	0.100 TO 4.290	0.764	1.39	15PPM
		TWA	4	37	0.010 TO 19.900	0.420	4.46	5PPM
	PIPEFITTERS	TWA	N/A	7	0.070 TO 132.000	0.673	21.19	5PPM

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