

## SECTION 4.0

### HYDROCARBON EMISSION CONTROL TECHNOLOGY

The objective of this section is to report on the state-of-the-art of hydrocarbon emission control technology, and specifically to identify those control methods applicable to the sources in the Basin and the cost-effectiveness of these methods in each application. The information presented was intended to be used for organic emission control strategy along with the basic inventory presented in Section 2.0. In this regard, those source categories with the largest and most reactive emissions and the lowest control system cost effectiveness should be the primary candidates for emission reductions. Because the cost and performance efficiency of control equipment varies with the specific application, a great deal of engineering judgment was exercised in generalizing the cost effectiveness numbers. However, the "average" values were felt to be of sufficient accuracy to validate the relative cost effectiveness between the various methods and applications.

The installed costs used in this report, unless specified to the contrary, are the costs that an owner would pay to a contractor to install that piece of equipment including the equipment purchase price and the contractor's fees for designing, supervising, and installing the equipment. But these are not the total costs to the owner. In addition to these direct costs are such indirect costs as the engineering and management time necessary to recognize the problem; find alternative solutions; select equipment and contractor; supervise the construction and integration with the plant; company lost revenues for the time the plant is inoperative while the equipment is being installed; changes elsewhere in the plant due to the new control equipment; and the company's general and administrative expenses (bookkeeping, accounting, legal, etc.) associated with these expenditures. These indirect items can add 50% to 100% additional cost to the owner.

KVB 5804-714

In the past year, the EPA has published a number of reports and guideline documents which contain extremely thorough treatments of the various aspects of organic emission control technology and its application to various industries and source types. Those documents, referenced in this section, were the basis for much of this discussion, and should be consulted for more detailed information.

A summary of the various control techniques and the sources to which they apply is shown in Table 4-1. This report section is based on this table. Control methods are discussed in Section 4.1, their application on the various sources listed in Table 4-1 are covered in Section 4.2, and cost effectiveness data are presented in Section 4.3.

KVB 5804-714

TABLE 4-1. ORGANIC EMISSION CONTROL OPTIONS FOR VARIOUS PROCESSES

Control	Carbon Adsorption	Thermal Incineration	Catalytic Incineration	Condensation	Absorption (Scrubbing)	Vapor Space Elimination (Floating Roof Tank)	Liquid/Vapor Exchange (Balance System)	Enclosure	Process and Material Changes	Improved Maintenance	Other	Remarks
Process	X	X	X	X	X	X	X	X	X	X	X	Plug valves frequently lubed
1. PETROLEUM OPERATIONS												
Production												
Valves, Flanges, etc.												
Pumps and Compressors												
Tanks (Prod. & Stor.)												
Waste Water Separators												
Wall Vents (Tertiary Recov.)												
Boilers & Heaters												
IC Engines												
Refining												
Valves, Flanges, etc.												
Pumps and Compressors												
Waste Water Separators												
Vacuum Jets												
Asphalt Air Blowing												
Boilers & Heaters												
Catalyst Regenerators												
Storage Tanks												
Transferring Blow Down												
Marketing												
Transferring Truck to Tank												
Tank to Car												
Tank Breathing												

NOTE: For each process, the X's indicate the candidate control devices to be considered. The final selection should be based on the most favorable economic factors.

KVB 5804-714

TABLE 4-1 (Continued)

Control Process	Carbon Adsorption	Thermal Incineration	Catalytic Incineration	Condensation	Absorption (Scrubbing)	Vapor Space Elimination (Floating Roof Tank)	Liquid/Vapor Exchange (Balance System)	Enclosure	Process and Material Changes	Improved Maintenance	Other	Remarks
<b>2. ORGANIC SOLVENT OPERATIONS</b>												
<u>Metal Coating</u>												
Automotive	X	X	X						X			Water-borne paint
Cans	X	X	X						X			Low Solv. Coatings
Coil Coating	X	X	X						X			Low Solv. Coatings
Appliances	X	X	X						X			Low Solv. Coatings
Machinery	X	X	X						X			Low Solv. Coatings
Commercial	X	X	X						X			Low Solv. Coatings
Products	X	X	X						X			Low Solv. Coatings
Furniture	X	X	X						X			Low Solv. Coatings
<u>Paper &amp; Film Coating</u>												
Adhesive tapes and Labels	X	X	X						X			Low Solv. Coatings
Decorated and Glazed Paper	X	X	X						X			Low Solv. Coatings
Photo Film & Paper	X	X	X						X			Low Solv. Coatings
Typewriter Ribbons	X	X	X						X			Low Solv. Coatings
Magnetic Tape	X	X	X						X			Low Solv. Coatings
<u>Fabric Coating</u>												
Dyeing	X	X	X						X			Water Sol. Dye
Scouring	X	X	X						X			Low Solv. Coating
Rubberizing	X	X	X						X			
Vinyl Coating	X	X	X						X			
Carpet Mfg.	X	X	X						X			
<u>Other</u>												
Printing	X	X	X						X			Water-borne Ink
Tire Mfg.	X	X	X						X			Detergent
Degreasing	X	X	X						X			Water vehicle
Pesticide Mfg.	X	X	X						X			Low Reactivity
Dry Cleaning	X	X	X						X			perchloroethylene
Architectural Coatings	X	X	X						X			Low Solv. Coatings
Wood Finishing	X	X	X						X			Low Solv. Coatings

NOTE: For each process, the 'X's indicate the candidate control devices to be considered. The final selection should be based on the most favorable economic factors.



#### 4.1 CONTROL METHODS

Emissions of organic air pollutants can be reduced by (1) add-on control devices that either destroy the vapor or collect it for reuse or disposal, (2) covers or seals which prevent vapors from escaping, and (3) process or material changes that reduce or eliminate the use of organics.

The principal add-on control devices for the control of volatile organics are:

- . Thermal and catalytic incinerators
- . Activated carbon and other types of adsorbers
- . Absorbers or liquid scrubbers
- . Condensers that use refrigeration or compression.

Incineration is the technique most universally applied by industry, but it usually requires measurable supplemental fuel. Incineration, therefore, is most acceptable where the developed heat can offset other fuel or energy needs. Adsorption, absorption, and condensation techniques - although effective - are limited to exhaust streams with a much narrower range of process characteristics than is incineration.

Covers and seals include floating roof tanks for petroleum and petrochemical storage and covers for waste water separators to prevent evaporative losses from open pools.

Process and material changes are the most diverse options and are used primarily by the surface cleaning and coating industries. Among the available process and material changes are:

- . New cleaning and degreasing techniques.
- . New coating technologies--e.g. water-borne, high-solids, and powder coatings.
- . Reduced ingestion of air into the gas stream requiring treatment.
- . Inert gas curing techniques for coating.
- . More efficient coating application methods.

KVB 5804-714

Although these changes offer great promise, almost each one is unique. Consequently the number necessary to meet all product and process requirements is large. Development and conversion costs are sometimes very high. Process and material changes, therefore, can often be implemented only over much longer time periods than those required for installing add-on devices.

Several factors influence the effectiveness, cost and applicability of available control devices or techniques to a given source category. Quite often the characteristics of a particular process or exhaust gas stream dictate the use of certain control techniques. Many control methods are equivalent in reducing pollution but vary in cost. In the latter instances, it is assumed that the company will select the option that provides the most reduction for the fewest dollars over the expected lifetime of the device.

Other less obvious factors that are unique to the control of organic emissions influence the selection of a control option. For example, virtually all organics are derived from petroleum, and the increasing cost of crude oil provides considerable economic incentive to both reduce solvent consumption and maximize recovery for use. Other regulatory requirements also can preclude - or dictate - the use of certain options. Insurance and occupational safety requirements that specify maximum allowable organic concentrations for fire prevention and operator safety are examples of such regulatory requirements. Finally, long-term warranties or customer requirements can limit the scope of material or process changes.

#### 4.1.1 Carbon Adsorption

Carbon adsorption uses a physical phenomenon to separate organic vapors from a gas stream and to concentrate these vapors to a more manageable form.

It is applicable to most organic-emitting industries (with a few solvents excepted) but the costs and difficulties will vary with the specific industry (Ref. 4-1).

The term "sorption" applies to two types of phenomena: (1) where vapor molecules are concentrated by adsorption on the surface, and (2) where vapors are concentrated by absorption of the vapor molecules into the mass of the sorbent. Adsorption is accomplished using four different types of materials: (1) chemically reactive adsorbents (2) polar adsorbents (3) molecular sieves, and (4) nonpolar adsorbents.

When adsorption is accompanied by chemical reaction, the process is termed "chemisorption," an exothermic process where molecules can only be one layer thick. It has been used for odorous sulfur compounds and some olefins but has little application at this time for organic solvent control.

When adsorption is not accompanied by chemical reaction, the process is termed physical adsorption. In general, polar adsorbents adsorb polar molecules (e.g., water) preferentially, while nonpolar adsorbents adsorb nonpolar molecules (e.g., hydrocarbon) preferentially. Physical adsorption is less selective than chemisorption, the process is reversible and vapor molecules can be adsorbed in more than one layer on the surface. Activated carbon is the only physical adsorbent presently in widespread use for organic vapor collection. It is a nonpolar adsorbent although it has some adsorptivity for water.

Activated carbon can be produced from a variety of carbonaceous materials, its characteristics depend on the raw material and the activation process. Carbon is activated by oxidation of portions of the carbon with steam or chemicals. The end-product of activation is a material with a fine, partially interconnected pore structure that has a very large surface area.

#### A. Adsorption--

The surface area of the activated carbon is the primary variable associated with carbon adsorption. The larger the available area, the larger the adsorption capacity of the carbon, other things being equal. A typical activated carbon may have a surface area of 1100 square meters per gram.

KVB 5804-714

The capacity of carbon is often represented by "adsorption isotherms" such as Figure 4-1 showing the effect of increasing molecular weight of organics on carbon capacity. The isotherms level out as the micropores are filled. For pollution control situations, the range of interest is below a partial pressure of 10 mm of Hg. The effect of temperature on adsorption is shown by Figure 4-2.

For a fixed-bed carbon adsorber, the concentration profile in the bed changes with time as the capacity of the bed is approached. "Breakthrough" time is usually defined as the time when the outlet of the adsorber reaches a defined level (usually 1 percent of the inlet concentration). The bed should be regenerated after the breakthrough has occurred.

For exhaust streams containing multiple solvents, vapors of higher molecular weight (M.W.)\* will displace vapors of lower M.W. As shown in Figure 4-3, adsorption will be as if each solvent was adsorbed independently in a bed when the vapors have very different M.W. As shown in Figure 4-4, there will be a co-adsorption when the vapors are close in M.W. In either case, the compound with the lowest M.W. will exit the adsorber bed first.

For more in-depth information on the theory of adsorption the reader should consult References 4-1 and 4-2.

#### B. Regeneration--

For concentrations greater than a few parts per million, carbon must be used many times for economic reasons. To desorb vapors and reuse the carbon, regeneration is necessary. Regeneration is accomplished by raising the temperature of the carbon, evacuating the bed, or both. Typical thermal regenerants are steam, hot air, and hot inert gas. The hotter the regenerant and the longer the regeneration, the more solvent will be desorbed from the bed. There is an economic optimum where adequate desorption occurs at reasonable energy cost. The residual solvent in the bed after regeneration is called the "heel" and "working capacity" the difference between full capacity and the heel.

---

\*Although molecular weight is used in this discussion, a more precise term is the liquid molar volume at normal boiling point usually denoted as  $V_m$ . M.W. is approximately proportional to  $V_m$  and is an easier property to perceive for the purposes of this discussion.

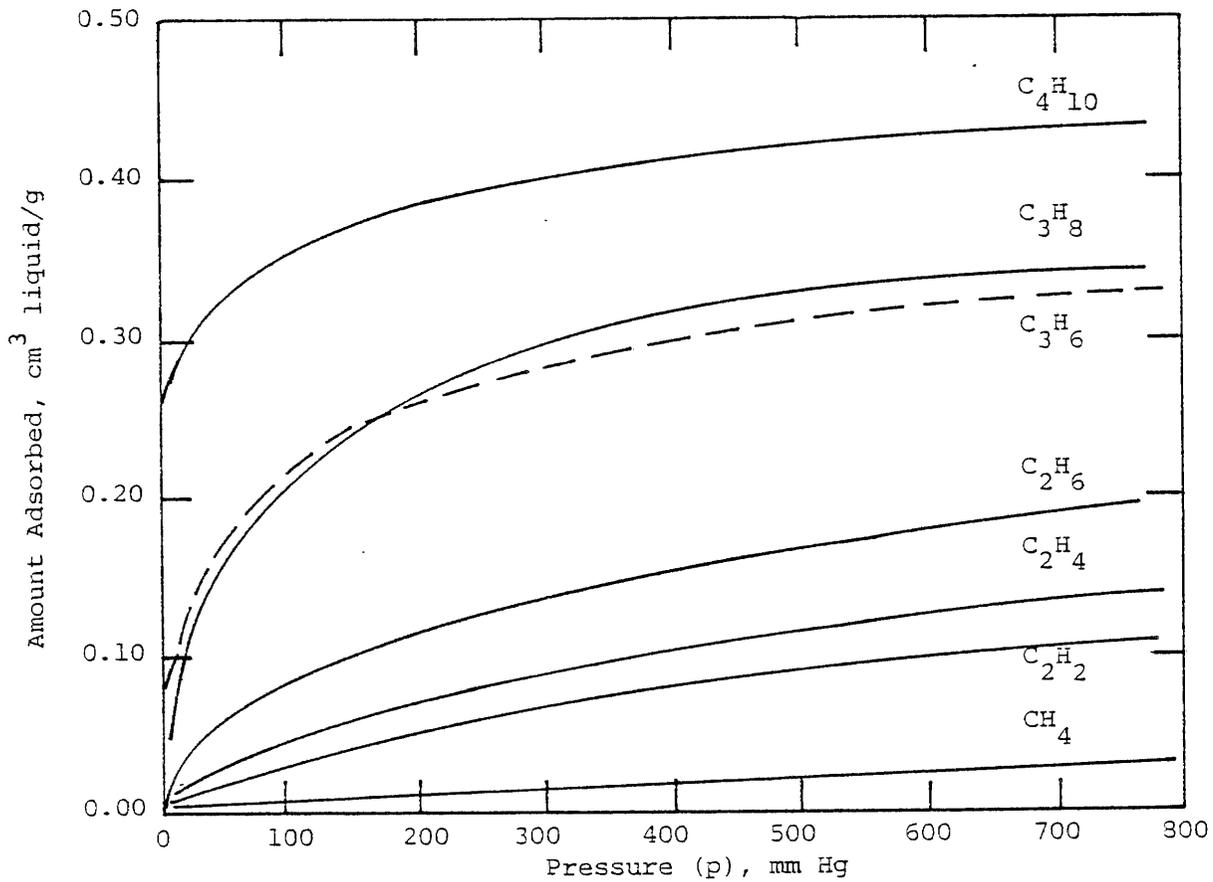


Figure 4-1. Adsorption isotherms of hydrocarbon vapors (amount adsorbed at pressure, p, on type Columbia L carbon at 100 °F, Ref. 4-1).

KVB 5804-714

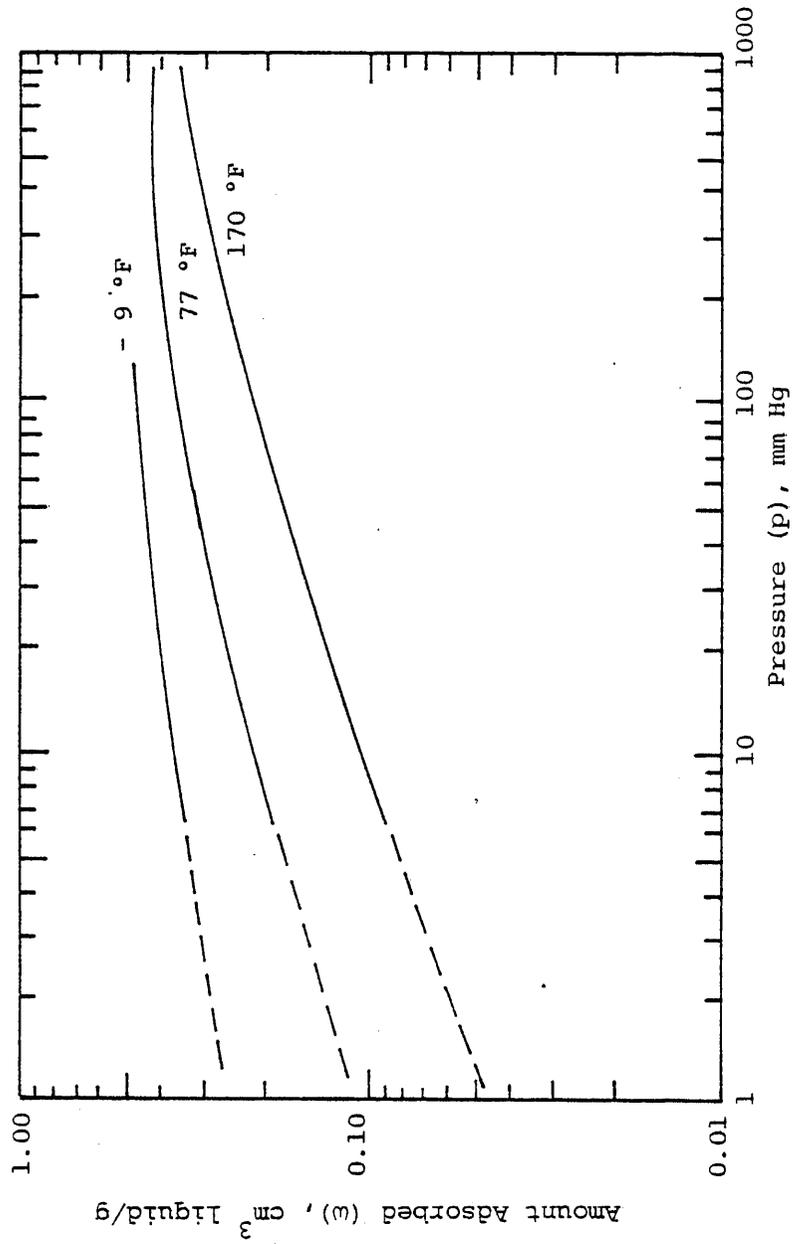


Figure 4-2. Adsorption isotherms of butane at three temperatures on Pittsburgh BPL type carbon (Ref. 4-1).

KVB 5804-714

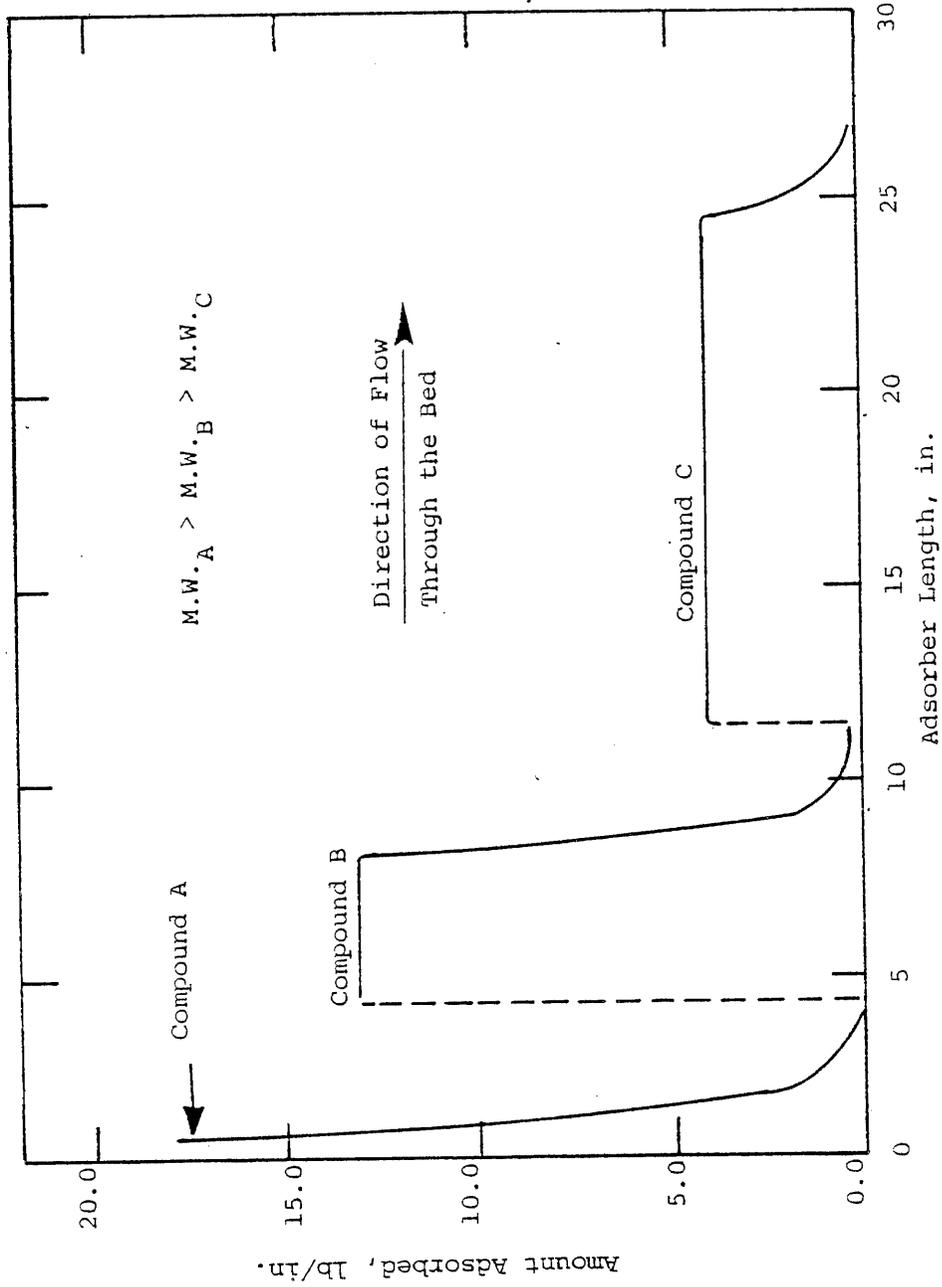


Figure 4-3. Adsorbed vapor profile in activated carbon bed after steady state is established but with no coadsorption (Ref. 4-1).

KVB 5804-714

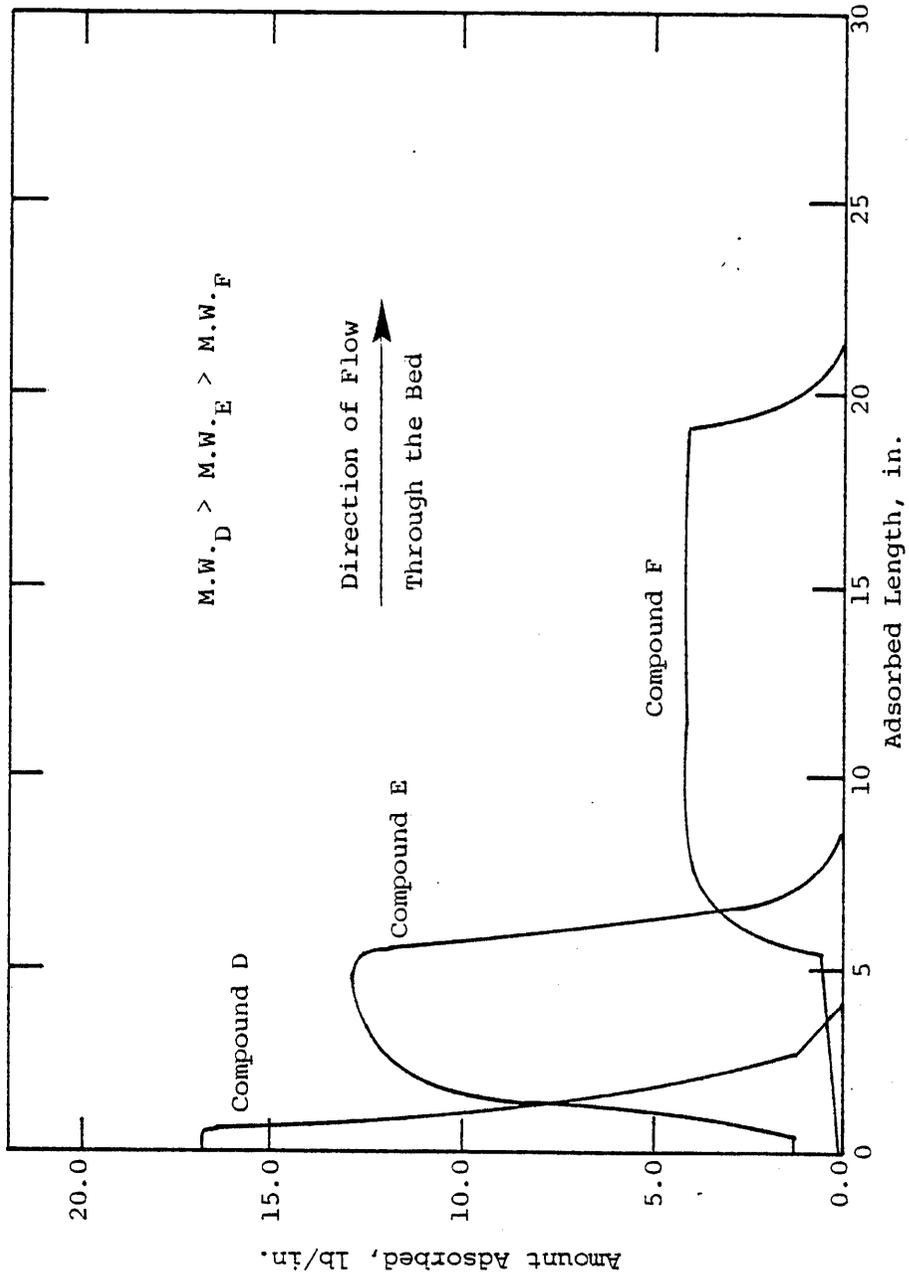


Figure 4-4. Adsorbed vapor profile in activated carbon bed after steady state is established with coadsorption (Ref. 4-1).

KVB 5804-714

Regeneration is typically about 50% complete for each cycle under proper (or economic) operation. To optimize the frequency of regeneration, an automatic device that signals breakthrough may be useful if the size of the adsorber warrants.

1. Thermal Description--Steam is the most widely used regenerant. The bed is closed off from pollutant flow, and steam is introduced into the bed. The steam and the pollutant vapors are routed to a condenser after which they can usually be separated by gravity or distillation. Steam regeneration has the advantage of leaving the bed wet. By control of the degree of wetness in the bed, various degrees of gas cooling can be accomplished. In a variation of this scheme, steam and pollutant can be incinerated without condensation.

As inlet concentration decreases, the bed capacity is reduced. In order to achieve adequate working capacity for low concentrations, the heel must be minimized with consequent increased steam usage. Figures 4-5 and 4-6 show the amount of steam and heated air necessary to desorb two solvents at various initial concentrations. The two compounds (propanone and 4-methyl-2 pentanone) span the range of M.W. for which carbon adsorption is applicable. For concentrations less than 700 ppm, air or inert gas should be considered for regeneration, especially if (1) the adsorbed solvent has no value, (2) the material has appreciable miscibility with water, or (3) the solvent does not contain large amounts of halogen-, nitrogen-, or sulfur-containing compounds.

If a noncondensable gas is used for regeneration, the organics can be removed by condensation, adsorption, and/or incineration. Condensation of virtually all organics in a stream is possible if the stream is cooled to a low enough temperature. A more practical approach is to condense a portion of the vapor and to recycle the remainder back through the operating bed.

Secondary adsorption of the vapors in a smaller adsorber offers a possible method of recovering vapors from a dilute source. The primary adsorber is regenerated by heated inert gas, yielding a gas stream in which the vapor concentration is about 40 times as high as in the original stream. After cooling, this stream can then be passed through a secondary adsorber which is regenerated by steam and the organic material recovered. Reference 4-1 gives further details for this scheme.

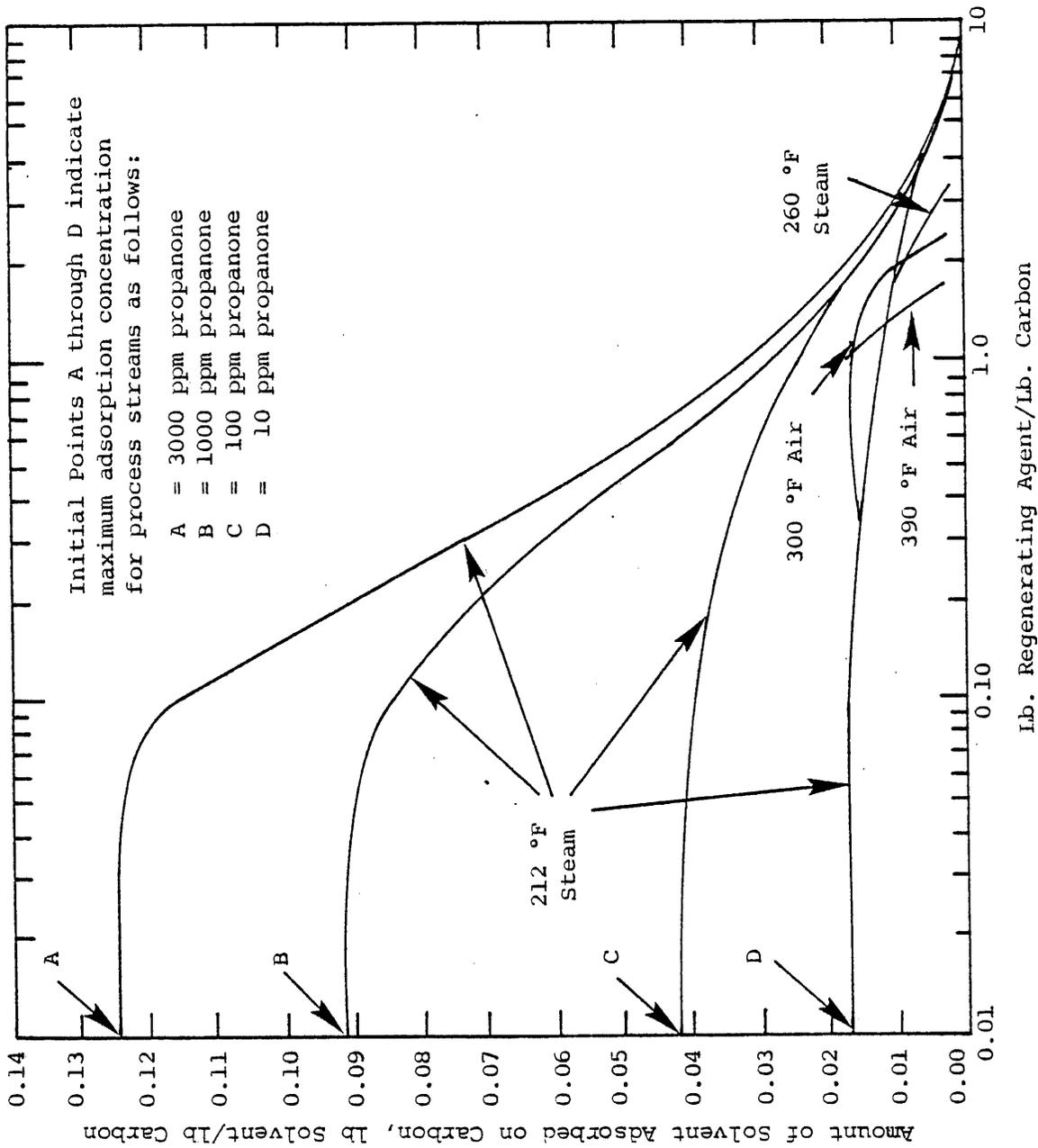


Figure 4-5. Amount of regenerating agent required to desorb BPL V type carbon equilibrated with propane at varied initial concentrations (Ref. 4-1).

KVB 5804-714

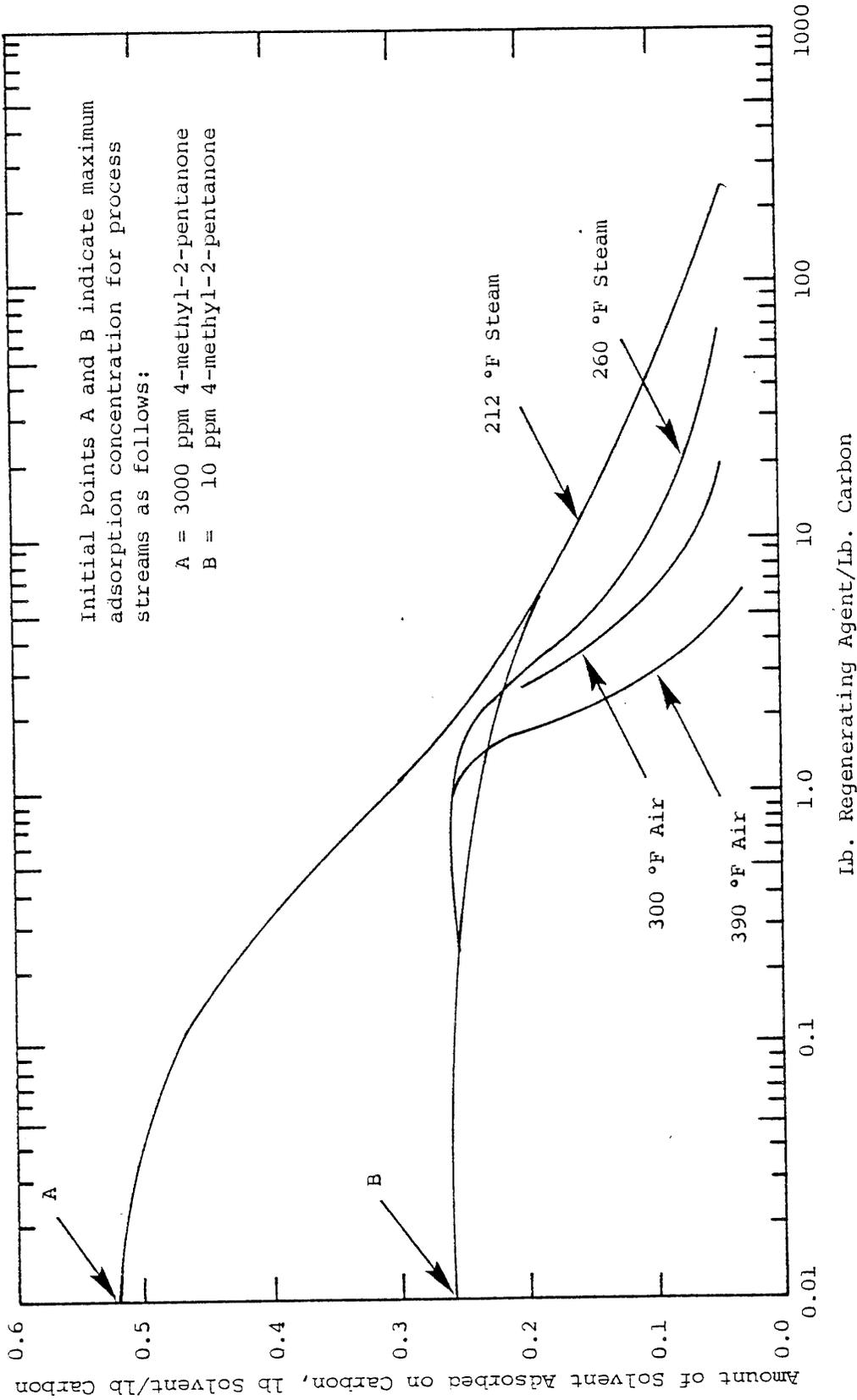
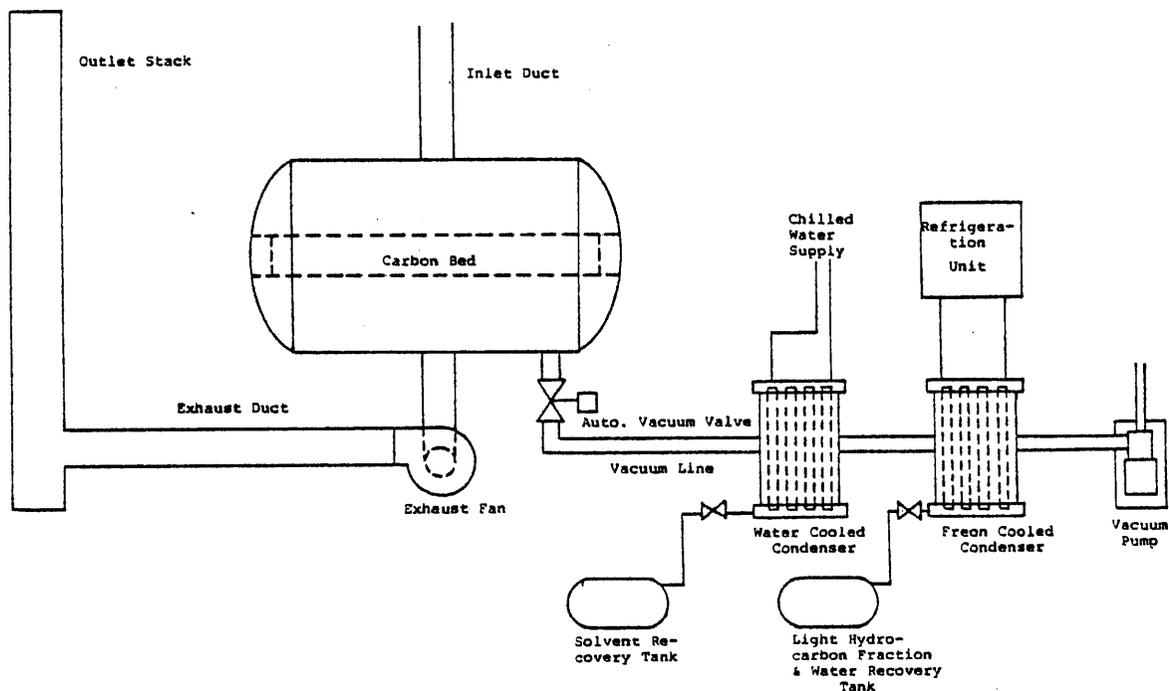


Figure 4-6. Amount of regenerating agent required to desorb GI type carbon with 4-methyl-2-pentanone by 10 and 3000 ppm process streams (Ref. 4-1).

KVB 5804-714

2. Vacuum Desorption--By evacuating the carbon bed to absolute pressures of approximately 1 mm Hg, the boiling point of the adsorbed organic compound is reduced substantially. For example,  $C_{14}$  to  $C_{18}$  hydrocarbon oils have a boiling point of approximately 500 °F at one atmosphere which is reduced to 200 °F at 1 mm Hg. This lowered boiling point facilitates the breaking of the adsorption bond allowing it to take place at lower temperatures which saves energy. Another benefit is that carbon adsorption can be used to recover thermolabile materials which are unstable when heated. These materials would pyrolyze or rearrange chemically at higher temperatures.

Regeneration systems employing vacuum are heated with radiation/conduction heaters. A schematic of a typical process is shown below.



The tank to be regenerated is removed from the adsorbate stream by automatically closing the process vacuum valves at the top and bottom of the tank. Then, a smaller vacuum valve is automatically opened connecting the

tank to a mechanical vacuum pump capable of producing a vacuum of 1 mm Hg in the tank. When the desired vacuum pressure is reached, heat is applied to the carbon bed through a series of cartridge heaters or, if economically practical, a recirculating heat transfer system. The simultaneous application of heat and vacuum strips the solvent from the carbon. The solvent is condensed in a water cooled chamber and then automatically flows into the condensate recovery tank to be returned to the process, or removed for disposal. The low-boiling hydrocarbons are trapped in a refrigerated condenser maintained at a temperature of about -40 °F. When the regeneration process is completed, the tank is once again returned on-stream.

#### C. Problem Areas with Carbon Adsorption--

Several problems are encountered in systems controlling the bake ovens which follow most surface coating operations. Thermal breakdown of the solvents and/or resins can generate a range of low M.W. compounds that cannot be adequately adsorbed. Examples are formaldehyde, methanol, and acetic acid. Polymerization reactions may produce tar-like products that will condense at the operating temperatures of carbon adsorbers and not be desorbed, causing fouling. These complications, if present, do not make carbon adsorption impossible for ovens, but they will necessitate precautions or lower carbon life.

Compounds such as acetone, methyl-ethyl ketone, and phenol, may cause problems because of high heat of adsorption. With proper design, however, problems can be avoided. The main requirement is the use of a wet bed and a controlled relative humidity in the inlet gases to provide a heat sink for the adsorbed vapors. Dimethyl formamide and nitropropanes are a more serious problem; carbon adsorption is probably not applicable where these solvents are used (Ref. 4-2).

1. Reuse of solvent--Unless a single solvent is used and breakdown is avoided, reuse of the solvent may not be feasible. Distillation is possible, but the complexity and cost are so variable that it is difficult to generalize. Reuse of mixed recovered solvents is unlikely if the source is one where many solvents are run on the same machine. In later cost studies it was assumed that if this type of mixed solvent is recovered, it had fuel value only.

2. Particulates--Particulate matter, if allowed to enter the carbon bed, can coat the carbon or plug the voids between carbon particles. Adsorbitivity is decreased and pressure drop increases. The net result is that the carbon must be replaced or cleaned more often. Siliconized coatings cause especially difficult problems.

A solution to a particulate problem is precleaning of the gas. Fabric collectors, mist eliminators, electrostatic precipitators, or scrubbers may be used. The particulate may be very small in particle size, viscous or tacky and hence difficult to remove. Mist eliminators may be used if the particulate is a liquid. If the condensed vapors harden at the operating temperature of the particulate collector, frequent cleaning may be necessary.

3. Temperature--Carbon capacity is greater at lower temperatures. Usually 100 °F is considered the maximum entry temperature. Cooling may be accomplished by direct water sprays or by cooling coils. If condensible gases are present, a spray cooler and mist eliminator should be placed ahead of the adsorber if possible.

4. Humidity--Although carbon preferentially adsorbs organic materials, water will compete with the organics for adsorption sites. To minimize this, relative humidity must be kept below about 50 percent. A minimum of 20 to 40 percent relative humidity should be maintained, however, especially if ketones are to be adsorbed. If gases are hot and wet, cooling followed by some reheat may be necessary. Water formed by fuel combustion must be considered.

5. Concentration--The range of concentrations for which carbon adsorption is applicable is limited. The increased operating cost of low concentrations has been discussed. There is also a potential problem with high concentrations. Adsorption is always an exothermic phenomenon; typically 200 to 300 Btu is generated per lb of solvent adsorbed. If sufficient air is not present to carry this off, the bed can overheat. This can result in poor adsorption and, in extreme cases, bed fires. For concentrations over 25 percent of the lower explosive limit (LEL),\* heating of the bed must be considered in calculations. The problem can be minimized by leaving the bed wet with water.

---

\*The lower explosive limit of a substance is the lowest volume percent concentration of the vapor in air which can be ignited at 70 °F and normal atmospheric pressure.

D. Equipment Design and Operation--

Although there are a great variety of possible schemes for carbon adsorption, most applications are similar in design.

The face velocity is defined as the flow rate divided by cross sectional area of the bed. At high face velocities, the pressure drop increases and is the controlling factor in practical cases. Flow velocities for regenerable systems vary from 30 to 110 feet per minute. The sizes of necessary vessels are shown in Table 4-2 assuming a face velocity of 90 feet per minute. In evaluating the applicability of carbon adsorption to a source, floor or roof space must be considered.

TABLE 4-2. TYPICAL BED SIZES FOR CYLINDRICAL CARBON ADSORBERS

Flow rate, cfm	Bed Diameter, ft
1,000	4
3,000	7
10,000	12
30,000	21
60,000	30

The usual practice is to install at least two adsorbers and operate so that one is adsorbing while the other is regenerating. The largest vessel that can be factory assembled handles about 30,000 cfm. Thus for larger sources the designer has to choose between multiple packaged units and field assembled adsorbers. The largest adsorbers in the South Coast Air Basin are located at California Rotogravure Division of Alco Gravure Corp. They have four 30 ft diameter carbon canisters capable of 60,000 cfm each. At maximum capacity the system operates with three of the units adsorbing and one unit desorbing at all times.

The materials of construction depend on the source to be controlled. If carbon dioxide is present, carbonic acid may be formed. If halogenated compounds are formed, halogen acids may form. Formaldehydes can yield formic acid. Often a stainless or high nickel steel is required.

Bed depths vary with the organic vapor type, with the concentration of organic vapors and with the desired time between regenerations. The lower the M.W., the lower the capacity of the carbon. Higher concentrations increase the capacity of the carbon, but also increase the amount of organic vapor to be adsorbed per unit volume of gas. The net effect is that at higher concentrations, the bed must be deeper for a given vapor, face velocity, and time between regeneration. Bed depths typically range from 1-1/2 to 3 feet but can be less at low concentrations. Cycle times for regenerable systems usually run about 2 hours. Higher flow rates cause the adsorption zone to be longer. For the bed depth range of interest for regenerable systems, this length of 2 to 4 inches will not be significant in comparison with total bed depth.

For a system in which there are no compounds with high molecular weight ( $> C_8$ ), and no polymer formers, or excessive particulates reaching the carbon, a carbon life of 5 to 10 years can be expected.

E. Control Efficiency--

Where carbon adsorption is applicable, 90 to 95 percent removal in the carbon adsorber is commonly attainable.

F. Adverse Environmental Effects of Carbon Adsorption--

If the organic solvents to be recovered are miscible with water, a potential water pollution problem exists. Ways to avoid this are to treat the water or to incinerate the desorbed vapor, together with the steam or air purge.

If incineration is used with solvents containing halogens, sulfur, or nitrogen compounds, acid gases, SO<sub>x</sub> and NO<sub>x</sub> will result.

4.1.2 Incineration

Incineration destroys organic emissions by oxidizing them to carbon dioxide and water vapor. Incineration is the most universally applicable control method for organics; given the proper conditions, any organic compound will oxidize. Oxidation proceeds more rapidly at higher temperatures and higher organic pollutant content. Catalysts are used on some systems to lower energy requirements. In the presence of a catalyst the oxidation

reaction rate is increased permitting a reduction in the reaction temperature for a given degree of oxidation. Incinerators (also called afterburners) have been used for many years on a variety of sources ranging in size from less than 1000 scfm to greater than 40,000 scfm.

A. Design Considerations--

1. Use of existing process heaters for incineration--The use of existing boilers and process heaters for destruction of organic emissions provides for the possibility of pollution control at small capital cost and little or no fuel cost. The option is, however, severely limited in its application. Some of the requirements are:

- . The heater must be operated whenever the pollution source is operated; it will be uncontrolled during process heater down time.
- . The fuel rate to the burner cannot be allowed to fall below that required for effective combustion. On-off burner controls are not acceptable.
- . Temperature and residence time in the heater firebox must be sufficient.
- . For proper control, the volume of polluted exhaust gas must be much smaller than the burner air requirement and be located close to the process heater. For most plants doing surface coating, especially if surface coating is their main business, the combustion air requirement is smaller than the coater-related exhaust. In many diversified plants, the coating operation may be distant from heaters and boilers.
- . Constituents of the coating-related exhaust must not damage the internals of the process heater.

Few boilers or heaters meet these conditions.

2. Use of add-on incinerators--In noncatalytic incinerators (sometimes called thermal or direct flame incinerators), a portion of the polluted gas may be passed through the burner(s) in which auxiliary fuel is fired. Gases exiting the burner(s) in excess of 2000 °F are blended with the bypassed gases and held at temperature until reaction is complete. The equilibrium temperature of mixed gases is critical for effective combustion of organic pollutants. A diagram of a typical arrangement is shown in Figure 4-7.

Path of Fume Flow (Fume Itself is Used as Source of Burner Combustion Oxygen, Eliminating Need for Outside Air Admission and Increased Btu Load.)

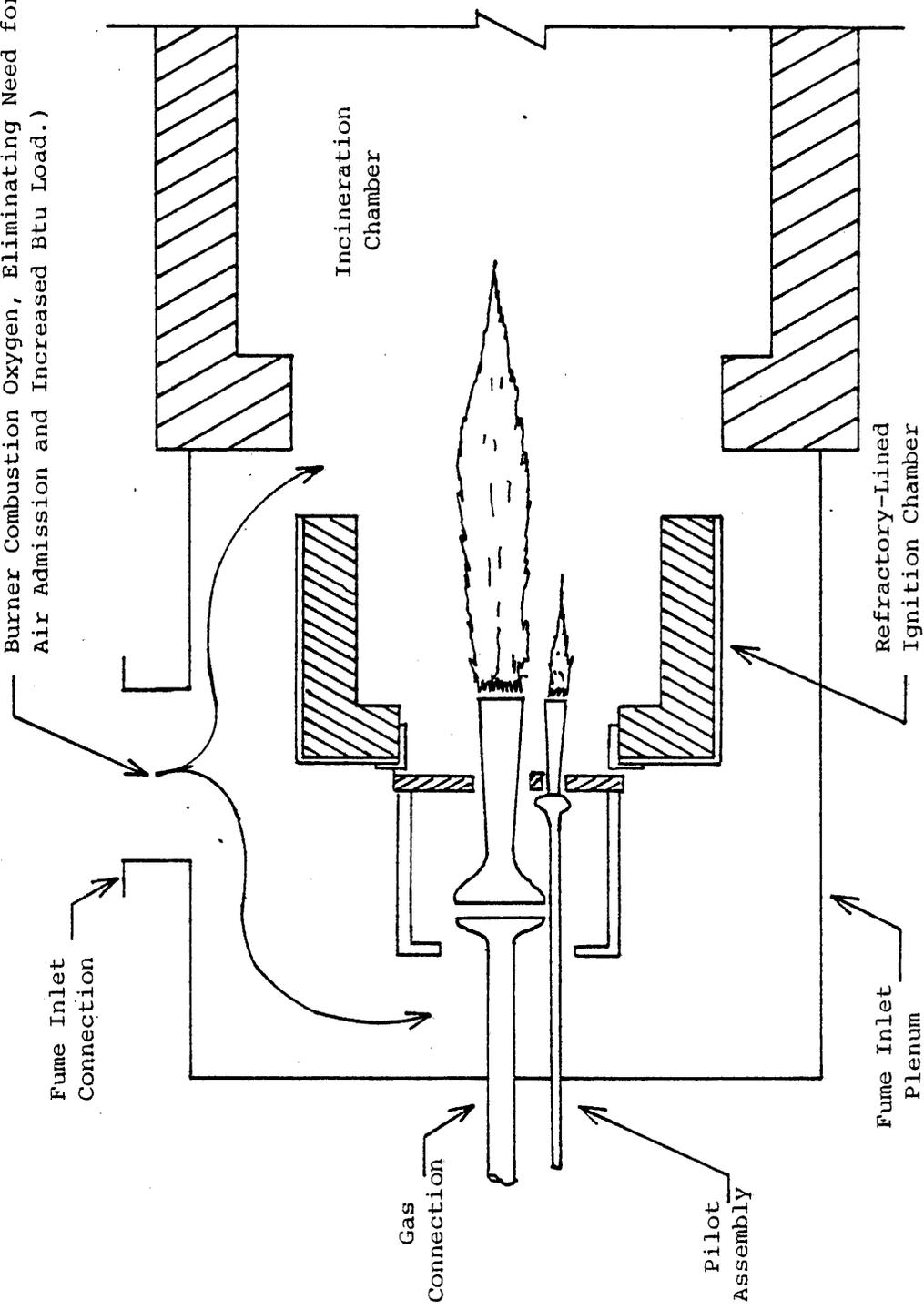


Figure 4-7. Typical burner and chamber arrangement used in direct-flame incinerator.

KVB 5804-714

The coupled effect of temperature and residence time is shown in Figure 4-8. Hydrocarbons will first oxidize to water, carbon monoxide and possibly carbon and partially oxidized organics. Complete oxidation converts CO and residuals to carbon dioxide and water. Figure 4-9 shows the effect of temperature on organic vapor oxidation and carbon monoxide oxidation.

A temperature of 1100 to 1250 °F at a residence time of 0.3 to 0.5 second (Ref. 4-3) is sufficient to achieve 90 percent oxidation of most organic vapors, but about 1400 to 1500 °F may be necessary to oxidize methane, cellosolve, and substituted aromatics such as toluene and xylene (Ref. 4-3).

3. Design--Incineration fuel requirements are determined by the concentration of the pollutants, the waste stream temperature and oxygen level, and the incineration temperature required. For most organic solvents, the heat of combustion level, and the incineration temperature required. For most organic solvents, the heat of combustion is about 0.5 Btu/scf for each percent of the LEL. This is enough to raise the waste stream temperature about 27.5 °F for each percent of the LEL (at 100 percent combustion). Thus, at 25 percent of the LEL, the temperature rise will be 620 °F for 90 percent conversion.

4. Fuel--Natural gas, LPG and distillate and residual oil are used to fuel incinerators. The use of natural gas or LPG results in lower maintenance costs; at present, natural gas also is the least expensive fuel. However, the dwindling natural gas supplies make it almost a necessity to provide newly installed incinerators with oil-burning capabilities.

In most cases where natural gas or LPG is not available, incinerators are fired with distillate fuel oil; residual oil is seldom employed. Oil flames are more luminous and longer than gas flames, thus require longer fireboxes. Almost all fuel oils, even distillate, contain measurable sulfur compounds. Residual oils generally have greater sulfur and particulate contents and many have appreciable nitrogen fractions. Sulfur oxides, particulates and NOx in combustion products from fuel oil increase pollution emissions and cause corrosion and soot accumulation on incinerator working and heat transfer surfaces.

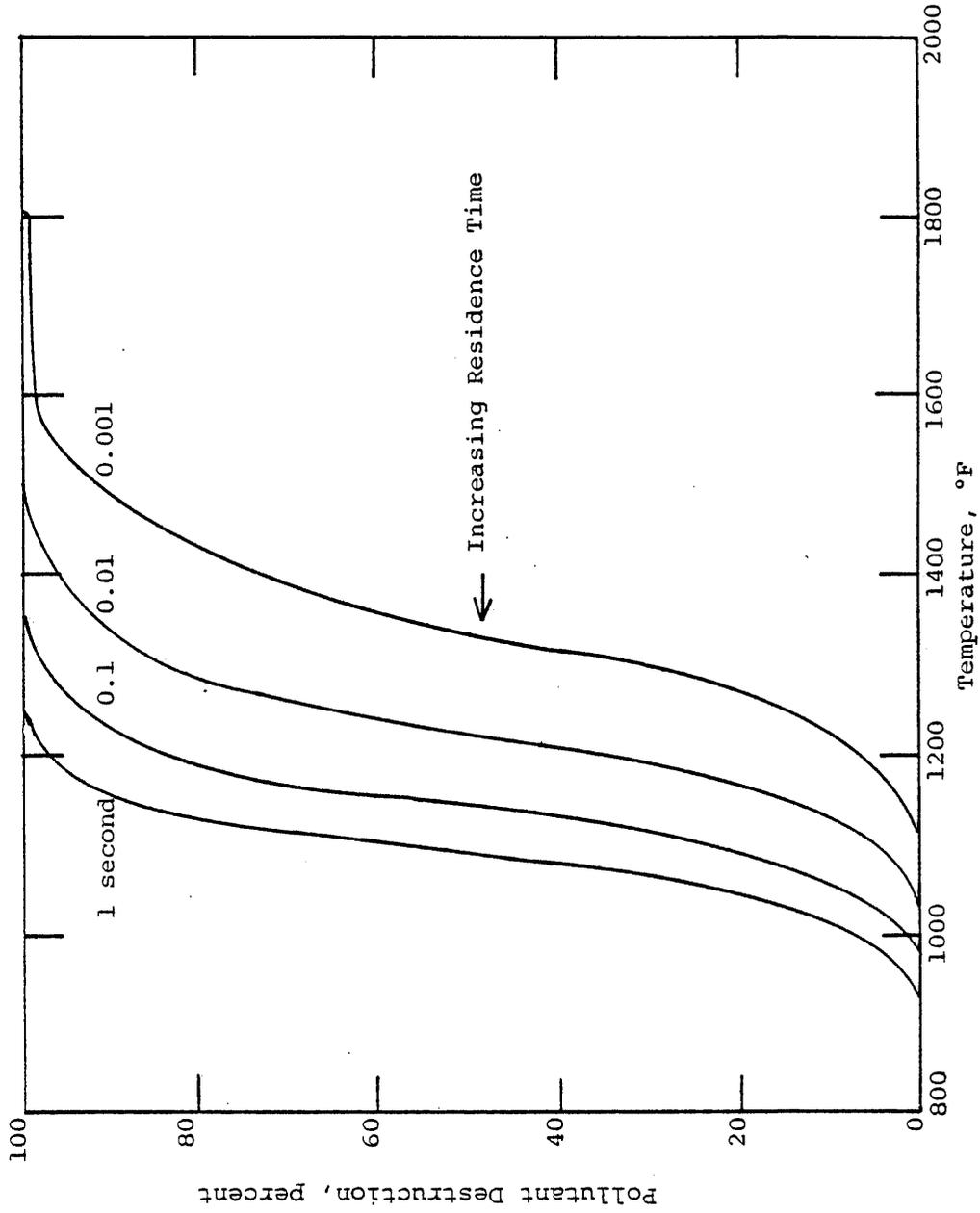


Figure 4-8. Coupled effects of temperature and time on rate of pollution oxidation (Ref. 4-1).

KVB 5804-714

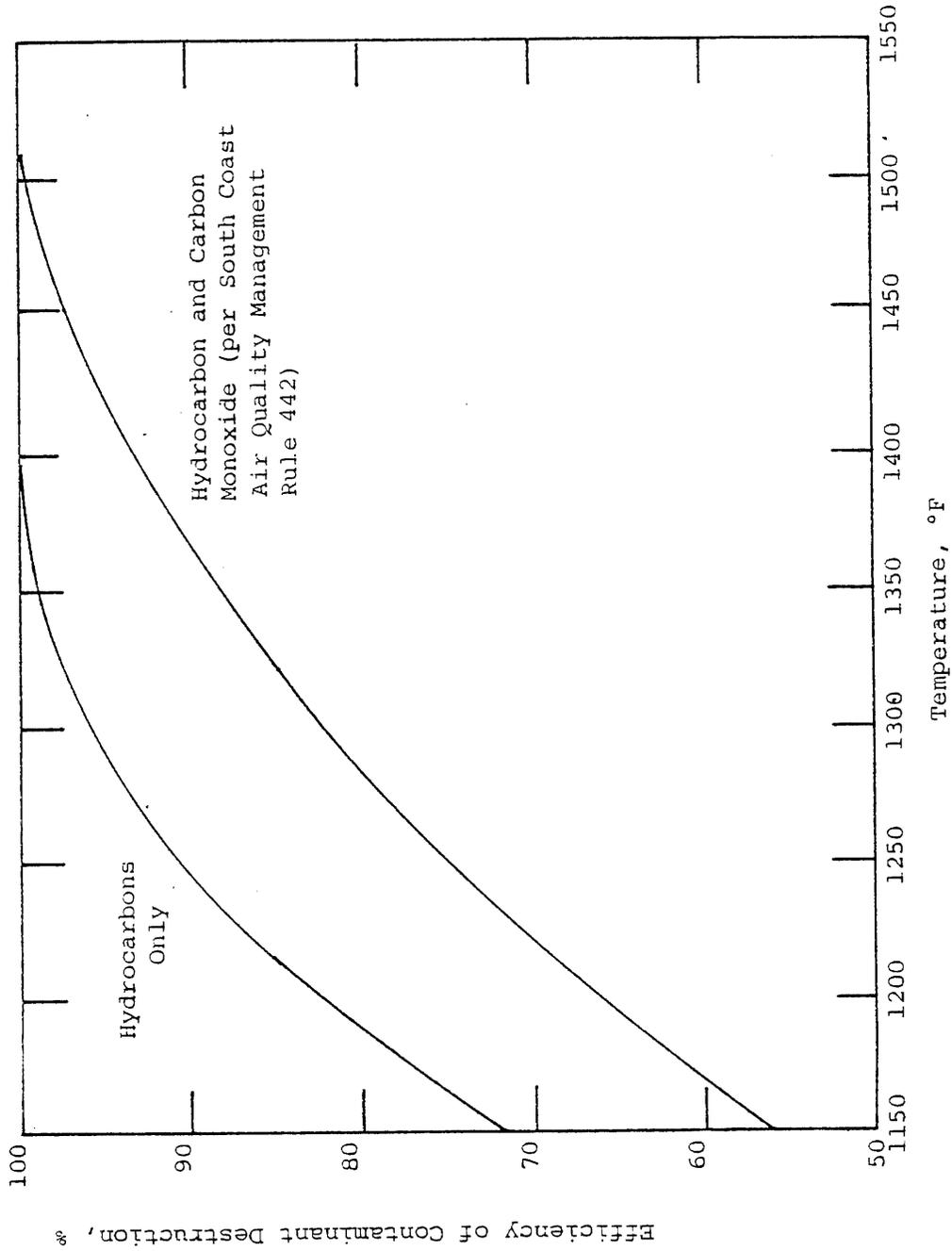


Figure 4-9. Typical effect of operating temperature on effectiveness of thermal afterburner for destruction of hydrocarbons and carbon monoxide (Ref. 4-1).

KVB 5804-714

5. Heat recovery--Heat recovery offers a way to reduce the energy consumption of incinerators. The simplest method is to use the hot cleaned gases exiting the incinerator to preheat the cooler incoming gases. Design is usually for 35 to 90 percent heat recovery efficiency.

The maximum usable efficiency is determined by the concentration of the organics in the gases, the temperature of the inlet gases, and the maximum temperature that the incinerator and heat exchangers can withstand.

In a noncatalytic system with a primary heat exchanger, the preheat temperature should not exceed 680 °F, at 25 percent LEL, in order to limit incinerator exit temperatures to about 1450 °F for the protection of the heat exchanger. The auxiliary fuel would heat the stream about 150 °F and oxidation of the solvent would heat it about 620 °F for an exit temperature of  $680 + 150 + 620 = 1450$  °F. At 12 percent LEL the preheat temperature should not exceed 930 °F. Most burners have not been designed to tolerate temperatures above 1100°F.

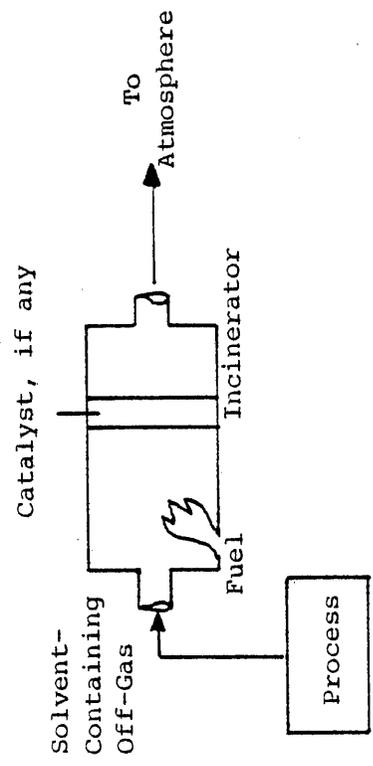
There are several types of heat recovery equipment using different materials at various costs. The most common is the tube and shell heat exchanger. The higher temperature exhaust passes over tubes, which have lower temperature gas or liquid flowing through the tubes; thus increasing the temperature of that gas or liquid. Another method uses a rotating ceramic or metal wheel whose axis is along the wall between two tunnels. Hot exhaust flows through one tunnel and heats half of the wheel. Lower temperature air flows through the other tunnel and is heated as the wheel rotates. Another method uses several chambers containing inert ceramic materials with high heat retention capability. The hot gas (e.g. from the incinerator) passes through these beds and heats the ceramic material. The air flow is then reversed, and lower temperature gas passes through the heated beds; thus raising the temperature of that gas to near incineration temperature. Further details on various heat recovery methods and equipment can be obtained from the vendors of incinerators.

The use of incinerator exhaust to preheat incinerator inlet air is often referred to as "primary" heat recovery as illustrated in Case 2 of Figure 4-10. Since some systems have a maximum allowable inlet temperature for the incinerator, it may not be possible to recover all of the heat available in the incinerator exhaust. In such case, the inlet to the incinerator is controlled to minimize fuel requirements. Note that a noncatalytic incinerator always requires some fuel to initiate combustion.

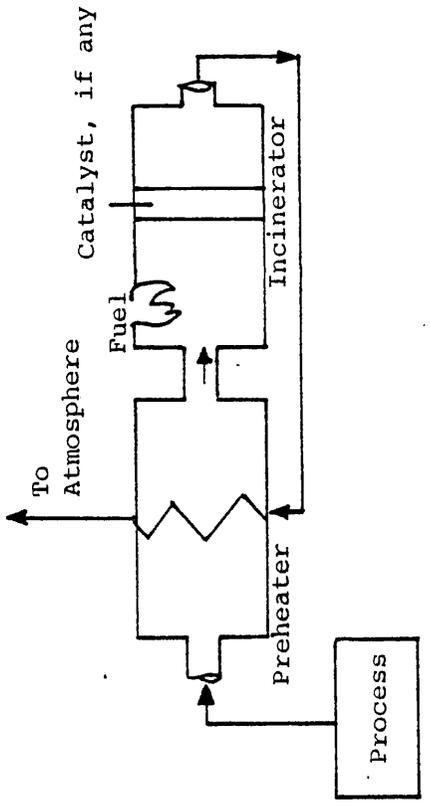
"Secondary" heat recovery uses incinerator exhaust from the primary heat recovery stage (or from the incinerator directly if there is no primary heat recovery) to replace energy usage elsewhere in the plant. This energy can be used for process heat requirements or for plant heating. The amount of energy that a plant can recover and use depends on the individual circumstances at the plant. Usually recovery efficiency of 70 to 80 percent is achievable, making the net energy consumption of an incinerator minimal or even negative if gases are near or above 25 percent of the LEL. The use of primary and secondary heat recovery is illustrated in Case 3 of Figure 4-10. It should be noted that heat recovery reduces operating expenses for fuel at the expense of increased capital costs. Primary heat recovery systems are within the incinerator and require no long ducts. Secondary heat recovery may be difficult to install on an existing process because the sites where recovered energy may be used are often distant from the incinerator. In applying calculated values for recovered energy values in Case 3 to real plants, the cost of using recovered energy must be considered. If secondary heat recovery is used, often the plant cannot operate unless the control system is operating because it supplies heat required by the plant.

If the gases in an oven are inert, that is, contain little oxygen, explosions are not possible and high concentrations of organic solvent vapor can be handled safely. The oven exhaust can be blended with air and burned with minimal auxiliary fuel. The incinerator may be the source of inert gas for the oven. Cooling of the incinerator gas is necessary, removing energy that can be used elsewhere. Case 4 of Figure 4-10 illustrates this scheme. A modification of the scheme shown is the use of an external inert gas generator. This scheme can have a significant energy credit because the otherwise discarded organics are converted to useful energy. Because of the

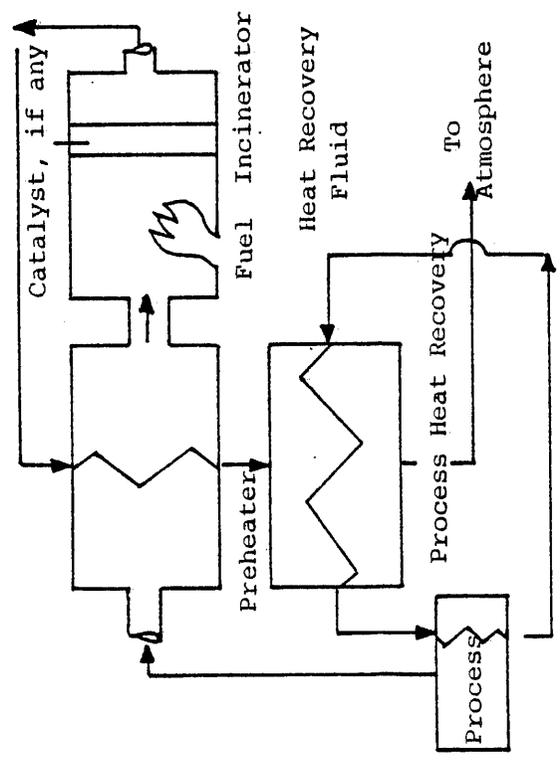
Case 1 - Basic System



Case 2 - Basic System with Gas Preheat



Case 3 - Process Heat Recovery with Gas Preheat



Case 4 - Inert Gas Generator

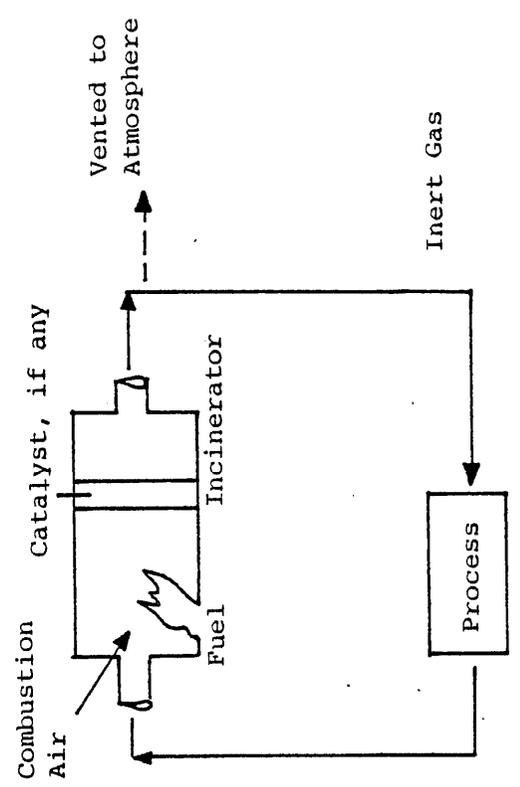


Figure 4-10. Configurations for catalytic and noncatalytic incineration.

specialized nature of Case 4, it may not be applicable to retrofits on existing ovens and costs for this case are not included in this study. Note that in this case the incinerator exhaust is in contact with the product. This limits the available fuel for this option to natural gas or propane. The use of this option would probably be impossible if any compounds containing appreciable sulfur or halogens are used.

To illustrate a specific case, Figure 4-11 outlines a source controlled by a noncatalytic incinerator. The source is assumed to operate 25 percent of the LEL and the incinerator has primary and secondary heat recovery. The primary heat exchanger raises the temperature to 700 °F, at 35 percent heat recovery efficiency. The heat of combustion of the organic vapors provides a 620 °F additional temperature rise at 90 percent combustion and the burner must supply only enough heat to raise the gases 80 °F to reach the design combustion temperature of 1400 °F. Combustion products pass through the primary heat exchanger--where they are cooled to 1025 °F--and enter a 35 percent efficient secondary heat exchanger. In the secondary heat exchanger, further energy is recovered for use in other areas. In this example, makeup air for the source is heated from ambient temperatures to source entrance temperatures (higher than oven exit temperatures).

The energy implications of this scheme can be seen by comparing the energy input of this controlled source with an uncontrolled source. In an uncontrolled source, fuel would be necessary to raise the temperature of the makeup air from 70 °F to 425 °F or 355 °F. For a controlled source, fuel would only need to raise the temperature 80 °F. Thus, the energy input would be reduced by over 80 percent by use of incineration simply because the organic vapors contribute heat when they burn.

In the above analysis, the assumptions made are important. If the organic vapors are more dilute, the temperature rise due to combustion will be less. Heat recovery can be more efficient than 35 percent, making up for all or some of this difference. Finally, the analysis assumes that the heat recovered in the secondary heat exchanger can be used in the plant. The heat can be used to produce steam, heat water, supply process heat or heat buildings. Obviously, a case-by-case analysis is necessary to ascertain how much recovered heat could be used.

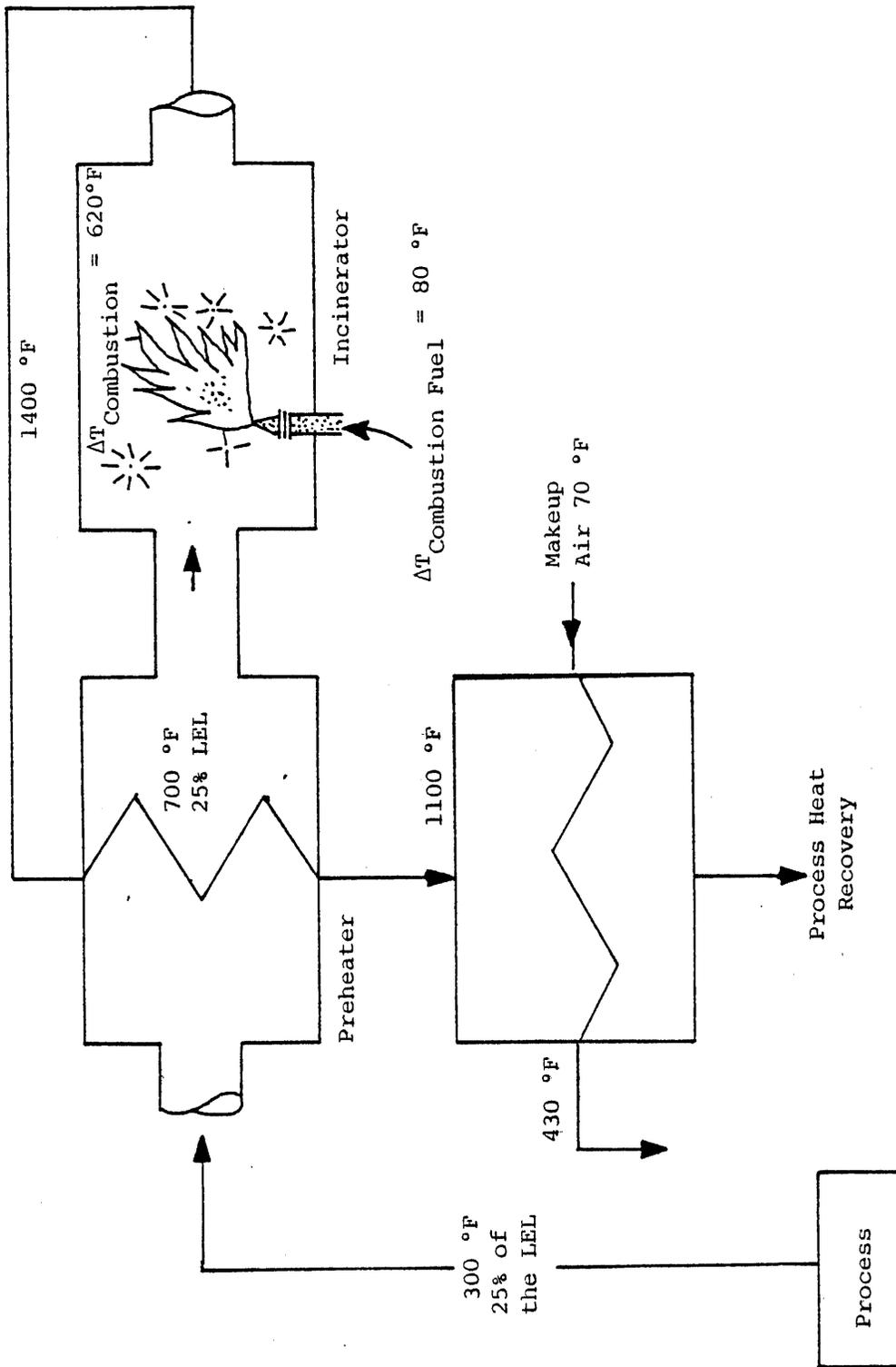


Figure 4-11. Example of incinerator on oven with primary and secondary heat recovery.

KVB 5804-714

6. Particulates--The level of particulate concentration found in surface coating operations should not pose any problems for noncatalytic volatile organic combustion. However, an incinerator designed for hydrocarbon removal usually will not have sufficient residence time to efficiently combust organic particulates.

7. Safety of preheat--(At 25 percent of the LEL), oxidation rates at temperatures below 1100°F are slow. Complete oxidation can take several seconds. Because the gases are in the heat exchanger for less than a second, preignition should not be a problem using heat recovery if temperatures are below approximately 1000 °F.

Some problems have occurred in the past with accumulations of condensed materials or particulates igniting in the heat recovery devices. If this occurs, the accumulations must be periodically removed from the heat transfer surfaces. The user should give careful consideration for his particular set of circumstances to potential safety problems. This is especially true if gases at a high percent of the LEL are preheated.

8. Adverse environmental effects--Sulfur-containing compounds will be converted to their oxides; halogen-containing compounds will be converted to acids. A portion of nitrogen-containing compounds will be converted to NO<sub>x</sub> and additional NO<sub>x</sub> will result from thermal fixation. If use of these compounds cannot be avoided, the benefit from incineration should be evaluated against the adverse effects and alternate methods of control should be thoroughly explored.

The concentration of oxides of nitrogen (NO<sub>x</sub>) is about 18 to 22 ppm for natural gas-fired noncatalytic incinerators and 40 to 50 ppm for oil-fired noncatalytic incinerators at a temperature of 1500 °F, assuming no nitrogen containing compounds are incinerated.

#### B. Special Design Considerations for Catalytic Incinerators--

A catalyst is a substance that speeds up the rate of chemical reaction at a given temperature without being permanently altered. The use of a catalyst in an incinerator reportedly enables satisfactory oxidation rates at temperatures in the range of 500 to 600 °F inlet and 750 to 1000 °F outlet. If heat recovery is not practiced, significant energy savings are possible

by use of a catalyst. The fuel savings become less as primary and secondary heat recovery are added. Because of lower temperatures, materials of construction savings are possible for heat recovery and for the incinerator itself. A schematic of one possible configuration is shown in Figure 4-12.

Catalysts are specific in the types of reactions they promote. There are, however, oxidation catalysts available that will work on a wide range of organic solvents. The effect of temperature on conversion for solvent hydrocarbons is shown in Figure 4-13. Common catalysts are platinum or other metals on alumina pellet support or on a honeycomb support. All-metal catalysts can also be used.

The initial cost of the catalyst and its periodic replacement represents, respectively, increased capital and operating costs. The lifetime of the catalyst depends on the rate of catalyst deactivation.

1. Catalyst Deactivation--The effectiveness of a catalyst requires the accessibility of "active sites" to reacting molecules. Every catalyst will begin to lose its effectiveness as soon as it is put into service. Compensation for this must be made by either overdesigning the amount of catalyst in the original charge or raising the temperature into the catalyst to maintain the required efficiency. At some time, however, activity decays to a point where the catalyst must be cleaned or replaced. Catalysts can be deactivated by normal aging, by use at excessively high temperature, by coating with particulates, or by poisoning. Catalyst lifetime of greater than 1 year is considered the minimum acceptable.

Catalyst material can be lost from the support by erosion, attrition, or vaporization. These processes increase with temperature. For metals on alumina, if the temperature is less than 1100 °F, life will be 3 to 5 years if no deactivation mechanisms are present. At 1250 to 1300 °F, this drops to 1 year. Even short-term exposure to 1400 to 1500 °F can result in near total loss of catalytic activity (Ref. 4-1).

The limited temperature range allowable for catalysts sets constraints on the system. As mentioned earlier, at 25 percent of the LEL and 90 percent combustion there will be about a 620 °F temperature rise as a result of organic combustion. Because an inlet temperature of 500 to 600 °F is necessary to initiate combustion, the catalyst bed exit temperature will be 1120 to 1220 °F at 25 percent of the LEL. This is the upper limit for good

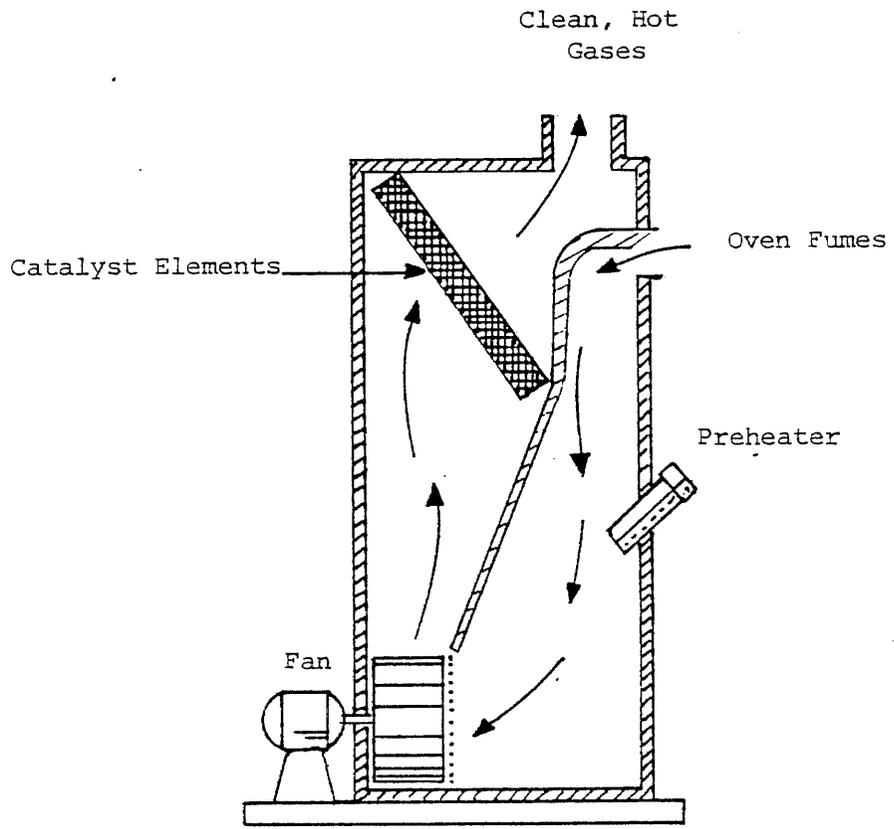


Figure 4-12. Schematic diagram of catalytic afterburner using torch-type preheat burner with flow of preheater waste stream through fan to promote mixing (Ref. 4-1).

KVB 5804-714

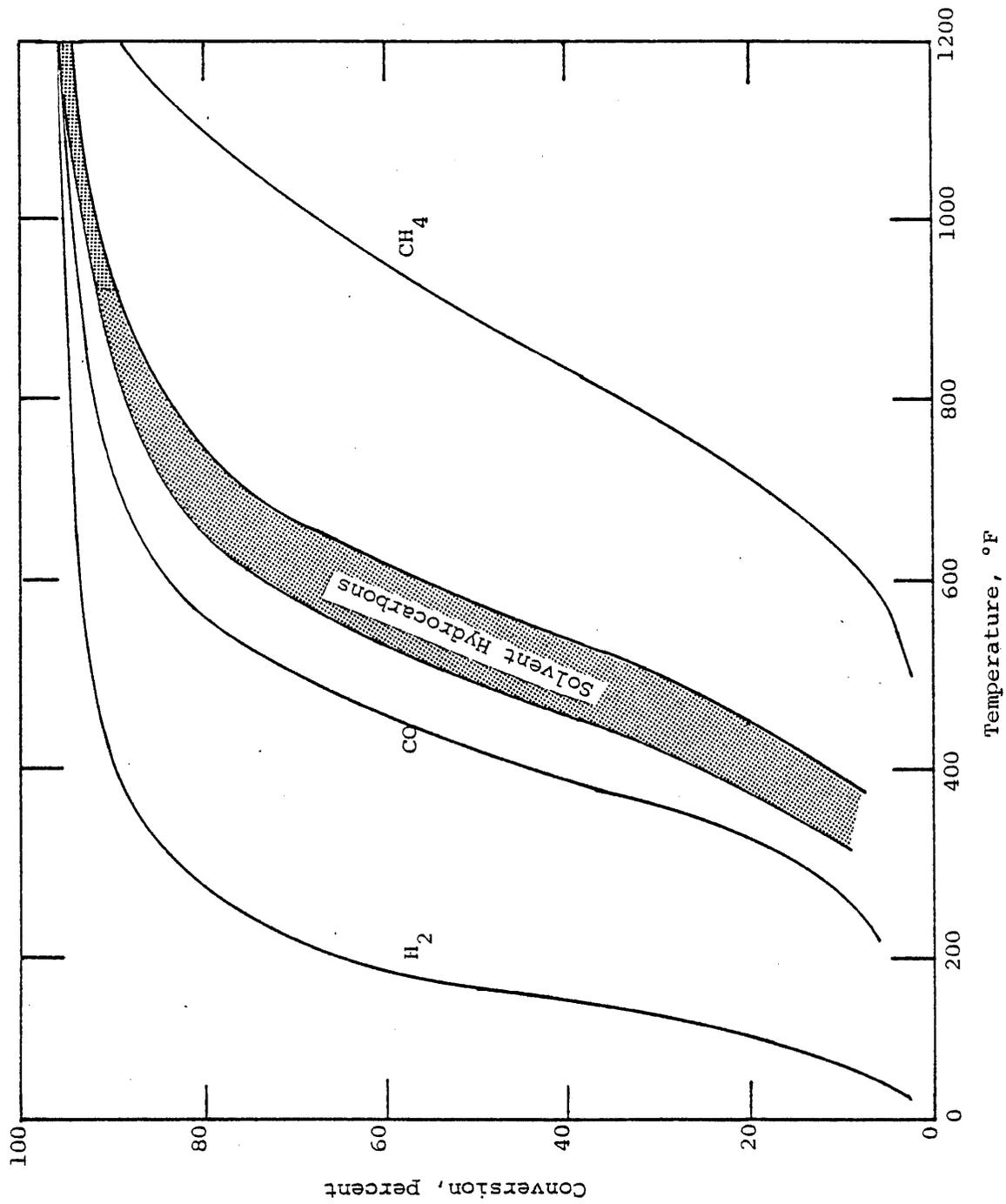


Figure 4-13. Effect of temperature on conversion for catalytic incineration (Ref. 4-1).

KVB 5804-714

catalyst life and thus concentrations of greater than 25 percent of the LEL cannot be incinerated in a catalytic incinerator without damage to the catalyst. Restrictions on heat recovery options are also mandated. These will be discussed later.

2. Coating with particulates--The buildup of condensed polymerized material or solid particulate can inhibit contact between the active sites of the catalyst and the gases to be controlled. Cleaning is the usual method for reactivation. Cleaning methods vary with the catalyst and instructions are usually given by the manufacturer.

3. Poisoning--Certain contaminants will chemically react or alloy with common catalysts and cause deactivation. A common list includes phosphorus, bismuth, arsenic, antimony, mercury, lead, zinc, and tin. The first five are considered fast acting; the last three are slow acting, especially below 1100 °F. Areas of care include avoiding the use of phosphate metal cleaning compounds and galvanized ductwork. Sulfur and halogens are also considered catalyst poisons, but their effect is reversible.

4. Fuel--Natural gas is the preferred fuel for catalytic incinerators because of its cleanliness. If properly designed and operated, a catalytic incinerator could possibly use distillate oil. However, much of the sulfur in the oil would probably be oxidized to  $SO_3$  which would subsequently form sulfuric acid mist. This would necessitate corrosive resistant materials and would cause the emission of that very undesirable pollutant. Therefore, the use of fuel oil (even low sulfur) in a catalytic incinerator is not recommended.

The oxidation of methane in natural gas, as discussed previously, requires higher flame temperatures than some of the heavier fumes. A problem found in the South Coast Air Basin is that the total hydrocarbon level sometimes increased in passing through the catalytic incinerator. The heavier fumes were oxidized but the methane in the fuel gas was released at a concentration level greater than that of the original process input stream.

5. Heat Recovery--The amount of heat that can be transferred to the cooler gases is limited. The usual design is to have the exit temperature from the catalyst bed at about 1000 °F. If the gas is at 15 percent of the LEL, for example, the temperature rise across the bed would be about 375 °F, and the gas could only be preheated to about 625 °F. Secondary heat recovery

is limited by the ability to use the recovered energy. If a gas stream is already at combustion temperature, it is not useful to use "primary" heat recovery but "secondary" heat recovery may still be possible. Note that for catalytic incineration, no flame initiation is necessary and thus it is possible to have no fuel input.

As in noncatalytic systems, heat recovery equipment may need periodic cleaning if certain streams are to be processed.

#### 4.1.3 Condensation

##### A. Application--

Any component of any vapor mixture can be condensed if brought to equilibrium at a low enough temperature. The temperature necessary to achieve a given solvent vapor concentration is dependent on the vapor pressures of the compounds.

When cooling a two-component vapor where one component can be considered noncondensable, for example, a solvent-air mixture, condensation will begin when a temperature is reached such that the vapor pressure of the volatile component is equal to its partial pressure. The point where condensation first occurs is called the dew point. As the vapor is cooled further, condensation continues such that the partial pressure stays equal to the vapor pressure. The less volatile a compound, that is, the higher the normal boiling point, the lower will be the amount that can remain vapor at a given temperature.

In cases where the solvent vapor concentration is high, for example, from the desorption cycle of a carbon adsorber, condensation is relatively easy. However, for sources where concentrations are typically below 25 percent of the LEL, condensation is very difficult. In some applications the concentration of the organic compound can be increased by compressing the process gas stream. Then condensation can take place at a higher temperature. Figure 4-14 shows the vapor pressure dependence on temperature for several compounds. Table 4-3 shows the temperature necessary to condense various amounts of compounds spanning the volatility range of compounds used for solvents.

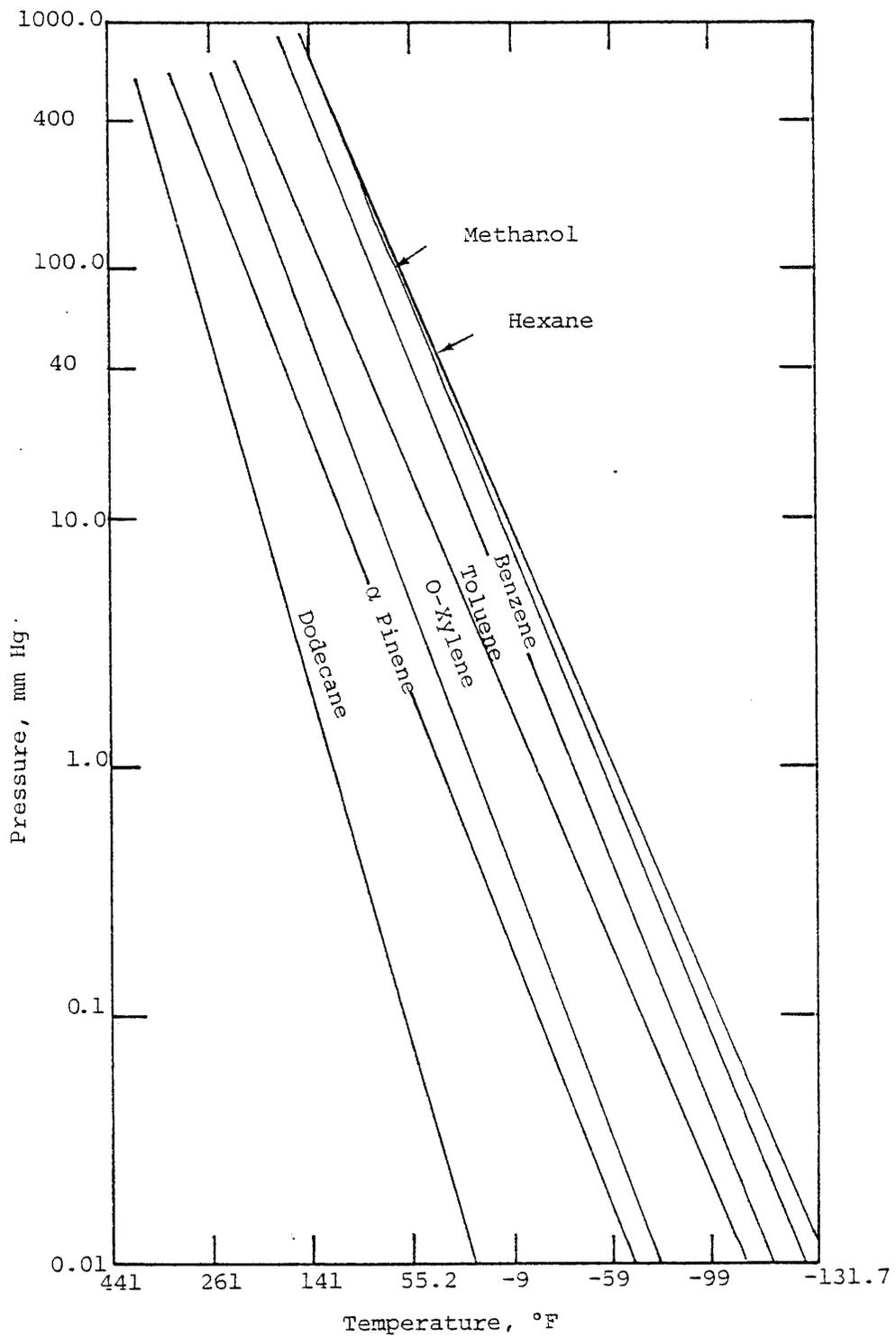


Figure 4-14. Vapor pressures of organic solvents versus temperature.

KVB 5804-714

TABLE 4-3. PHYSICAL CONSTANTS AND CONDENSATION PROPERTIES OF SOME ORGANIC SOLVENTS

Compound	Normal Boiling Point, °F	LEL, %*	25% of LEL Concentration		90% Condensation from 25% of LEL †		95% Condensation from 25% of LEL †		90% Condensation from 200 ppm †		95% Condensation from 50% Concentration †	
			Partial Pressure, mm of Hg	Dew Point, °F	Partial Pressure, mm of Hg	Temp., °F	Partial Pressure, mm of Hg	Temp., °F	Partial Pressure, mm of Hg	Temp., °F	Partial Pressure, mm of Hg	Temp., °F
Dodecane	421	0.6	1.1	120	0.11	61	0.55	54.4	0.15	19	19	200
Pinene C <sub>10</sub> H <sub>16</sub> (Terpentine)	300	0.7	1.3	53	0.13	16	0.065	-31.4	0.015	-60	19	130
O-xylene C <sub>8</sub> H <sub>10</sub>	280	1.0	1.9	26	0.19	-31	0.095	-36.5	0.015	-72	19	80
Toluene C <sub>7</sub> H <sub>8</sub>	211	1.4	2.7	5	0.27	-51	0.135	-54.3	0.015	-103	19	60
Benzene	175	1.4	2.5	-15	0.25	-69	0.125	-96.4	0.015	-114	19	30
Methanol C <sub>2</sub> H <sub>6</sub> O	147	6.0	11.4	2	1.14	-41	0.57	-68.7	0.015	-126	19	10
Hexane	155	1.2	2.3	-39	0.23	-93	0.115	-108	0.015	-129	19	0

\*From Reference 4-1

†From Figure 4-14

Except for dodecane, which is not volatile enough to be a major component in an industrial solvent, all of the solvents require a low process temperature to condense 90% of the pollutant from a 25% LEL stream. This would be very uneconomical. However, as indicated by the last column in Table 4-3, if the concentration of the solvent is 50%, then the temperature to condense 95% of the material is in a practical range. Thus in applications like dry cleaning, degreasing and storage tank vapor recovery the condensation approach is practical. For surface coating, condensation is generally not applicable except in rare cases where high concentrations of relatively nonflammable materials are present.

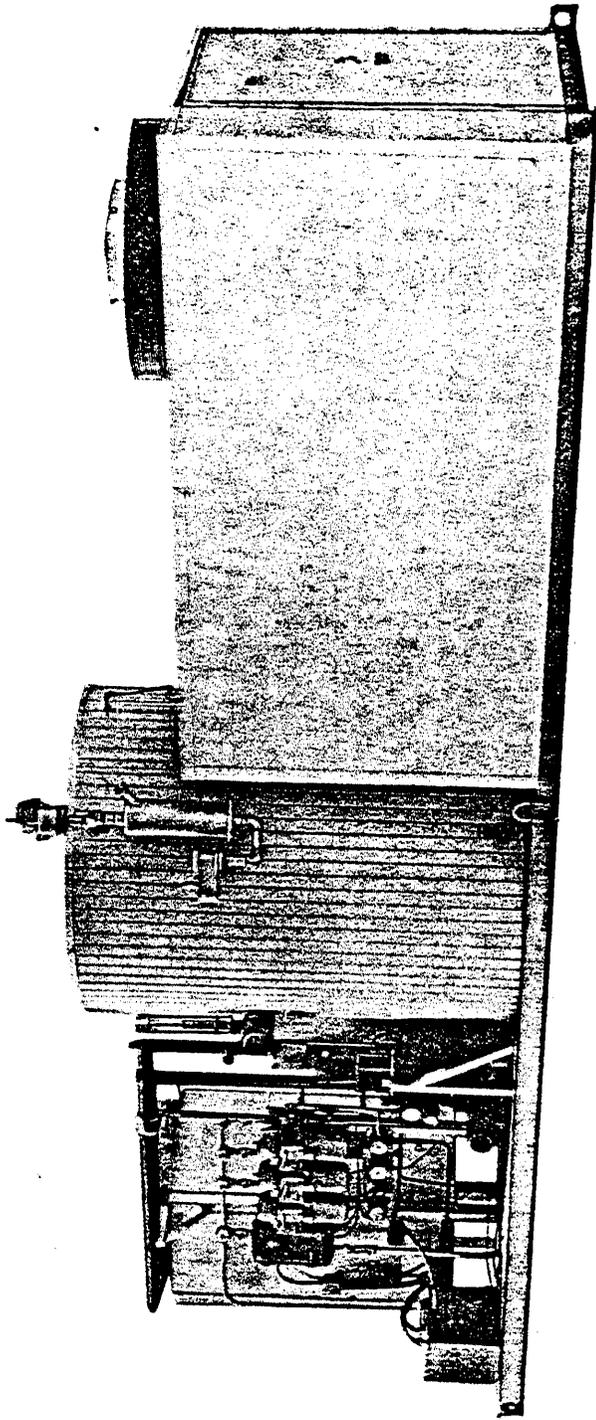
The above calculations are for single condensable compound systems. The calculation methods for multiple condensable component systems are complex, particularly if there are significant departures from ideal behavior of the gases and liquids. As a simplification, the temperatures necessary for control by condensation can be roughly approximated by the weighted average of the temperatures necessary for condensation of a single condensable component system at concentrations equal to the total organic concentration.

Totally chlorinated and fluorinated compounds, for example, carbon tetrachloride and perchlorethylene, are nonflammable and may be handled safely in all concentrations for nonoccupied areas. Condensation may be practical if high concentrations of these solvents are present. In fact, condensation is widely used in drycleaning and vapor degreasing for perchloroethylene recovery, because the relatively high cost of chlorinated solvents makes recovery attractive. Totally chlorinated compounds, however, are not used extensively in the surface coating industry; therefore, condensation is rarely used as a control method in that industry. Other applications for condensation systems for organic vapor control are in the petroleum industry in various storage and transfer operations.

#### B. Equipment Design and Operation--

Many petroleum vapor recovery systems use refrigeration to condense and collect hydrocarbons. A typical installation in a gasoline bulk loading terminal is pictured in Figure 4-15 and shown schematically in Figure 4-16.

KVB 5804-714



# Hydrocarbon Vapor Recovery Unit

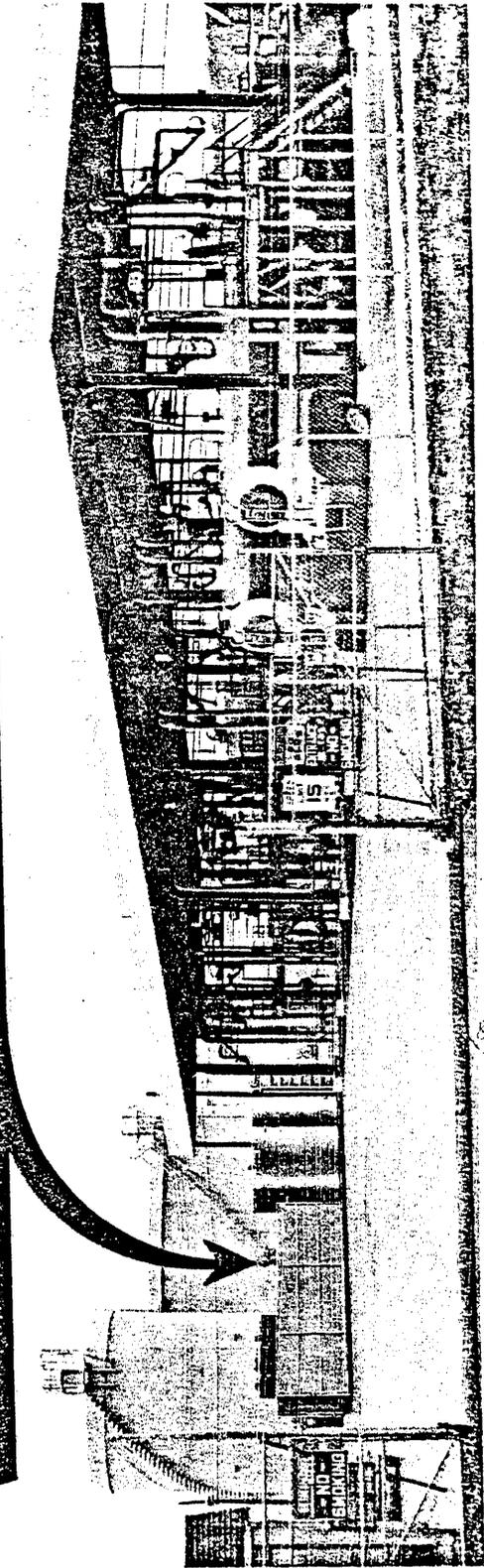


Figure 4-15. Condensation vapor recovery system in a gasoline bulk loading terminal.

KVB 5804-714

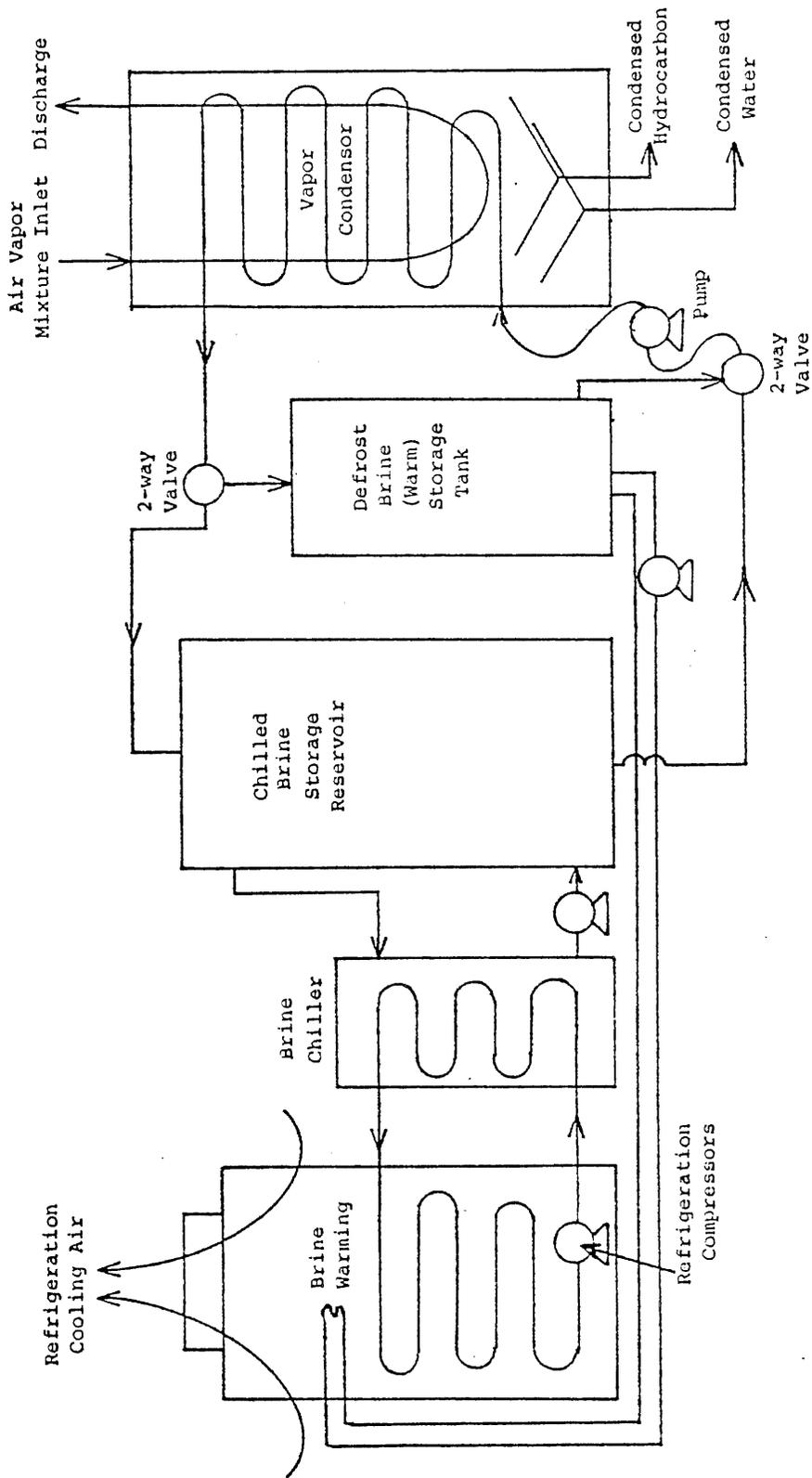


Figure 4-16. Schematic of condensation vapor recovery system.

KVB 5804-714

This cascade refrigeration system follows conventional design producing temperature in the brine chiller of on the order of -90 °F to -100 °F. A cold brine pump circulates methylene chloride brine from the brine storage reservoir through the brine chiller to obtain the appropriate low temperature fluid (approximately -90 °F) for use in the vapor condenser.

In turn, the low temperature brine coolant is circulated through the finned tube sections of the vapor condenser. Hydrocarbon vapor and air mixture from the various bulk station filling points is passed over the finned tube sections of the vapor condenser. Entrained moisture in the entering vapor-air mixture condenses and collects as frost on the cold plate fins. Condensed liquid hydrocarbon is collected at the bottom of the vapor condenser.

At periodic intervals, defrosting of the finned surfaces is accomplished by circulation of warm brine stored in a separate reservoir. The temperature of the warm defrost brine is maintained by heat reclamation from the refrigeration equipment. Defrosting is completed in 10 to 30 minutes, depending upon the amount of frost collected on the finned coil.

A similar system is used in dry cleaning equipment. Heat vaporizes the solvent in the fabric and this vapor laden mixture is carried through refrigerant coils or through water. Solvent vapor is condensed, decanted from water and returned to the machine tank. The air is recirculated through the heater to the tumbling fabric. When the concentration of solvent vapor in the air stream from the drum drops below its dew point, and the solvent no longer can be condensed, a small amount of solvent will remain in the fabric being dried. At this point, the air is no longer recirculated to the heater but is exhausted to the atmosphere after one pass. This cools the fabric and deodorizes it by serving to evaporate and remove the final traces of solvent.

In solvent degreasers, refrigerated freeboard chillers can be added to control emissions. The freeboard is the distance from the surface of the solvent to the cover flange at the top of the unit (see Figure 4-17). The vapors created within a vapor degreaser are prevented from overflowing out of

KVB 5804-714

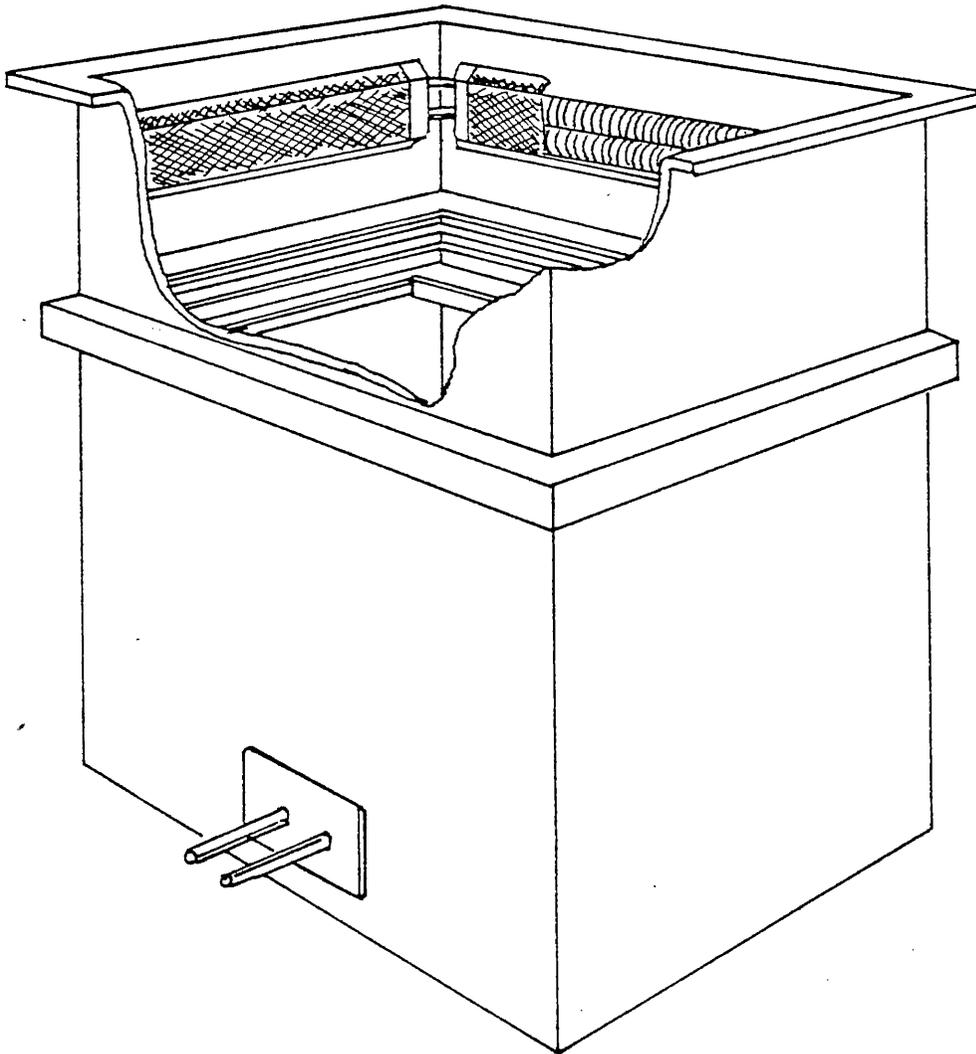


Figure 4-17. Refrigerated freeboard chiller.

KVB 5804-714

the equipment by means of condenser coils and a freeboard water jacket. Refrigerated freeboard chillers are an addition to this basic system. In appearance, they seem to be a second set of condenser coils located slightly above the primary condenser coils of the degreaser. Functionally, however, they achieve a different purpose. The primary condenser coils control the upper limit of the vapor zone, while the refrigerated freeboard chilling coils impede the diffusion of solvent vapors from the vapor zone into the work atmosphere. This is accomplished by chilling the air immediately above the vapor zone and creating a cold air blanket. The cold air blanket also reduces the mixing of air and solvent vapors by narrowing the air/vapor mixing zone, which results from a sharper temperature gradient. In addition, the chilling decreases the upward convection of warm solvent laden air.

#### 4.1.4 Absorption (Scrubbing)

Absorption, as an air pollution control process, involves dissolving a soluble gas component in a relatively nonvolatile liquid. The absorption step is only the collection step. After the gas is dissolved, it must be recovered or reacted to an innocuous form.

Common absorbents for organic vapors are water, nonvolatile organics, and aqueous solutions (Ref. 4-4). Absorption is increased by lower temperatures, higher solubility of the gas, higher concentrations of the gas, higher liquid to gas ratios, lower concentrations of gas in the liquid, and greater contacting surface. Absorption has been widely used as a product recovery step in the petroleum and petrochemical industry where concentrations are typically very high. These products are generally recovered by heating to lower the solubility, or by distillation.

If a chemical oxidizer is present in the liquid stream, organics can be oxidized in the stream. This technique has been used to convert low concentrations of odorous compounds to less odorous forms. The expense of the oxidizing chemical, however, prevents its use where concentrations greater than a few parts per million are present.

The absorption-regeneration approach for organic solvents is severely limited by the low concentrations and consequent low solubilities of most organic gases in the absorbent. Exceptions are alcohols, ketones, amines, glycols, aldehydes, phenol, and organic acids. Gases may be regenerated by heating and reclaimed by condensation or destroyed by incineration.

Direct contact with water may be used as a cooling method for removal of organic particulates or high boiling compounds to avoid opacity problems in the exhaust. It may also be used to preclean the air before a carbon absorber, but in most cases the materials do not go into solution to any appreciable extent. Figure 4-18 illustrates various types of scrubbers designed to provide thorough contact between the polluted gas stream and the water. If water is used for condensation in this way, water treatment may be necessary before discharge.

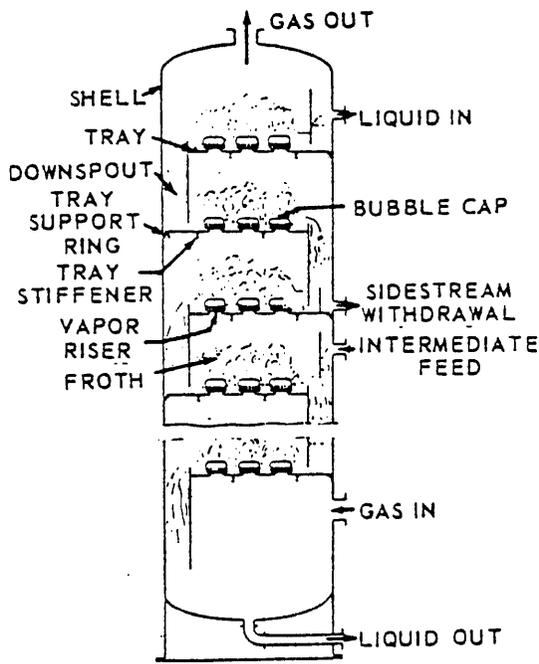
In summary, except for a few specialized cases involving water soluble compounds, absorption is not applicable to control of organic solvent emissions from surface coating except as a preliminary step for particulate and high-boiling compound removal.

#### 4.1.5 Vapor Space Elimination

In storing or enclosing volatile organic liquid provisions must be made to control the escape of vapor due to temperature cycling or the change in liquid level. In a tank of fixed dimensions the organic vapors expand and contract with diurnal temperature changes and changes in the liquid contents. The pressure in the vapor space must be held constant within a few inches of water. Thus a fixed dimension tank must allow for vapor pressure compensation by venting organic vapor or intaking air as pressure or level changes occur.

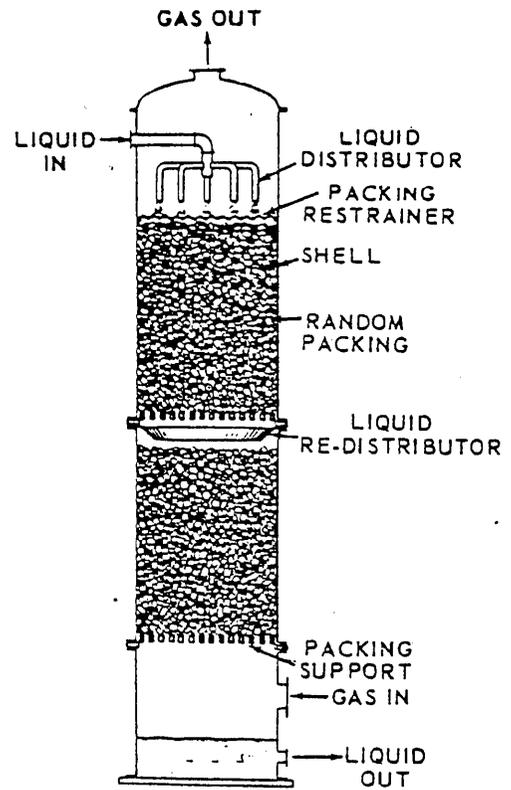
The concept of a floating roof tank has developed over the years to eliminate the vapor space in storage tanks. The roof floats directly on the liquid in the tank moving up and down with changes in liquid level. At the periphery of the roof is a moving seal which rides against the tank wall. Compared to a fixed dimension or fixed roof tank, the emissions from a properly sealed floating roof tank is approximately 95% less (Refs. 4-5, 4-6).

KVB 5804-714



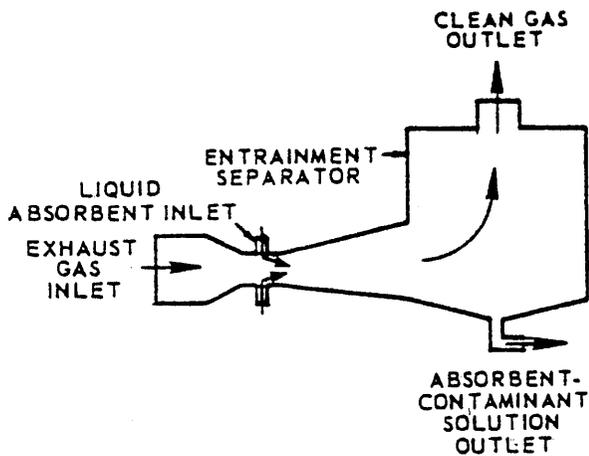
Schematic diagram of a bubble-cap tray tower.

(A)



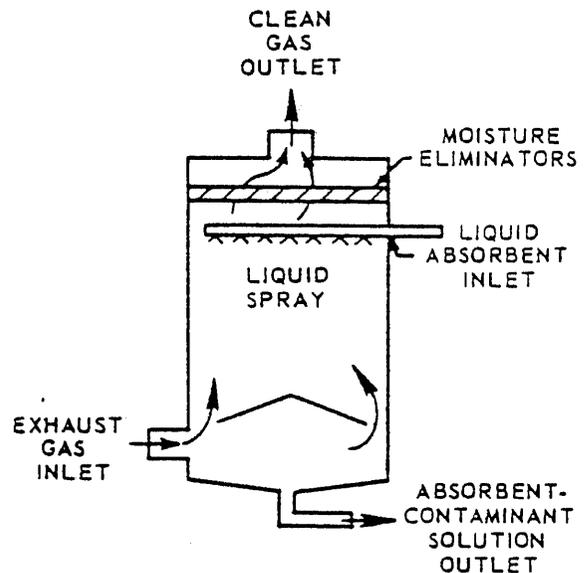
Packed tower.

(B)



Venturi scrubber.

(C)



Spray tower.

(D)

Figure 4-18. Types of absorption systems.

While the floating roof concept is universally accepted as the proper method to store petroleum products, there has been an extensive amount of effort in the past year 1976-1977 to investigate the effects of the integrity of the roof-to-wall seal on the emissions from the floating roof tanks. In spite of work by the Western Oil and Gas Association (Ref. 4-7) and a joint effort by SOHIO and the Chicago Bridge and Iron Corp. (a tank manufacturer) (Ref. 4-8), the quantitative effects of the joint seal has not been rigorously measured. The API is currently undertaking a program to again attempt to measure actual tank emissions and to determine the effects of design and environmental parameters on the emission rate.

In the meantime the only "official" method of determining floating roof tank emissions is to use the calculation method of API Bulletin 2517 (Ref. 4-9). Although it is generally believed that this approach will not provide a accurate prediction of a given tank, it is felt to be as good a prediction as currently exists for the tanks in the field today. (Refer to further discussion in Section 2.0.)

The ARB has amended Rule 463, Storage of Organic Liquids, for the South Coast Air Quality Management District (SCAQMD) which requires floating roof tanks to have two seals with allowable gap requirements for the two seals specifically defined. Under these conditions some unofficial estimates of emissions are that they will be approximately 1/3 of those predicted by the equations in API 2517. SCAQMD's Rule 463 in its form at time of publishing this report is presented in the Appendix.

The concept of floating covers for waste water separators and other hydrocarbon pools can be used to reduce organic emissions. The problem is one of proper design to prevent the roof from sinking during adverse wind or precipitation conditions.

KVB 5804-714

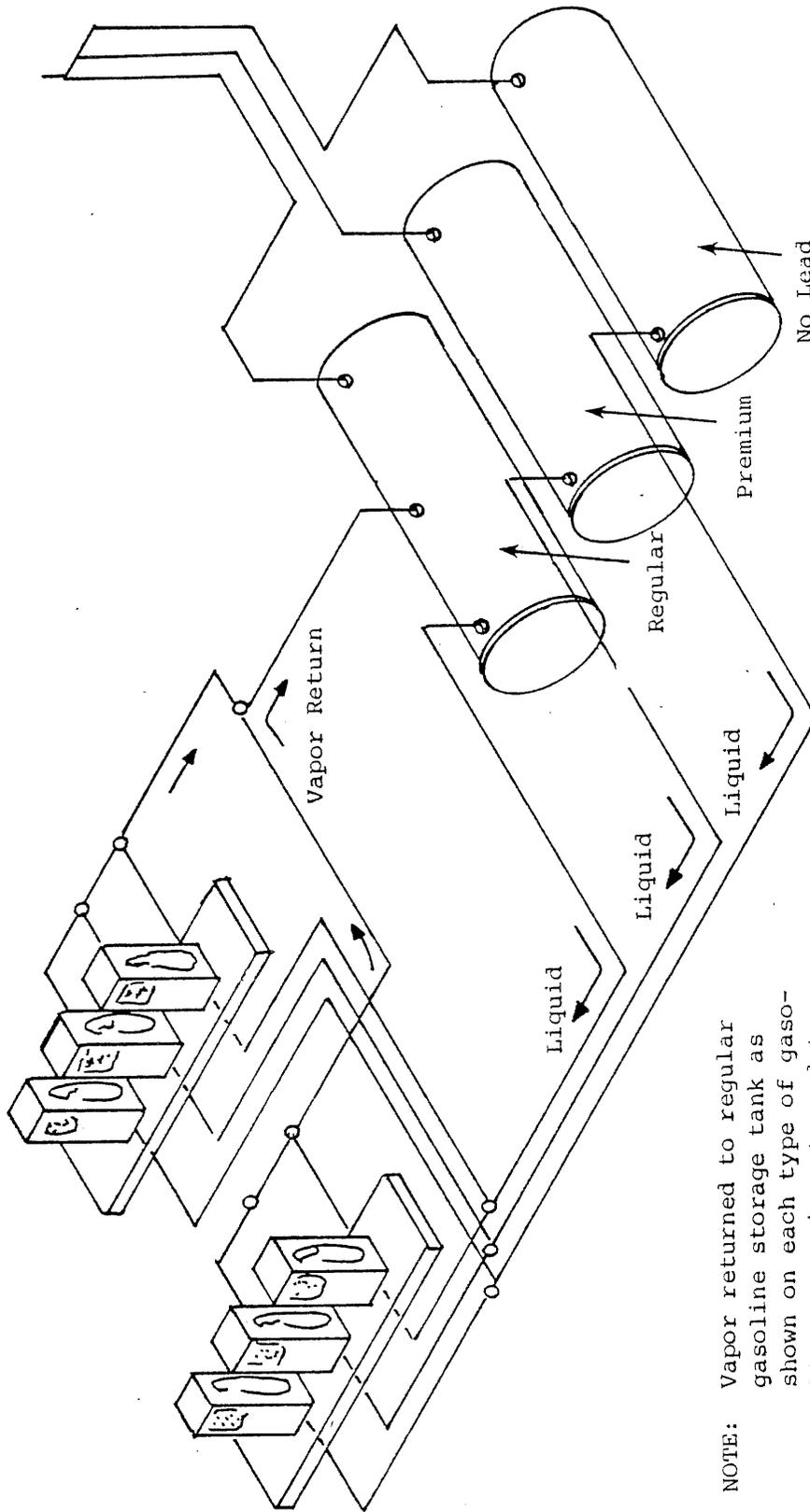
#### 4.1.6 Liquid/Vapor Exchange (Balance System)

As organic liquid is transferred, the associated vapors are displaced by liquid. Instead of allowing these vapors to escape, they are ducted back to the transmitting vessel to complete a balanced system - hence the name, Balance System. As a tank truck is filled from a bulk loading tank the vapor from the truck is returned to the bulk tank. This is repeated as the tank truck fills the service station tank and again when an automobile's tank is filled. This is assuming that the equipment for balancing is available.

In the Basin most of the bulk terminals use the balance system. Very few service stations have installed systems yet. Bulk terminal systems have efficiencies ranging from 98-100%. Service station equipment has been demonstrated to have at least 90% efficiency\*. However, the auto filling nozzles (specifically the nozzle to spout seal) are still in the development stage. The problem is to provide a reliable seal design that will stand up to the rugged handling of a self-service station.

Most automobile filling development activities are occurring in San Diego under the surveillance of the APCD. Several systems are being investigated: the balance system (Fig. 4-19); an augmented system in which a slight vacuum is created at the tank seal (Fig. 4-20); and the system in which the fumes are vacuum gathered for thermal incineration (Fig. 4-21), called the Hasselmann system. At the time of this writing, only the Hasselmann system has California ARB certification. It routes the vapors to a process unit where excess vapors are incinerated and provision is made to route liquids recovered back to the tank. A variation routes the vapors first through an underground storage tank, there via a vacuum pump to the process unit for incineration. The balance system is simple but it can be fouled by liquid gasoline blocking the return lines. If the nozzle seal is good and the tank overfills, the excess flows into the vent line. The second system uses an aspirator on the liquid fill line to create a slight vacuum on the vapor return line to assist in gathering the vapor at the vehicle tank interface. This should overcome any liquid blockage. That system (Fig. 4-20) also employs an enlarged vent pipe on

\*The balance system (Fig. 4-19) is rated at 90% efficiency. The vacuum assisted systems (Figs. 4-20 and 4-41) have demonstrated 95% efficiency but they are not widely accepted.



NOTE: Vapor returned to regular gasoline storage tank as shown on each type of gasoline vapor is returned to its respective storage tank.

Figure 4-19. Diagram of a typical vapor balance system.

KVB 5804-714

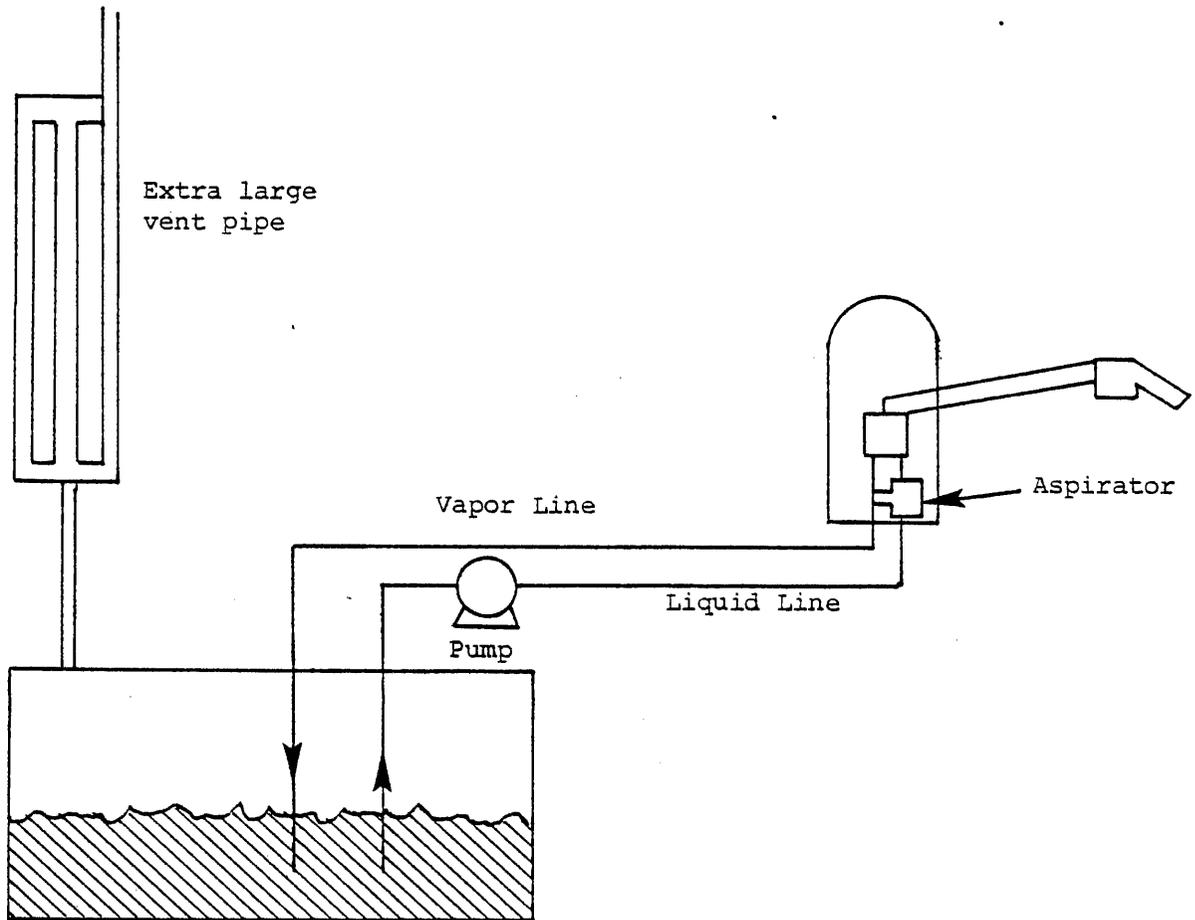


Figure 4-20. An augmented vapor recovery system for automobile refueling.

KVB 5804-714

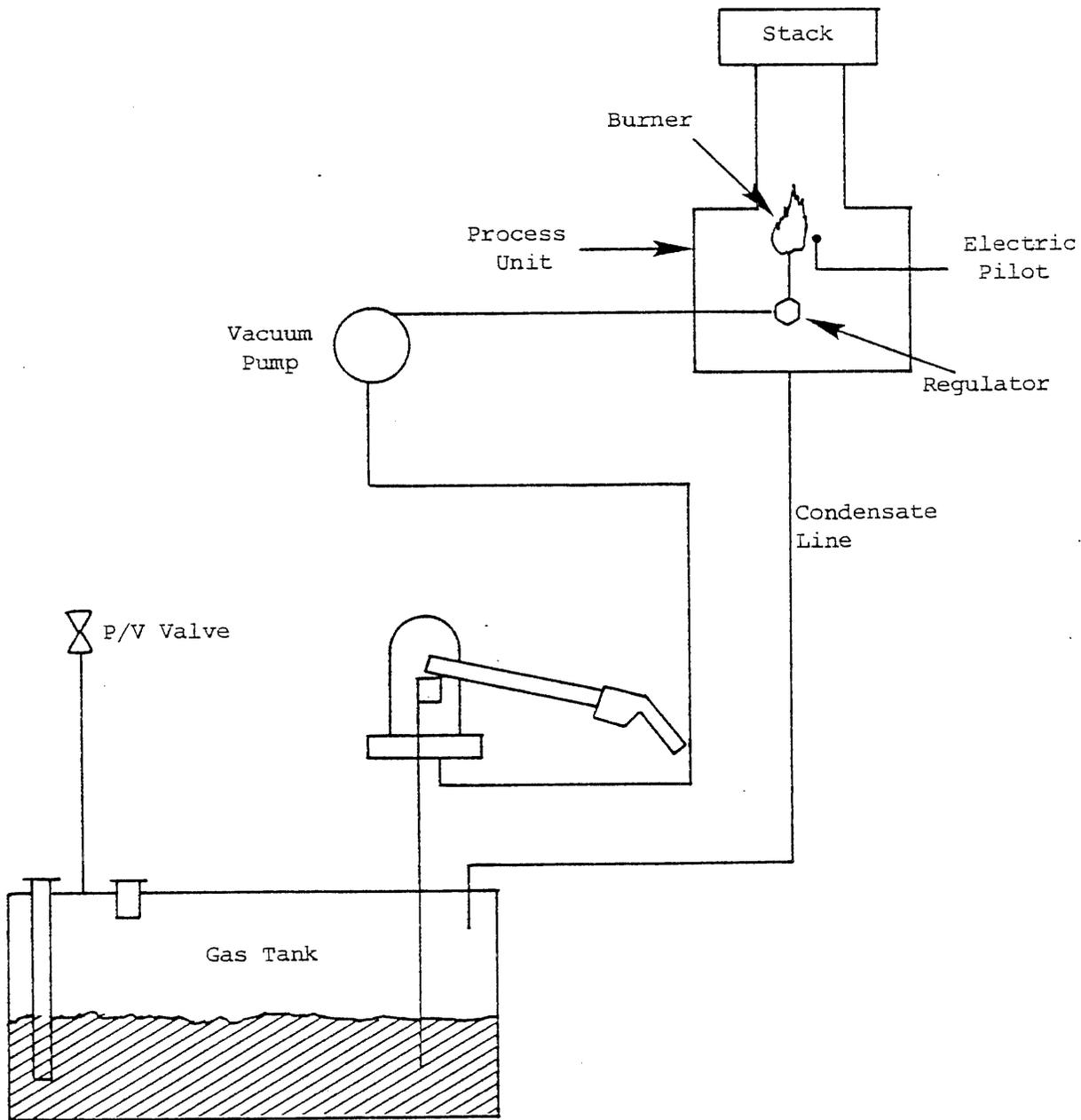


Figure 4-21. Hasselmann thermal oxidation system for control of automobile refueling vapors.

the underground tanks to contain the hydrocarbon gases ( $> C_3$ ) in a stratified layer while air moves in and out slowly due to temperature cooling effects. The third system can be installed above ground. A vacuum pump pulls the vapors into a processing unit where condensation allows the return of the liquid to the storage tanks. The excess gases are then passed to the oxidation unit. The processing unit adds air to the hydrocarbon stream in a controlled amount to support combustion.

For a detailed treatment of the balance system and other systems of vapor recovery associated with petroleum marketing the reader should consult Reference 4-10.

#### 4.1.7 Enclosure

In petroleum operations open pits, sewers and separators are still in use. As discussed in Section 2.0 these are significant sources of emissions depending on the temperature and vapor pressure of the source. Enclosing these open sources would reduce these fugitive emissions. Since an explosive mixture could be produced in this manner, care should be taken to adequately shield these enclosures from ignition sources. Vapor recovery devices or floating seals can reduce the explosion hazard.

Another version of enclosure is the variable vapor space tanks. These systems are primarily designed to limit breathing loss from fixed roof tanks. They are generally used for gasoline storage where tank throughput is low (less than 6 to 12 turnovers per year).

Usually a series of fixed roof tanks are connected to a variable vapor space tank by a series of manifolds. Vapors evolving from the products stored in the fixed roof tanks during periods of thermal expansion or reduced barometric pressure are temporarily stored in the variable vapor space tank. During periods when the vapors are contracting, such as at night, they are transferred back to the storage tanks. In this manner, normal breathing losses are effectively controlled. Filling losses are also controlled up to the point where the expelled vapor exceeds the capacity of the variable vapor space system. Figure 4-22 shows a tank designed to hold the vapors from another fixed roof tank.

KVB 5804-714

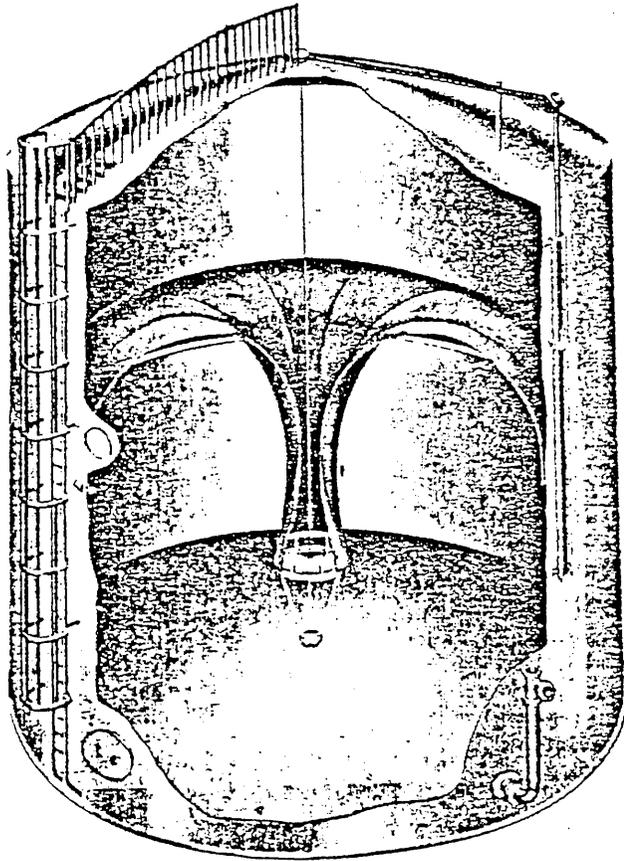


Figure 4-22. Separate variable vapor space tank  
(Ref. 4-11).

KVB 5804-714

#### 4.1.8 Process and Material Changes

##### A. Water-borne Coatings--

There is much confusion over the terminology of coatings containing water as part of their solvent content. Water-borne, water-reducible, water-based, water-thinnable, and latex are all used to describe these coatings. Strictly speaking, water-borne is the correct generic term for coatings containing water (Ref. 4-12). The base of a coating is the polymer or resin, but many use the term water-based interchangeably with water-borne.

There are three types of water-borne coatings: water-solutions, water-emulsions, and water-dispersions. Water-solution coatings feature very small particles dissolved in a mixture of water and a coupling solvent (Ref. 4-13). The water-soluble resins normally contain ionizable amine or carboxylic acid groups that solubilize the molecules (Ref. 4-12). These systems are more easily mixed and applied than other water-borne systems. However, resin properties that make the resin soluble can also cause water sensitivity after curing unless additions are made to eliminate this sensitivity.

Water-emulsions are high molecular weight particles suspended in water by some stabilizing, dispersing agent (Ref. 4-13). The resins, of which vinyls and acrylics are the most prominent, have very few functional groups and require emulsifying agents to maintain their form (Ref. 4-12). Emulsion coatings generally have the highest water resistance of the water-borne systems.

Water dispersion coatings are intermediate in particle size, in use of functional groups, and in water sensitivity.

1. Application techniques--Water-borne coatings may be applied using any of the methods used for organic solvent-borne coatings, that is, knife, blade, roller, dip, flow coat, and spray. The conductivity of water also enables use of electrophoresis to deposit a coating on conductive materials. By using a direct current potential in a bath and grounding the item to be coated, the item can act as an anode or cathode and be coated. Conversely, the conductivity makes electrostatic spray more difficult, although still feasible. Also, a new dip process is available in which the driving forces are chemical rather than electrical in nature (Refs. 4-2, 4-14, 4-15).

KVB 5804-714

Water-borne spray coating solvent is typically 70 to 80 percent water and 20 to 30 percent organic solvent. The organic solvent is a necessary part of the coating that gives proper leveling and performance properties. Unlike organic solvent mixtures, water is only one compound with one evaporation rate and boiling point. The heat of vaporization is much higher than organic solvents and the rate of evaporation from a coating is very dependent on the relative humidity of the air surrounding the coating as well as the cosolvents used. Roller application followed immediately by curing has little humidity problem. When spray coating with water-borne coatings, humidity control is required. This increases energy consumption. This is an especially severe problem when spray booths are occupied.

2. Performance and appearance--Appearance of water-borne enamels can be as good as organic solvent-borne enamels if proper curing procedures are used. "Orange peel," that is, bumpiness of the surface, is greater for any enamel than for lacquer. The organic solvent portion of water-borne coatings minimizes this "orange peel" effect. Only a limited number of resins are available that allow the generation of high-gloss water-borne coatings. Water-borne coatings for aluminum are farthest advanced with tin-plate steel second. Coaters producing a wide variety of products and coaters who must warrant products for long periods of time in severe environments have the same problems with water-borne coatings as they do with other process changes.

3. Energy consumption--The energy required to remove the solvent is greater for a given amount of water than for the same amount of organic solvent. The heat of vaporization of water is about 1000 Btu/lb, about five times that of most organic solvents. The curing temperatures and time for water-borne coatings is greater than for organic solvent-borne coatings. It should be noted that the energy for heating the part itself often exceeds the energy to remove the solvent and cure the coating, particularly with large metal parts. Counterbalancing these higher energy items is a significant savings in oven air heating costs. Air recirculation is governed by

KVB 5804-714

the necessity to maintain levels below 25 percent LEL (or somewhat greater with proper safety controls). Because of the lower solvent content per unit weight of solids, the volume of exhaust air can be safely reduced somewhat. In some cases, however, the coating quality can be adversely affected by too large a reduction, because of the drying properties of the coating. The net result is that the energy required to cure water-borne coatings is approximately equal to that for organic solvent-borne coatings for some applications but will be somewhat higher for most applications.

4. Safety--One of the major advantages of water-borne coatings is their non-flammability and low toxicity. Considerable savings in insurance costs can be realized in some cases.

B. High-solids Coatings--

The basic ingredient in an organic coating is the binder or resin. A resin is a film-forming organic polymer having glassy, plastic, or rubbery properties in the dried state. As applied the resins are liquids of controlled viscosity. On drying and curing (baking) the materials undergo polymerization and cross-linkage to form a solid film of the desired properties.

The materials for resins to be used in conventional solvent-borne coatings are "cooked" in resin kettles to yield liquids which have a high viscosity at ambient temperatures. To facilitate compounding with pigments the resins are dissolved in organic solvents which reduce the viscosity. To facilitate application more solvent may be added. After application, the solvent evaporates and the resins further polymerize to yield the solid film.

The viscosity of the coating as applied can be reduced by using low molecular weight monomers or "prepolymers," which are applied and then polymerized (cured) to the high molecular weight solid film. The amount of solvent required decreases with decreasing reactant molecular weight. However, as the molecular weight of the resin formers are reduced, the difficulty of controlling the polymerization reactions increases. The application and curing conditions must be precisely fitted to the reactant characteristics to yield a film of the desired properties.

Another method of reducing viscosity of high-solids coatings is by heating the coating material. As a rule of thumb an increase in temperature from 70 °F to 125 °F is equivalent to a 10 percent solvent reduction. However, heating can cause loss of solvent crucial to the application performance of high-solids coatings. Heating can also cause premature gelation of coatings, particularly on standing.

The solids content of a coating is expressed as the volume or weight of the final cured coating per volume or weight of the coating as applied. The term "high solids coatings" is usually reserved for low solvent coatings which are applied and cured by conventional means. Low molecular weight materials which are cured by radiation (ultraviolet, infrared, and electron beam) are classified separately. Radiation-cured coatings are discussed below.

High solids coatings were first defined by the Los Angeles County Air Pollution Control District in its Rule 66; coatings of 80 percent or more solids (by volume) were exempt from emission limitations.

1. Materials and processes--Most high solids resins fall into two categories, two component ambient temperature cured and single component heat converted. The most important types are as follows:

<u>Two Component Ambient Cure</u>	<u>Single Component Heat Converted</u>
Urethane	Epoxy
Acrylic-Urethane	Acrylic
Epoxy/amine	Polyester
	Alkyd

Many two component systems use a catalyst to increase the curing reactions. Although these chemical reactions can take place at room temperature, many plants use low-temperature ovens to cure two-component systems rapidly so that the coated product can be handled sooner. The oven temperatures required are much lower than for conventional ovens and the amount of solvent is lower. This will result in large energy savings. Most thermo-setting high-solids coatings are based on epoxy or urethane resins. The

KVB 5804-714

most popular two-component coatings are based on polyurethane resins. Coatings properties compare favorably with those obtained from conventional based enamels. Toxicity of the isocyanates used for urethanes is a potential problem.

Fast-reacting two-component systems are usually applied with special spray guns that mix the two components at the spray nozzle. This equipment, more complicated than conventional spray equipment, is also more expensive. Some slower-reacting two-component coatings can be applied with conventional spray equipment.

High-solids coatings can be used in a variety of industrial coating processes. Two-component catalytically cured coatings are presently being air sprayed to coat small metal products. It might be possible to coat larger products such as automobiles with such systems. The coil coating industry is currently investigating the possibility of using high-solids coatings, especially two-component coatings (Ref. 4-16). The can industry is testing a roll-coat-applied high solids coating for can exteriors. Interiors of cans can possibly be coated with spray-applied high-solids coatings. Coatings of high viscosity can be applied with a knife coater, therefore, the paper and cloth industry may be able to apply high-solids coatings using existing knife coating equipment.

2. Advantages of high-solids coatings--In addition to reduction of solvent emissions high-solids coatings have other advantages:

- . In most cases conventional application methods can be used. Therefore, conversion costs are low.
- . In many cases, the energy required for curing is less than either conventional solvent coatings or water-borne coatings. However, in some cases higher curing temperatures are required and energy usage is greater than for conventional coatings.
- . In some cases thick coatings can be applied, that mask surface defects (if desired), so that less surface preparation for a product is needed.

KVB 5804-714

3. Disadvantages of high-solids coatings--The limitations of high-solids relate to the properties and availability of these coatings:

- . Achieving the desired properties in the finished coating is difficult. In conventional coatings the necessary functional properties are created by polymer building in the resin kettle. Solvents are then added to optimize application and appearance. Most of the polymerization in high-solids coatings occurs after application and controlling the conditions so as to produce the desired properties is much more difficult.
- . The availability of high-solids coatings is very limited. These coatings are just beginning to be converted from laboratory coatings to proven industrial finishing systems. Coating manufacturers report that efforts to produce coatings of 80 percent solids by volume have been unsuccessful. Coatings of 70 percent solids are still in the developmental stage. Only coatings in the 50 to 60 percent solids range appear to offer immediate prospects for expansion to widespread usage.
- . Pot-life of two component systems is very short, leading to application difficulties.
- . There is a health hazard associated with the isocyanates used in some two-component systems (urethanes).

4. Organic solvent emission reduction potential--In order to compare emissions for coatings of various formulations a common basis is necessary, such as a given volume or weight of cured solids. Table 4-4 makes such a comparison for organic solvent-borne coatings and water-borne coatings. The water-borne coating is assumed to have a volatile portion containing 80 percent water and 20 percent organic solvent. Such coatings are exempt from emission limitations by Rule 66 type regulations (Ref. 4-2). The last column shows the equivalent control device performance efficiency to achieve the same emission reductions.

C. Powder Coatings--

Powder coating involves the application of finely divided coating solids to a surface, followed by a melting of the coating solids into a continuous film. Very little solvent is used (less than one percent), and the process is thus almost pollution free. Several types of resins may be applied as a powder, but there are limitations on the type of objects that can be powder coated.

KVB 5804-714

TABLE 4-4. COMPARISON OF EMISSIONS FROM ORGANIC SOLVENT-BORNE AND WATER-BORNE COATINGS

Basis: 1 gal. of solids weighing 11 lbs.

Organic Solvent-borne Coating	Organic Emissions*	Water-borne Coatings**	Organic Emissions	Percent Reduction
Percent Solids by Vol	gal.	Percent Solids by Vol	gal.	
by Wt.	lbs.	by Wt.	lbs.	
12	7.3	10	1.8	72
20	4.0	15	1.1	72
30	2.3	20	0.8	65
40	1.5	25	0.6	60
50	1.0	30	0.5	53
60	0.67	35	0.37	44
70	0.43			
80	0.25			

\*No control device.

\*\*Volatile portion is assumed to be 80 percent water and 20 percent organic solvent.

1. Advantages of powder coating--In addition to the almost total elimination of organic solvent emissions, powder coating has several advantages over solvent-borne coating:

- . Single coat application is possible with the fluidized bed technique for thickness up to 0.040 in. with one application versus several applications necessary for solvent-borne coatings.
- . Material utilization can approach 100 percent if the powder can be collected and reused. This factor allows powder coating to be potentially the most economical coating material. The difficulty with the reuse of powder occurs if multiple colors are used. This will be discussed later.
- . Safety aspects of powder coatings offer some advantages. Powders are low in toxicity and nonflammable in storage; however, virtually any organic powder suspended in air can be explosive.
- . Maintenance is generally less because the powder can be vacuumed from any unbaked areas. Likewise the paint from any mistakes can simply be vacuumed off from unbaked items.
- . Exhaust air volume is greatly reduced from that used for solvent-borne spray because application is generally either automatic or else done in a much smaller area. Spray booth air theoretically could be filtered and returned to the plant interior. Fan power is reduced as are space cooling or heating requirements.
- . Water pollution problems are absent because dry particulate collection is possible.
- . Natural gas usage can be theoretically decreased because little dilution air is required in ovens. However, higher bake temperatures are usually required, which may result in increased gas usage.

2. Disadvantages of powder coating--Some of the specific problems with different methods of application are discussed later. General problem areas include the following:

- . Color change is a difficult problem for powder. The automobile and truck assembly industry has this problem in its extreme. Hence, color changes can occur as often as once a minute and with as little as 15 seconds to change colors between vehicles. Furthermore, more than a dozen colors are usually applied. For fluidized bed methods, considerable time would be necessary

KVB 5804-714

to switch colors because cleanout of the equipment would be necessary. A separate dip for each color would be necessary if color were changed more than once a day. For spray operations, the problem of changing colors can be solved by switching coating supply lines and purging the small amount of powder in the nozzle. This can, however, be a difficult mechanical problem. A remaining difficulty with color change is the problem of reusing overspray. If colors become mixed in the collection device, reuse of powder is impossible for any applications that change colors more than about once a day, unless the number of colors are few and it is feasible to use separate spray areas for each. Without the ability to reuse the oversprayed powder, powder coating loses one of its chief economic advantages-- low materials loss.

- . Color masking is more difficult for electrostatically applied powder coatings than for solvent-borne coatings. Fine detail, such as printing, is not possible and even two-tone automobiles present a problem, albeit a solvable one.
- . Powder coating materials are discrete particles each of which must be the same color. Thus, there can be no user tinting or blending and all colors must be available from the manufacturer. For a coater that must match a given color, such as in a trademark, the necessary color may not be available. Color matching problems can occur when using recycled powder.
- . The high curing temperature required for powder coatings makes them applicable only for metals and some plastics.
- . A typical particle size for sprayed powder coating materials is generally greater than 15 micrometers (Ref. 4-18). Because 1 mil is about 25 micrometers, it is obvious that thin, uniform spray coatings are difficult to achieve at coating thickness of less than 2 to 3 mils. Fluidized bed coating materials are usually about 200 micrometers in diameter and thus are not applicable for thin coatings.

3. Application methods--The three general application methods for powder coatings are electrostatic spray, conventional fluidized bed, and electrostatic fluidized bed. For further details consult References 4-2 and 4-17.

D. Hot Melt Formulations--

Hot melt coatings are applied in a molten state. The molten resin film cools soon after being applied to the substrate. Because there is no solvent to evaporate, virtually 100 percent of the materials that are

KVB 5804-714

deposited remain as a solid part of the coating. Hot melt coatings are most often applied to paper, paperboard, cloth, and plastic.

When the hot melt coating has been applied and cooled, the film does not need further heat curing. Since the only heat required is that to melt the coating initially and to heat the coating applicator, a considerable energy savings can result compared to oven curing. Also, because an oven is not needed, less floor space is needed for the coating line. The line can be run faster with hot melts than with organic solvent-borne coatings. A chilled roll can be used to speed cooling, if necessary.

Hot melt coatings are applied at a variety of temperatures. Low melting point coatings are applied at temperatures as low as 150 to 210 °F. These are materials such as waxes or paraffin coatings that are soft and easy to scratch. To improve scratch resistance, higher melting resins are added. These are usually synthetic organic compounds. Hot melt blends with melting points in the range of 300 to 450 °F usually contain no paraffin, waxes, or other low melting point ingredients but rather are composed of film forming resins and plasticizers. The resultant films from such high melting point formulations show properties that are comparable to high grade solvent-borne coatings (Ref. 4-18).

Hot melt coatings must, of course, be applied at temperatures that are higher than the melting point of the coating. Because the substrate may be harmed by high temperatures, hot melt coatings with melting points above 400 °F cannot be used for some applications. However, some extrusion coatings are heated to 600 °F to achieve proper adhesion between the polymer and substrate (Ref. 4-19).

Hot melts may be applied in a variety of ways. Usually special heated coating equipment is required. Lower melting hot melts may be applied by heated rotogravure or roll coaters. Extrusion coaters are widely used also, especially with higher melting point materials.

KVB 5804-714

Extrusion coatings are a large subclass of hot melt coatings. In this type of coating a screw extruder discharges a molten plastic sheet onto the substrate. Food containers such as milk cartons are often coated with extrusion coatings because the plastic film provides a good moisture barrier.

Ethylene/vinyl acetate copolymer, low and medium density polyethylenes are the resins most widely used for hot melt coatings. Polyethylene forms a strong film, mixes well with other resins and waxes, has good water resistance, has good flexibility at low temperatures, and is relatively low in cost. Other resins used include vinyls, cellulose esters, alkyl esters, maleic esters, and polystyrenes. All of these materials must have viscosities suitable for application and they must be chemically stable for long periods in the molten state.

Hot melts are applicable to the paper and fabric coating industry, although only for certain applications. Thus, hot melt coatings cannot be judged to be universally applicable in the paper and fabric coating industry at this time.

#### E. Electrostatic Spray Coating--

Electrostatic spray coating utilizes the attractive force between materials of opposite electrical charge as an aid in applying a uniform coating to various surfaces. The method reduces overspray and waste and thereby increases the coatings application efficiency over conventional spray coating processes. In the case of solvent- and water-borne coatings, this will in effect reduce the amount of coating solids and corresponding solvent carrier needed for a specific coating job. Electrostatic spray coating can be used to apply solvent-borne, water-borne, or powder coatings.

In typical electrostatic spray coating processes where relatively nonconductive solvent-based coatings are used, coating particles are charged up to 100,000 volts with an electrode (Ref. 4-20). The grounded object then attracts the negatively charged particles, which are captured to form

a film. In instances where conductive coatings are used, water-borne coatings, for example, it is possible to use reverse polarity, that is, charging the object to be coated and grounding the spray equipment (Ref. 4-21).

Electrostatic spray coating is primarily applicable to metal surface coating. It is of particular value for complex shapes. Glass, plastics, paper and fabric have been successfully coated with this technique. Corners or extreme concave shapes on objects may escape coating due to the "Faraday cage" effect (Ref. 4-21). This phenomenon results from the repulsive electrical forces in corners or concave areas.

Electrostatic spray coating has the potential of reducing organic emissions since it can improve the efficiency of application of solids over ordinary spray. This results in less organic solvent emissions.

#### F. Electron Beam Curing--

The electron beam curing process uses high energy electrons to promote curing of electron beam-curable coatings. Electrons bombard a coating to produce free radicals throughout the coating. This initiates a cross-linking reaction that continues until the coating is cured. The entire process takes only a few milliseconds to complete (Ref. 4-22). Since most free radicals are terminated by oxygen, an inert atmosphere is desirable so that the surface of the coating will not be less highly crosslinked than the interior.

The energy requirements for electron beam curing are dependent on the size of the unit and the coating thickness but are typically lower than for thermal curing. There is an additional energy savings because of the instant startup and shutdown capability of the electron beam unit.

Electron beam curing units must be shielded properly to avoid radiation exposure. According to occupational Safety and Health Administration regulations, exposure should not exceed 5 millirems of radiation in 1 hour and 100 millirems in any 5 consecutive days (Ref. 4-23).

KVB 5804-714

Some electron beam-curable coatings may contain monomers that are toxic. Caution should be taken when using such monomers.

There have been few, if any, tests performed to quantify organic vapors emitted during the curing process. It is generally assumed that some low molecular weight organic compounds are emitted during curing even though all the components are reactive. There also may be some ozone generated from the curing process itself (Ref. 4-24).

The use of electron beam curing is most effective on flat surfaces where the electron beam strikes the surface vertically. If the beam strikes the surface at an angle closer to the horizontal, the amount of absorbed energy can be too small and the coating will not cure properly.

Electron beam curing, unlike ultraviolet light curing, can cure thick and pigmented coatings because of the penetrating power of the electrons.

Because electron beam curing uses relatively new technology, the coatings necessary for the electron beam curing process are in the early stages of research and development. The use of electron beam curing is very limited at the present time.

#### G. Ultraviolet Curing--

In ultraviolet curing, ultraviolet light reacts with photosensitizers in the coating to initiate crosslinking to form a solid film. The basic components of an ultraviolet curable coating are: an ultraviolet-curable base polymer, diluent monomers, and ultraviolet photochemical initiators (Ref. 4-25).

The ultraviolet-curable polymers provide most of the desired coating properties. The diluent monomers decrease the viscosity of the polymers, increase the crosslinking density, and improve other features of the coating such as gloss, hardness, and curing speed. The photochemical initiators are unstable chemicals that form free radicals when bombarded by ultraviolet light to initiate the crosslinking process (Ref. 4-26).

The energy source used for ultraviolet curing is electrically produced ultraviolet light energy such as from mercury vapor lamps. The use of ultraviolet light for curing is most effective on flat surfaces where the light reaches the surface vertically. When the ultraviolet light strikes a surface at an angle closer to the horizontal, the amount of absorbed light can be too small for effective curing. Obviously, no curing will occur if an area is shielded from the light.

The actual performance and appearance of ultraviolet-curable coatings is not only dependent on the base polymers, diluent monomers, and photochemical initiators, but also on other agents such as pigments, fillers, and mar resistors added to the coating to provide the desired properties.

In certain industries, the use of ultraviolet light curing has been successful, although this success has been limited mostly to semitransparent coatings, such as inks. Ultraviolet cured polyester based coatings have made a significant penetration into the forest products industry as filler coatings for particle board. Most uses of ultraviolet coatings, however, are still in the research and development stage. Major problems are curing of thick coatings and coatings with pigmentation. The main difficulty with pigmentation is that the pigment particles absorb or reflect ultraviolet light, thus reducing the light energy available to cure the coatings in the deeper layers of the coating.

Because little if any flammable solvent is emitted, the amount of dilution air flow through ovens can be greatly reduced. There is a substantial decrease in energy usage compared with thermal curing. An ultraviolet curing unit may use only one-third the energy of a standard thermal oven (Ref. 4-27).

The ultraviolet curing equipment must be shielded properly to avoid exposure of the equipment operator. Exposure at short distances can cause severe burns to the skin and the eyes (Ref. 4-28).

KVB 5804-714

Certain ultraviolet coating materials may produce skin and eye irritation. Others, such as those containing "the more volatile acrylic monomers, are considered toxic and hazardous chemicals" (Ref. 4-28). The handling of ultraviolet-curable coatings requires care and caution.

There have been few, if any, emission tests performed to determine whether volatile organics are emitted during ultraviolet curing. Some low molecular weight organic compounds are probably emitted during the ultraviolet curing process even though all the components of the coating are reactive.

#### 4.1.9 Improved Maintenance

The release of fugitive organic emission from leaks in process equipment and pipeline fittings as well as from spills and other equipment failure can be reduced by improved maintenance. In the field testing performed on this program at oil production fields and refineries it was found that more than 50% of the leaks found by the test crew could be stopped by a simple tightening of a valve packing nut or applying grease to seal a plug valve. Similarly, immediate attention given to liquid leaks developed in pumps or compressors can reduce the amount of evaporative loss.

Based on field test data taken during this program (see Section 3.0), an average leak rate of 0.15 lb HC/day was determined. Using the spray and sniff (soap bubbles and an explosimeter) technique developed by KVB for locating leaks, a single workman can locate and tighten the leaks in several hundred valves and fittings a day. Using the leak rate and assuming hypothetical workman efficiency and employee costs, KVB arrived at a figure which reflected possible savings. Those computations were submitted to Mr. J. H. Caldwell, Jr., Manager of Refinery Operations at the Carson plant of Atlantic Richfield Company for evaluation. His letter is included on the following pages.

According to the analysis set forth by Mr. Caldwell, it would seem that the cost of additional maintenance programs would exceed the economic gains. ARCO's present maintenance program coupled with the enforcement efforts of the SCAQMD represents what they believe to be the most cost effective approach.

KVB 5804-714

Products Division  
Watson Refinery  
1801 East Sepulveda Boulevard  
Carson, California 90745  
Telephone 213 834 7221

J. H. Caldwell, Jr.  
Manager  
Refinery Operations



August 4, 1977

Hal Taback  
KVB Incorporated  
17332 Irvine Boulevard  
Tustin, California 92680

Subject: Fugitive Hydrocarbon Emissions - Valves and Fittings

Dear Mr. Taback:

As we indicated at our meeting of July 20, we have attempted to quantify the costs and benefits of a total monitoring and leak repair program for valves and fittings along the lines suggested by your draft report and the EPA draft document. At this time, our best guess is that a monthly survey of all valves and fittings in the refinery, including maintenance on leaks discovered, would cost approximately \$1,500,000 per year in addition to our current maintenance budget. The value of the hydrocarbon product recovered by this maintenance expense would be only about \$15,000 at a net cost of about \$20,000/Ton of hydrocarbon emissions. Although this number may seem high, please recognize that there are over 1,000,000 valves and fittings in our refinery and a cost of about \$0.10 each (\$1.00 to \$1.50/year) to survey and maintain these fittings is very reasonable.

These figures were arrived at in the following manner. A crude distillation unit with a rated capacity of 38,000 B/D was chosen for the experiment. This unit contains 3 fractionating towers, 8 other hydrocarbon pressure vessels, 2 fired heaters, 23 shell and tube heat exchangers and 22 hydrocarbon pumps. Its purpose is to fractionate incoming crude oil into the following streams: propane/butane, light gasoline, heavy gasoline (naphtha), kerosine, diesel and residuum. Normal operating and maintenance personnel were relieved of their normal duties and instructed to count all valves and fittings containing hydrocarbons, visually inspect for liquid leaks and soap test for vapor leaks and repair as many leaks as possible without shutting down the unit. No records were made other than the raw count of valves and fittings and time and materials spent on the job. For this unit, 65 man hours were spent for survey and repair and about \$500 of materials were used. As shown on the attached table, 11,414 leak sources were identified and tested, 38 leaks were discovered of which 31 were repaired without a unit shutdown. All of the leaks were considered minor and most were barely detectable. Of the 7 leaks that could not be easily repaired, 6 were low vapor pressure liquid (4 flanges and 2 exchanger heads). One valve in propane service could not be repaired or replaced without a unit shutdown.

KVB 5804-714

Mr. Hal Taback  
August 4, 1977  
Page 2

The basis for extrapolation of these results to the entire refinery is by the number of pumps. Many of the valves and fittings are directly associated with pumps and the number of manifolds, exchangers, etc. are related more nearly to pumps than other major equipment. Volumetric through-put is a very poor scaling factor as we have previously discussed. The crude distillation unit contains 1% of the hydrocarbon pumps in the refinery and is therefore assumed to contain 1% of the valves and fittings.

The basis for calculating emission reductions is a little more speculative. Obviously the only way to make a precise calculation is to assume "virgin territory" for a base line and run longitudinal studies with several surveys over an extended time period to determine the reoccurrence rate. The first such survey and at least some of the subsequent surveys would have to include bagging observed leaks to quantify emissions/leak. Even then, some arbitrary correction factor would have to be applied to relate an obviously experimental situation to the real world. In the absence of this data, the following was assumed:

1. "Large" leaks are identified and corrected as quickly as possible under present conditions for safety and economic reasons. This may not be true for all refineries in all locations but is reasonably accurate for major refineries under current standards. Our excellent safety record attests to this fact. Obviously there may be a difference of opinion as to what constitutes a "large" leak.
2. Most "medium" leaks and many "small" leaks are repaired in a timely fashion either because of safety and economic reasons or due to current weekly enforcement inspections by the SCAQMD. Full blown, total facility inspections are not likely to speed up this process and in fact may divert resources currently expended from repairing a few "large" leaks to many inconsequential ones.
3. Pre-turnaround inspections are currently conducted to identify the remaining minor leaks for repair during unit maintenance shutdowns when resources can be efficiently utilized. These turnarounds take place semi-annually to bi-annually depending on the type of process involved.

With this in mind, assuming 80% of the minor leaks discovered (0.3% of the valves and fittings surveyed) are repaired and stay repaired with a 50% reoccurrence rate multiplied by your factor for emissions per "small" leak (52 lb/day) gives about 100 tons/year emission reduction resulting from total monthly surveys in this plant. This result would

KVB 5804-714

Mr. Hal Taback  
August 4, 1977  
Page 3

only be valid for the first year of the program. Subsequent years would show diminishing returns since hopefully leaks would be repaired faster than they occur.

Finally, I cannot close without making a rather personal observation. Under normal circumstances my professional standards would not allow me to extrapolate limited data to the extent done above. However, I feel that in this case it is in the public's interest to give the fairest assessment possible in the limited time available. Both by corporate policy and personal commitment, I would not hesitate to recommend a program of the cost outlined if it meant a meaningful contribution to improvement in air quality in the Los Angeles Basin. Our current maintenance program coupled with the present enforcement efforts of the SCAQMD represents the most cost effective approach to reduction in fugitive emissions from valves and fittings. Nonproductive programs requiring large manpower expenditures only serve to divert precious resources from the real issue of supplying the energy requirements of society in an efficient, environmentally sound manner.

Very truly yours,

  
J. H. Caldwell, Jr.

JHC:pm

Attachment

KVB 5804-714

SURVEY RESULTS

<u>Fittings</u>		<u>Valves</u>	<u>Total</u>
<u>Bolted</u>	<u>Screwed</u>	<u>Stems, Bonnets</u>	<u>Leak Sources</u>
3117	5465	2832	11414
7 leaks repaired	8 leaks repaired	16 valves repaired or replaced	31 leaks stopped
*6 leaks not repaired		1 valve yet to be repaired	7 leaks not stopped

\* 2 exchanger heads leaking - unable to stop.

4 flanges leaking on vocss system - unable to take system out of service.

All leaks considered small - most barely detectable.

While KVB's tests at ARCO revealed leaks averaging 0.15 lb/valve/day, the major amount of the leakage (80%) occurred in the large leakers which Mr. Caldwell contends would have been eventually discovered.

#### 4.2 APPLICATION

In the previous subsection, 4.1, the various control methods were reviewed in some detail. In this section, various industry devices and processes are discussed with regard to the types of control methods that are applicable. Table 4-1 summarizes the various devices and processes, and the applicable control technology.

##### 4.2.1 Petroleum Operations

###### A. Production--

1. Valves, flanges, etc.--Fittings in oil fields are used in either gas or liquid service. Most leakage is found in the gas service pipelines. The most effective control was found to be improved maintenance. In the field tests by KVB on this program, a number of leaks were detected which could be stopped by simple tightening of valve packing nuts. This indicated that an improved maintenance program might be an effective measure. However, when the same approach was suggested for a refinery operation, it was refuted by refinery management as not being cost effective (see Section 4.1.9).

Although no data have been found to support this, it is the general consensus of the people in the petroleum business that plug valves are better than gate valves from a leakage standpoint. This would suggest that switching to plug valves would offer some advantage. Most plug valves rely on grease to seal them. KVB actually found proportionally more plug valves leaking than gate valves. However, the simple injection of grease into the valve always stopped the leak whereas on gate valves it was not always possible to stop a leak by merely tightening the packing nut. In some cases it was necessary to replace the entire packing.

KVB 5804-714

If some data could be developed to establish which type of valves have the least leak rate, then the gradual switching to that type of valve should be initiated. Two programs are currently in progress in which petroleum valve leakage data will be obtained, an oil refinery emissions measurement program sponsored by EPA (Ref. 4-29) and a production field test program sponsored by API (Ref. 4-30). These results should be monitored in developing valve emission control techniques.

2. Pumps and compressors--The use of mechanical seals and a preventive maintenance program of testing and repairing will result in reduced emissions. The EPA and API studies mentioned above should provide further information as to the compressor and pump leakage rate and the difference between packed and mechanical seals.

3. Tanks, storage and production--Crude oil processing involves heating and compression for water, oil and gas separation. Production and storage vessels are usually of the fixed or cone roof type. The most effective emission control system is the vapor recovery units used to retain as much of the gaseous product as possible. A typical installation is shown in Figure 4-23.

A battery of cone (fixed) roof storage tanks are connected by a series of gas manifolds to a gas holder (usually a low pressure diaphragm type design).

Provision is made for removing excess gas from the gas holder with a compressor. To make up for this lost gas a blanket gas is allowed to flow into the vapor space of the cone roof tanks during periods of vapor contraction (due to cooling or barometric pressure changes) or during periods of liquid withdrawal. The blanket gas usually consists of natural gas and its purpose is to maintain a non-explosive mixture in the vapor space of the cone roof tanks. The natural gas vapors recovered from the gas holder represent a high grade combustible fuel gas. This gas may or may not be processed through various stages of refinement such as cooling to condense low volatile liquids separating them from the gas stream as shown in Figure 4-23. The fuel gas can be used as an energy source for the various gas-fired devices in the production field.

KVB 5804-714

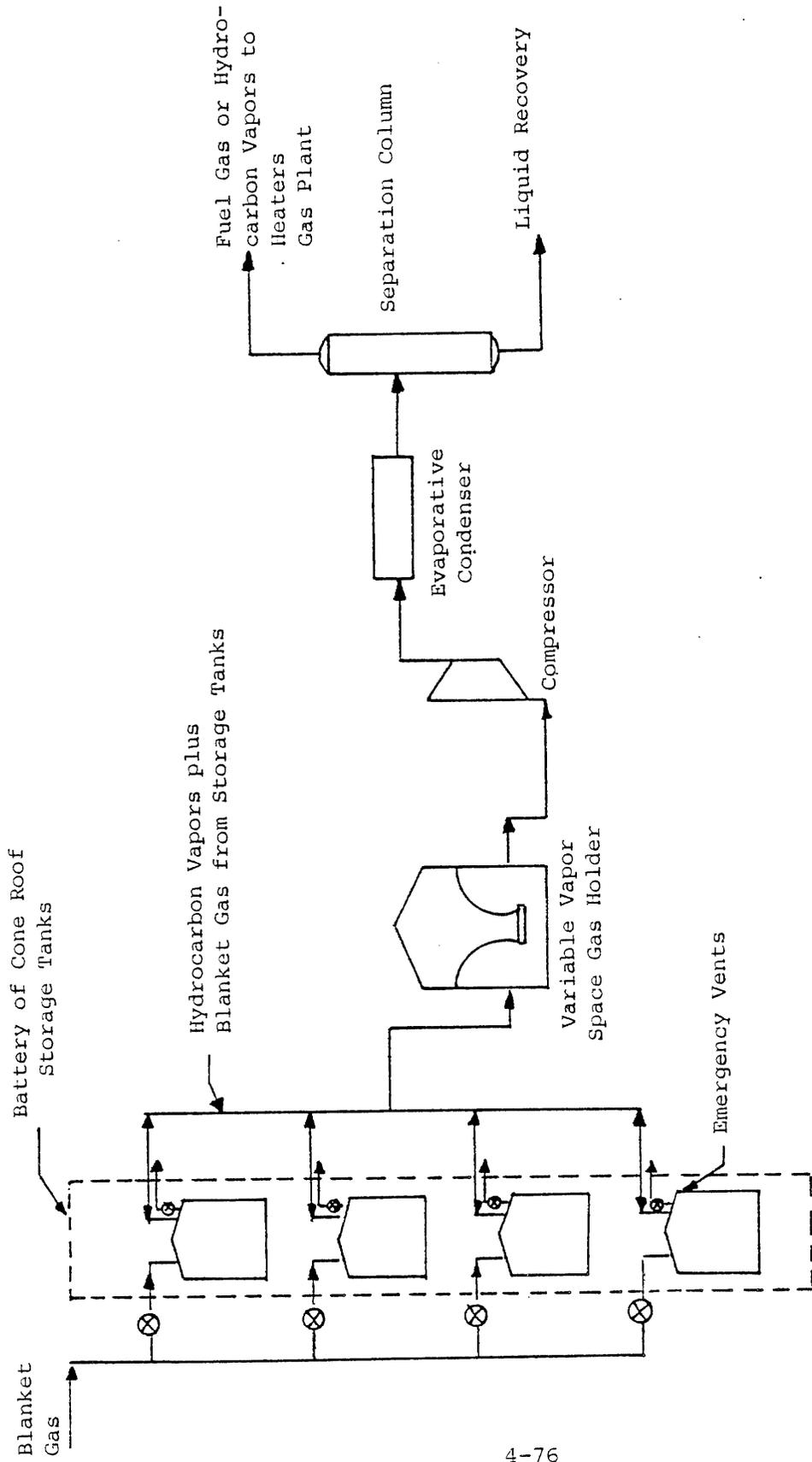


Figure 4-23. Simplified schematic of a typical vapor recovery system (Ref. 4-6).

KVB 5804-714

Where no vapor recovery system is used, painting the tanks white will minimize breathing losses.  $H_2S$  gas sometimes present in crude oil was found to have corrosive effects on tank sample port covers. Leaks in these covers can result in significant loss since the gas blanket is at a slight positive pressure to prevent air intrusion. Therefore maintenance is required to insure tight cover fit.

4. Waste water separators--Most oil fields process waste water from their heater treaters and water knockout tanks in open pools, skimming off the oil in various stages. In the final stage a vacuum truck periodically removes the oil layer. This has been an acceptable practice under current rules because it was felt that the Reid vapor pressure was below 0.5 psi. KVB tests conducted as part of this program suggest that a significant amount of H/C emissions may be evolved from the surface of the pool. Solid or floating covers will reduce these emissions by up to 95%.

5. Well vents--In certain oil fields in the Basin, steam is injected into oil wells to stimulate the recovery of crude oil. This form of tertiary oil recovery along with another method, referred to as in-situ burning or fire flooding, causes gaseous hydrocarbons to be emitted from well vents. Fire flooding involves pumping air underground to burn some of the oil to heat the remaining oil and lower its viscosity. The emissions contain hydrocarbons and some odorous compounds like  $H_2S$  and mercaptans. The hydrocarbon emissions are in relatively high concentration, 2-3,000 ppm, and the odorous compounds are in low concentration, a few ppm or less. The control devices applied are water cooled finned condensers and charcoal-absorbers to collect the  $H_2S$  and mercaptans.

6. Boiler and heater--Boilers are used to create the steam to be injected into the ground. Process heaters are used to separate crude oil from the associated water. Both of these devices emit low concentrations of hydrocarbons. The best way to minimize these emissions is to keep the device well maintained and to use optimum burner designs which will have good atomization and mixing.

KVB 5804-714

7. IC engines--Natural gas fired piston engines are often used to drive oil well pumps. Two stroke engines emit a substantial amount of gaseous H/C's because part of the fuel never burns. On a two stroke engine intake and exhaust occur on the same stroke so that some of the fuel is scavenged with the exhaust products. The best control approach is to replace the two stroke engines with four stroke engines and to keep the engines well tuned.

B. Refining--

Valves and flanges--

Compressors and pumps--

Waste water separators--

Boilers and heaters--

The approach for these items in a refinery is identical for the respective devices in an oil field as presented above.

1. Vacuum jets--These vacuum ejectors are used on vacuum distillation towers. With the exception of the stripping steam the ejected stream is all hydrocarbon which may be condensed by a water cooler and vented to the refinery fuel gas. Condensable products are collected and processed further.

2. Asphalt air blowing--Asphalt is normally obtained from select crude oils by means of vacuum distillation or solvent extraction. To make it suitable for paving, roofing, or pipe coating, asphalt is sometimes reacted with air. Air-blowing is mainly a dehydrogenation process. Oxygen in the air combines with hydrogen in the oil molecules to form water vapor. The progressive loss of hydrogen results in polymerization or condensation of the asphalt to the desired consistency.

Blowing is usually carried out in batches, starting with the asphalt at a temperature of 300 °F to 400 °F. Little additional heat is needed since the reaction becomes exothermic.

Effluents from the asphalt air-blowing stills include oxygen, nitrogen, water vapor, sulfur compounds, and hydrocarbons in the forms of gases, odors, and aerosols. Discharge of these odors and airborne oil particles can be disagreeable.

KVB 5804-714

Control of emissions from asphalt air-blowing stills has been accomplished by scrubbing and incineration, singly or in combination. Most installations use the combination. For scrubbing alone to be effective, a very high water-to-gas ratio of about 100 gallons per 1,000 standard cubic feet per minute is necessary.

Where removal of most of the potential air pollutants is not feasible by scrubbing alone, the noncondensibles must be incinerated. Essential to effective incineration is direct-flame contact with the effluents, a minimum retention time of 0.3 second in the combustion zone, and maintenance of a minimum combustion chamber temperature of 1,200 °F. Other desirable features include turbulent mixing of vapors in the combustion chamber, and adequate instrumentation. Primary condensation of steam and water vapor allows use of smaller incinerators and results in fuel savings. Some of the heat released by incineration of the waste gases may be recovered by using it to generate steam (Ref. 4-4 ).

3. Catalyst regenerators--Petroleum fractions are cracked to produce compounds of lower molecular weight. Catalysts in the form of powders or beads are utilized. The catalyst particles become coated with carbon and high-molecular-weight compounds. These materials must be burned off the catalyst in order to maintain its activity. The catalyst continuously circulates from the reactor chamber to the regenerator chamber. In the regenerator, a controlled amount of air is admitted to burn off the coatings. This causes the formation of CO and hydrocarbons. These emissions can be controlled by incineration using a waste heat boiler. These boilers are commonly referred to as CO boilers (Ref. 4-4 ).

4. Storage tanks--In a refinery both fixed roof and floating roof tanks are employed. In the Basin the storage of organic liquids is controlled by SCAQMD Rule 463 which, if the Reid vapor pressure is greater than 0.5 psi, requires the use of floating roof tank with double seals or fixed roof tanks with variable vapor space or vapor recovery. If the RVP is lower than 0.5 psi, then the liquid may be stored in a fixed roof tank without control.

5. Transferring--Movement of hydrocarbons throughout a refinery from vessel to vessel can produce working losses. To minimize these losses the vapors created and displaced must be minimized or handled to prevent their

KVB 5804-714

escape. Floating roof tanks, variable vapor spaces and vapor recovery systems can be employed. In filling tankers and tank trucks, bottom filling procedures minimize the escaping hydrocarbons. Liquid/vapor exchange is also used to reduce emissions as well as for vehicle safety. Reference 4-10 has a thorough treatment of these methods.

6. Blow downs--Refinery units are periodically shut down and emptied for internal inspection and maintenance. The process of unit shutdown, repair or inspection, and start-up is termed a unit turnaround. The purging of the contents of a vessel to provide a safe interior atmosphere for workmen is termed a vessel blowdown. In a typical process unit turnaround the liquid contents are pumped from the vessel to some available storage facility. The vessel is then depressurized, flushed with water, steam, or nitrogen and ventilated. Depending on the refinery configuration, the vapor content of the vessel may be vented to the fuel gas system, flare, or if released directly to the atmosphere, it is through a blowdown stack which is usually remotely located to ensure that combustible mixtures will not be released within the refinery.

The emission factor for refinery blowdown is 856 kilograms per 1000 cubic meters ( $\text{kg}/10^3 \text{m}^3$ ) of refinery throughput (Ref. 4-31). This factor is based on a one-year (1956) record of refinery turnarounds in Los Angeles County. In this one-year period, eight refineries reported 382 turnarounds with blowdown; 56 percent of these resulted in emission to the atmosphere, while 44 percent resulted in no emissions (Ref. 4-32).

#### C. Marketing - Transferring--

In gasoline marketing the product is transferred from the bulk station to the local service station and then to the automobile. Vapor control can be maintained by the balance system of vapor liquid exchange. The losses are further reduced by using the procedure of bottom filling the tank trucks and service station tanks to minimize the amount of aerosol in the vapor being transferred. In terms of control strategies to reduce hydrocarbon emissions in the Basin, the implementation of auto refueling vapor recovery systems should have the most significant benefit. This is discussed further in Section 5.0.

KVB 5804-714

#### 4.2.2 Organic Solvent Operations

With few exceptions organic solvent operations have the choice of four candidate emission control systems; charcoal adsorption, thermal incineration, catalytic incineration, or process and material changes. The choice must be made after a detailed study of the particular constraints on a given installation. However in this section a few pertinent observations regarding the peculiarities of certain operations will be presented.

##### A. Metal Coating--

Automotive--The automobile assembly industry is most adaptable to incineration and adsorption. Both thermal and catalytic incineration are in use in the two assembly plants in the Basin. Because of the color changes required on the assembly line certain of the low solvent coatings are not applicable. But water-borne paint has proved to be feasible and is now being used as a top coat by GM in their plants in Los Angeles. The switch-over has been expensive. An estimate of costs associated with switching an entire assembly plant to using water-borne paint (electrophoretic primer and spray-applied top coat) is between \$30 and \$50 million capital cost depending on whether booths and ovens are replaced or retrofitted, and \$6 million per year operating costs (Ref. 4-33). The equipment and process modifications necessary to implement a complete water-borne paint system are as follows (Refs. 4-33 and 4-10):

1. Special primer facilities--The electrophoretic primer requires better precleaning and a de-ionized water bath before priming. It requires a large tank with extensive controls on temperature, pH, solids, and voltage. A final rinse usually with de-ionized water is also required.

2. Lengthening of ovens--Water-borne coatings require a longer flash tunnel prior to drying. Temperatures must also be raised more slowly and brought to higher levels in order to evaporate the water slowly enough to avoid pitting the coating. This necessitates longer ovens, which in turn may force some existing equipment to be moved to other locations at considerable cost.

3. Cleanliness requirements--Water-borne coatings do not "touch dry" as quickly as solvent-borne coatings. Thus, they are much more susceptible to dirt pickup. This necessitates filtration of incoming air. Overhead conveyors may also be inadequate because of potential for dropped dirt.

4. Humidity and temperature requirements--Because the major solvent being evaporated is water, proper temperature and humidity conditioning of the air is vital. If the humidity is too high or the temperature too low, the coating will sag on vertical surfaces. Conversely, if the humidity is too low or the temperature too high, the water will evaporate too rapidly and the coating will "orange peel" or pit. Each coating must be formulated for a narrow humidity range, but formulations for different humidities are possible.

Water can be removed from incoming air by chemical or mechanical means. The chemical means involves use of a hygroscopic solution; the mechanical means involves use of a refrigeration cycle. The proper choice depends on both the climate and the availability of energy at the plant. The chemical choice involves more complexity, but less energy consumption than the mechanical method. Steam availability favors the chemical choice.

5. Shutdown problems--Because of the potential for rusting and dirt pickup, vehicles coated with water-borne coatings cannot be left wet overnight or during shift changes. The assembly line must have facilities for carrying painted vehicles through the following oven after shutdowns. Accommodations must also be made for storage of these vehicles until the process resumes. These requirements necessitate special ovens, surge storage areas, and independent conveyor chains for each of the dip tables and spray booths with resultant controls and costs.

6. Clean-up problems--Unlike organic solvent-borne coating, water-borne coating overspray does not dry in the air before being drawn through the particulate collector. This results in an increased clean-up problem for water-borne coatings with attendant increased clean-up labor costs. The fans also become coated with over-spray and require frequent cleaning.

7. Sludge handling problems--Water-borne coatings do not harden in the water of the water-wash particulate collectors on the spray booth. Sludge handling is thus more difficult for water-borne systems.

8. Corrosion problems--The black iron pipes commonly used to pump solvent-borne coatings from central mixing areas to the spray booth are not suitable for water-borne coatings and must be replaced with a non-corrosive. The lifetime of steel spray booths may also be lessened where water-borne coatings are used.

9. Maintenance requirements--Maintenance requirements are increased by the new air conditioning and humidity control systems required.

Can coating (Ref. 4-33)--Can coating includes: the roller coating of one or both sides of metal sheets to be used for can bodies or ends, the side seam spray coating of three-piece cans, the interior body spray coating and side seam spray coating of three-piece beer and beverage cans, the exterior roller coating and the interior body spray coating of two-piece cans, and the sealing compound coating of can ends. The fabricated cans are used as containers for products ranging from beverages to tennis balls.

Lacquers or other coatings for the interior base coat are used in the three-piece cans to provide a protective lining between the can metal and product, especially for food products. It is important that the interior lacquer does not react with the product to alter the product taste, odor, or appearance. All interior coatings for cans that will contain edible products must be approved by the Food and Drug Administration (Refs. 4-34, 4-35).

Some common resins used in can coating lacquers are butadienes, phenolics, epoxies and vinyls that range from 30 to 40 percent solids content by weight and organosols that range from 52 to 66 percent solids content by weight (Refs. 4-34, 4-35).

The exterior base coat is usually a white coating used to provide adhesion and background for the lithographs or printing operation. Some of the coating resins used are polyesters, alkyds, and acrylics at approximately 55 to 65 percent solids content by weight.

The solvents most often used in the interior and exterior base coats, the over varnish, and the primer are mineral spirits, xylol, toluol, diacetone alcohol, methyl iso-butyl ketone, methyl ethyl ketone, isophorone Solvesso 150 (TM), Cellosolve (TM), ethanol, cyclohexanone, Butyl Cellosolve (TM), Cellosolve acetate (TM), n-butanol, isopropanol, butyl carbinol, propylene oxide, mesityl oxide, aliphatic petroleum hydrocarbons, di-iso-butyl ketone, di methyl formamide, and I-nitropropane.

KVB 5804-714

A new coating formulation for the cans not only has to satisfy the can manufacturers but also must be approved by the customer. Customer approval of a new coating formulation may take a minimum of 6 to 9 months. Federal Food and Drug Administration approval for a new coating to be used for edible products may take as long as 4 years.

Incineration is a proven retrofit control system that can control organic solvent emissions from can coating facilities. Although incineration without heat recovery is a considerable energy user, installation of primary and secondary heat recovery systems significantly reduce the incremental consumption of energy. Incineration is the most economical retrofit control option when combined with heat recovery.

Water-borne, high-solids, powder and ultraviolet curable coatings can reduce organic solvent emissions with the same efficiency as incineration and may use less energy than solvent-borne coatings. Conversion to water-borne, high-solids, powder and ultraviolet curable coatings has been successful on some can coating formulations; however, many coatings are still in the development stages or are undergoing tests by both the Food and Drug Administration and the customers. The ability to convert to water-borne, high-solids, powder and ultraviolet curable coatings as a control option will vary from plant to plant depending on the type of product for which the cans are being coated or manufactured.

A carbon adsorption unit retrofitted on a sheet or can coating facility can reduce organic solvent emissions even though additional measures are needed in some cases to clean the process gas stream prior to adsorption. Because different mixtures of solvents are used, there is little market value for the solvent. The solvent can be recovered and used as fuel for the boiler to generate steam for the regeneration of the carbon bed; however, the recovered solvent may not be enough for the required boiler if concentrations are low. The cost of removing each ton of organic emissions using carbon adsorption without any credit for recovered solvent is greater than incineration but will approach the cost of incineration without heat recovery if the recovered solvent can be used as fuel.

KVB 5804-714

The cost of controlling each ton of organic emissions from the can coating industry using water-borne, high solids, powder or ultraviolet curable coating is difficult to determine because of the variable factors of the manufacturing process.

It would be costly to retrofit add-on control devices to reduce organic emissions from the three-piece can side seam spray coaters, the beer and beverage can interior spray coaters and ovens, and the can end sealing compound coaters and ovens because 75-100 percent of the organic solvent vapors are emitted within the plant and not from the oven. Conversion to water-borne, high solids or powder coatings is the best control option for those systems. Moreover, conversion to water-borne, high solids, powder or ultraviolet-curable coatings for the two-piece can coating lines and the sheet coating lines would be the best and most economical control options if such coatings have been developed to replace original organic solvent-borne coatings. Otherwise, incineration with heat recovery or carbon adsorption with solvent recovery for fuel purposes is recommended.

Coil coating--Coil coating is defined as the coating of any flat metal sheet or strip that comes in rolls or coils (Ref. 4-36). The metal is typically roll coated on one or both sides on a continuous production line basis. The metal may also be printed or embossed. The coated metal is slit and fabricated by drawing, stamping, roll-forming, or other shaping operations into finished products to be used for cans, appliances, roof decks, shelving, industrial and residential siding, cameras, culvert stock, cars, gutters, and many other items. The metals coated in the coil coating industry include various types of aluminum alloys; steel; plate steel; steel alloys; and some zinc, brass, and copper.

Some plants may use as many as 900 different coatings each containing four to ten different solvents, and some use as much as 40,000 gallons of coatings per month. Coatings and approximate percentage of volatiles in these coatings most often used in the coil coating industry are shown in Table 4-5.

TABLE 4-5. COATINGS USED IN COIL COATING (Refs. 4-37, 4-38, 4-39)

Coatings	Volatiles, percent
Acrylics	40-45
Adhesives	75-80
Alkyds	35-40
Epoxies	45-50
Fluorocarbons	55-60
Lumar (TM)	55-60
Organosols	10-15
Phenolics	45-50
Plastisols	10-50
Polyesters	45-50
Silicones	35-40
Vinyls	60-70
Zincromet (TM)	--
Dacromet (TM)	--

The solvents most often used in the coil coating industry include xylol, toluene, methyl ethyl ketone, Cellosolve acetate (TM), butanol, diacetone alcohol, Cellosolve (TM), butyl Cellosolve (TM), Solvesso 150 (TM), isophorone, butyl carbitol, mineral spirits, ethanol, 2-nitropropane, tetrahydrofuran, Panasolve (TM), and methyl iso-butyl ketone.

Coil coating line configurations differ from one another. On some lines, the metal is uncoiled at one end of the line and recoiled at the opposite end. On other coil coating lines, called "wrap around" lines, the metal is uncoiled and recoiled at about the same point on the line. Some coil coating lines have a single coater and one curing or baking oven; other coil coating lines, called "tandem" lines, have several successive coaters each followed by an oven so that several different coatings may be applied in a single pass. Figure 4-24 is a schematic of a "tandem" coil coating line.

KVB 5804-714

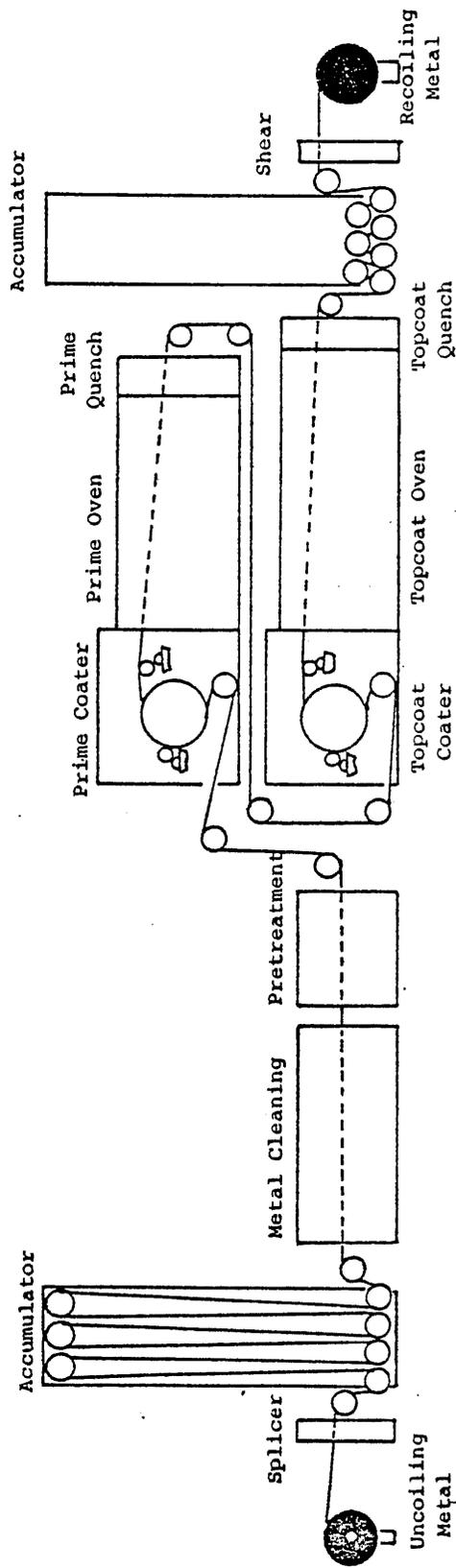


Figure 4-24. Diagram of coil coating line.

The use of carbon adsorption is limited because the high oven discharge temperatures necessitate a large amount of cooling upstream of the adsorber. Also polymerization and cracking of organics form condensable products that can foul or poison the adsorbent, necessitating pretreatment. (Pretreatment by water scrubbing may produce a potential water pollution problem.) Moreover, some products will still foul the carbon bed, even with scrubbing or filtering, resulting in an inefficient collection of organic vapors. There would be little market value for recovered solvents because of the mixtures of solvents used.

Incineration and conversion to water-borne or high-solids coatings have been determined to be the most reasonable control options for reducing organic emissions from coil coating lines because of the typically high curing temperatures and the various mixtures of organic solvents found in the coatings used by the coil coating industry. Incineration and water-borne coatings have been successfully applied to existing coil coating lines. Over 90 percent reduction of organic emissions is achievable with incineration and 80-95 percent reduction is achievable with water-borne coatings, depending on the processes solvent-borne coatings used.

There are limitations on these control options. Some coatings used in the industry can poison an incinerator catalyst. There is a lack of water-borne and high-solids coatings equivalent to solvent-borne coatings for some metal uses, especially where resistance to corrosion or wear is critical or to withstand certain forming operations. Incineration, especially noncatalytic, may increase the use of natural gas or other fuels if there are no nearby facilities where recovered energy can be used. Carbon adsorption may be applicable to certain coil coaters who use uniform coating formulations and operate low temperature ovens. If carbon adsorption is considered, it is advisable to analyze the gaseous and condensable organics in the gas stream coming out of the ovens.

There does not appear to be a single best control system for the entire coil coating industry; therefore, each plant must be considered separately in selecting the best system applicable to that plant's situation (Ref. 4-37).

KVB 5804-714

Appliances and other commercial products--These items are smaller and more uniform in size and color. Unlike automotive coating, long runs of the same color can be made. This makes the use of solventless coatings very attractive. As the size of some of the companies producing these products is small, developing a new coating could involve indeterminate risk, whereas the selection and installation of an adsorption or incineration system involves a more clearly assessable cost and performance.

Machinery--These products range from stationary machine shop equipment to automatic processing and assembly devices to large earth moving equipment. The coating requirements are more for service and less for aesthetic quality. The relative cost of coating for this type of product is less than most commercial products because of the normally high basic cost. Powder coatings and other low solvent coating with high durability would be excellent candidates for this application.

B. Paper and Film Coatings--

1. Adhesive tapes and tables--Paper is coated for a variety of decorative and functional purposes, using water-borne, organic solvent-borne, and solventless extrusion materials. Because the organic solvent-borne coating process is a source of hydrocarbon emissions, it is an air pollution concern. Among products that are coated using organic solvents are: adhesive tapes; adhesive labels; fancy paper, coated, and glazed paper; book covers; office copier paper (zinc oxide coated); carbon paper; typewriter ribbons; and photographic films.

In organic solvent paper coating, resins are dissolved in an organic solvent or solvent mixture and this solution is applied to a web (continuous roll) of paper. When the coated web is dried, the organic solvent evaporates and the coating cures. Use of an organic solvent has several advantages: it allows organic resins to be made soluble, its components can be changed to affect drying rate, and it creates coatings that show superior water resistance and better mechanical properties than some other coatings. In addition, a large variety of finishes can be obtained with solvent coatings (Ref. 4-39).

KVB 5804-714

The ingredients usually used in organic solvent-borne paper coatings may be divided into the following classes: film-forming materials, plasticizers, pigments, and solvents. Dozens of organic solvents are used for paper coating. The major ones are: toluene, methyl ethyl ketone, isopropyl alcohol, methanol, acetone, and ethanol.

Although a single solvent is frequently used, often a solvent mixture is necessary to allow the drying rate to be controlled. Too rapid drying results in bubbles and an "orange peel" effect in the coating; whereas, too slow drying can require excessive oven lengths. Variations in the composition of the solvent mixture affect the solvency power of the mix.

The main classes of film formers used in paper coating are cellulose derivatives and vinyl resins. The most commonly used cellulose derivative is nitrocellulose. The most commonly used vinyl resin is the copolymer of vinyl chloride and vinyl acetate.

Nitrocellulose has been used for paper coating since the 1920's for decorative paper and book covers and other items. It is relatively easy to formulate and handle and dries quickly, allowing lower oven temperatures to be used than for vinyl coatings.

The vinyl copolymers have superior toughness, flexibility, and abrasion resistance compared with nitrocellulose. They also show good resistance to acids, alkyds, alcohols, and greases, and are nonflammable. Vinyl coatings tend to retain solvent, however, so that comparatively high temperatures are needed for drying. In general, nitrocellulose is most applicable to the decorative paper field, whereas vinyl copolymers are used for function papers (Ref. 4-39).

Plasticizers are often added to the coating to improve its flexibility. Some of the many common plasticizers are dioctyl phthalate, tricresyl phosphate, and castor oil. Each type resin has an optimum plasticizer concentration. As plasticizer concentration increases, the coating becomes more flexible until it begins to be soft and tacky.

KVB 5804-714

In the production of pressure sensitive tapes and labels, adhesives and silicone release agents are applied with organic solvents. The adhesive layer on a tape or label is usually based on one of the following organic solvent-borne resins: natural rubber, synthetic rubber, acrylic, and silicone.

Because of their low cost, natural and synthetic rubber compounds are the main film formers used for adhesives in pressure sensitive tapes and labels, although acrylic and silicone adhesives offer performance advantages for certain applications.

The paper to which adhesive labels are attached must be treated with a release agent so that the adhesive tag may be removed. This release agent is usually a silicone coating that is applied with solvents. Silicone and other types of release agents are applied with organic solvents to the backside of pressure sensitive tapes so that tapes can be unwound.

Figure 4-25 shows a typical paper coating line. Components of a coating line include an unwind device, a coating applicator (knife, reverse roll, or gravure), an oven, various tension and chill rolls, and a rewind device. The unwind, rewind, and tension rolls display various degrees of complexity depending on the design of the line. The coating applicator and the oven are the main areas of organic emission in the paper coating facility.

Most solvent emissions from paper coating come from the dryer or oven. Ovens range from 20 to 200 feet in length and may be divided into two to five temperature zones. The first zone, where the coated paper enters the oven, is usually a low temperature ( $\sim 110$  °F) area. Solvent emissions are highest in this zone. Other zones have progressively higher temperatures that cure the coating after most of the solvent has evaporated. The typical curing temperature is 250 °F, although in some ovens temperatures of 400 °F are reached. This is generally the maximum because higher temperatures can damage the paper. The oven zones may be exhausted independently to the atmosphere or exhausted into a common header, with the total effluent sent to some type of air pollution control device. The average exhaust temperature is about 200 °F.

KVB 5804-714

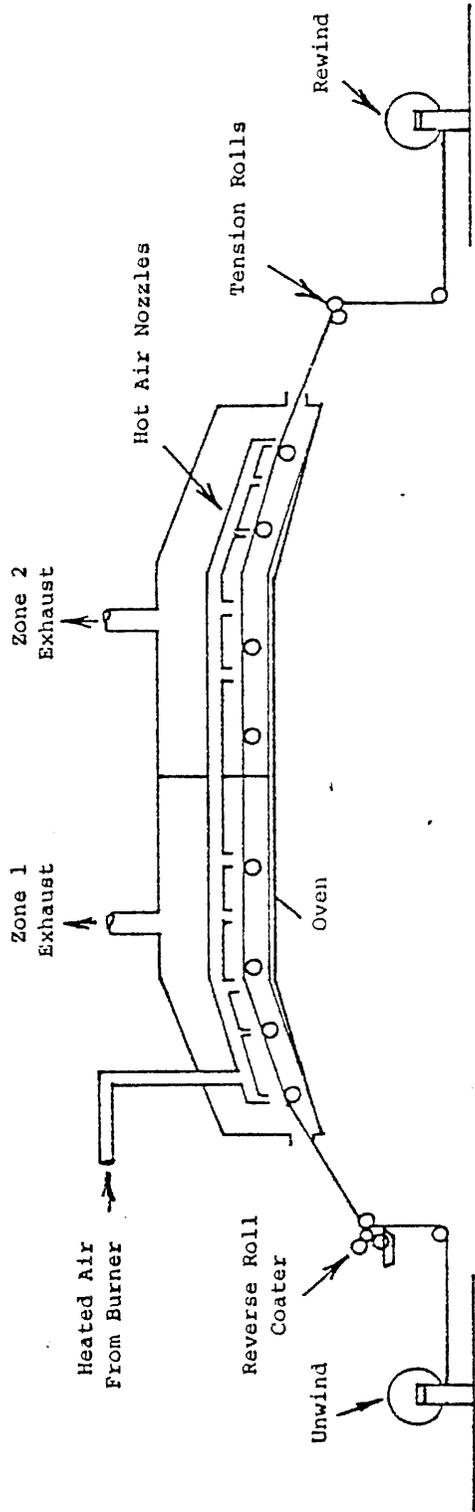


Figure 4-25. Diagram of typical paper coating line.

Most paper coaters try to maintain air flow through their ovens so the solvent concentration will be 25 percent of the LEL, although many ovens are actually run at much lower solvent concentrations. As energy shortages intensify, coaters are becoming aware that such low solvent concentrations require the heating of unnecessarily large amounts of intake air for their ovens.

Insurance and safety requirements permit even higher solvent concentrations than 25 percent LEL in some instances. The Handbook of Industrial Loss Prevention notes that flammable vapor concentrations up to 50 percent of the LEL may be tolerated if approved continuous vapor concentration indicators controllers are used (Ref. 4-40). The controller must sound an alarm when concentrations reach 50 percent, and shut the oven down automatically when concentrations reach 60 percent of the LEL.

Part of the solvent remains in the finished product after it has cured in the oven. For example, certain types of pressure-sensitive tapes have 150 to 2,000 ppm by weight of solvent in the adhesive mass on the finished tape. One coater has claimed that 3 to 10 percent of his solvent remains in the product.

The manufacture of photographic film exhibits special solvent control problems. Four or more layers of coatings may be applied to a photographic film, using equipment and coating techniques similar to those used for other paper coatings. Because the coatings on the photographic film later undergo chemical reactions, the composition and quality of the coatings must be tightly controlled. Because of the nature of these coatings, certain control options may not be possible. For example, it may be impossible to recover solvents in a carbon adsorption unit and then reuse these solvents in new photographic coatings since the reclaimed solvents may contain enough impurities to contaminate the film.

The two well proven add-on control devices for controlling organic solvent emissions from paper coating lines are incinerators and carbon adsorbers. Both of these control devices have been retrofitted onto a number of paper coating lines and are being operated successfully.

KVB 5804-714

The only constraint to the use of incinerators is the possible shortage of natural gas. However, in many cases the combination of afterburner and oven will use no more fuel than the oven alone if proper heat recovery is used. Incinerators can be altered to operate on No. 2 fuel oil if new natural gas is not available. If recovered solvent has no value, incineration with heat recovery is more economical than carbon adsorption.

The major drawback to the use of carbon adsorption is that in some cases solvent mixtures may not be economically recoverable in usable form. If the recovered solvent can be used as fuel, then carbon adsorption compares favorably in operating cost with an incinerator. If the solvent can be recovered as usable solvent, use of carbon adsorption represents an economic advantage to the paper coater.

It is more difficult to estimate costs for low solvent coatings, because the cost will vary depending on the type of coating used. For some applications, the use of low organic solvent coatings will cost less in dollars per pound of coatings solids applied than will conventional organic solvent coatings when some type of add-on control device is used.

Low solvent coatings have been well developed for some applications, but considerable development is needed in other areas. The main incentive paper coaters will have to develop new low solvent coatings will be strict requirements for add-on control devices if conventional organic solvent coatings are used.

An estimate of solvent emission reduction using low solvent coatings is presented in Table 4-6.

#### C. Fabric Coating--

Fabric coating involves the coating of a textile substrate with a knife or roller spreader to impart properties that are not initially present, such as strength, stability, water or acid repellancy or appearance (Ref. 4-41).

KVB 5804-714

TABLE 4-6. ACHIEVABLE SOLVENT REDUCTIONS USING LOW SOLVENT COATINGS IN PAPER COATING INDUSTRY (REF. 4-33)

Type of Low Solvent Coating	Reduction Achievable, %*
Water-borne coatings	80-99
Plastisols	95-99
Extrusion coatings	99+
Hot melts	99+
Pressure sensitive adhesives	
Hot melt	99
Water-borne	80-99
Prepolymer	99
Silicone release agents	
Water-borne emulsions	80-99
100 percent nonvolatile coatings	99+

\*Based on comparison with a conventional coating containing 35 percent solids by volume and 65 percent organic solvent by volume.

The fabric coating industry is a diverse industry, concentrated in the East with a few plants in the South Coast Air Basin. The industry consists mainly of small to moderate sized plants each of which specialize in a limited product line.

Substrates (textile materials used for coating purposes) can be either natural or man-made. Although polyvinyl chloride (PVC) sheets are not technically fabrics, coating of these sheets is covered in this section.

Coatings used include latexes, acrylics, polyurethanes, and natural and synthetic rubbers.

It is estimated that between 85 and 96 percent of the solvent emissions from fabric coating are from the drying process (Refs. 4-42, 4-43). Estimated and reported solvent concentration levels from drying operations range between 0.05 and 0.4 percent by volume (Refs. 4-42, 4-43). Typically, drying ovens are designed to process fabric on a continuous basis operating with a web or conveyor feed system. Ovens can be enclosed or semienclosed and may exhaust from a few thousand cubic feet per minute to tens of thousands of cubic feet per minute of air (Ref. 4-44).

KVB 5804-714

Drying ovens in older plants are often only semienclosed and operate with low solvent concentrations. Calculated and reported solvent levels in the exhaust streams are between 5 percent and 12 percent of the LEL. Newer installations, however, are reported to be operating at exhaust solvent concentrations up to 40 percent of the LEL (Refs. 4-42, 4-43).

Reductions of 90 percent of contained emissions are achievable using catalytic or noncatalytic incineration. Because of the so-called fugitive emissions, the overall reduction in plant emissions is less than 90 percent.

Carbon adsorption can remove over 90 percent of the organic vapors from the gases that pass through it. Overall plant reductions will be less percent due to losses during handling. Experience has shown that in facilities using activated carbon, the greatest losses of solvent occur in handling.

Organic emissions can be reduced by 80 to 100 percent by the use of low organic solvent coatings such as high-solids or water-borne. The actual reduction depends on the previous coating and the organic solvent to solids ratio of the new coating.

Carbon adsorption and incineration are most applicable to those sources that cannot use low polluting coatings. Carbon adsorption is most economical for sources that use a single solvent or solvent mixture for all uses. The large capital investment requirement, however, may impose major problems for some companies.

Incineration with primary and secondary heat recovery is most applicable at those sources that use a large variety of solvents and cannot reuse them.

The most desirable strategy is probably the conversion to low polluting coatings but this is limited by the lack of such coatings for some uses.

D. Other Solvent Operations--

1. Printing--There are four main types of printing operations: letterpress, lithographic, flexographic and gravure.

Letterpress, the oldest printing process, is defined as printing from raised type. The process is based on the simple stamping principle and produces a high quality of print on almost any type of paper or board. There are essentially three types of letterpresses in commercial use; platen, flat-bed, and web rotary. Platen presses can print a variety of jobs, from a simple one-color to multicolor. The flat-bed press is widely used in printing catalogs, books, and booklets. The web rotary press consists of two cylinders, one for the plate and the other for impression. This equipment is capable of very high speeds and is used for publications, packaging and commercial printing.

Lithographic printing is based on the principal of oil and water immiscibility. The level printing surface is prepared chemically resulting in the image area accepting oleophilic ink and the nonprinting area accepting water. Lithography has many advantages. Plate making is simple, fewer mechanical operations are required and it is economical for short runs.

Flexographic printing is a special form of relief printing. A flexible typographic rubber plate is mounted on a cylinder and is used to transfer the lacquer-type ink. This type of operation allows printing on hard surfaces, such as plastic films, calendered papers and metallic foils. Equipment for flexographic printing is divided into two classes; stack presses and common-impression equipment. In stack presses each color has its own unit consisting of fountain, roller, plate cylinder and impression cylinder. In common-impression, one large cylinder is used for several printing units, and is particularly useful for the decoration or plastic films.

Gravure printing utilizes a recessed surface for transferring the lacquer-type ink. It is the only process in which the ink film does not contact a flexible synthetic roller. Gravure ink is instant drying and the polymers must be preformed to be useful. The resins must be tack

free and have excellent solvent release properties. Unlike other printing processes, the pressure is not transmitted through the ink film; instead it is only on the cylinder plate, impression roller, and substrate.

Certain types of inks are used with certain methods. Table 4-7 indicates the range of percent solvent content in inks for two drying methods versus the four printing processes.

TABLE 4-7. PERCENTAGE OF INK SOLVENT CONTENT FOR TWO DRYING METHODS VERSUS FOUR PRINTING PROCESSES

Drying Method	Letterpress	Flexographic	Lithographic	Gravure
Evaporation	--	(40-75%)*	--	40-75%
Heat set	-10%	(0-30%)†	-16%	--

\*Solvent-base ink

†Water-base ink

The flexographic and gravure process account for approximately one-third of all inks used. They mainly use solvent-based inks containing 40 to 75 percent solvent, which is then evaporated on drying. Water-borne inks are also coming into use in the flexographic process. Some of these water-borne inks also contain solvent (0-30 percent) for faster drying. The screen process uses oil and lacquer-type inks which contain 0 to 60 percent solvents. However, this class accounts for less than 6 percent of the national total solvent used for inks. Letterpress and lithographic inks, which account for about one-third of the total inks used, are oil-based and emit some solvents when heat-set letterpress or heat-set web offset is used.

Where available, the use of water-borne ink is the most economical emission control technique. However, because water-borne inks are not sufficiently versatile in color and substrate compatibility, most large presses in the Basin depend on carbon adsorption and incineration. The largest gravure printing plant in the Basin has installed a 180,000 CFM carbon adsorption system which has an efficiency of over 95% and the solvent is 100% recoverable. The condensed water from the steam desorption system is separated from the solvent so efficiently that it is reused as boiler feed water.

KVB 5804-714

2. Rubber Manufacturing (Ref. 4-4 )--The most important operations in the manufacture of rubber are as follows: (1) physical treatment of raw rubber to prepare it for addition of compounding ingredients; (2) incorporation of various substances, especially fillers; (3) pretreatment of mix to make it satisfactory for preparing the final product; (4) forming the final product; and (5) vulcanization or curing the molded article.

The compounding ingredients added to rubber are as follows: (1) plasticizers or softeners, (2) vulcanizing agents, (3) accelerators, (4) activators and retarders, (5) antioxidants, (6) fillers, and (7) miscellaneous ingredients such as pigments, rubber substitutes, odorants, abrasives, stiffeners, and blowing agents.

The first step in this process is plasticization which can be done in several ways. Mechanical plasticization is accomplished on a mixing mill or internal mixer which rolls the rubber and makes it soft and plastic. Heat plasticization is accomplished by heating in ovens for about 24 hours at 300 ° to 400 °F. Chemical plasticization is accomplished by adding peptizing agents on the mills and is more rapid and economical than other means under certain conditions. Typical peptizing agents are naphthyl mercaptan, xylyl mercaptan, zinc salt of pentachlorothiophenol and dithio-bis-benzanilide.

Typical antioxidants that create hydrocarbon and organic pollutants are aromatic amines, aldehyde-amine condensation products, derivatives of secondary naphthylamines, aromatic diamine derivatives, and ketone-amine condensation products.

To vulcanize or cure the molded article, the material is held at elevated temperatures of 200 ° to 300 °F from a few seconds to several hours. This is the operation during which many of the plasticizers, accelerators, and other organics are volatilized and driven off as air pollutants. One of the major problems associated with rubber production is odor.

The principal methods used to control air pollutants from rubber manufacture are; reformulation, condensation, adsorption, absorption, and incineration. Many of the rubber manufacturers have been recovering solvents

KVB 5804-714

for economic reasons. In one case, a rubber company installed an activated-carbon adsorption system and found that with a 65 percent recovery figure for a base, the system could save them up to \$39,000 in the first full 12 months of operation (Ref. 4-45).

In reformulation, use of nonreactive solvents in place of reactive ones would alleviate hydrocarbons and odor problems.

Direct-flame incineration has proved to be very successful in controlling both hydrocarbons and odors. In one rubber processing plant, tests of a direct-flame incineration system showed that for a total system flow of 31,000 pounds per hour, and an incineration temperature of 1,120 °F, total hydrocarbons were reduced from 1,305 to 207 ppm by weight with an efficiency of 84 percent (Ref. 4-46) (calculations based on reduction of total hydrocarbons in pounds per hour). With allowance for the contribution of fuel oil, as established during the blank run, the efficiency of process contamination removal became 89 percent. This was stated to be closer to the overall efficiency expected if the incinerator were fired with natural gas.

In a similar run at an incineration temperature of 1,190 °F, total hydrocarbons were reduced from 1,155 to 89 ppm by weight for an efficiency of 92 percent. Allowing for fuel oil contribution would increase this efficiency to 97 percent.

Catalytic-type combustion has been investigated thoroughly for removing pollutants from rubber plants. In some cases, however, it has been found that temperatures only 100 °F below those required for direct-flame incineration were required, and thus increased costs of catalyst-type operations would not be justified. In other tests (Ref. 4-46), this type of combustion was abandoned because of (1) the danger of poisoning of the catalyst and (2) the impairment of its effectiveness as the catalyst became coated with carbonaceous deposits.

KVB 5804-714

3. Degreasing--Metal parts must be thoroughly cleaned of all grease and oil before they can be plated, painted, or further processed.

If solvent is used for cleaning and it is maintained by heat input at its atmospheric boiling point in the process equipment, and if this equipment is designed to control and minimize solvent losses to the air, then the cleaning process is called "vapor degreasing."

If the solvent used for cleaning is at or near room temperature and if the equipment used is not designed to control solvent losses, then such a process is referred to as "solvent cleaning" or "cold solvent cleaning." The solvents used in these processes may be halogenated, non-halogenated or mixture of them.

In other words, vapor degreasing is a specific type of cleaning process designed to use only halogenated solvents, which are essentially nonflammable and have a relatively high vapor density. Complete descriptions of "solvent cleaning" and "vapor degreasing" are presented in the chapter on metal cleaning in the Metals Handbook (Ref. 4-47).

A typical degreaser is pictured in Figure 4-18. The methods that can reduce emissions are (1) improved covers, (2) high freeboard with water cooled walls, (3) refrigerated chillers, (4) carbon adsorption and process change. Incineration is generally impractical because chlorinated solvents are usually used which form highly toxic fumes when burned.

Efficient covers are the most effective means of containing the vapor. Automatic covers open when a work piece is to be inserted and withdrawn. Horizontally acting doors cause the least disturbances of the vapor. A high freeboard with cooled walls help retain the heavier than air vapors inside the cover. A refrigerated chiller around the upper part of the freeboard condenses fumes that would curl over the upper edge. A hood, fan and charcoal adsorption system will also capture vapors that escape. Finally, the substitution of steam, detergent or other nonorganic cleaning methods where the work permits will eliminate nearly all vapor emissions.

4. Pesticide manufacture (and use)--A pesticide is a compound or mixture of compounds intended for preventing, destroying, or repelling or mitigating any insects, rodents, nematodes, fungi, or weeds or any other forms of life declared to be pests; and any compound or mixture of compounds intended for use as a plant regulator, defoliant, or desiccant.

Pesticides are rarely used in their pure form, but usually are first combined with other materials into what is called a formulation. The common formulations are powders or dusts, wettable or soluble powders, emulsifiable concentrates, granules, and aerosols. In addition to the active ingredient, each pesticide formulation may contain one or more of the following: a carrier or diluent, a solvent, an emulsifier, a spreading and sticking agent, or others. Each of these additives are usually inert as far as the pesticide action is concerned but provide a mechanism for even distribution of the pesticide. There are about 500 active ingredients and about 50,000-60,000 different formulations on the market today (Ref. 4-48).

Any or all of the constituents of a pesticide formulation can be a volatile organic compound including the active ingredient itself. Some typical active ingredients are listed in Table 4-8. Typically 90-90% of the applied formulations are volatile. Depending on the active ingredient and the application the carrier can be organic or water.

The control of organic air pollutants from pesticides can be performed by minimizing the use of solvent or petroleum borne formulation and substituting, where possible, water-borne or dry formulations. The other method is to use more efficient application techniques to reduce the amount of over spray necessary to obtain the desired coverage. In the latter case electrostatic spraying has been shown to reduce the amount of pesticide required by as much as 80% (Ref. 4-49). Personnel contact with the pesticide is also reduced.

5. Dry cleaning--Clothing and other textiles may be cleaned by treating them with organic solvents. This treatment process involves agitating the clothing in a solvent bath, rinsing with clean solvent, and drying with warm air.

TABLE 4-8. SOME VOLATILE ORGANIC PESTICIDES (Ref. 4-50)

---

Aromatic Petroleum Solvents (liquids)	Mineral Oil (liquid)
Butoxyl polypropylene glycol (liquid)	Omite-R (viscous liquid)
2,4-D Butoxyethanol (liquid)	Parathion (yellow liquid)
Chlordane (C <sub>10</sub> H <sub>6</sub> Cl <sub>8</sub> ) (liquid)	Petroleum Distillates (liquid)
Chlorobenzene (liquid)	Petroleum Distillates, Aromatic (liquids)
Chlorobenzilate (liquid)	Petroleum Hydrocarbons (liquids)
Chloropicrin (liquid)	Petroleum Oil, unclassified (Stoddard solvent and diesel oil)
2,4-D Isopropyl Ether (liquid)	Phorate (Thimet) (clear liquid)
2,4-D Propylene Glycolbuty Ether (liquid)	Phosdim-R (yellow to orange liquid)
Dalapan (Sodium Salt) CH <sub>3</sub> CCl <sub>2</sub> COOH (liquid)	Phosphamidon (oily liquid)
DBCP Dibromochloropropane (liquid)	Phosphamidon, other related (oily liquid)
D-D Mixture (a mixture of 1,2-Dichloropropane (1) and 1,3-Dichloropropene (1) and related C <sub>3</sub> compounds)	Pine Oil (liquid)
DDVP (Dichlorvos) 2,2-Dichlorovinyl-0,0-di-Methyl Phosphate (liquid)	Piperonyl Butoxide (liquid)
DEF S, S, S-Tributyl Phosphoro-trithioate (liquid)	Pyrethrins (I and II) (viscous liquid)
Demeton (Systox) 0,0-Diethyl 0-2-ethylthio ethyl phosphorothioates	Telone-R (Dichloropropene) (liquid)
Diazinon (colorless liquid)	Xylene (liquid)
2,2-Dichloropropionic Acid (liquid)	Xylene Range Aromatic Solvent (liquid)
DNBP 2,4-Dinitro-6-sec butylphenol (brown liquid)	
2,4-DP Butoxylthanol (liquid)	
Ethylene Dibromide (liquid)	
Fenthion (Baytex) yellow tan liquid	
Malathion (liquid)	
Metalddehyde (sublimable) (white crystals)	

---

KVB 5804-714

There are basically two types of dry-cleaning installations: those using petroleum solvents (Stoddard), and those using chlorinated synthetic solvents (perchloroethylene). The Stoddard solvent in use in the South Coast Basin is about 48% paraffin, 44% naphthenes and 8% aromatics. Compared to perchloroethylene the Stoddard solvent is less expensive by a factor of ten, less corrosive to the cleaning equipment, less toxic, but more hazardous from a fire safety standpoint and more reactive from a photochemical smog standpoint. Perchloroethylene is used exclusively in the neighborhood cleaning plants while Stoddard solvent is used in some larger industrial cleaning plants.

In a petroleum-solvent dry-cleaning plant, the equipment generally consists of a washer, centrifuge (extractor), tumbler, filter, and often a batch still. The centrifuge is used to recover solvent by spinning it from the clothes. The clothes then enter a tumbler where they are dried with warm air. The tumbler is usually vented through a lint trap to the atmosphere in this type of plant.

In synthetic solvent plants, the washer and extractor are a single unit. The tumbler operates as a closed system, having a condenser for vapor recovery. The tumbler is vented to the atmosphere or to a carbon adsorber only during a short deodorizing period.

Both adsorption and condensation systems may be used to control solvent emissions from dry-cleaning plants using synthetic solvents. Solvent recovery systems are not only commercially available as part of a synthetic solvent cleaning plant, but they are also economically attractive. The primary control element is a water-cooled condenser, which is an integral part of the closed cycle in the tumbler or drying system. Up to 95 percent of the solvent that is evaporated from the clothing can be recovered here. About half of the remaining solvent can then be recovered in an activated-carbon adsorber, giving an overall control efficiency of 97-98 percent.

There are no commercially available control units for solvent recovery in petroleum-solvent plants because it is not economical to recover the vapors. The vaporized solvent is not condensible at the temperatures employed, and

KVB 5804-714

thus the whole solvent recovery burden would fall on an adsorption system, necessitating equipment up to 20 times larger than that used in a comparable synthetic solvent plant.

Another way of controlling solvent emissions from petroleum plants is through direct-fired afterburners. Estimates show that a saving in capital cost could be achieved, but an increase in operating costs would also be incurred compared to carbon adsorbers. Afterburners are not suitable for synthetic chlorinated hydrocarbons because of the danger of producing hydrogen chloride, phosgene, or other toxic gases.

A complete treatment of emission reduction from the dry cleaning industry is contained in Ref. 4-64.

6. Architectural coatings--Architectural coating consist of those paints, varnishes, stains, sealers, etc. used on the exterior or interior surfaces of buildings, homes, civil engineering structurals, etc. These are the coating to which add on controls do not normally apply.

This is currently the area of greatest application of water-borne paints. Besides lower emissions water-borne paints offer easier application and cleanup and equivalent or superior durability. Except for aerosols, clear coatings and metal paints the water-borne paints are growing in popularity. A survey by the ARB indicated that 60% of the architectural paint sold in the state was water-borne.

The control methods for architectural coatings are to continue to persuade the professionals and non-professionals to substitute water-borne paint for solvent based paint; and to use, when possible, other solventless coatings as colored stucco, epoxy, and other low solvent coatings, prefinished panels, etc.

7. Wood finishing--Wood finishes involve varnishes, shellac, stain, wax, and plastic coatings. Water-borne and low solvent coatings are the primary method of solvent emission control in this area. However, certain pigments and high gloss finishes can only be accommodated with the solvent based formulations. In this case add-on devices like charcoal adsorbers as well as thermal and catalytic incinerators can be used to control air pollution emissions.

#### 4.2.3 Chemical Manufacturing

Manufacturers of synthetic organic chemicals such as elastomers, dyes, flavors, perfumes, plastics, resins, plasticizers, pigments, paints, varnishes, rubber processing chemicals, pharmaceuticals, and miscellaneous solvents have the problems of controlling emissions of hydrocarbons from raw materials and from products made from these materials.

Of the thousands of chemical manufacturing processes, each has unique control problems. The types of chemical conversions utilized in these processes are classified below.

Alkylation is the union of an olefin with an aromatic or paraffinic hydrocarbon. Ethyl benzene is produced by alkylating benzene with ethylene, and naphthalene, by dealkylation of a petroleum fraction.

In amination, an amino compound is formed by using ammonia (or a substituted ammonia) as the agent. Other amines are made by reducing a nitro compound. Ethanolamines, for example, are obtained when ethylene oxide is bubbled through an ammonia solution.

Hydrogenation, the addition of hydrogen, is used to manufacture a broad range of products. For example, methanol is made by reacting CO with hydrogen.

Dehydrogenation, the removal of hydrogen, produces unsaturated compounds. Benzene is made by dehydrogenation of substituted cyclohexanes.

Dehydration, the removal of water, produces ethers from alcohols. Hydration, the addition of water, produces ethyl alcohol from ethylene.

In esterification, an alcohol reacts with an organic acid to form an ester. Ethyl alcohol reacts with acetic acid to form ethyl acetate, an important solvent.

Halogenation and dehalogenation are the addition or removal of a halogen. Methyl chloride is made by chlorination of methane. Chlorine, bromine, iodine, and fluorine are the halogenation agents.

KVB 5804-714

Oxidation, the addition of oxygen, is one of the most valuable conversion processes. Ethylene oxide is made by oxidation of ethylene. The cheapest oxidizing agent is air, but pure oxygen has advantages in many applications.

Nitration introduces nitrogen into hydrocarbons. Nitrobenzene is an important product of nitration.

Polymerization is the reaction of simple molecules to form more complex polymers. For example, ethylene is polymerized to polyethylene.

The raw materials and the products are potential sources of emissions in any chemical conversion operation. Chemical reactions for production of a desired product usually result in several by-products. Although the formation of by-products is minimized by adjusting the conversion conditions, the quantities formed must be either recovered for use or be properly disposed of as wastes. Waste disposal is a primary problem, complicated by the fact that wastes may be highly toxic. Thus air-cleaning methods that merely transfer the emissions to streams or other waters are not satisfactory.

The major sources of emissions to the air are streams of waste gases, vapors from distillation columns, and leakage from feed and product transport lines. Many chemical plants generate their own steam for use in refining and for supplying power; therefore, emissions characteristic of power plants are an inherent part of the total. The manufacture or regeneration of catalysts usually result in nonhydrocarbon emissions.

Often, control of emissions by the chemical industry is based on economic incentives. In other words, condensers are used to recover vapors containing usable reactants, and wastes are burned to recover heat value. This is not possible for all processes, however. For example, catalytic oxidations are seldom, if ever, free of odor. Large quantities of air are pumped through the reaction system to provide the oxygen necessary for the conversion. Low concentrations of the main reactants are carried into the air. Existing methods for recovery of these low concentrations are often unattractive economically, in the sense that the recovered material does not pay for the cost of recovery.

Recently, however, new developments in recovery methods using automated jet compressors (Ref. 4-51) have begun to reduce the economic burden of recovery or disposal.

A. Halogenates--

Organic emissions containing a halogen (primarily chlorine) are a special problem, because the halogen atoms are not combustible. Accordingly, incineration of chlorine-containing organic compounds can produce HCl, elemental chlorine, or other chlorinated compounds.

The problem is to design an incineration system that will first produce the hydrogen halide gas and then absorb it. Experimentation has shown that if the hydrogen-to-halogen ratio is high enough, approximately 5 to 1, essentially all of the halogen in the products of combustion will be in the form of the hydrogen halide (Ref. 4-4).

To maintain this ratio for substances like ethylene or propylene dichloride, some hydrocarbon fuel must be added to the combustion system to supply hydrogen. A technique developed to do this for organic chlorides recovers up to 99 percent of the hydrogen chloride as 18° Baumé acid from gas streams containing as little as 3 percent hydrogen chloride (Ref. 4-52).

In this recovery system, the waste is incinerated in a vortex-type burner and immediately quenched in a graphite- or carbon-lined tower; the resulting vapors are processed through a series of impervious, graphite, tubular cascade absorbers, which are designed to produce 18° Baumé acid, with up to 100 ppm of hydrogen chloride in the vent gas. If additional treatment is required, another scrubbing station is provided to produce very weak hydrochloric acid to be used as make-up liquor in the main absorption equipment. The remaining vapors usually contain fewer than 50 ppm hydrogen chloride. This recovery system, depending on the disposal rate, can produce a positive return on investment.

B. Coal Gases--

Catalytic vapor incinerators can eliminate essentially all hydrocarbons contained in a relatively cool waste gas stream. The heart of the system is a catalyst that makes it possible to burn ethylene that is present in concentrations too low to support normal incineration. The treated stream does not contain catalyst poisons.

KVB 5804-714

C. Varnishes (Paints, etc.)--

The vapors emitted from varnish cookers possess penetrating and disagreeable odors and other irritating characteristics. These vapors consist of (1) low-melting-temperature constituents of natural gums, synthetic acids, and resins, some of which are purposely driven off for process reasons; (2) thermal decomposition and oxidation products volatilized during bodying of oils; and (3) volatile thinners, which distill off during thinning of hot varnish.

Total emissions to the atmosphere depend on the composition of the batch, rate of temperature application, maximum temperature of the process, method of adding solvents and driers, amount of stirring employed, extent of air-blowing, length of cooking time, and amount of pollution of other process control equipment employed. Typical losses from various cooking processes are as follows:

1. Total loss from oleoresinous varnish cooks average 3 to 6 percent, with some losses as high as 10 to 12 percent.
2. Losses from alkyd resin cooks range from 4 to 6 percent.
3. Cooking and blowing of oils produce losses of 1 to 3 percent.
4. Heat polymerization of acrylic resins produces losses of less than 1 percent unless the reaction gets out of control.

The most effective means of controlling emissions from varnish-making operations has been combustion (Ref. 4-4). Vapor disposal by combustion has several advantages over other control methods because it requires a minimum of equipment, assures complete vapor elimination from the atmosphere, and consumes very little fuel in correctly designed furnaces. Incineration, of these hot combustible vapors calls, however, for special devices to protect against flame propagation in the opposite direction of the flow of vapors between the kettle and the incinerating furnace. In some systems, a series of water jets or a water scrubber are interposed between the varnish kettle and the furnace. In another system, the vapors are passed first through a water-cooled condenser and then to a combustion hearth. In still another, the varnish vapors are assisted from the kettle by means of a steam nozzle. The mixture of steam and vapor is condensed. The reduced pressure, which results from the vapor condensation pulls the vapors from the kettle. The noncondensibles are then burned.

KVB 5804-714

In designing condensers to control emissions from varnish-making operations, the standard design factors such as the type(s) of compounds and their physical properties, such as temperature, volume, concentration, vapor pressure, and specific heat must be considered. In addition, in many of these processes noncondensable substances must be removed by other means. Many of the lower-boiling-point noncondensable hydrocarbons are very inflammable, and provision must be made to remove the risk of flashes. For example, to remove copal vapors, a satisfactory condensation unit should include the following:

1. A condenser to remove most of the vapors, followed by scrubbing and combustion, charcoal adsorption, or a ventilating stack to remove the traces.
2. Means for vapor withdrawal.
3. Provision for cooling and collecting a large volume of distillate.
4. Corrosion-resistant materials of construction.
5. Precaution against flashes.
6. Provision for overflow between cooking kettle and first condenser.
7. Recirculation of cooling water to reduce quantities required.
8. Separate unit for each kettle if possible.

Both surface-type and direct-contact-type condensers have been employed in this industry.

Several different types of scrubbers have been used by the varnish industry. These include (1) a countercurrent device in which the vapors enter at the bottom against a descending water stream and leave through the top, (2) a parallel-current water scrubber succeeded by smaller countercurrent scrubbers, (3) water jet scrubbers, and a (4) scrubber with spinning discs located on a revolving vertical spindle.

#### D. Pharmaceuticals--

Pharmaceuticals encompass a broad spectrum of materials, ranging from purified anesthetic-grade ethers and other anesthetics to the extraction and purification of cod-liver oil. "Biological" odors are conventionally controlled

KVB 5804-714

by incineration. Solvents may be recovered by adsorption. Usually there is no provision for recovery of the adsorbed materials. Frequently, the use of packaged replaceable adsorption units is feasible.

#### 4.2.4 Other Industrial Processes

##### A. Metallurgical--

Metallurgical processes are some of the largest sources of pollution in the Basin. However, compared to carbon monoxide, particulate and sulfur emissions these sources emit small amounts of hydrocarbons. These sources include coke ovens, blast furnaces, steel making furnaces, remelting processes as in a foundry or reheating processes as in forming or heat treating. Hydrocarbons are emitted from stacks as exhaust gas from fuel combustion and as fugitive emissions from openings or leaks in material processing retorts. References 4-53, 4-54, 4-44, 4-2, and 4-55 contain descriptions of these processes and details of emission sources and control measures. Reference 4-54 is a comprehensive report by the ARB staff on a steel mill in the Basin. Table 4-9 summarizes the emissions from that plant and shows the relatively small amount of organic gases emitted. However, since 25 tons/yr constitute a major source in this study, the 865 tons/year listed does make this plant a significant hydrocarbon source.

TABLE 4-9. AMOUNT OF POLLUTANTS GENERATED BY KAISER STEEL AT FONTANA, CALIFORNIA (REF. 4-54)

	Organic Gases, Tons/Year				
	Total	NOx	SO <sub>2</sub>	CO	Particulate
Kaiser emissions	865	8,107	13,636	78,267	2,475
Percent of Kaiser's contribution to all pollutants emitted into atmosphere from all stationary sources in the SCAQMD	0.37%	5.6%	10.0%	69.3%	8.2%

KVB 5804-714

KVB's measurements of stack emissions (refer to the Appendix) account for 75% of the organic gases shown in the table. The remainder could well be fugitive emissions, from leaks that escape directly into the air. Actually, the hydrocarbons emitted from the stacks are most likely caused by internal leakage from the coke ovens into the combustion gas stream near the end of the gas pass. The combustion gases apparently are no longer hot enough to react all of the leaking coke oven gases. In KVB's tests of two different coke oven exhaust stacks 200 and 700 ppm of methane were found respectively. CO levels were 1 and 2% respectively. These hydrocarbon and CO values are very high, indicating incomplete combustion. But since the O<sub>2</sub> levels in these gases were 7 and 15% respectively, which is very excessive, the possibility of incomplete combustion is not reasonable. One possible explanation is that methane is leaking into the exhaust gases through the metal and ceramic heat transfer wall at a point where the combustion gases have cooled down sufficiently that some of the methane does not have time to oxidize.

Methods for controlling hydrocarbon emissions from coke ovens and metal manufacturing processes are essentially the same as those for controlling particulate and sulfur emissions, i.e., seal up the leaks or enclose the processes in a vapor collector and remove the pollutants. After the vapor collected has been scrubbed for sulfur and particulate removal, the remaining gases can be adsorbed on charcoal to increase the concentration and recycled into the fuel gas supply. Other hydrocarbon emissions from combustion of fuel associated with these metallurgical processes should be very low in hydrocarbon concentration (of the order of 1 to 10 ppm). If combustion processes are found where emissions are greater than this level, the best approach is to improve burner design, recirculation patterns, air/fuel ratio to bring the emissions to acceptable levels. In some cases, where oil coated scrap material is charge into a furnace for instance, the hydrocarbon content of the exhaust gas becomes high enough to require a secondary incineration process.

KVB 5804-714

B. Mineral--

Most of the mineral processes are primarily particulate emitters and have little hydrocarbon emissions. Asphalt is often used for paving or roofing applications. Freshly applied asphalt concrete does emit some hydrocarbon emissions. KVB measured an emission factor of  $10^{-6}$  lb hydrocarbon per lb of asphalt hot mix paving material (including aggregate). Midwest Research (Ref. 4-56) recently measured a weight loss rate for the list melt asphalt (without aggregate) of  $4 \times 10^{-3}$  lb hydrocarbon loss/lb asphalt. Assuming the asphalt is 5% of the paving mixture (5-10% is the normal range) this emission factor would become  $2 \times 10^{-4}$  lb hydrocarbon/lb of paving material or 200 times greater than KVB's measurement. Since both emissions are small, this variation could be well within the experimental error. Reference 4-57 contains emission data from the preparation of hot mix which indicates that these emissions are of the order of  $10^{-9}$  lb hydrocarbon/lb asphalt paving material, negligible compared to the emission from the paving operations. Based on a geometric average of the MRI and KVB data (i.e.,  $10^{-5}$  lb/lb) a mile of asphalt paving, 60 ft wide and 3 inches thick would emit 300 lb plus or minus a factor of ten.

Although these emissions are low in rate they were found to be high olefinic species which are most reactive in smog formation.

The best control option is to substitute Portland cement type concrete for the asphalt type. This doubles the installed cost but saves some of this extra cost in maintenance and repair. When cutback asphalt is used (i.e. asphalt mixed with a petroleum thinner) the emissions can be 10 to 100 times higher according to MRI (Ref. 4-56). Where cutback asphalt has been used the emission can be reduced by as much as 95% by substituting water emulsified asphalt. The water emulsified asphalt has good fluidity but emissions as low or lower than the basic uncut asphalt.

Roofing operations also use asphalt, the type that has been oxidized by air blowing as discussed above under oil refining. This type of asphalt is uncut and the practice is to use heat to melt and apply the material to the roof. In this operation the principal emissions come from the roofing

KVB 5804-714

kettles. The control methods involve the use of enclosed kettles in which the solid asphalt "keg" is inserted into the kettle through quick opening/closing doors. Liquid asphalt is tapped off into buckets that are quickly applied to the roof where the material cools rapidly minimizing the emissions. Some emissions escape through door seals and other leaks in the kettles. Any system for evacuating the vapors from inside the kettle have been rejected because of the possible of drawing air into the kettle causing an explosive mixture.

C. Food Processing--

Food sources of hydrocarbons include operations such as the cooking, frying, broiling, baking, and roasting of vegetables, fruits, nuts, meat, fish, and fowl. These operations may involve food processing for commercial or domestic consumption, restaurant food preparation, or fermentation processes. Emissions range from light hydrocarbons from fermentation to medium from baking and roasting of vegetable products to heavy hydrocarbons from meat cooking. The disposition or concentration of inedible parts of meat and fish cause objectionable odorous emissions in the form of trimethylamine. Alcohols, esters and aldehydes constitute a large part of these emissions which are highly reactive from a photochemical smog standpoint.

The universal method for controlling these emissions is incineration which is usually an effective measure for odor control. Often, however, the medium to heavy emissions tend to condense and form organic particulates that can be filtered out of the gas stream mechanically. Condensation can be promoted by use of cold surface contact and direct water scrubbing. For low concentration streams where malodorous pollutants are concerned, charcoal adsorption can be employed with the desorbed products concentration and burned.

D. Combustion of Fuel--

The combustion of fuels may result in the emission of hydrocarbons and other organic material if combustion is not complete. When properly operated and designed, however, stationary fuel combustion equipment is not a large source of organic emissions, and control equipment is not required.

KVB 5804-714

Fuels are burned in a wide variety of equipment ranging from small hand-fired coal furnaces to large oil, gas, and coal-fired steam-electric generating plants. Due to variations in combustion efficiency and type of fuel, hydrocarbon emissions will depend on the particular type of combustion device. Table 4-10 presents some typical hydrocarbon emissions for various types of fuels and furnace sizes. Considerable variation in these emissions can occur, however, depending on the operation of an individual unit.

TABLE 4-10. TYPICAL HYDROCARBON EMISSIONS FROM STATIONARY FUEL COMBUSTION SOURCES (lb/10<sup>9</sup> Btu)

Fuel	Size Range		
	Steam-Electric	Industrial	Domestic and Commercial
Oil	5	10	20
Gas	0.01	0.1	0.5

Hydrocarbon emissions from fuel combustion can be reduced or eliminated by essentially three techniques: improved operating practices, improved equipment design, and fuel substitution.

Good operating practice is the most practical technique for reducing hydrocarbon emissions from existing stationary combustion sources. Even the best equipment will perform poorly if improperly applied, installed, operated, or maintained and emit hydrocarbons, smoke, and other pollutants. Hydrocarbon emissions are directly related to the three common combustion parameters of time, temperature, and turbulence. A high degree of fuel and air turbulence will greatly reduce hydrocarbon emissions, increase combustion efficiency, and reduce fuel consumption. Flue gas monitoring systems such as oxygen and smoke recorders are helpful in indicating the operation of the furnace and are useful in keeping emissions at a minimum.

In the Basin very little waste disposal is performed by burning because the best control for this process is to substitute sanitary landfills as discussed in the next section.

KVB 5804-714

E. Waste--

The primary waste disposal technique in the Basin is sanitary landfills. Collected waste is dumped into natural or excavated cavities and mixed and covered with earth. The decay process which takes place causes copious quantities of light hydrocarbons (primarily methane) to be emitted.

Until the recent awareness of an energy shortage these emissions were ignored except where a specific problem (odors, etc.) was generated by encroachment of residential areas on landfill sites. In this event a control method of collecting the generated gases was instituted. To collect the gas a network of perforated PVC pipe was buried in the landfill. The pipes were connected to a vacuum pump through which the gas was discharged to atmosphere or incinerator. Recently, with energy conservation incentives there has been an effort made to use the collected gases to augment the fuel supply in utility or industrial boilers.

4.3 COST EFFECTIVENESS

Cost effectiveness has been defined as the total cost associated with the reduction of one ton of pollution. There are many factors effecting the investment and annual cost of gaseous organic control systems such as the:

- a. Gas stream volumetric flow rate
- b. Gas stream temperature
- c. Organic specie concentration in the gas stream
- d. Specific organic compounds contained in the stream
- e. Present degree of control
- f. Facility modifications required
- g. Energy consumption
- h. Operating and maintenance labor
- i. Waste heat applications
- j. Usefulness of recovered materials.
- k. Available space and structural requirements

With so many factors involved, it is only possible to present costs that represent some typical situations and which might apply to an industry average but not necessarily for a specific plant. For any real applications,

a more specific look at these cost elements should be made in determining the optimum system. KVB has attempted to assemble cost data from the literature and from equipment manufacturers to provide the ARB with an indication of the cost impact of any control strategy that they may consider. As discussed in Section 4.1, the total cost for any control scheme includes the installed costs plus operating costs, as well as the indirect costs which can add 50% to 100% to the direct costs.

#### 4.3.1 Carbon Adsorption

The cost effectiveness study presented was based on an extensive effort by the EPA Emission Standards and Engineering Division in Durham, NC as presented in Reference 4-2. The study considered both investment and operating cost and included all of the typical facility modification costs associated with an add-on system. Operating costs were adjusted for solvent recovery.

The basic assumptions used in developing this cost were as follows:

- a. Exhaust gases contain benzene and hexane (50/50 weight percent) mixture in air
- b. Exhaust gas temperatures of 70, 170, and 375 °F
- c. Hydrocarbon concentrations of 100 ppm, 15 percent of the lower explosion limit (LEL) and 25 percent of the LEL
- d. Exhaust gas flow rates of 1,000, 10,000, 50,000 scfm
- e. Fuel costs of \$1.50/million Btu\*
- f. Electricity at \$0.03/kW-hr
- g. Activated carbon at \$0.68/lb
- h. Water at \$0.04/thousand gallons
- i. Steam at \$2/thousand lb
- j. 5-year life of activated carbon
- k. Adsorber operating at 100. °F
- l. Market value (December 1975) of benzene = \$0.85/gallon;  
market value (December 1975) of hexane = \$0.465/gallon.
- m. Normal retrofit situation
- n. Direct labor assessed at 0.5 hr/shift x 730 shifts/yr x \$8/hour = \$2920/yr

---

\*September 1977 fuel costs in the Basin were \$1.85/million BTU per Southern California Gas Company.

- o. Annual maintenance, taxes, insurance, building overhead, depreciation, and interest on borrowed money taken at 25 percent of capital investment
- p. Operating time = 5840 hr/yr.

In addition the recovered solvent was valued at three levels:

- a. no value
- b. fuel value - \$1.50/MMBtu (\$0.20/gal)
- c. market value - see above list

The assumed solvent concentration levels of 15 and 25% of LEL is based on typical fire safety standards which specify 25% of LEL as a maximum safe concentration level for normal operations. In some areas plants can operate up to 50%. Some typical solvents and their LEL are as follows:

<u>Solvent</u>	<u>LEL, ppm</u>
Acetone	25,000
Benzene	14,000
Carbon Disulfide	12,000
Dichloroethylene	62,000
Ethyl Alcohol	35,000
Ethylene Glycol	32,000
Gasoline	13,000
Hexane	12,000
Methyl Alcohol	67,000
Methyl Butyl Ketone	14,000
Methyl Ethyl Ketone	18,000
Tolulene	13,000
Turpentine	8,000

No provisions were made for any distillation or water treatment equipment. If a plant emits water soluble organics in the exhaust, the cost would be considerably higher. The estimates did not include any particulate removal equipment. Finally, it was assumed that the solvents to be collected were of the middle range with regard to adsorptivity. Compounds which are difficult to adsorb (light compounds) or desorb (heavy compounds) can add considerably to both installation and operating costs.

Capital costs for adsorption systems designed to recover the solvent are presented in Figure 4-26.

Annual control costs for adsorbers are presented in Figures 4-27 through 4-29. For figures that give total annual cost, cost effectiveness information is also presented, that is, the cost per ton of hydrocarbon removed. Cost effectiveness information is a useful criterion when trying to devise air pollution control strategies to reduce the total amount of a pollutant emitted at a minimum cost. In this study annual depreciation was viewed as a cost, not as a credit, against taxable income. Thus the analysis was simplified and the resulting effect may be a slightly higher annual control cost. The curves indicate the importance of the value of the recovered solvents.

KVB obtained some case history data to check these curves as follows:

Case 1 - A Magnetic Tape Manufacturer

A 10,000 scfm, three-canister, activated carbon system with steam regeneration and distillation for solvent recovery was installed to collect methyl isobutyl ketone (MIBK) vapors which were originally emitted at a rate of 500 lb/hr or 3000 ppm (22% LEL) at that flow rate. The system recovered 450 lb/hr of MIBK at a cost of \$10/hr excluding equipment depreciation, taxes, insurance, building overhead, etc. and the price of the recovered solvent.

A comparison of the reported cost parameters with the parameters predicted by the cost curves presented is as follows:

<u>Parameter</u>	<u>Reported Actual (Ref. 4-58)</u>	<u>Predicted by Study</u>
Installed Cost, \$	250,000	270,000
Annual Cost, \$ (no credit for recovered solvent)	110,000*	100,000
Annual Wt. of Solvent Recovered, tons	1,300	--
Cost Effectiveness, \$/ton	85	125

\*Include 25% of Installed Cost for depreciation, taxes, insurance, overhead, etc. the same as used in the study.

KVB 5804-714

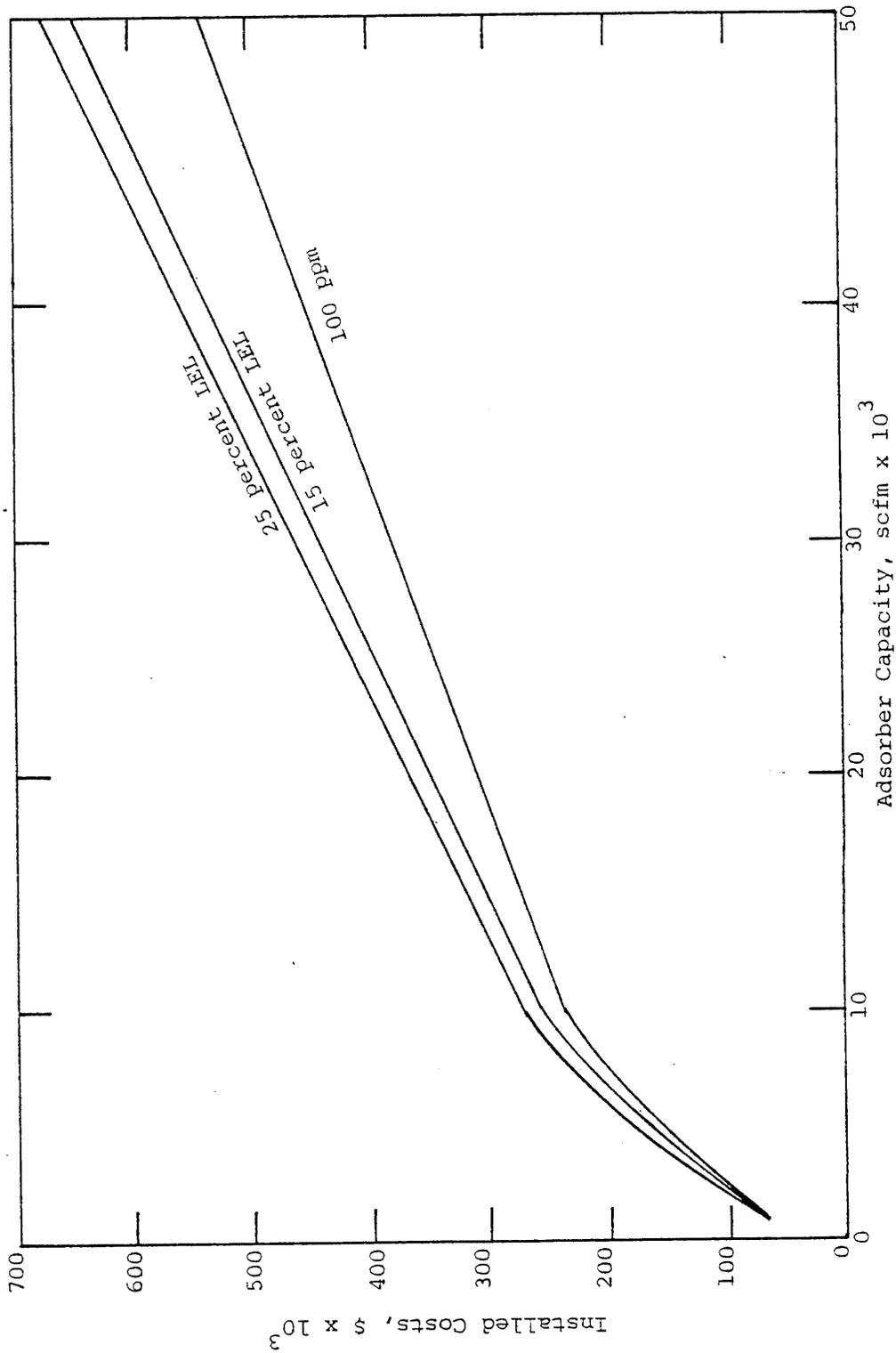


Figure 4-26. Estimated installed adsorption system cost (Ref. 4-2) (1976 prices).

KVB 5804-714

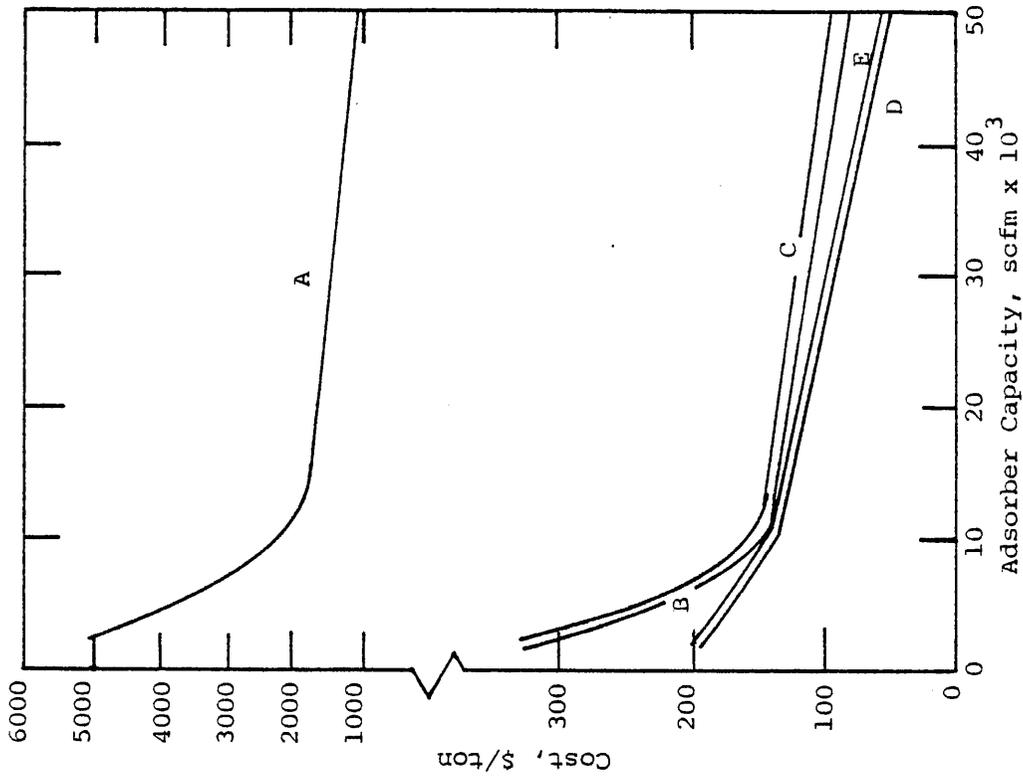
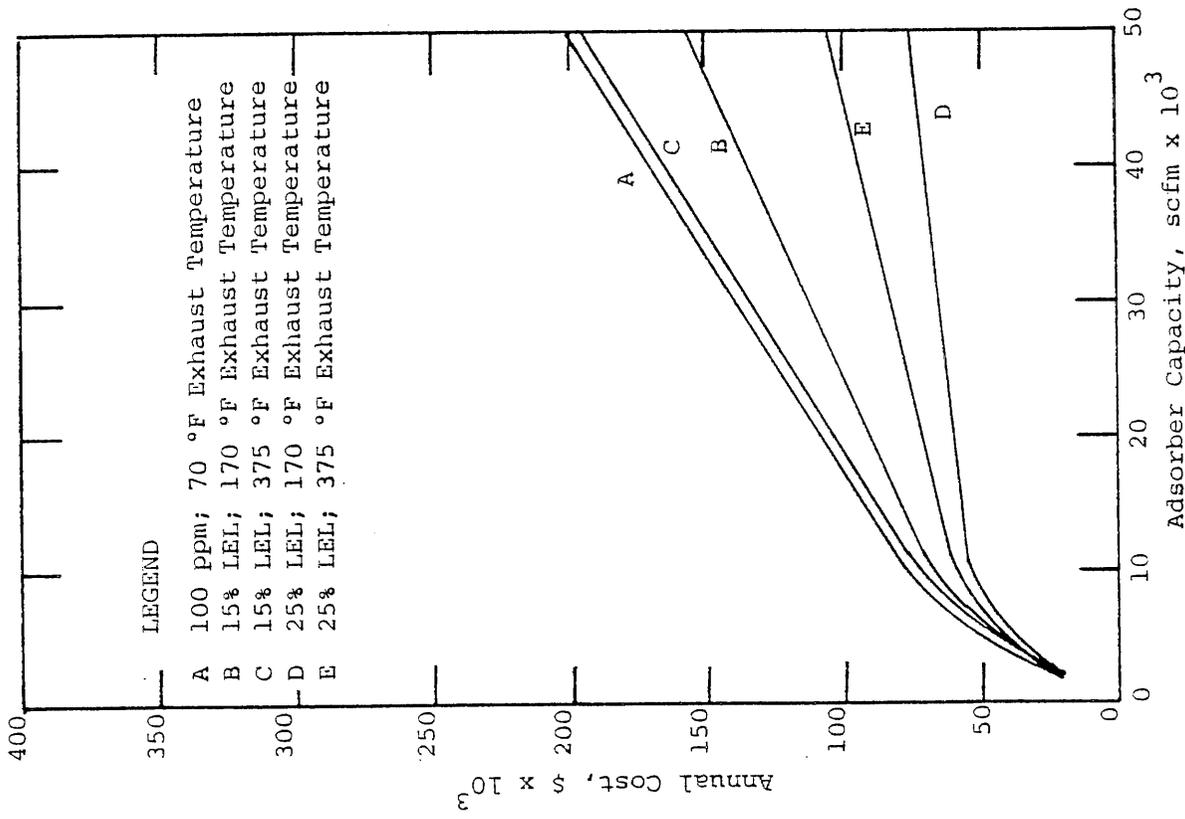
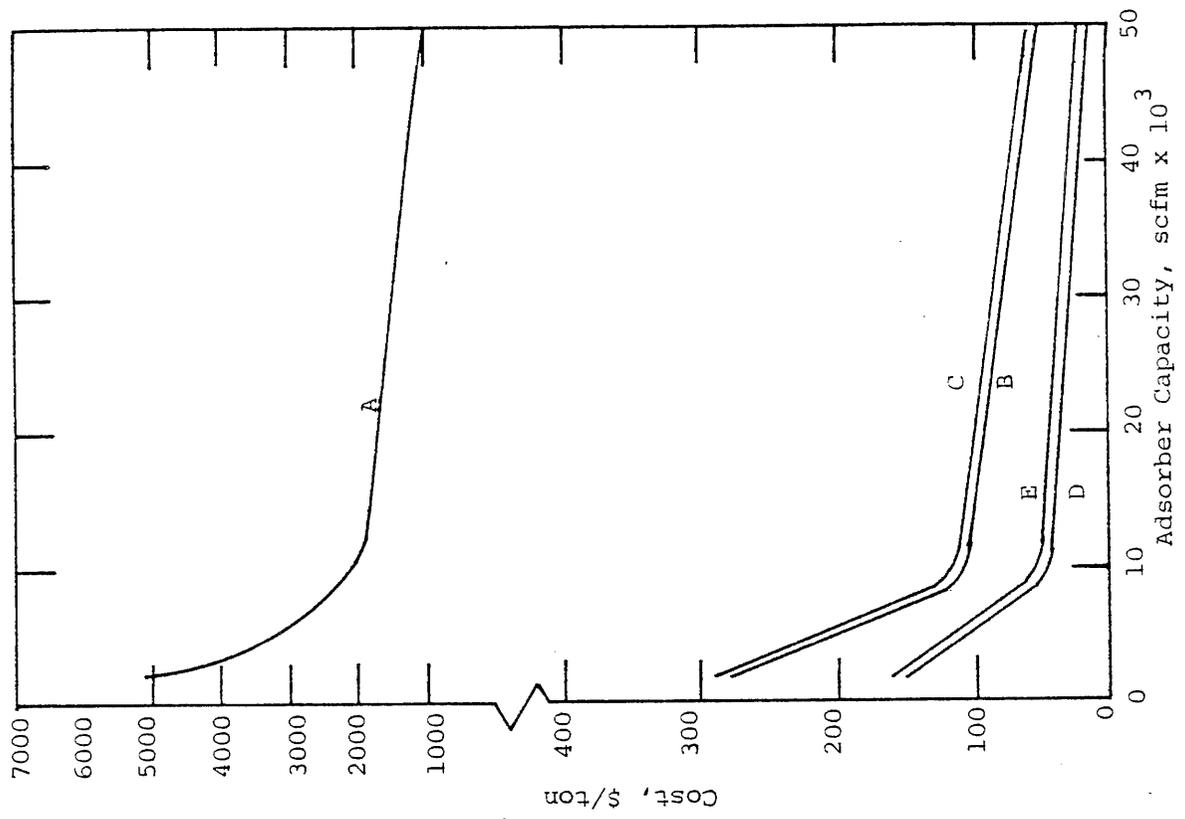


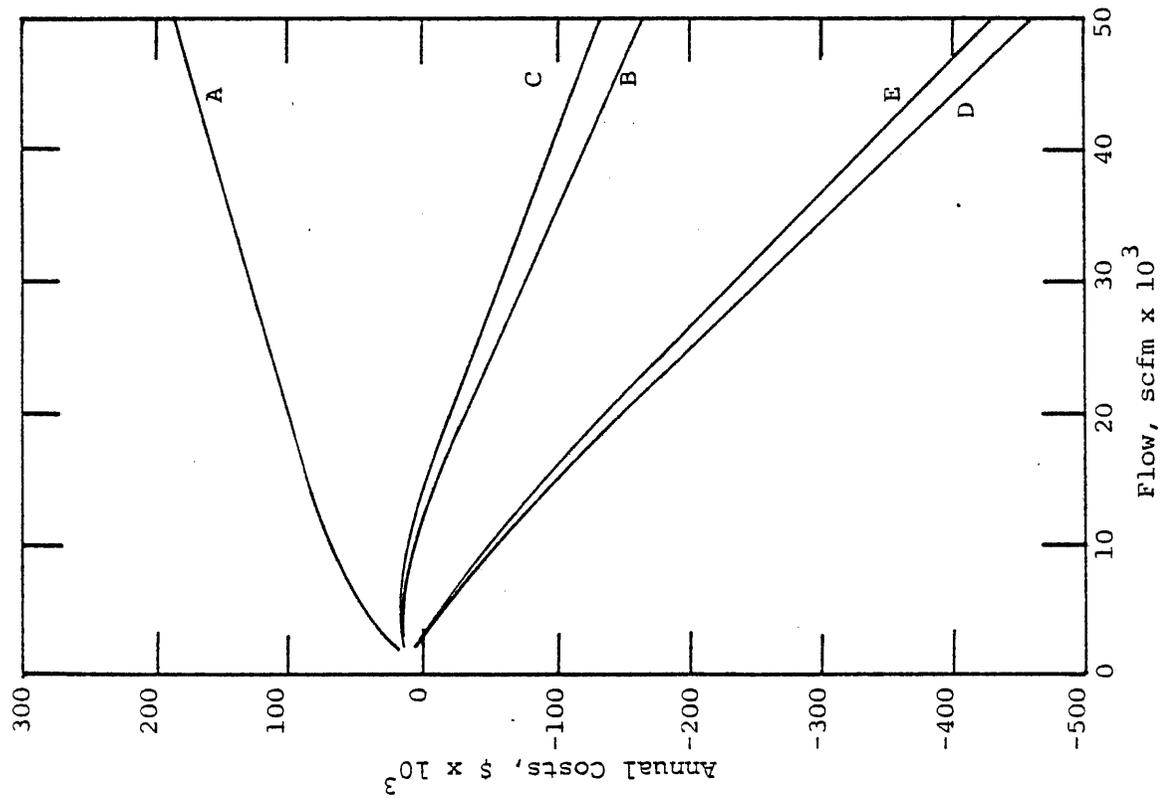
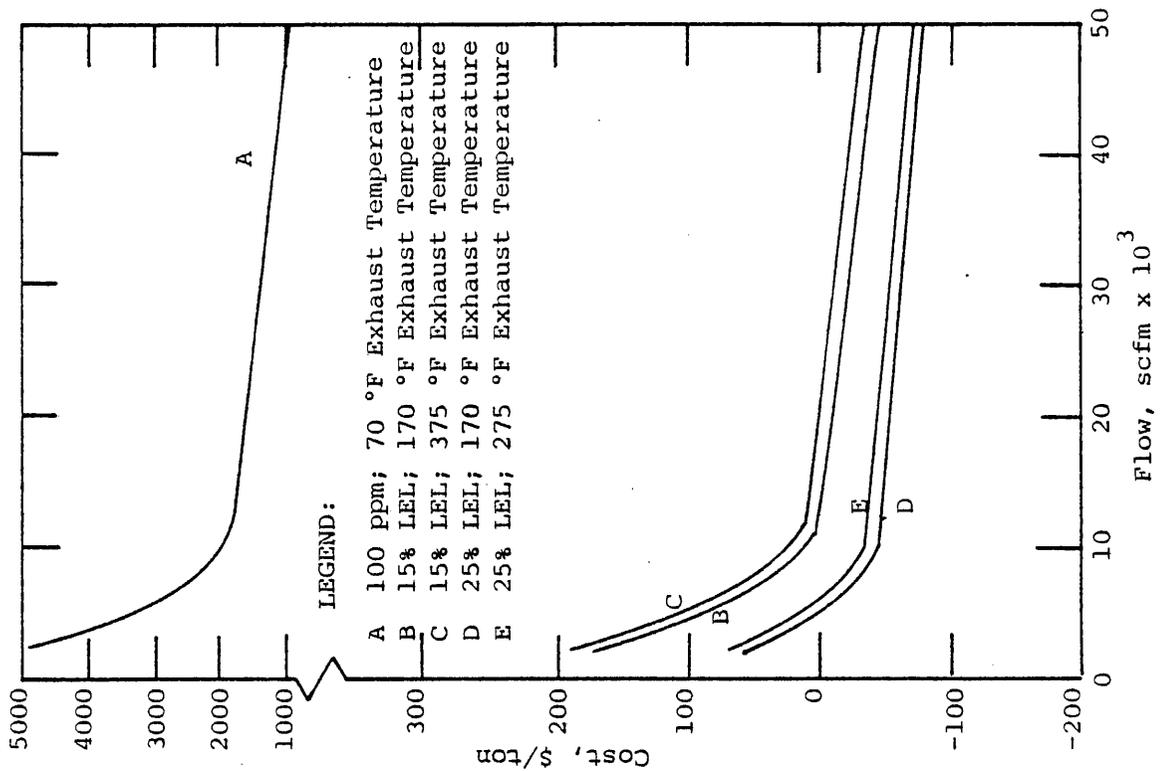
Figure 4-27. Annual cost and cost-effectiveness of carbon adsorption systems (1976 prices) (no credit given for recovered solvents) (Ref. 4-2).

KVB 5804-714



LEGEND  
 A 100 ppm; 70 °F Exhaust Temperature  
 B 15% LEL; 170 °F Exhaust Temperature  
 C 15% LEL; 375 °F Exhaust Temperature  
 D 25% LEL; 170 °F Exhaust Temperature  
 E 25% LEL; 375 °F Exhaust Temperature

Figure 4-28. Annual cost and cost-effectiveness of carbon adsorption systems (recovered solvent credited at fuel value) (Ref. 4-2)  
 NOTE: Fuel price used was \$1.50/MMBtu compared to \$1.85/MMBtu which is the September 1977 fuel price in the Basin.



LEGEND:

- A 100 ppm; 70 °F Exhaust Temperature
- B 15% LEL; 170 °F Exhaust Temperature
- C 15% LEL; 375 °F Exhaust Temperature
- D 25% LEL; 170 °F Exhaust Temperature
- E 25% LEL; 275 °F Exhaust Temperature

Figure 4-29. Annual cost and cost-effectiveness of carbon adsorption systems (recovered solvent credited at market chemical value) (1976 prices) (Ref. 4-2).

KVB 5804-714

The MIBK was valued at \$2.50/gal. which means that the 1300 tons of solvent recovered was worth approximately \$800,000, over three times the original investment.

Case 2 - A Pharmaceutical Company

A 10,000 scfm, three-canister, activated carbon system with distillation for solvent recovery was installed to collect acetone vapors which were emitted at a rate of 500 lb/hr or 5000 ppm (20% LEL) at that flow rate. The system recovered 450 lb/hr of acetone at cost of \$10/hr excluding equipment depreciation, taxes, etc. and the price of the recovered solvent. The comparison of reported cost and those predicted by the study are:

<u>Parameter</u>	<u>Reported Actual (Ref. 4-58)</u>	<u>Predicted by Study</u>
Installed Cost, \$	250,000	270,000
Annual Cost, \$ (no credit for recovered solvent)	120,000*	100,000
Annual Weight of Solvent Recovered, tons	1,300	--
Cost Effectiveness, \$/ton	90	125

\*Includes 25% of Installed Cost

The acetone was valued at \$1.25/gal which means that the 1300 tons recovered was worth approximately \$500,000 or twice the original investment.

Case 3 - A Gravure Printing Plant

This plant has an 180,000 scfm, four-canister, activated carbon system with a solvent recovery system. The solvent concentration is 1000 to 3000 (10-25% LEL) ppm of a blend of aliphatic and aromatic (< 20%) hydrocarbons. The installed cost of this system was reported as \$5 million compared to a predicted \$3.5 million

KVB 5804-714

extrapolated from Figure 4-26. The operating costs were not disclosed, however, a payback period of 12 to 15 years was estimated. This would reflect an approximate operation cost of from \$100 to \$200/ton of pollutant compared to \$10 to \$50/ton from Figure 4-29.

Case 4 - An Automotive Spray Paint Booth

100 ppm hexane - 90% removal - 5840 hrs of operation/year

<u>Parameter</u>	<u>Reported Actual (Ref. 4-33)</u>	<u>Predicted by Study</u>
Solvent Concentration	100 ppm	100 ppm
Flow Rate, SCFM	248,000	248,000
Wt Recovered, tons	870	---
Installed Cost, \$	2,700,000	2,200,000
Annual Cost, \$ (no credit for solvent)	1,000,000	900,000
Cost Effectiveness, \$/ton	1150	Beyond Extrapolation

Case 5 - An Automotive Spray Booth

<u>Parameter</u>	<u>Reported Actual (Ref. 4-64)</u>	<u>Predicted by Study</u>
Solvent Concentration	100 ppm	100 ppm
Flow Rate, SCFM	1,815,000	1,815,000
Installed Cost, \$	19,600,000	15,000,000
Annual Cost, \$	7,300,000	2,700,000
Cost Effectiveness, \$/ton	1150	Beyond Extrapolation

4.3.2 Incineration (Thermal and Catalytic)

The cost effectiveness data presented in this section are taken from a 1976 EPA study, Reference 4-2. For additional cost data, especially on automobile painting incinerators, consult Reference 4-33. Incineration can be an economical control alternative if heat recovery techniques can be utilized. To illustrate the importance of heat recovery, three cases were investigated:

- . No heat recovery
- . 25 percent primary heat recovery
- . 35 percent primary heat recovery and 55 percent secondary heat recovery of the remaining 65 percent.

For each case, cost estimates were made for three inlet flow rates (5,000, 15,000, and 30,000 scfm), two inlet stream temperatures (70 and 300 °F), and three stream concentrations (0, 15, and 25 percent of the LEL\*). Other assumptions used in developing the estimates are as follows:

- a. Noncatalytic incinerators designed for both oil and natural gas operation
- b. Catalytic incinerators designed for natural gas and propane operation
- c. Catalytic incinerators capable of 800 °F operation below 6 percent LEL; 1200 °F design capability for operation from 6 percent to 25 percent LEL
- d. 3-year catalyst life
- e. Costs based on outdoor location
- f. Rooftop installation requiring structural steel
- g. Fuel cost of \$1.50/million Btu\*\*(gross). Correction factors were provided to determine operating costs at higher fuel prices
- h. Electricity at \$0.03 kW-hr
- i. Depreciation and interest was taken as 16 percent of capital investment. Annual maintenance was assumed to be 5 percent of capital cost, taxes and insurance, 2 percent, and building overhead, 2 percent
- j. Direct labor assessed at 0.5 hr/shift x 730 shifts/yr x \$8.00/hr = \$2920/yr direct labor expense
- k. Operating time: 2 shifts/day x 8 hr/shift x 365 days/yr = 5840 hr/yr. Correction factors are provided to determine annual cost at different operating times

\*See Section 4.3.1 for Lower Explosion Limit (LEL) values.

\*\*Actual fuel cost (gas) in the Basin in September 1977 was \$1.85/million Btu.

1. The noncatalytic incinerator utilized was based on:
  - . 1500 °F capability
  - . 0.5-second residence time
  - . Nozzle mix burner capable of No. 2 through No. 6 oil firing
  - . Forced mixing of the burner products of combustion using a slotted cylinder mixing arrangement. This cylinder allows the burner flame to establish itself before radial entry of the effluent through slots in the far end of the cylinder
  - . A portion of the effluent to be incinerated is ducted to the burner to serve as combustion air. This allows the burner to act as a raw gas burner, thus saving fuel over conventional nozzle mix burners. This design can only be used, however, when the O<sub>2</sub> content of the oven exhaust is 17 percent by volume or above
  
- m. The catalytic afterburner was costed for two design points, 800 and 1200 °F; the higher temperature design required for LEL levels exceeding 6 percent. (At 600 °F into the catalyst and a 6 percent LEL, the outlet temperature of the catalyst is approximately 800 °F; at a 25 percent LEL condition and a minimum initiation temperature of 500 °F, the catalyst reaches an outlet temperature of around 1200 °F.)

Based upon the results of the cost estimates, cost curves were developed (Figures 4-30 through 4-44). Because of the unique plant facility characteristics, actual control costs for some plants can be substantially higher than estimates given here. To adjust for the differences between the \$1.50/MMBtu used in the study and the current fuel price of \$1.85/MMBtu or to adjust for different operating times, refer to Figures 4-45 and 4-48.

A. Installed Cost of Incinerators--

Figures 4-30, 4-35, and 4-40 give the installed cost for incinerators designed for (1) no heat recovery, (2) primary heat recovery, and (3) primary and secondary heat recovery. The costs were intended to represent typical retrofit situations. However, further investigation has revealed that the costs are more representative of the minimum retrofit situation, essentially the same as installation during the construction of a new plant. The installed cost in more typical retrofit situations will be 1.5 to 2 times the values shown in Figures 4-30, 4-35, and 4-40. In very difficult cases, the cost can be 3 to 5 times that shown in the figures.

KVB 5804-714

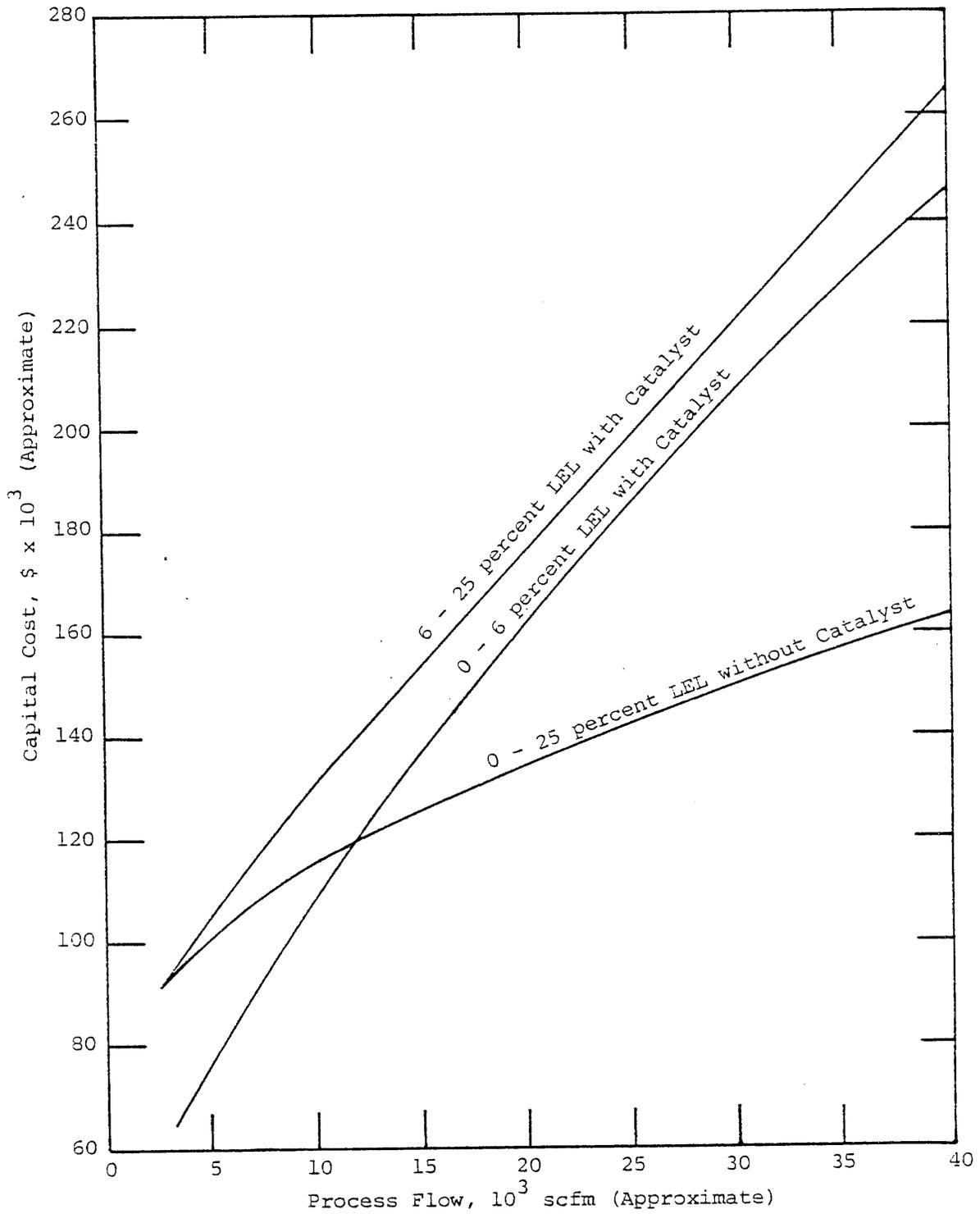


Figure 4-30. Capital cost for direct flame and catalytic afterburners without heat recovery (70 - 300 °F process gas inlet) Case 1 (1976 prices) (Ref. 4-2).

KVB 5804-714

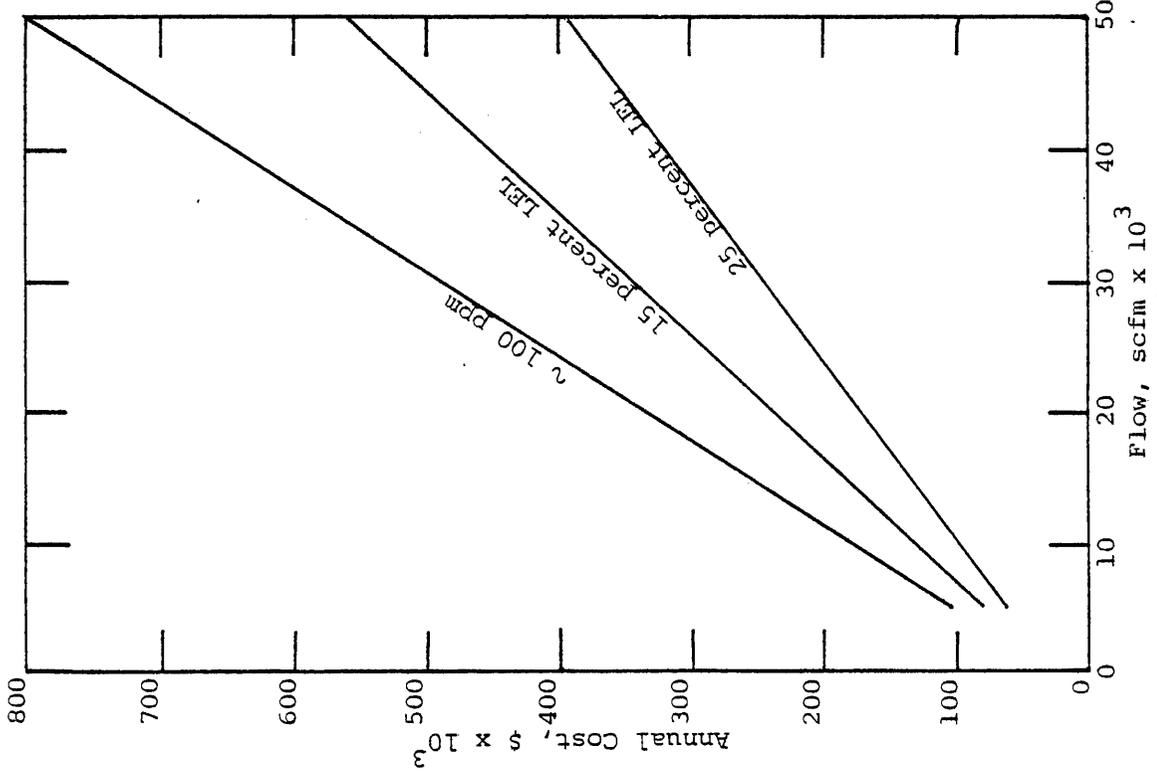
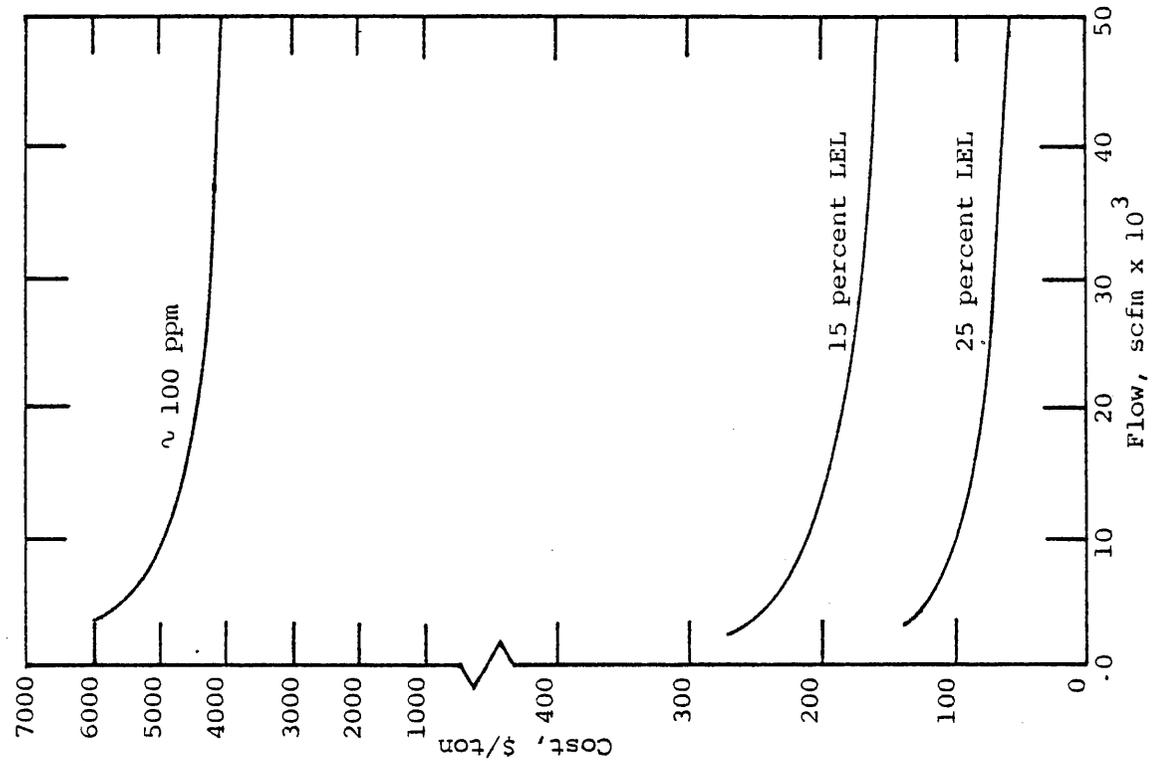


Figure 4-31. Annual cost and cost-effectiveness of direct flame incinerators (1976 prices) (no heat recovery, process temperature = 70 °F) Case 1 (Ref. 4-2).

KVB 5804-714

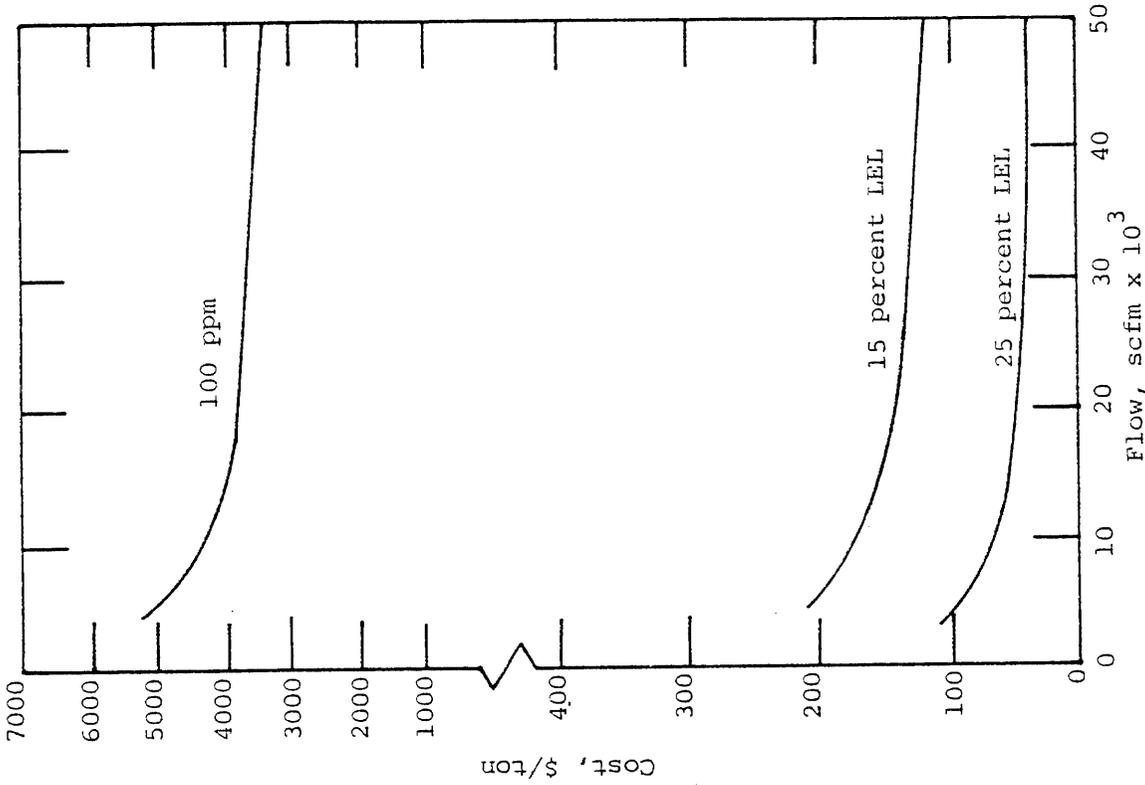


Figure 4-32. Annual cost and cost-effectiveness of direct flame incinerators (1976 prices) (no heat recovery - process temperature = 300 °F) Case 1 (Ref. 4-2).

KVB 5804-714

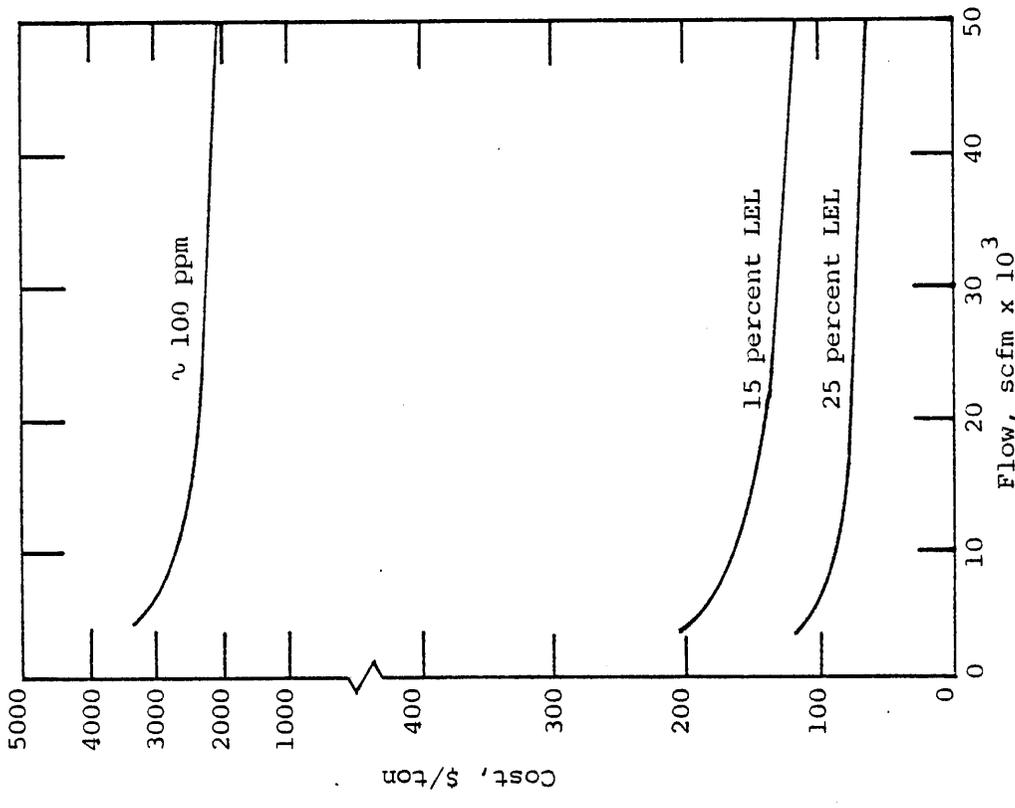
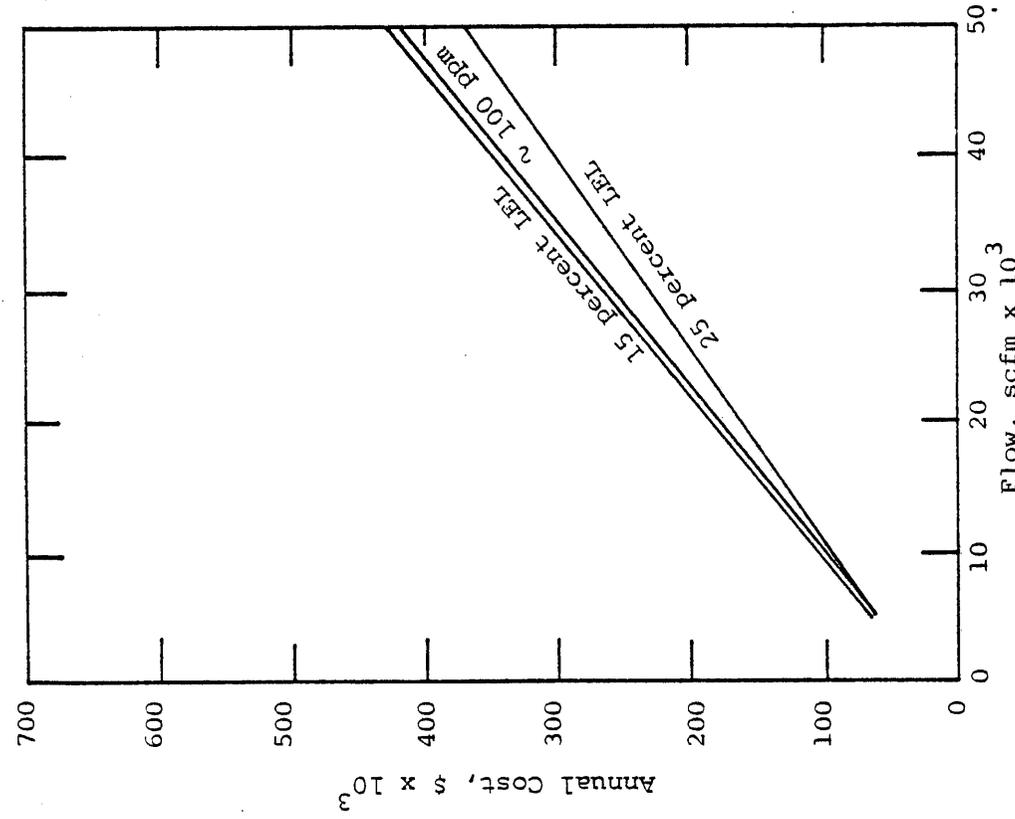


Figure 4-33. Annual cost and cost-effectiveness of catalytic incinerators (1976 prices) (no heat recovery - process temperature = 70 °F) Case 1 (Ref. 4-2).

KVB 5804-714

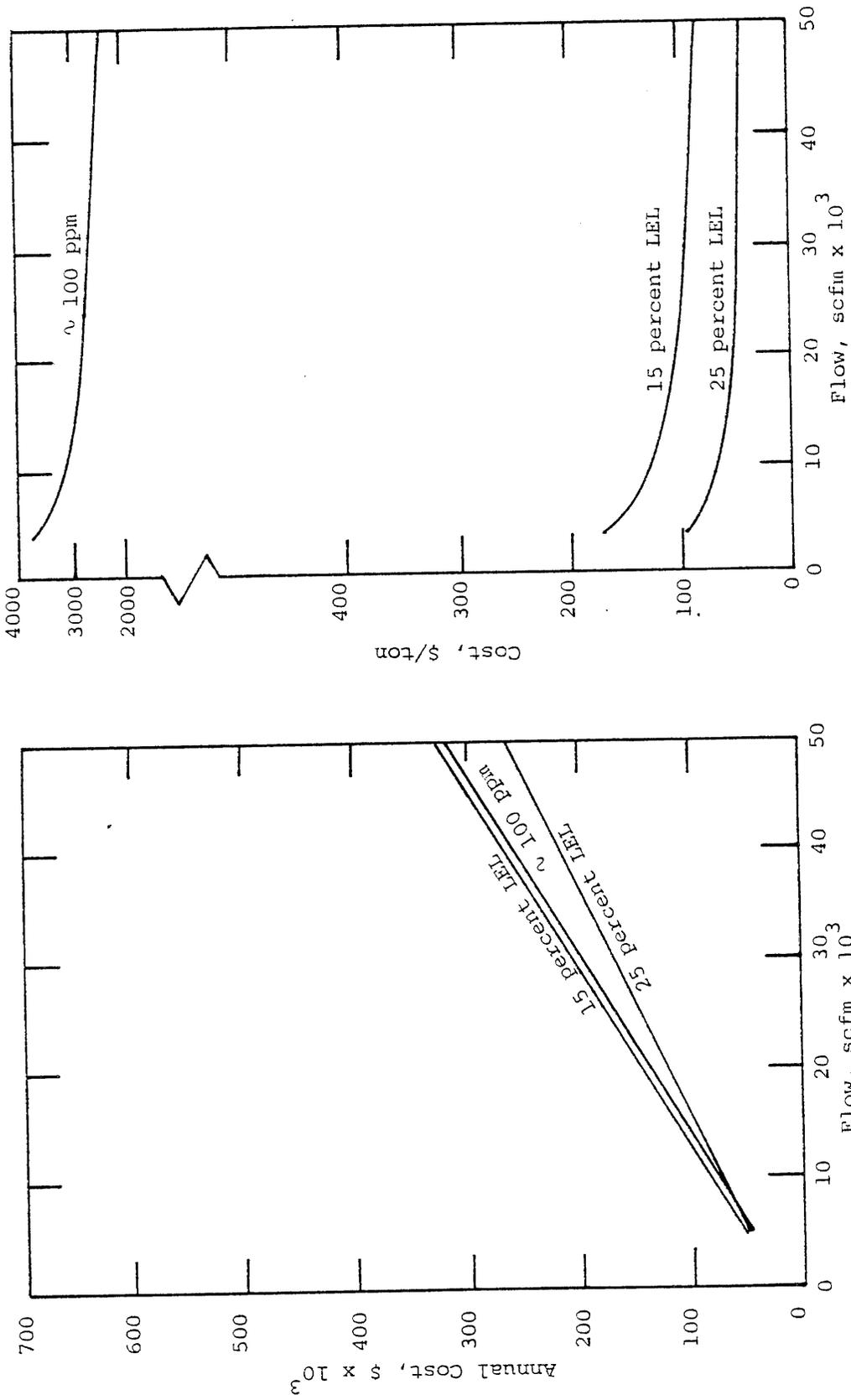


Figure 4-34. Annual cost and cost-effectiveness of catalytic incinerators (1976 prices). (no heat recovery - process temperature = 300 °F) Case 1 (Ref. 4-2).

KVB 5804-714

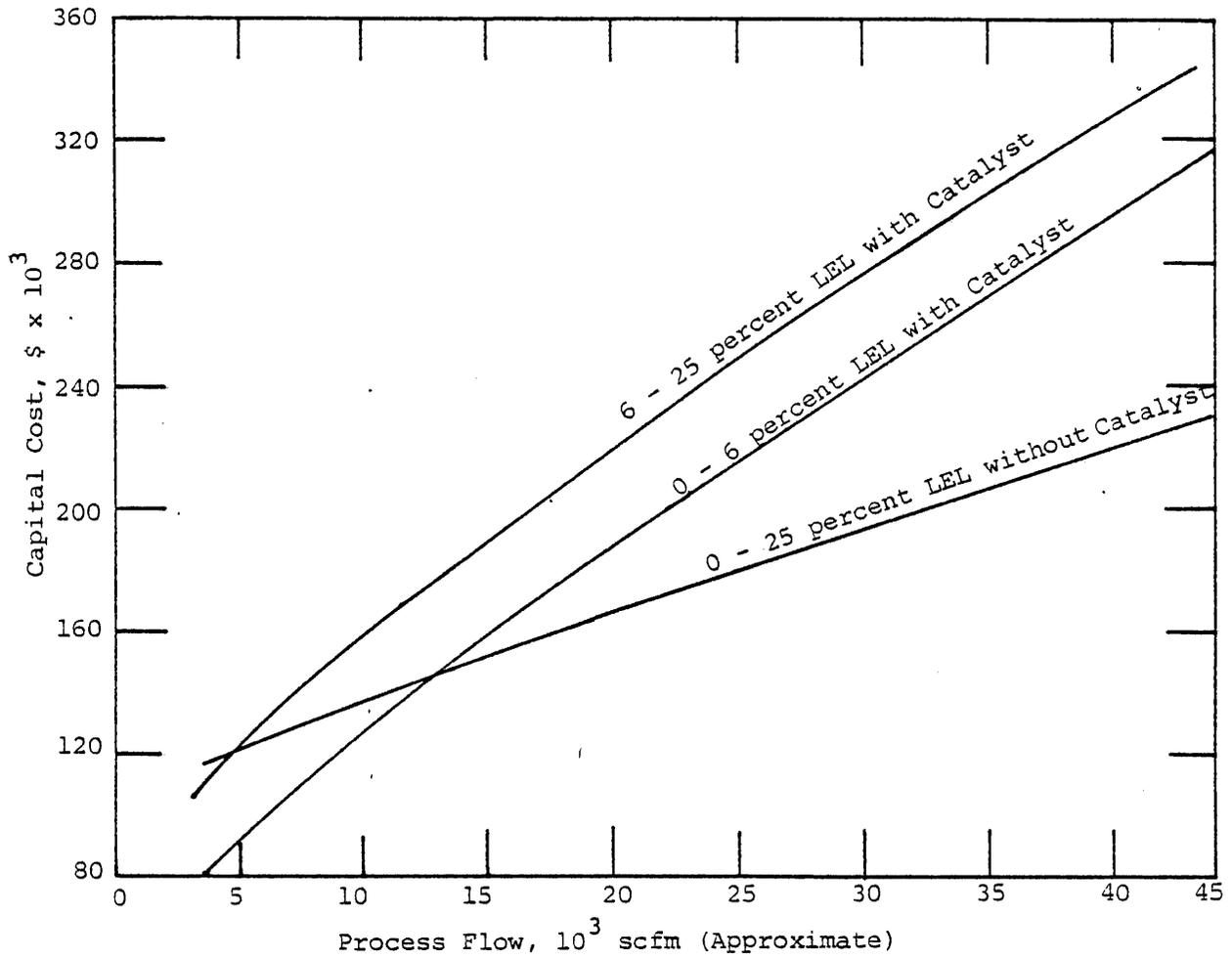


Figure 4-35. Capital cost for direct flame and catalytic afterburners with primary heat recovery (70 - 300 °F process gas inlet) (1976 prices) Case 2 (Ref. 4-2).

KVB 5804-714

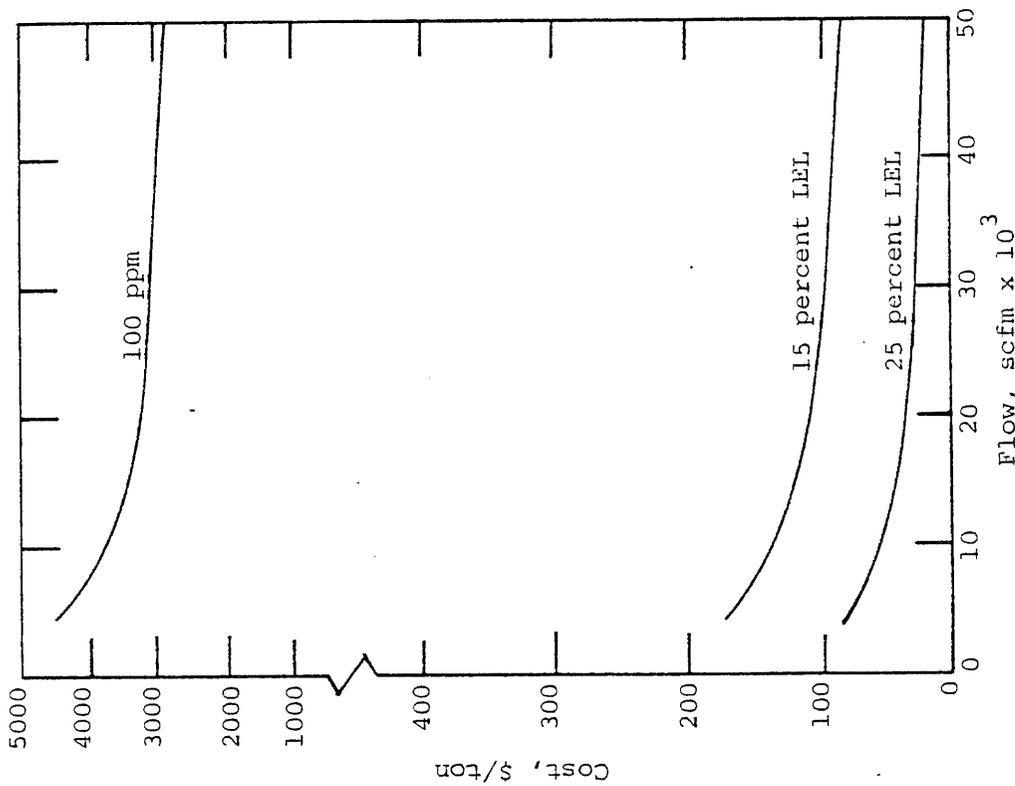
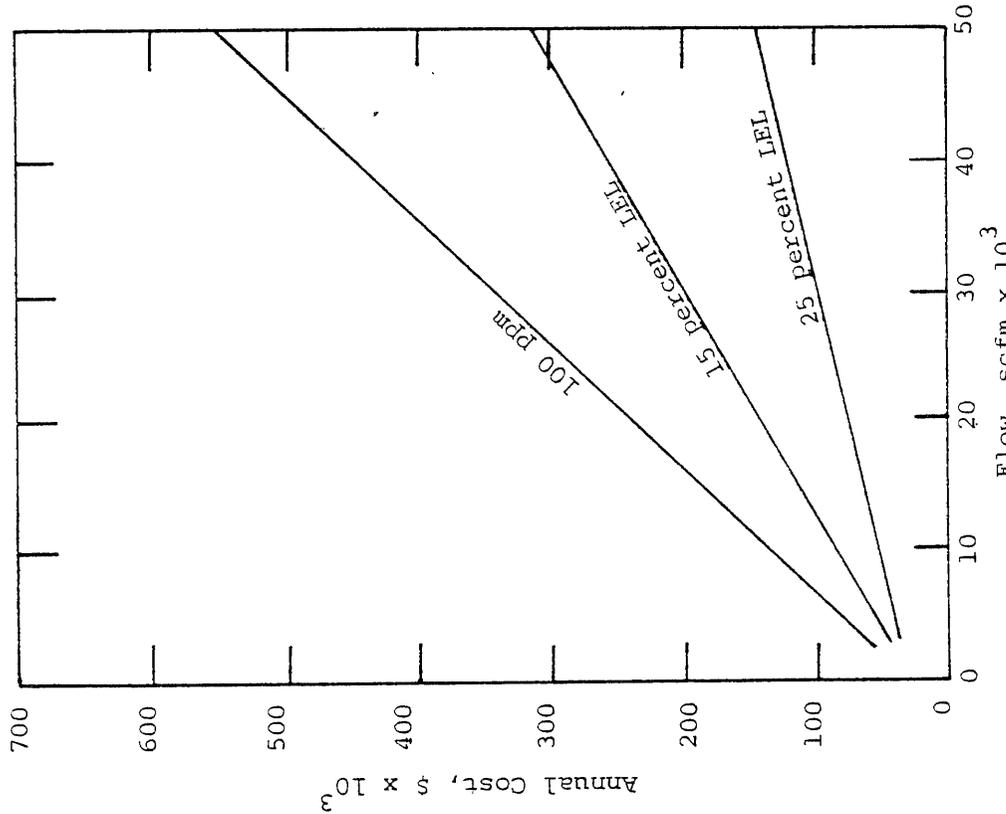


Figure 4-36. Annual cost and cost-effectiveness of direct flame incinerators (primary heat recovery - process temperature = 70 °F) Case 2 (1976 prices) (Ref. 4-2).



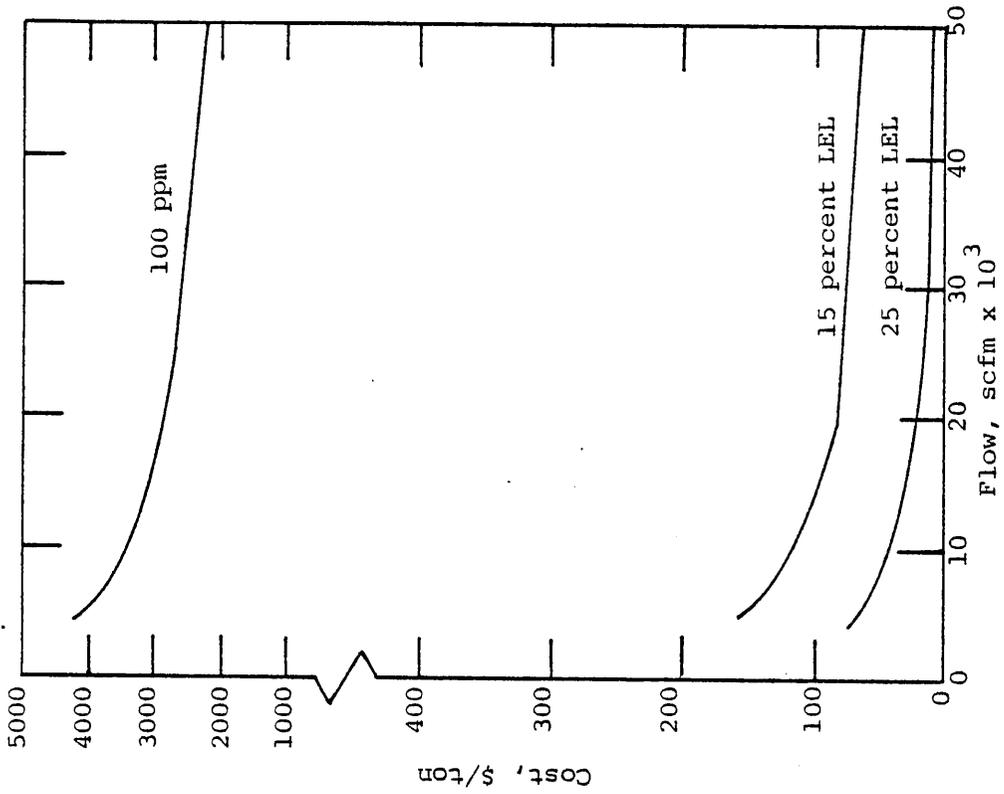
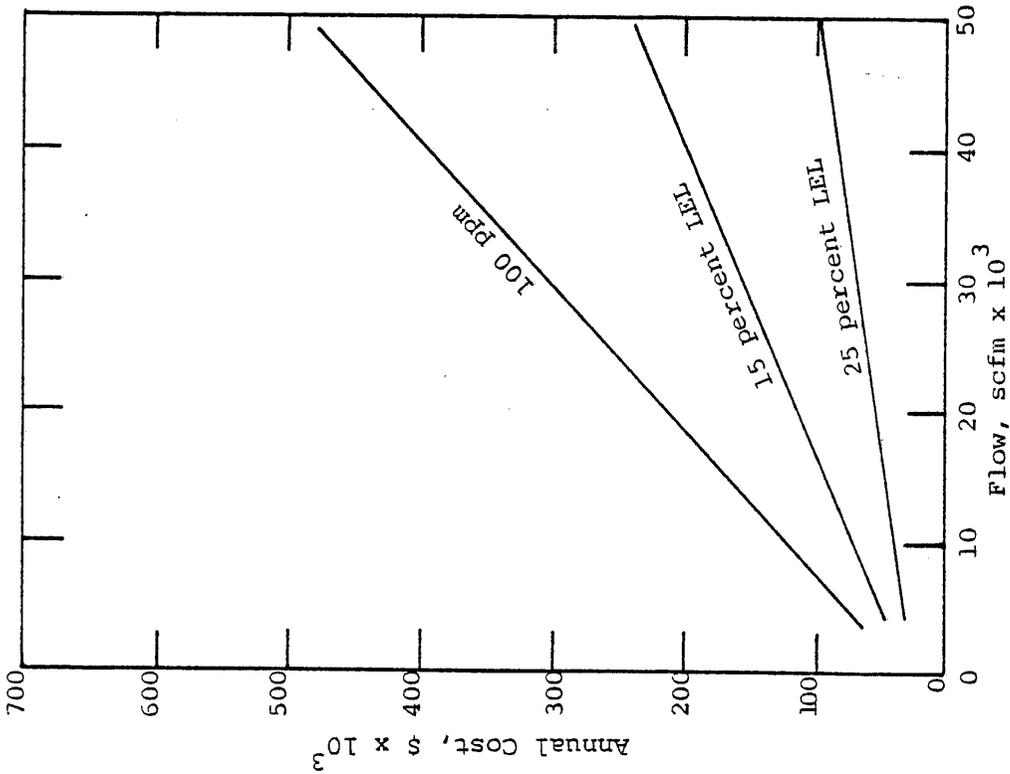


Figure 4-37. Annual cost and cost-effectiveness of direct flame incinerators (primary heat recovery - process temperature = 300 °F) Case 2 (1976 prices) (Ref. 4-2).

KVB 5804-714

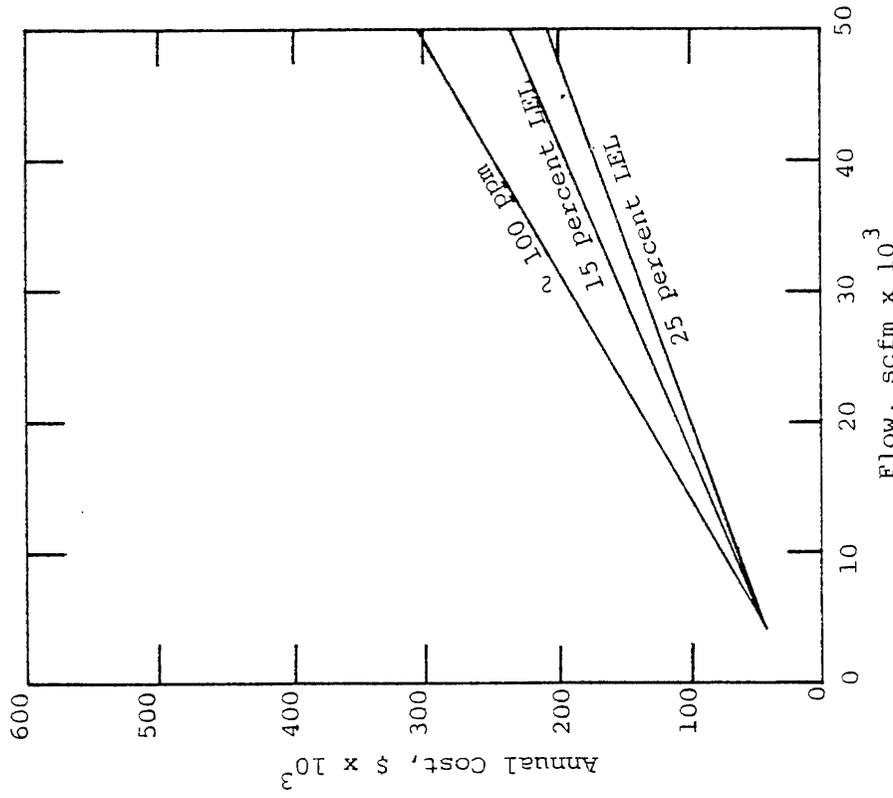
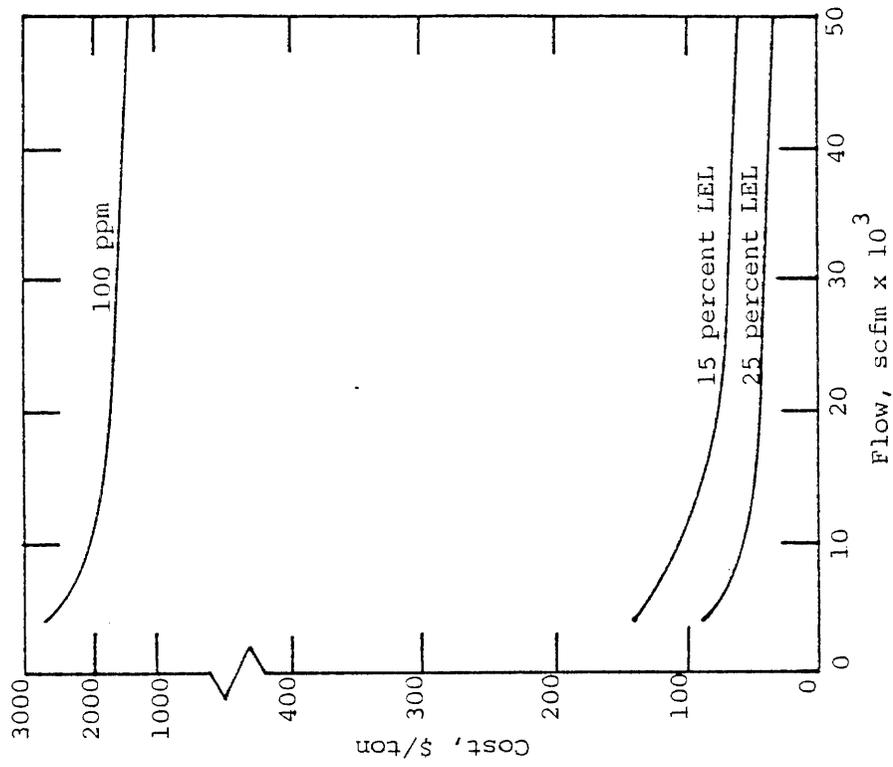


Figure 4-38. Annual cost and cost-effectiveness of catalytic incinerators (primary heat recovery - process temperature = 300 °F) Case 2 (1976 prices) (Ref. 4-2).

KVB 5804-714

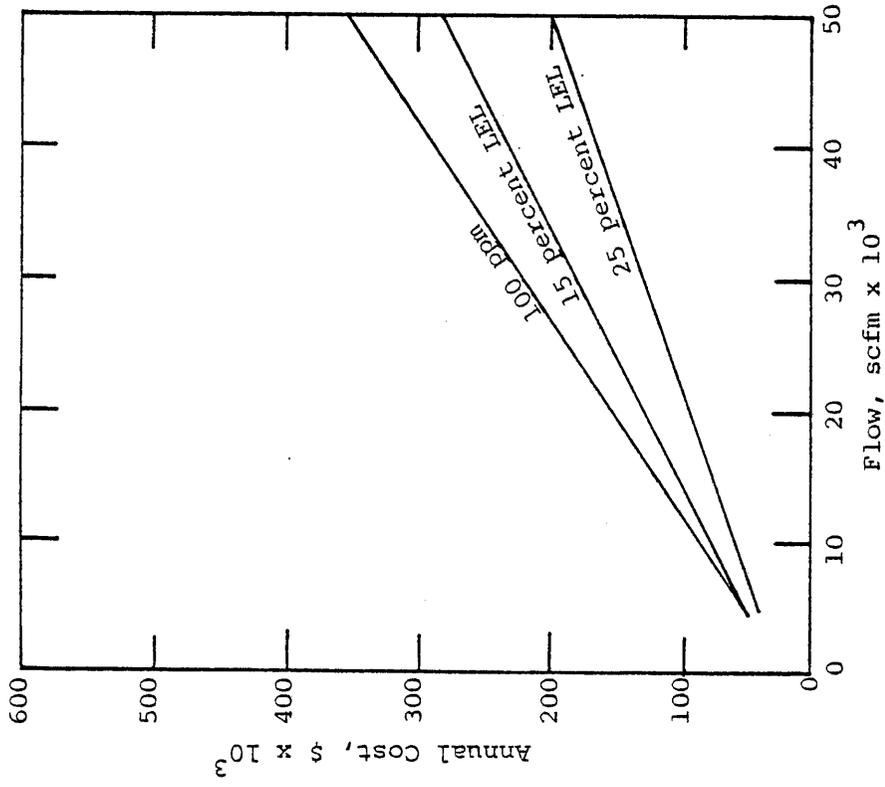
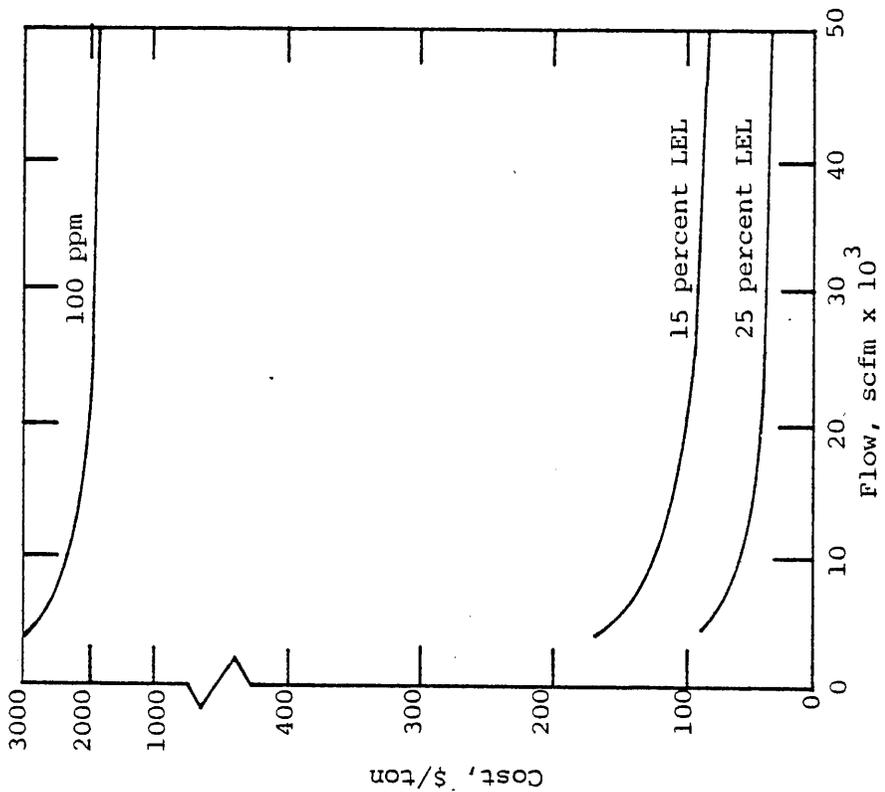


Figure 4-39. Annual cost and cost effectiveness of catalytic incinerators (primary heat recovery - process temperature = 70 °F) Case 2 (1976 prices) (Ref. 4-2).

KVB 5804-714

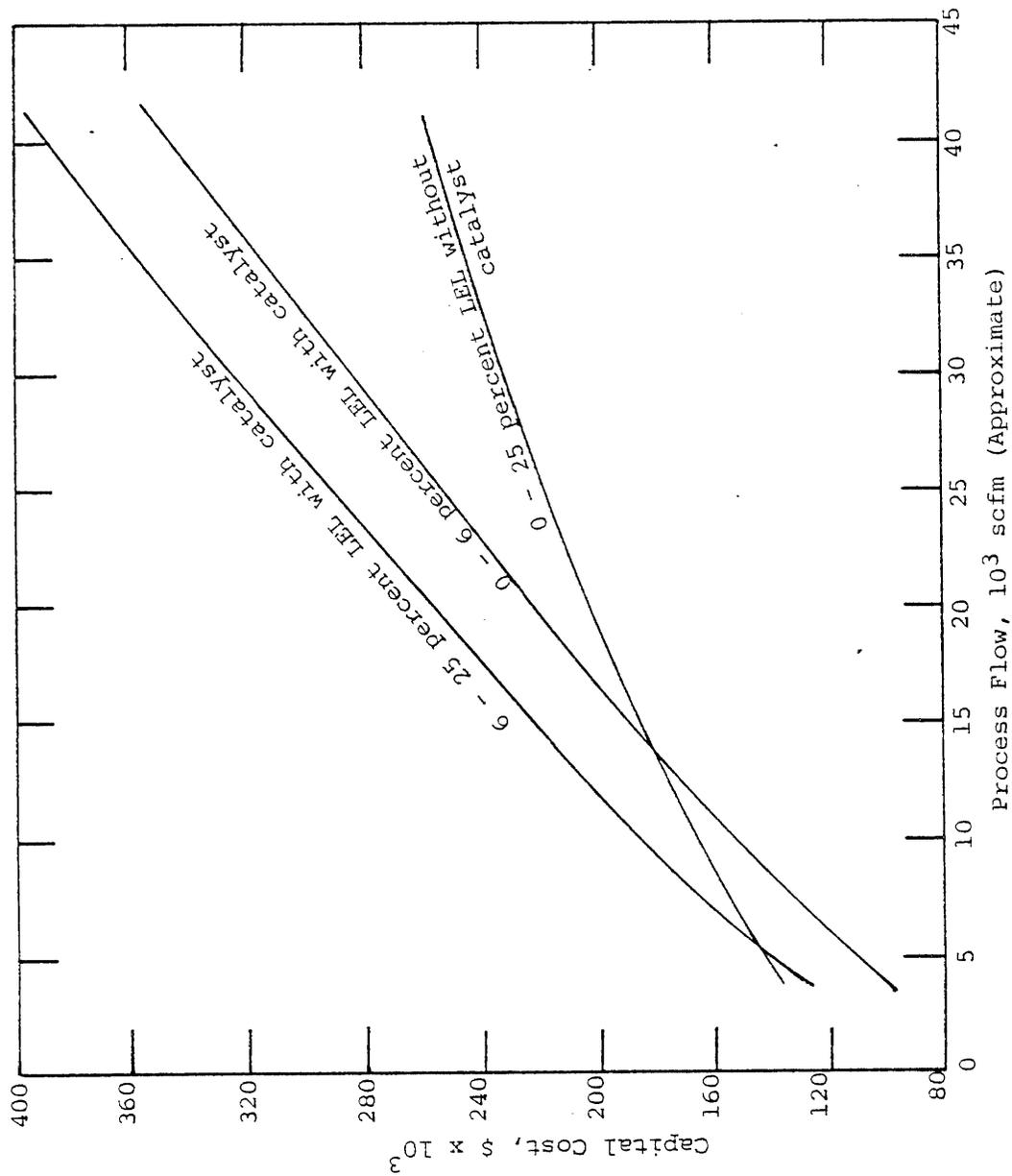


Figure 4-40. Capital cost for direct flame and catalytic afterburners with primary and secondary heat recovery (70 - 300 °F process gas inlet) Case 3 (1976 prices) (Ref. 4-2).

KVB 5804-714

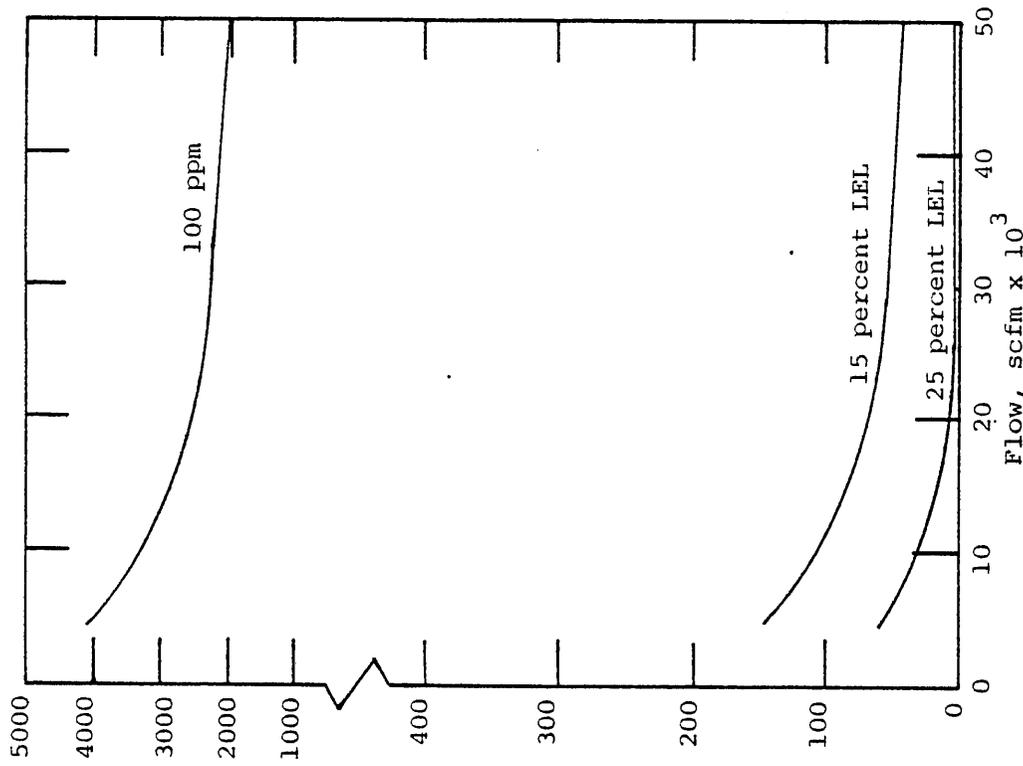
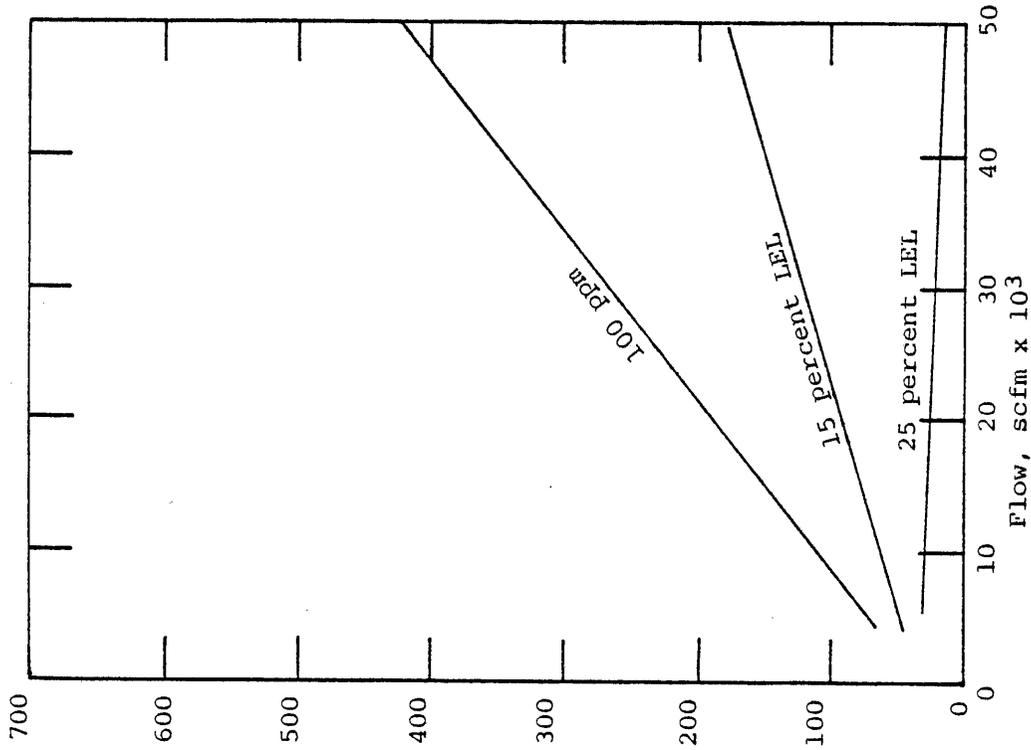


Figure 4-41. Annual cost and cost-effectiveness of direct flame incinerators (primary and secondary heat recovery - process temperature = 70 °F) Case 3 (1976 prices) (Ref. 4-2).

KVB 5804-714

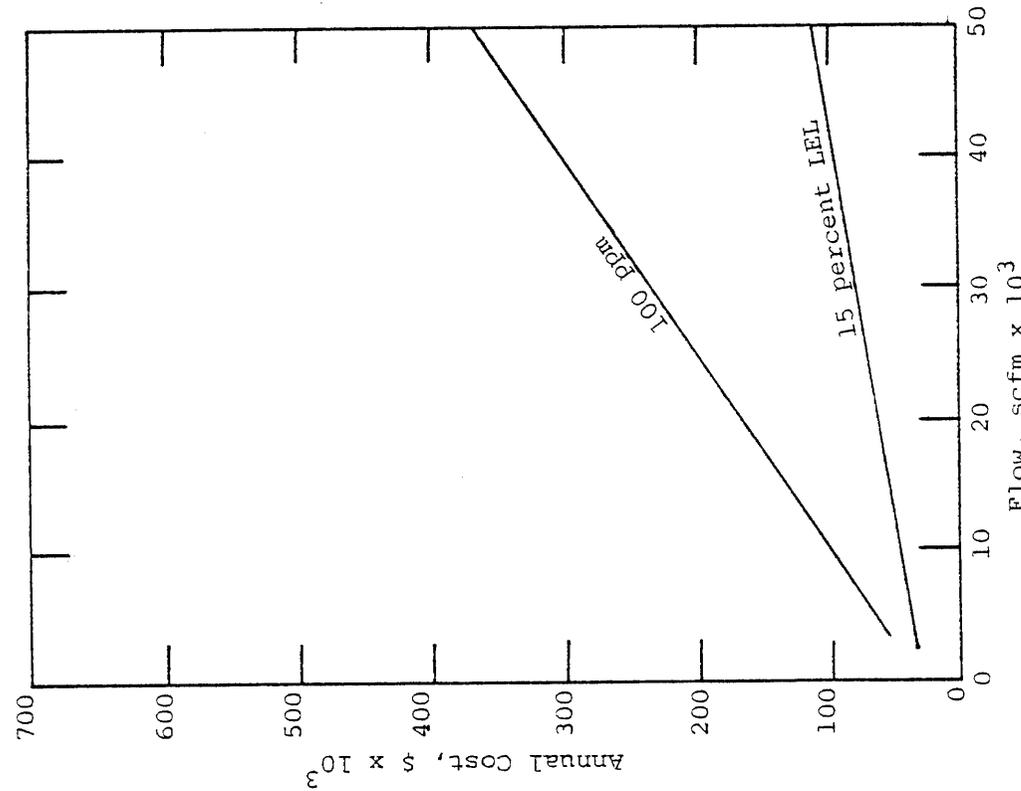
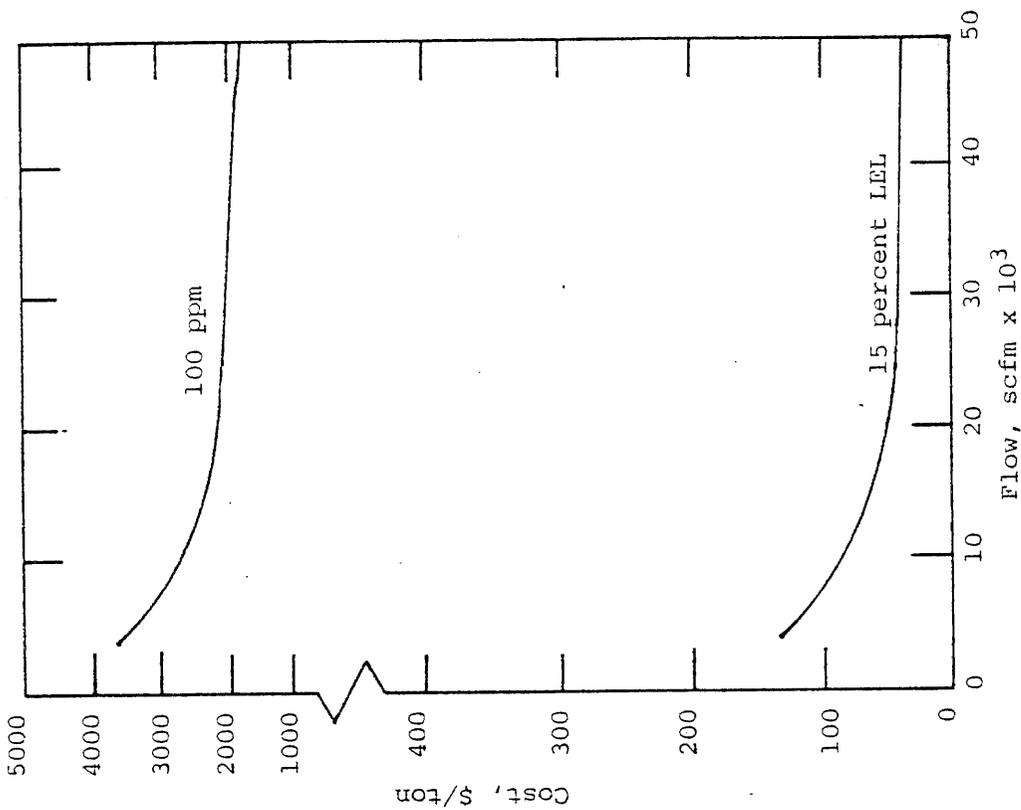


Figure 4-42. Annual cost and cost-effectiveness of direct flame incinerators (primary and secondary heat recovery - process temperature = 300 °F) Case 3 (1976 prices) (Ref. 4-2).

KVB 5804-714

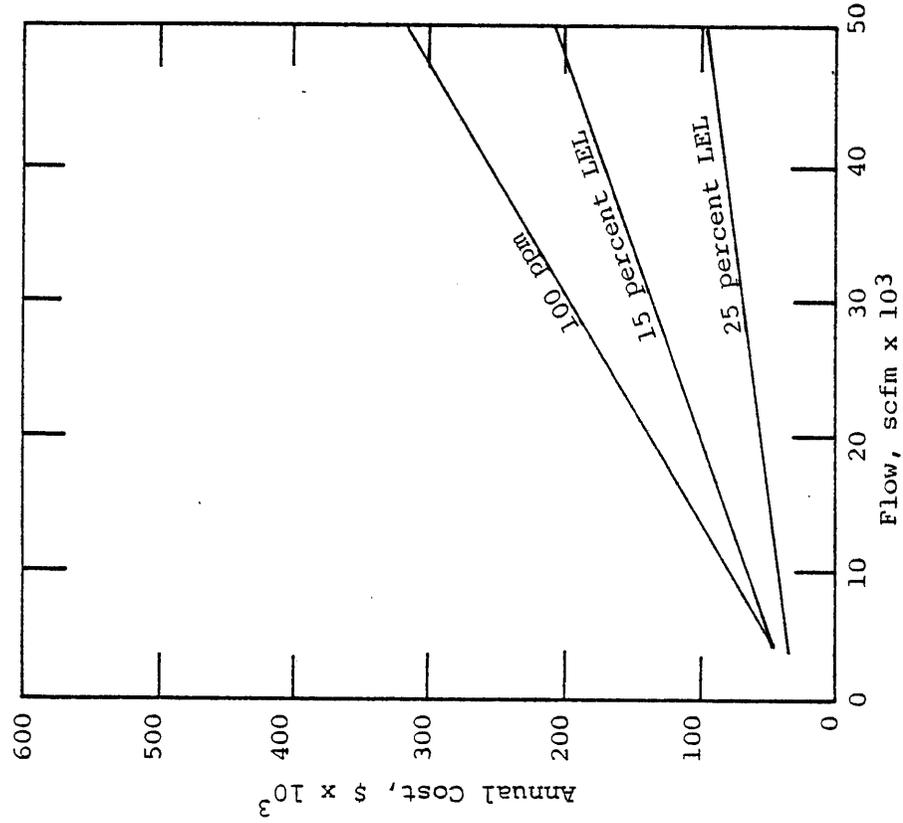
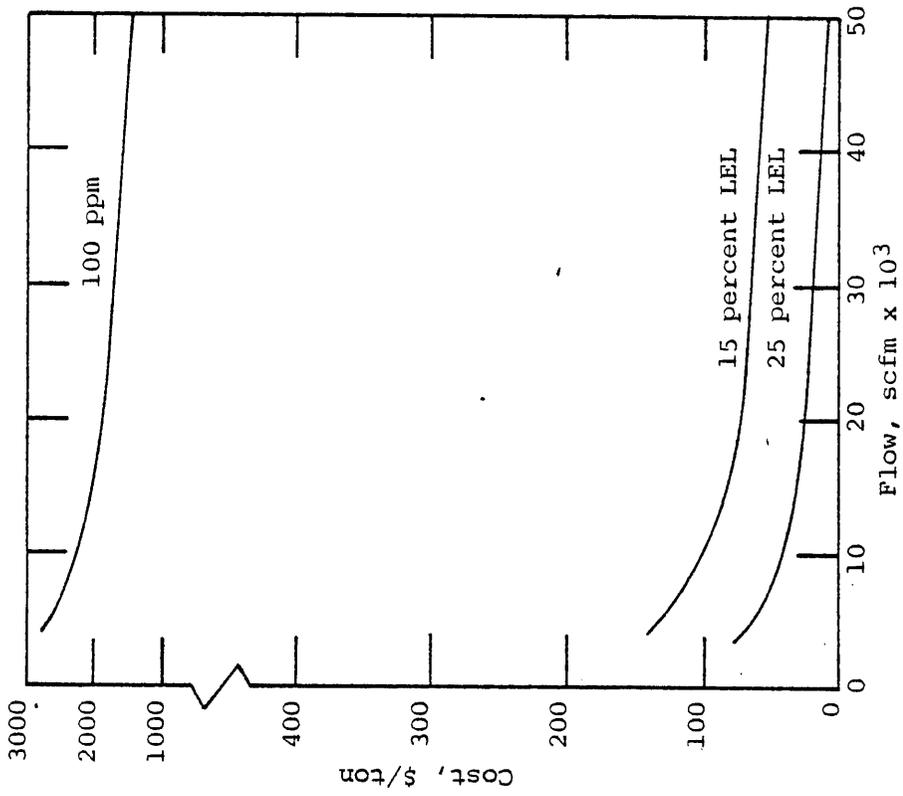


Figure 4-43. Annual cost and cost-effectiveness of catalytic incinerators (primary and secondary heat recovery - process temperature = 70 °F) Case 3 (1976 prices) (Ref. 4-2).

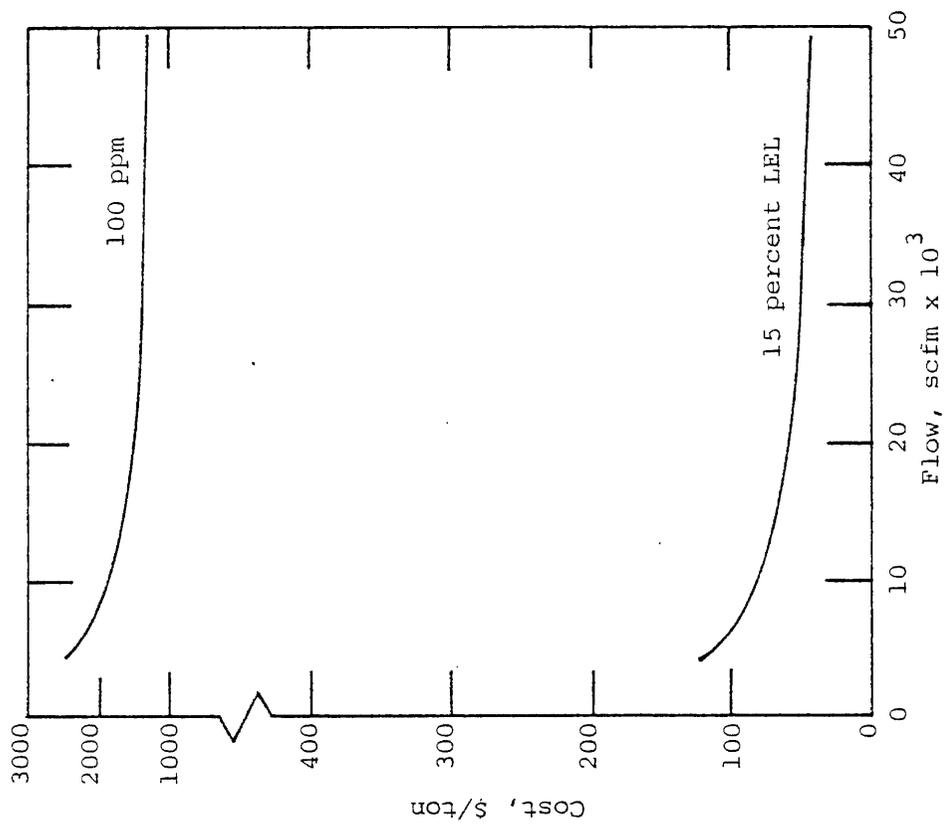
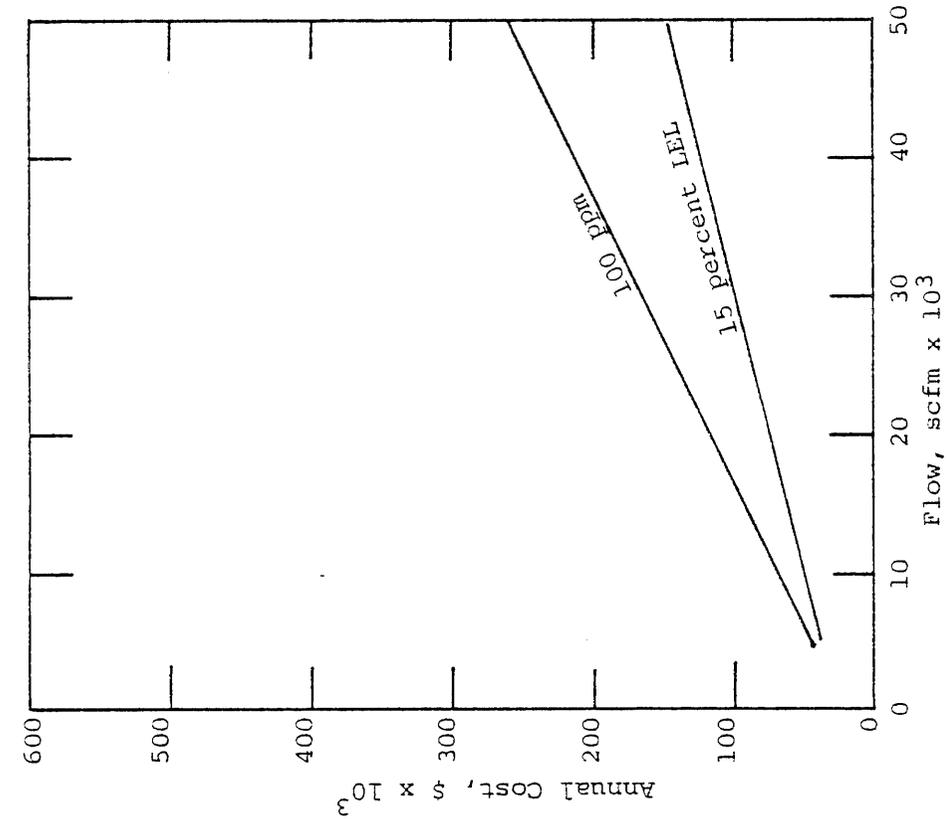


Figure 4-44. Annual cost and cost-effectiveness of catalytic incinerators (primary and secondary heat recovery - process temperature = 300 °F) Case 3 (1976 prices) (Ref. 4-2).

KVB 5804-714

The average installed cost of incinerators with primary heat recovery is roughly 25 to 30 percent greater than incinerators without heat recovery. Incinerators with primary and secondary heat recovery have roughly 50 to 60 percent higher installed costs than incinerators without heat recovery.

B. Annual Control Cost of Incinerators--

Annual control cost curves are given in Figures 4-31 through 4-34, Figures 4-36 through 4-39, and Figures 4-41 through 4-44 for the three heat recovery cases investigated. The costs obtained from these figures include a fuel cost of \$1.50/million Btu and operating time of 5840 hr/yr. If fuel cost and/or operating time for a specific installation differ from these values, the annual costs obtained from these figures can be adjusted by correction factors obtained from Figures 4-45 through 4-48. The annual costs read from the figures are multiplied by the correction factor(s). The cost effectiveness can be corrected by the following equation:

$$CE_c = CE_i \times F_f \times F_h \times \frac{5840}{\text{actual hours operated}}$$

where:

$CE_c$  = corrected cost effectiveness

$CE_i$  = cost effectiveness read from the appropriate figure

$F_f$  = correction factor for fuel cost

$F_h$  = correction factor for hours operated

The costs given in annual cost figures include depreciation and interest for the capital investment at a minimum retrofit cost situation. In cases where retrofit difficulties cause the installed cost to be increased substantially, an appropriate multiplying factor (retrofit difficulty factor) can be used to obtain the increased capital cost. The increase in annual cost, for a given retrofit difficulty factor, will be a varying amount for the different cases of vapor concentration, initial temperature, and heat recovery. The increase in the annual cost for the different cases is given in Tables 4-11 and 4-12. The annual cost is first read from the applicable figure, then is increased by the percentage given in Tables 4-11 and 4-12 under the appropriate difficulty factor.

KVB 5804-714

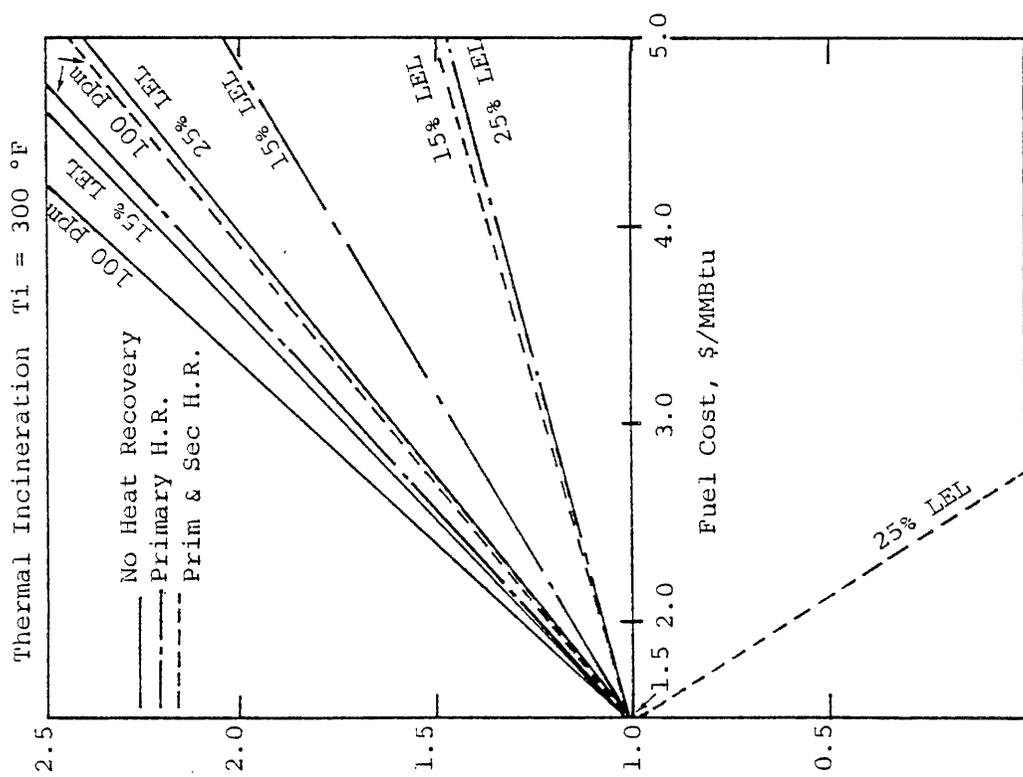
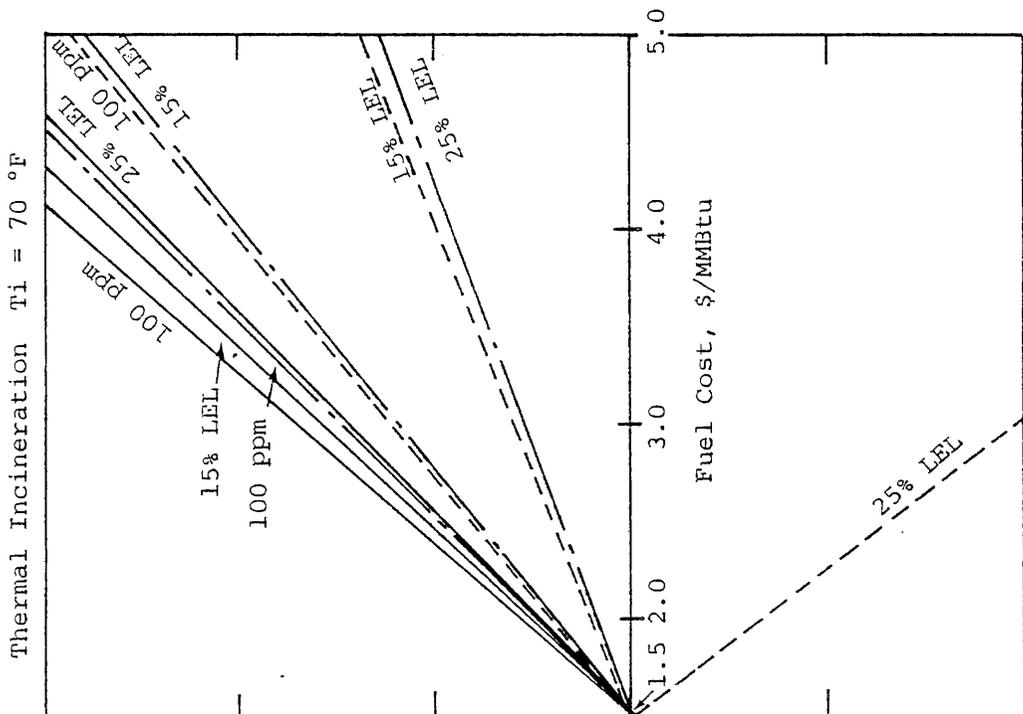


Figure 4-45. Factors to correct annual cost of thermal incineration for varying fuel cost (Ref. 4-2).  
Baseline cost \$1.50/MMBtu.

KVB 5804-714

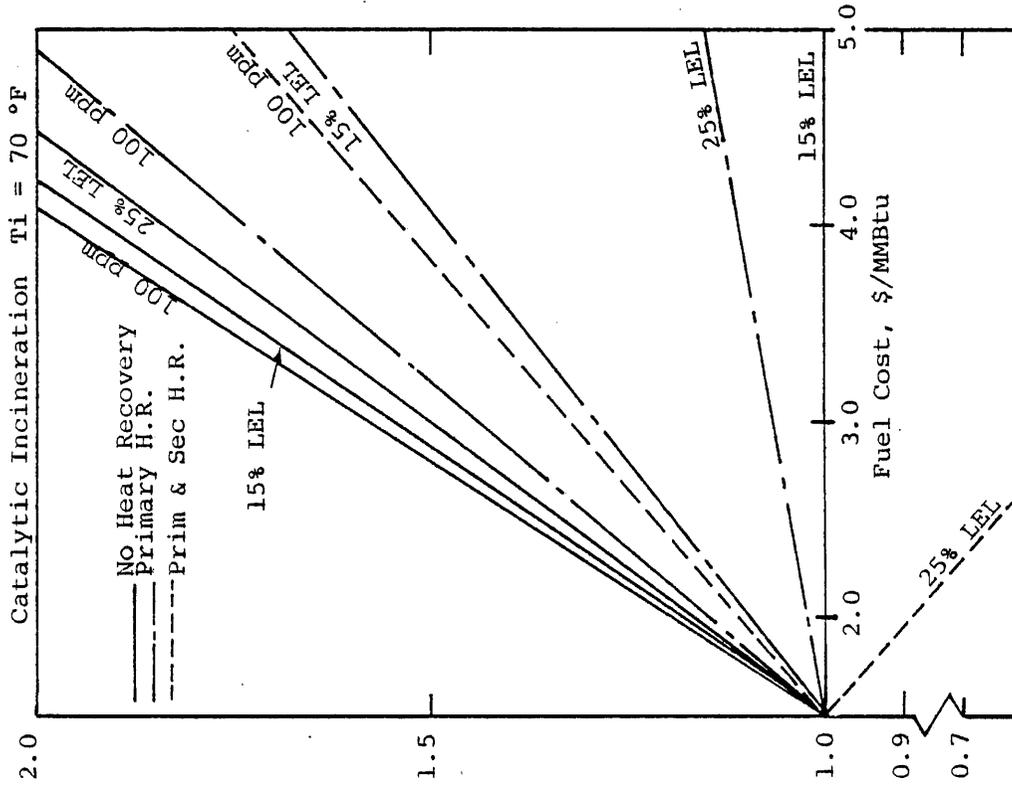
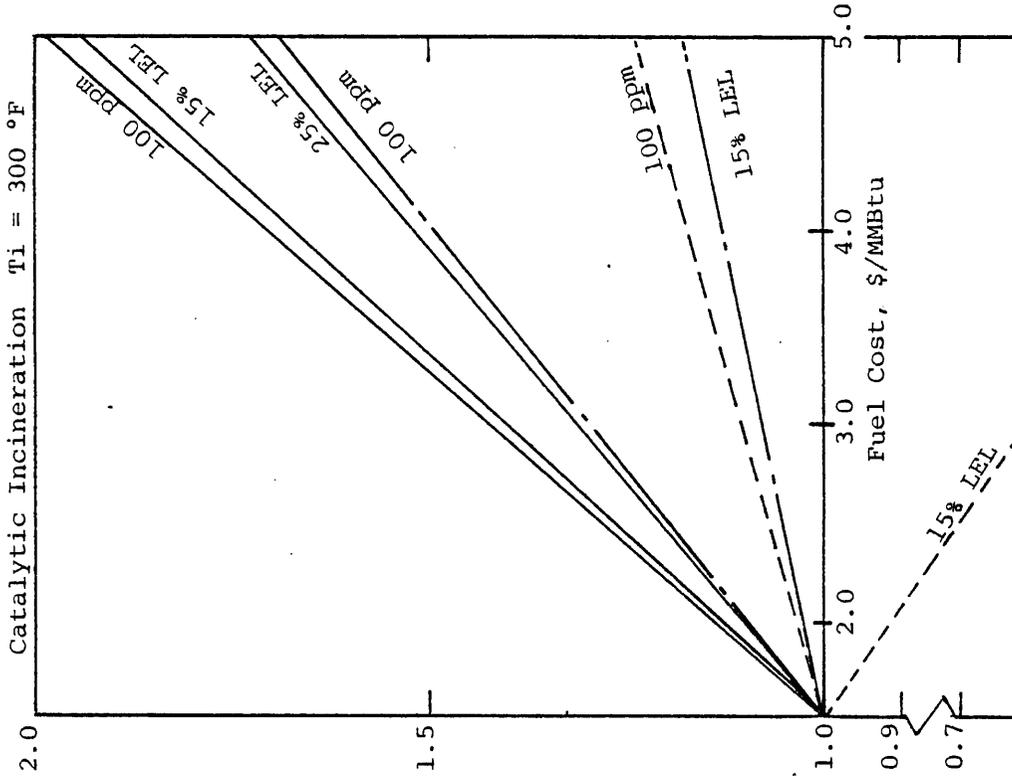


Figure 4-46. Factors to correct annual cost of catalytic incineration for varying fuel cost (Ref. 4-2). Baseline cost \$1.50/MMBtu.

KVB 5804-714

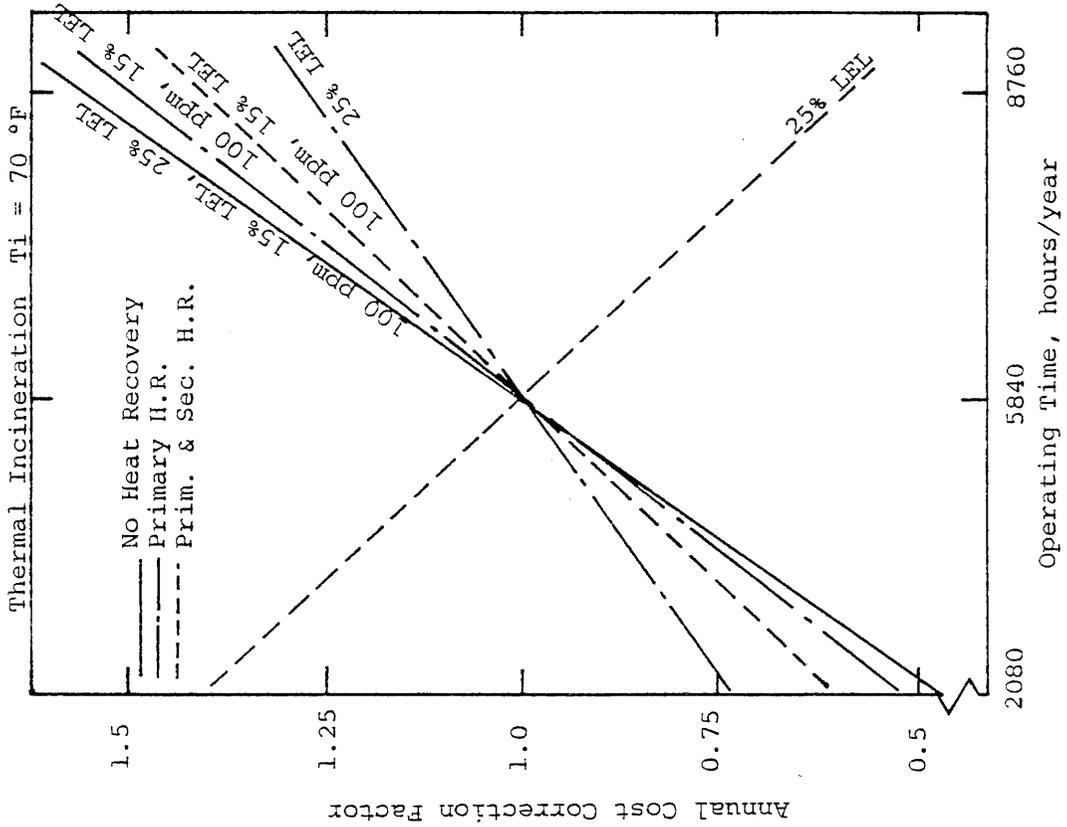
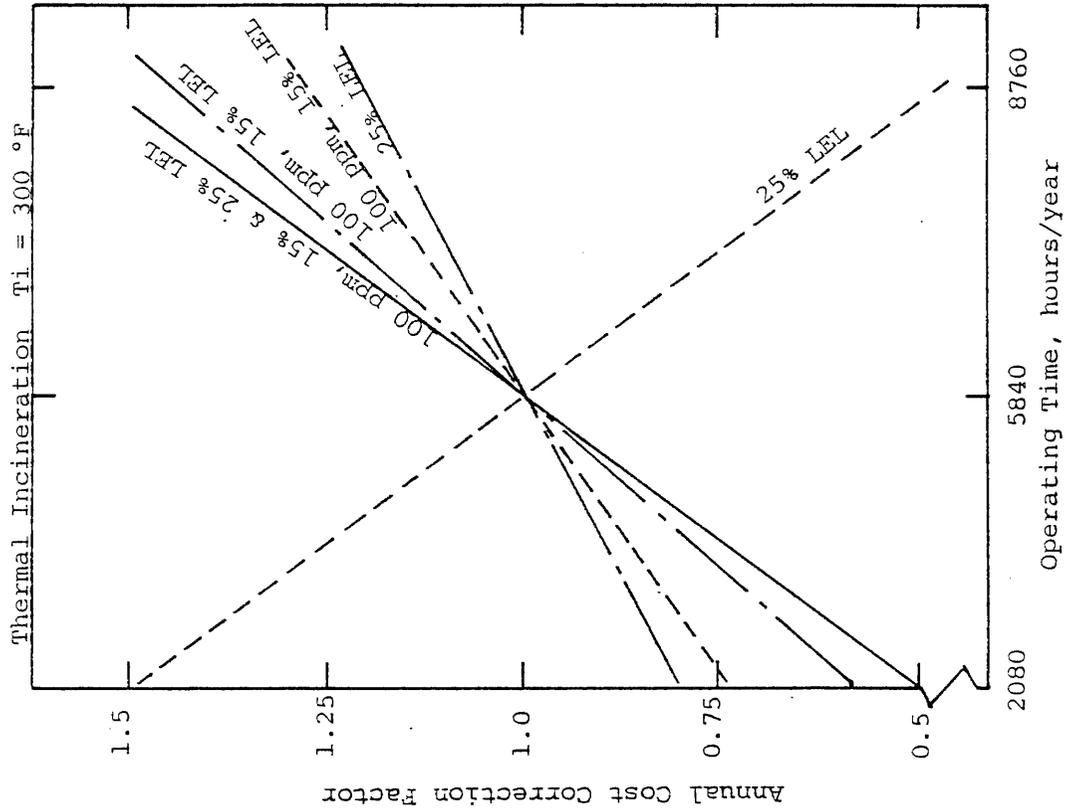


Figure 4-47. Factors to correct annual cost of thermal incineration for varying operating time (Ref. 4-2). Baseline operating time - 5840 hrs/yr.

KVB 5804-714

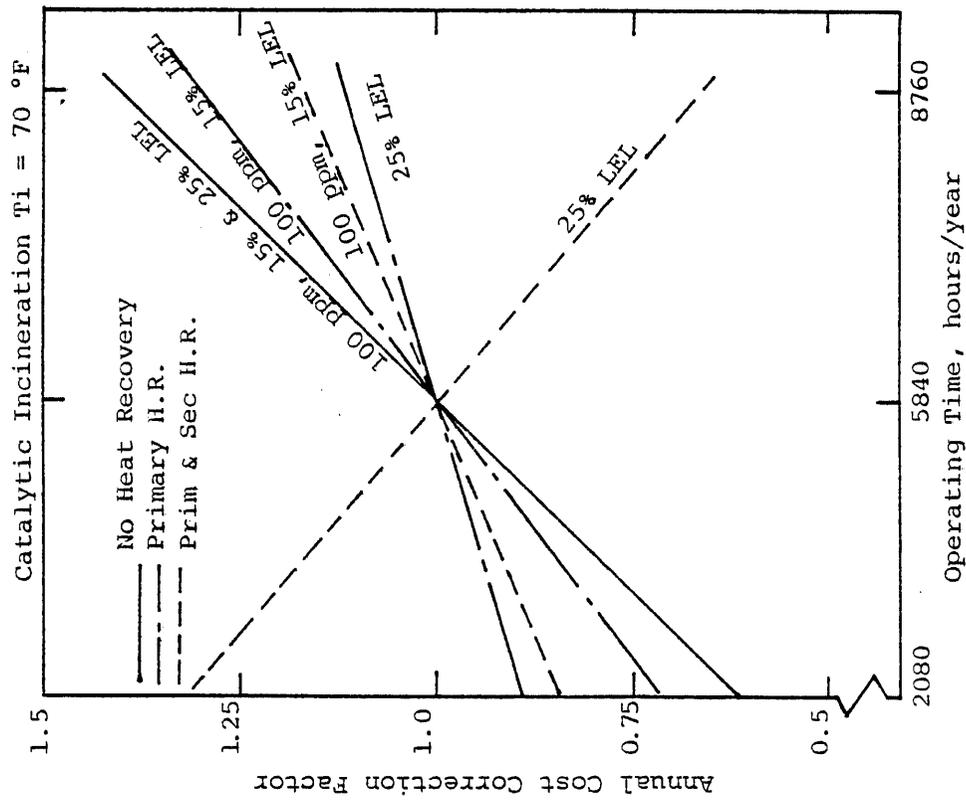
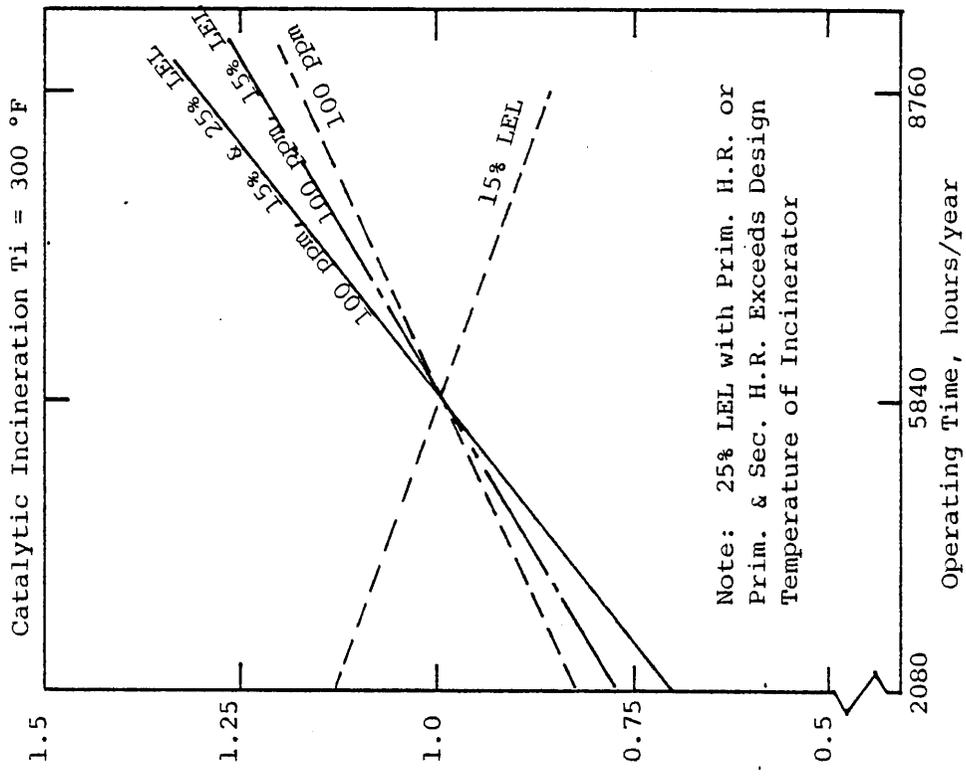


Figure 4-48. Factors to correct annual cost of catalytic incineration for varying operating time (Ref. 4-2). Baseline operating time - 5840 hrs/yr.

KVB 5804-714

TABLE 4-11. INCREASE IN ANNUAL COST OF DIRECT FLAME INCINERATORS  
DUE TO RETROFIT DIFFICULTY FACTORS (Ref. 4-2)

Vapor Concentration	Process Temperature	Heat Recovery	Percent Increase in Annual Cost At Retrofit Difficulty Factor:		
			1.5	2	3
100 ppm	70 °	None	2	5	9
15 percent LEL	70 °	None	4	7	14
25 percent LEL	70 °	None	5	10	20
100 ppm	300 °	None	3	6	11
15 percent LEL	300 °	None	4	8	16
25 percent LEL	300 °	None	7	15	30
100 ppm	70 °	Primary	4	9	18
15 percent LEL	70 °	Primary	8	16	32
25 percent LEL	70 °	Primary	17	33	66
100 ppm	300 °	Primary	5	10	20
15 percent LEL	300 °	Primary	10	20	40
25 percent LEL	300 °	Primary	20	40	80
100 ppm	70 °	Pri. & Sec.	8	16	32
15 percent LEL	70 °	Pri. & Sec.	16	32	64
25 percent LEL	70 °	Pri. & Sec.	80	160	320
100 ppm	300 °	Pri. & Sec.	10	20	40
15 percent LEL	300 °	Pri. & Sec.	25	50	100

KVB 5804-714

TABLE 4-12. INCREASE IN ANNUAL COST OF CATALYTIC INCINERATORS  
DUE TO RETROFIT DIFFICULTY FACTORS (Ref. 4-2)

Vapor Concentration	Process Temperature	Heat Recovery	Percent Increase in Annual Cost At Retrofit Difficulty Factor:		
			1.5	2	3
100 ppm	70 °	None	6	13	25
15 percent LEL	70 °	None	6	13	26
25 percent LEL	70 °	None	8	15	30
100 ppm	300 °	None	8	16	33
15 percent LEL	300 °	None	9	17	34
25 percent LEL	300 °	None	11	22	43
100 ppm	70 °	Primary	6	13	25
15 percent LEL	70 °	Primary	11	22	45
25 percent LEL	70 °	Primary	22	44	88
100 ppm	300 °	Primary	10	20	40
15 percent LEL	300 °	Primary	15	30	60
25 percent LEL	300 °	Primary	16	33	65
100 ppm	70 °	Pri. & Sec.	12	24	48
15 percent LEL	70 °	Pri. & Sec.	18	36	72
25 percent LEL	70 °	Pri. & Sec.	36	72	144
100 ppm	300 °	Pri. & Sec.	14	28	56
15 percent LEL	300 °	Pri. & Sec.	25	50	100

KVB 5804-714

C. Case Histories--

To check the data developed by EPA, KVB investigated several incinerator installations as follows:

Case 1 - A Metal Lithographic Sheet Coating

<u>Parameter</u>	<u>Actual Case (Ref. 4-59)</u>	<u>Predicted by Study</u>
Pollutant	Toluol 19	
Flow Capacity, scfm	6,000	6,000
Type Equipment	Direct Flame	Direct Flame
Concentration, ppm	2,500 (20% LEL)	20% LEL
H/C Flow, lb/hr	215	
Heat Recovery, 2 stage	31%/80%	35%/65%
Process Temperature, °F	300	300
Installed Cost, \$	<u>152,000</u>	<u>150,000</u>
Annual Cost, \$	<u>65,000</u>	<u>40,000</u>

Case 2 - An Antibiotic Spray Drying System

<u>Parameter</u>	<u>Actual Case (Ref. 4-59)</u>	<u>Predicted by Study</u>
Equipment Type	Direct Flame	Direct Flame
Pollutant	Soy & Corn Oil	
Flow Capacity, scfm	23,000	23,000
Heat Recovery, 2 stage	65%/43%	35%/65%
Installed Costs, \$	<u>240,000</u>	<u>210,000</u>
Annual Cost, \$	<u>150,000</u>	<u>180,000</u>

Case 3 - A Carbon Bake Oven

<u>Parameter</u>	<u>Actual Case (Ref. 4-59)</u>	<u>Predicted by Study</u>
Equipment Type	Direct Flame	Direct Flame
Pollutant	H/C & Particulate	
Flow Capacity, scfm	22,000	22,000
Heat Recovery, 2 stage	65%/62%	35%/65%
Installed Cost, \$	<u>235,000</u>	<u>200,000</u>
Annual Cost, \$	<u>150,000</u>	N/A

KVB 5804-714

#### Case 4 - A Meat Rendering Plant

<u>Parameter</u>	<u>Actual Case</u>	<u>Predicted by Study</u>
Equipment Type	Direct Flame	Direct Flame
Pollutant	Odor	
Flow Capacity, scfm	6,800	6,800
Heat Recovery	2 stage	2 stage
Installed Cost, \$	<u>47,000</u>	<u>140,000</u>
Annual Cost, \$	<u>14,000</u>	<u>50,000</u>

#### Case 5 - A Rubber Processing Device

<u>Parameter</u>	<u>Actual Case</u>	<u>Predicted by Study</u>
Equipment Type	Direct Flame	Direct Flame
Pollutant	Mineral Oil	
Flow Capacity, scfm	4,000	4,000
Heat Recovery	2 stage	2 stage
Installed Cost, \$	<u>30,000</u>	<u>11,000</u>
Annual Cost, \$	<u>11,000</u>	<u>40,000</u>

#### 4.3.3 Condensation

Condensation is used for recovery of organic vapor in various industries. The most frequent application is in the gasoline marketing field especially at bulk terminals where nearly saturated gasoline vapors are collected, condensed, and returned to liquid stage. Radian (Ref. 4-60) reviewed the various vapor recovery systems including costs using a 250,000 gal/day bulk terminal as a basis for comparison. Three systems were compared as follows:

1. Compression/Refrigeration/Adsorption (CPA)  
(The vapor is condensed by raising the pressure, cooling and spraying with liquid product)
2. Compression/Refrigeration/Condensation (CRC)  
(The vapor is condensed by pressure and cooling alone)
3. Refrigeration (R)  
(The vapor is condensed by a chiller alone)

KVB 5804-714

A comparison of the three systems is presented in Table 4-13. The costs presented in this table have been escalated for inflationary trends from 1974 to 1976 over the costs presented in Reference 4-60. Escalation was according to the labor and equipment rates present in Chemical Engineering, May 9, 1977 (16% for equipment and labor).

In a vapor degreaser, chillers are used to reduce vapor emissions. EPA (Ref. 4-61) reports the following costs for refrigerated chillers:

	<u>New Units</u>	<u>Retrofit</u>
Installed Cost, 10 <sup>3</sup> \$	2.7 - 5.0	4.0 - 7.5
Net Annual Cost, \$	(1066) to (24)	(646) to 204
Ton/year Saved	1 to 5	1 to 5
Cost Effectiveness, \$/ton	(200)	(100)

This shows that both for new and retrofit applications the refrigerated chillers will pay for themselves in two to three years.

#### 4.3.4 Absorption (Scrubbing)

Scrubbers are used primarily to remove SO<sub>2</sub> and particulates of all types - sulfates, nitrates and organics. In a few cases they may be used to control gaseous organic emissions particularly where the pollutant is water soluble. "Lean oil" has also been used as an absorbent in a scrubber to collect organic vapor such as gasoline. The "lean oil" absorption vapor recovery system is based on the absorption of gasoline vapors into lean gasoline stripped of light ends. Gasoline vapors are displaced through a packed absorber column where they are absorbed by cascading lean gasoline (also termed "sponge oil") at atmospheric temperature and pressure. Cleaned air is vented from the top of the absorber column. The enriched gasoline is returned to storage. Lean gasoline for the absorber is generated by heating gasoline from the storage tanks and evaporating off the light ends. The separated light ends are compressed, condensed, and returned to storage, and the lean gasoline is stored separately for use in the absorption column.

KVB 5804-714

TABLE 4-13. COST COMPARISON FOR VARIOUS CONDENSATION VAPOR RECOVERY SYSTEM  
FOR A 250,000 GAL/DAY BULK GASOLINE TERMINAL (Ref. 4-60)

System	SCFM	Installed Cost 10 <sup>3</sup> \$	Annual <sup>†</sup> Cost 10 <sup>3</sup> \$	Recovery Efficiency %	Tons Recovered/yr from 65/35 (V) Gasoline/Air Ratio <sup>§</sup>	Cost Effectiveness \$/ton
CRA*	150	120-200	36-60	90-97	4,000	9-15
CRC*	150	100-145	30-45	90-96	4,000	8-11
R*	370	85-95	20-25	93-99	9,700	2-3

\*CRA - Compression/Refrigeration/Adsorption

CRC - Compression/Refrigeration/Condensation

R - Refrigeration

<sup>†</sup> Annual Cost includes 25% of Installed Cost for depreciation, taxes, insurance, facilities overhead, etc.

<sup>§</sup> 50.23 lb/ft<sup>3</sup> (gasoline vapor) x scfm x 0.65 x 60 min/hr x 5840 hr/yr x ton/2000/lb = tons/yr

The reader is directed to the McIlvane Scrubber Manual (Ref. 4-62) for comprehensive cost data. The cost of a scrubber as with most add on systems depends on the volumetric flow rate and the properties of the exhaust stream. For an example, according to McIlvane (Ch. XI, Figure 8.2) scrubbers on an asphalt batching plant and animal rendering plant require the least amount of auxiliary equipment. The installed price for this type of scrubber at a flow of 50,000 ACFM would be approximately \$70,000. A basic oxygen furnace closed hood system is among the most complex systems and a 50,000 ACFM scrubber would cost approximately \$4 million. Thus it can be seen that the installed cost can run from \$1 to \$100 per CFM.

4.3.5 Vapor Space Elimination

A. Floating Roof Tanks--

The most common application of vapor space elimination is the use of floating roof tanks to replace fixed roof tanks. The EPA published some comparative costs for floating vs. fixed roof tanks and some cost effectiveness data for retrofitting fixed roof tanks to floating roofs (Ref. 4-63). These data are presented in Tables 4-14 and 4-15. The costs have been escalated by 20% to allow for the difference between prices in 1974 when Reference 4-63 was published to the present. Note that the storage of gasoline in floating-roof tanks rather than fixed-roof tanks, results in a slight savings, while the storage of the less volatile jet naphtha in floating-roof tanks rather than fixed roof tanks, results in a slight cost.

TABLE 4-14. INVESTMENTS - FLOATING ROOF VS. FIXED ROOF TANKS (Ref. 4-63)

Tank Size		Cost to Retrofit		Δ Cost for New Construction		
		Fixed Roof to:		Floating Roof Type vs. Fixed Roof		
Diameter in feet	Normal Capacity bbl*	Covered	Internal	External	Covered	Internal
		Floating Roof	Floating Cover	Floating Roof	Floating Roof	Floating Cover
20	1,100	--	\$3,400	--	--	\$3,400
40	9,000	\$20,000	\$7,800	--	NA	\$8,000
60	22,000	\$31,000	\$14,000	+\$24,000	+\$20,000	+\$14,000
90	54,000	\$50,000	\$26,000	+\$30,000	+28,000	+\$29,000
110	80,000	\$64,000	\$48,000	+\$32,000	+\$40,000	--

\*42 gals/bbl

TABLE 4-15. CONTROL COSTS FOR RETROFITTING FIXED ROOF TANKS (Ref. 4-63) TO COVERED FLOATING ROOFS

Product	Gasoline			Jet Naphtha		
Tank Size ( $10^3$ bbls)	1.1	22	80	1.1	50	80
Investment Floating vs. Fixed ( $10^3$ \$)	3.4	31	64	3.4	31	64
Annualized Cost* ( $10^3$ \$)	(0.2)	(2.3)	(18)	0.4	2.9	3.4
Cost per gallon thruput ¢/gal	(0.04)	(0.04)	(0.04)	0.06	0.02	0.01

\*Savings represented by parentheses

Recently, the ARB passed a new regulation for the South Coast Air Quality Management District (Rule 463) requiring double seals on floating roof tanks storing organic liquid with a true vapor pressure of 1.5 psi or greater. The installed cost of retrofitting existing tanks with a double seal which would comply with this rule has been estimated at \$30 to \$55 per linear foot of tank seal (Ref. 4-8). Since most storage tanks are field erected the additional cost for a double seal on a new tank would only be slightly less than the retrofit cost and probably within the range of \$30 to \$55 per foot indicated above.

B. Floating Covers on Oil/Water Separators--

The EPA (Ref. 4-65) based on their contacts with oil companies, provided an estimate of \$8/ft<sup>2</sup> for covering a new API separator with a floating roof and \$13/ft for a retrofit. For a 5000 ft<sup>2</sup> forebay and waste water separator, the estimated costs were as follows:

<u>Floating Cover</u>	<u>Capital Cost</u>	<u>Annual Cost*</u>	<u>Cost Effectiveness<sup>†</sup></u>
New	\$40,000	\$12,000	\$140/ton
Existing	\$65,000	\$20,000	\$230/ton

\*Includes 10% of capital used for operation and maintenance plus 10% interest for 10-year life.

† Based on an emission factor of 0.1 lb/day/ft<sup>3</sup> and a 95% control efficiency.

KVB 5804-714

#### 4.3.6 Liquid/Vapor Exchange

The primary use of liquid/vapor exchange emission control is for the transfer of petroleum and solvent products especially in gasoline marketing which is a major source of hydrocarbon emissions. In 1974 the EPA issued a study of control methods for gasoline marketing operations (Refs. 4-60 and 4-63). The following liquid/vapor exchange systems were proposed:

##### Tank Truck Delivery - Balance System

Per Service Station Delivering 25,000 gal/month of gasoline

	<u>Recycled Vapor to Tank Truck</u>	<u>Vapor Recovery at Bulk Terminal</u>	<u>Total</u>
Installed Cost, \$	1,200	800**	2,000
Annual Cost,* \$/yr	220	150	370
Emission Red., #/yr	1,900	1,700	3,600
Cost Effectiveness, \$/ton	230	170	400
Cost per Gallon, \$	0.001	0.0005	0.0015

\*Includes 10% of Installed cost for amortization, etc.

\*\*Bulk terminal cost indicated reflects proportioned amount per service station.

All costs escalated 15% from 1974 values in Ref. 4-63.

##### Automobile Filling - Balance System

25,000 gal/month Stations (Ref. 4-65)

Installed Cost - Retrofit, \$	9,000
Installed Cost - New, \$	3,000
Annual Cost (Retro)*, \$	1,500
Emission Reduction, lb/yr	1,600
Cost Effectiveness, \$/ton	1,875
Cost per Gallon, \$	0.005

\*Includes 10% of Installed cost for depreciation, etc.

From these data it can be seen that while the cost effectiveness \$/ton is relatively high the actual price per gallon is minor.

KVB 5804-714

#### 4.3.7 Enclosure

The installed cost for 90-ft dia., 50,000 bbls, variable-vapor-space tanks are as follows:

Lifter Roof 5' dia.	\$140,000
Lifter Roof 10' dia.	\$170,000
Flexible	\$180,000

These costs are based on values in Reference 4-60 escalated from 1961 to 1977 prices. Based on recent costs of \$160,000 for a 50,000 bbl fixed roof tank in the same publication the escalation of the tabulated numbers seems reasonable. Based on AP-42 a 50,000 bbl, fixed roof tank would have breathing losses of 90 ton/yr of gasoline vapor. If 95% were recovered by addition of a variable vapor space tank at an annual cost of \$17,000 (10% of the total tank price) the cost effectiveness would be \$200/ton. The recovered vapor would be worth approximately \$100/ton so the net cost effectiveness would be approximately \$100/ton. In comparing this with the results in Table 4-16 it appears that the variable vapor space tank may be less cost effective than the floating roof tank. However, in view of the additional cost associated with the SCAQMD Rule 463 (double seal FRT) the variable vapor space tank may be reconsidered for storage applications.

The cost of covering drains as separators is difficult to estimate and no values could be found in the literature. Recently KVB investigated a technique for reducing emissions from refinery sewer systems. It was noted that vapors were emitted from the sewer opening where drainage pipes from various items of equipment discharged their leakage into the sewer. The emissions from the sewer opening were measured as a function of the wind blowing over the opening. It was noted that the emissions increased significantly with wind velocity and it was felt that a jet pumping action was produced by the wind.

KVB 5804-714

#### 4.3.8 Process and Material Charges

##### A. Automotive--

1. Electrophoretic dip premixing (Ref. 4-33)--The installed cost of an electrophoretic system for a typical vehicle assembly plant would be about \$8 million. Costs will vary considerably depending on what building alteration and relocation of existing equipment is necessary. Table 4-16 gives increased operating costs for electrophoretic primer, based on electricity of \$0.03/kWhr, interest and depreciation at 12 percent of capital costs, and operation for 4000 hours per year.

2. Low solvent primer and top coat (Ref. 4-33)--The achievable reduction depends on both the old coating and its replacement. For example, the 50 volume percent coating achieves an 86 percent reduction if it replaces a lacquer with 12 volume percent solids, but only a 53 percent reduction if it replaces an enamel with 32 volume percent solids. Obviously, even further reductions can be achieved if an add-on control device is also installed.

Typical capital costs for this option are difficult to assess because they depend completely on the specific plant situation. It is estimated that a change from lacquer to enamel would require a capital cost (including engineering) of \$1,000,000. (General Motors claimed that it would be higher.) Based on a rule of thumb 12 percent of capital investment, annualized operating costs could be as high as \$120,000 per year although this would be affected by the lower manpower required to apply enamels and the increased manpower which would be needed to repair damaged coatings.

3. Water-borne top coats--The cost of converting to water-borne top coats for an existing plant will vary. A major variable will be the age of the existing coating equipment. If near retirement, it may be better to build entirely new spray booths and ovens. This was done at one of two automobile plants in the Basin which converted to water-borne coatings. If the coating equipment is still relatively modern, however, retrofitting will entail lengthening of ovens and modification of spray booths and conveyors. This was the approach taken at the other automobile plant in the Basin using water-borne top coats.

KVB 5804-714

TABLE 4-16. INCREASED ANNUAL OPERATING COST FOR ELECTROPHORETIC  
DIP PRIMERS COMPARED TO SOLVENT-BORNE PRIMER (REF. 4-33)

---



---

Utilities:		
Electricity	$\$0.03/\text{kWhr} \times 4000 \text{ hrs/yr} \times 1400 \text{ kW}$	168,000
Direct labor:		
Savings of	$8 \text{ hrs/shift} \times 500 \text{ shift/yr}$ $3 \text{ workers/shift} \times \$15/\text{hr}$	-180,000*
Interest and depreciation	$12 \text{ percent} \times (1,000,000 \text{ to } 8,000,000)^{\dagger \$}$	120,000 to 960,000
<hr/>		
Total increased operating cost --- 108,000 to 948,000 \$/yr		
<hr/>		

\*There is a net credit for labor cost for electrophoretic dip coating. The calculation is for the difference between one operator versus four in a conventional spray booth applying organic solvent-borne primer.

<sup>†</sup> Assuming 20 year life, 10 percent interest.

<sup>§</sup> The range of values is for different ages of the existing prime line. The lower value represents the increased total installed cost of an electrophoretic dip line over an organic solvent-borne prime line for a plant with an old prime line ready for replacement. The higher value represents the total installed cost for a plant with a new solvent-borne prime line.

KVB 5804-714

Capital costs for a switch to water-borne top coats employing all new spray booths and ovens was estimated at \$10 million while for a plant where the booths and ovens were retrofitted, the capital costs would be about half that amount.

Incremental operating costs include increased electrical requirements and increased maintenance labor. Coating material costs are approximately the same. Higher oven temperature causes an increase in natural gas usage. Annualized operating costs for the model are given in Table 4-17.

TABLE 4-17. INCREASED ANNUAL OPERATING COST ESTIMATE FOR WATER-BORNE TOP COATS OVER ORGANIC SOLVENT-BORNE TOP COATS (Ref. 4-33)

Utilities:		
Electricity	$\$0.03/\text{kWhr} \times 4000 \text{ hrs/yr} \times 5000 \text{ kW}$	\$600,000
Direct labor:		
	20 additional hrs/shift x 500 shifts/yr \$15/hr	\$150,000
Maintenance	} 21 percent x capital costs = 0.21 x \$20,000,000	\$4,200,000
Building overhead		
Taxes and insurance		
Interest and depreciation*		
Total increased operating cost		\$4,950,000/yr

\*Assuming a 20 year life and 10 percent interest charge

B. Paper Coating - Low Solvent Coatings--

Costs will vary for low solvent systems depending on the type of low solvent coating and the particular end use. The low solvent coatings will be economical once the technology has been established, but there can be large costs involved in initially developing the coatings, purchasing new application equipment and learning to use the new systems.

KVB 5804-714

Cost comparisons between various low solvent coatings are not as easy to make as are cost comparisons between various types of add-on control systems. However, a detailed cost comparison has been made between various types of silicone application systems. This comparison is shown in Table 4-18. The cost of learning to apply water-borne systems to paper could be very large.

TABLE 4-18. CAPITAL COST OF SILICONE COATING SYSTEMS IN PAPER COATING INDUSTRY

Coating systems	Net Cost \$/lb of Silicone Solids on Paper
Solvent (with solvent recovery)	8.20
Solvent (with solvent incineration)	7.38
Solventless (heat cure)	7.11
Solvent (with no recovery)	6.69
Water emulsion system	5.28

The emulsion system is the lowest in cost, but the 100 percent solventless (pre-polymer) process may prove to be the most practical system in the long run. It may be difficult for paper coaters that are familiar with organic solvent-borne systems to switch to a water-borne system because of wrinkling of the paper and other application problems.

Additional costs will be associated with switching to 100 percent nonvolatile (pre-polymer) coatings. Most organic solvent-borne silicone release coatings are currently applied by gravure or reverse roller. None of these are suitable for solventless coatings. Solventless coatings must be applied with 3-roll or 4-roll offset gravure presses. These cost from \$25,000 to \$200,000 per coating line. A cost of \$100,000 would be about average. Because of these costs, availability of capital can be an impediment to the adoption of solventless silicone coatings.

#### 4.3.9 Maintenance

The cost effectiveness is impossible to generalize. As discussed in Section 4.1.9, it is debatable as to whether a special leak control program in a refinery would be cost effective. (The leak control program would be beyond the scope of normal maintenance.) A study more comprehensive than afforded by this program would be required to completely assess this prospect.

The EPA (Ref. 4-65) provided some interesting cost data which could contribute to a study of overall costs of reducing fugitive emissions from refineries. Their information came from equipment manufacturers and oil companies, and are based on 1976 prices:

##### A. Pump Seals--

###### 1. Mechanical seals (cost per pump)

<u>Extra cost</u> for mechanical seals on new pumps (shaft size 1" to 3")	\$200 to \$1200
<u>Retrofit cost</u> for mechanical seals on used pumps (shaft size 1" to 3")	\$2000 to \$3000
<u>Annual cost</u> to replace seals every two years (shaft size 1" to 3")	\$500 to \$1200

###### 2. Dual mechanical seals (cost per pump)

<u>Extra cost</u> for new pumps (shaft size 1" to 3")	\$800 to \$3000
<u>Retrofit cost</u> (shaft size 1" to 3")	\$3000 to \$3500
<u>Annual cost</u> to replace seals every two years (shaft size 1" to 3")	\$1300 to \$2700

The costs vary with the shaft size over the range indicated.

##### B. Compressor Seals--

1. Centrifugal--Centrifugal compressors may be equipped with oil seals which collect hydrocarbon emissions. The oil is processed by a system which reclaims the product collected in the oil. The 1976 costs for an oil seal system on a compressor between 1500 and 10,000 HP, based on the EPA data from industry, is as follows:

KVB 5804-714

<u>New compressor cost including oil system</u>	\$700,000
<u>Retrofit cost</u>	\$150,000
<u>Annual cost</u>	\$ 45,000

2. Reciprocating compressors--Reciprocating compressors may be equipped with labyrinth type mechanical seals. An estimate of costs for a double labyrinth seal compressors in the size range of 50 to 1500 HP is as follows:

<u>New compressor</u>	\$50,000 to \$500,000
<u>Extra cost for double labyrinth seal</u>	\$1,000 to \$8,000
<u>Retrofit cost</u>	\$25,000 to \$250,000 (up to cost of new unit)
<u>Annual cost</u>	\$7,000 to \$80,000

These and other miscellaneous refinery costs should be published by the EPA in a report entitled "Control of Hydrocarbon Emissions from Miscellaneous Refinery Sources."

REFERENCES FOR SECTION 4.0

- 4-1. Package Sorption Systems Study, MSA Corporation, Evans City, PA, Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC under Contract EHSD 71-2, Publication No. EPA R2-73-202, April 1973.
- 4-2. U. S. Environmental Protection Agency, "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface-Coating Operations," EPA 450/2-76-028, November 1976.
- 4-3. Rolke, R. W., et al., "Afterburner Systems Study," Shell Development Company, Emeryville, CA, Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC under Contract No. ESHD 71-3, Publication No. EPA-R2-72-062, August 1972.
- 4-4. U. S. Department of Health, Education and Welfare, National Air Pollution Control Administration, Washington, D.C., "Control Technology for Hydrocarbons and Organic Solvent Emissions from Stationary Sources," Publication No. AP-68, March 1970.
- 4-5. American Petroleum Institute, "Hydrocarbon Emissions from Refineries," API Bulletin 928, 1973.
- 4-6. U. S. Environmental Protection Agency, "Evaluation of Methods for Measuring and Controlling Hydrocarbon Emissions from Petroleum Storage Tanks," EPA 450/3-76-036, November 1976.
- 4-7. Western Oil and Gas Association, "Hydrocarbon Emissions from Floating Roof Petroleum Tanks," January 1977.
- 4-8. Chicago Bridge and Iron Co., "Western Oil and Gas Association Metallic Sealing Ring Emission Test Program," Supplementary Report, June 30, 1971.
- 4-9. American Petroleum Institute, "Evaporation Loss from Floating Roof Tanks," API 2517, February 1962.
- 4-10. U.S. Environmental Protection Agency, "A Study of Vapor Control Methods for Gasoline Marketing Operation, Vol. I," EPA 450/3/75-046a, PB 246 088, April 1975.
- 4-11. American Petroleum Institute, "Use of Variable-Vapor-Space Systems to Reduce Evaporation Loss," API 2520, September 1964.
- 4-12. Wildman, G. C. and Buřkin, B. G., "Waterborne's Position in the Spectrum of Industrial Coatings: Comparison to Solvent Types and Availability," American Paint and Coatings Journal, p. 18-22 and 56-59, July 14, 1975.

KVB 5804-714

- 4-13. Anisfield, J., "Powder's Competition," Canadian Paint and Finishing, December 1974.
- 4-14. "Electroless Electrocoat" now in Production at Chrysler, Industrial Finishing, 51(10):72, October 1975.
- 4-15. Schrantz, Joe, "How Autodeposited Coating Benefits Chrysler," Industrial Finishing 51(11):14-22, November 1975.
- 4-16. "Coil Coaters Discuss Anti-Pollution Systems," Industrial Finishing, 49(7): 48-54, July 1973.
- 4-17. Miller, E. P. and Taft, D. D., "Fundamentals of Powder Coating," Society of Manufacturing Engineers, Dearborn, MI, 1974.
- 4-18. Miller, B. C. and Yoder, P. H., "Hot Melt Coatings," in Industrial and Specialty Papers, Volume I - Technology, Mosher, R. H. and D. Davis (eds.), NY, Chemical Publishing Co., 1968.
- 4-19. Reichner, R. F., "Extrusion Coating," in 1973-1974 Modern Plastics Encyclopeddia, NY, McGraw-Hill, Inc., p. 315-320, 1974.
- 4-20. Roberts, A. G., "Organic Coatings, Properties, Selection and Uses," U. S. Department of Commerce, National Bureau of Standards, Washington, D.C., February 1968.
- 4-21. Poll, G. H., Jr. (ed.), "Electrostatic Spraying of Water-Borne Paints," Products Finishing, 40(4): 34-41, p. 34-41, January 1976.
- 4-22. Berbeco, G. R. and Nablo, S. V., "Electron Beam Curing," Paint and Varnish Production, 64(9): 39-42, August 1974.
- 4-23. Hoffman, C. R., "Electron Beam Curing a Non-Polluting System," High Voltage Engineering Corporation, Burlington, Mass.
- 4-24. Miranda, T. J. and Huemmer, T. F., "Radiation Curing of Coatings," Journal of Paint Technology, 41(429): 118-128, February 1969.
- 4-25. Rybny, C. B., et al., "Ultraviolet Radiation Cured Coating," Journal of Paint Technology, 46(596): 60-69, September 1976.
- 4-26. Billmeyer, F. W., Jr., Textbook of Polymer Science, Interscience Publishers of John Wiley and Sons, NY, March 1966.
- 4-27. "Radiation Curing Goes Begging for Coaters," Iron Age, p. 43-52, August 18, 1975.
- 4-28. Shahidi, J. K., et al., "Multifunctional Monomers for UV Cure," Paint and Varnish Production, August 1974.

KVB 5804-714

- 4-29. Private communication, Dr. Donald Rosebrook, Radian, Inc., Austin, Texas, Program Manager of EPA refinery emissions investigation.
- 4-30. Private communication, Dr. Kyle Charleton, Rockwell Air Monitoring Center, Newberry Park, Calif., Program Manager of API oil production emissions program.
- 4-31. U. S. Environmental Protection Agency, "Revision of Evaporative Hydrocarbon Emission Factors," EPA Report No. 450/3-76-039, August 1976.
- 4-32. Joint District, Federal, and State Project for the Evaluation of Refinery Emissions, "Emissions to the Atmosphere from Eight Miscellaneous Sources in Oil Refineries, Report No. 8, June 1958.
- 4-33. U.S. Environmental Protection Agency, "Guidelines for Control of Volatile Organic Emissions from Existing Stationary Sources, Vol. II - Coating of Auto and Light Trucks, etc.," EPA-450/2-77-008, May 1977.
- 4-34. Gallagher, V., Environmental Protection Agency, Research Triangle Park, NC, reports of trips to various can coating facilities in 1975 and 1976.
- 4-35. Read, R. T., "Recent Developments in Protective Finishes for Metal Containers, Part I: Internal Organic Coatings," Oil Colour and Chemists Association 58: 51-56, 1975.
- 4-36. National Coil Coaters Association, "National Coil Coaters Association Fact Sheet 1974," Philadelphia, PA.
- 4-37. Scott Research Laboratories, Inc., "A Study of Gaseous Emissions from the Coil Coating Processes: Volume II - Survey Results," Prepared for the National Coil Coaters Association, March 1971.
- 4-38. "An Answer to Road Salt Corrosion," Products Finishing, p. 165, November 1974.
- 4-39. Mosher, R. H. and Davis, D., Industrial and Specialty Papers, Volume I - Technology, Chemical Publishing Co., NY, 1968.
- 4-40. "Industrial Ovens and Driers," Handbook of Industrial Loss Prevention, McGraw-Hill Book Co., Hightstown, NJ, 1967.
- 4-41. Smith, J. C., "Coating of Textiles," The Shirley Link, The Shirley Institute, England, p 23-27.
- 4-42. Johnson, W. L., U. S. Environmental Protection Agency, Trip Report--Tuck Industries, Beacon, NY, December 2, 1975.
- 4-43. Darwin, C., U. S. Environmental Protection Agency, Trip Report--Alden Rubber Co., Philadelphia, PA, January 26, 1976.

KVB 5804-714

- 4-44. Air Pollution Engineering Manual, U. S. Environmental Protection Agency, Research Triangle Park, NC, Publication No. AP-40, p. 866.
- 4-45. "Solvent Recovery System Saves \$39,000 First Year," Air Eng. 10:31, April 1968.
- 4-46. Sandomirsky, A. G., et al., "Fume Control in Rubber Processing by Direct-Flame Incineration," J. Air Pollution Control Assoc. 16:673-676, December 1966.
- 4-47. Metals Handbook, Vol. 2, 8th edition, The American Society of Metals, Cleveland, Ohio, 1964.
- 4-48. Alexandria, Lorenzo, "Investigation of Emission of Volatile Organic Material from Pesticide Application," San Diego APCD, Inter-Dept. Correspondence, Sept. 23, 1975.
- 4-49. Low, Dr. Edward, Research Professor, University of Georgia, Reported in an article by Evan Powell, "Electrostatic Sprayer Reduces Pesticide in Crops," Popular Science, April 1977.
- 4-50. Pesticide Use Report by Commodity, State of California, 1974.
- 4-51. Weekley, G. H., Jr. and Sheehan, J. R., "Jet Compressors Recover Waste Gases," Hydrocarbon Processing, 45:165-170, October 1966.
- 4-52. Ross, R. D. and Hulswitt, C. E., "Safe Disposal of Chlorinated and Fluorinated Waste Materials," Paper No. 69-114, Presented at 62nd Air Pollution Control Association Meeting, New York, June 22-26, 1969.
- 4-53. Barnes, T. M., et al., "Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke," Battelle Memorial Institute, Columbus, Ohio, PB 189 266, Jan. 1970.
- 4-54. California Air Resources Board, "Coke Oven Emissions, Misc. Emissions, and their Control at Kaiser Steel Corp.'s Fontana Steel Making Facility," Report L&E-76-11, Nov. 1976.
- 4-55. Environmental Protection Agency, "Background Information for Proposed New Source Performance Standards: ...Iron & Steel Plants, Brass or Bronze Ingot Production Plants... etc.", PB 221 736, June 1973.
- 4-56. Keller, R. M., Midwest Research Institute, private communication, July 26, 1977.
- 4-57. Puzinauskas, V. P., and Corbett, L. W., "Report on Emissions from Asphalt Hot Mixes," The Asphalt Institute, College Park, Md., May 1975.

KVB 5804-714

- 4-58. Phone conversation with T. Cannon, Vic Manufacturing Company, 1620 Central, Minneapolis, MN
- 4-59. C-E Air Preheater, "Report of Fuel Requirements, Capital Cost and Operating Expense for Catalytic and Thermal Afterburners," Contract No. 68-02-1473, Task 13, Wellsville, NY.
- 4-60. Burklin, C. E. et al., "A Study of Vapor Control Methods for Gasoline Marketing Operation, Vol. I," EPA Report 450/3-75-046a, April 1976.
- 4-61. EPA Office of Air Quality and Standards, "Emission Reduction of Solvent Degreasers," Advanced Copy.
- 4-62. McIlvaine Co., The McIlvane Scrubber Manual, Volume III, Chapter XI, Northbrook, IL.
- 4-63. "Systems and Costs to Control Hydrocarbon Emissions from Stationary Sources," EPA 450/2-74-006, NTIS PB 236 921, Sept. 1974.
- 4-64. EPA Office of Air Quality, Planning and Standards, "An Investigation of the Best Systems of Emission Reduction for the Dry Cleaning Industry," July 1976.
- 4-65. Private communication with Mr. Richard A. Schippers, EPA Office of Air Quality, Planning and Standards, Economic Analysis Branch, September 1, 1977..

KVB 5804-714

## SECTION 5.0

### ANTHROPOGENIC EMISSION FORECAST

With the inventory results presented in Section 2.4 as a baseline, a ten-year forecast was made of the stationary source anthropogenic emissions. The forecast was based on the industry growth projections prepared by the ARB (Ref. 5-1) and some unpublished projections provided by SCAG (Ref. 5-2). Table 5-1 summarizes the projection calculations. The 1975-76 emissions come from Table 2-40. The industrial growth factor was based on the projections in the above references. A weighted average of the various county growth factors was determined. Weighting was distributed according to the point source emissions, which emphasize emissions in LA County. The general industrial growth is 3%/year. Combustion of fuel was projected at a lower rate because of natural gas curtailment and because of the anticipated requirements for adding sulfur dioxide scrubbers on oil-fired units. Probably no additional utility boilers will be built in the Basin and the numbers of new industrial boilers will be few. Also since the population in the Basin is projected to increase 10 to 15% (mostly in counties other than LA), there will be some increase in domestic fuel consumption.

The projections of emission reductions due to controls was based on the impetus provided by the Clean Air Act as amended in 1977. This requires each state and air quality control region to implement a plan to achieve the national ambient air quality standards for oxidant by 1987.

An estimated 80 to 85% reduction for petroleum sources is based on recent ARB/AQMC/APCD efforts to control pipeline and storage tank leakage. Improved valve maintenance and retrofit double seals on floating roof tanks is predicted.

Combustion of fuels offers little potential for organic emission reductions. In most instances, the organic emission concentration is of the order of 1 to 10 ppm. There are no practical methods to reduce emissions at this level. Only in the case of poorly maintained combustion devices, some

significant improvement may be made. Some of these maintenance improvements, which will be made, account for the 5% reduction estimate. The surface coating reduction of 75% is attributed to improved controls on industrial operations, the changing to water-borne paints, etc. However, recognition is given to the continued use of solvent based paints for repainting operations as well as for numerous specialized commercial and domestic painting applications.

The dry cleaning reduction of 40% may seem low; although exhaust emission can be controlled to better than 99%, many of the emissions are fugitive. Solvent, which adheres to the cleaned clothes, eventually evaporates.

The reduction of methane emission can be accomplished by preventing leaks (of all types.) Other control techniques like adsorption or incineration are not very effective for abating methane emissions. Therefore, the 50% reduction of methane emissions was assumed for petroleum sources due to improved maintenance practices reducing leaks.

The projected emissions are a simple calculation of baseline emissions  $\times (1 + \text{projected growth}) \times (1 - \text{control efficiency})$ . The results are tabulated in Table 5-1. Figure 5-1 shows a plot and summary of the emissions projected for the next ten years. The percent reductions at the end of the ten years are summarized on the figure.

TABLE 5-1. STATIONARY SOURCES IN THE SOUTH COAST AIR BASIN  
 ANTHROPOGENIC EMISSIONS PROJECTION  
 1976-1986

Application Categories	1975-76 Emissions, Ton/Day		Projected In- dustry Growth By 1986 %	Aver. Control Ef- ficiency by 1986 % Reduction		Projected Emissions Ton/Day	
	Nonmethane	Methane		Nonmethane	Methane	Nonmethane	Methane
Petroleum Production	56	38	6	85	50	11	20
Petroleum Refining	107	8	20	85	50	19	5
Petroleum Marketing	110	80	0	80	50	22	40
Surface Coating	115	8	30	75	25	38	8
Dry Cleaning	38	0	0	40	---	22	0
Degreasing	33	0	30	80	---	8	0
Other	18	1	30	90	---	2	1
Chemical	4	0	50	85	---	1	0
Metallurgical	1	1	15	50	---	1	1
Mineral	1	0	10	90	---	0	0
Waste Burning	0	1	0	40	---	0	1
Combustion of Fuel	12	4	6	5	---	12	4
Food & Agriculture	1	0.4	15	80	---	0	0
Pesticide	15	0.4	10	50	---	8	0
Misc. Industrial	1	11	30	90	---	0	1
	510	150				150	80

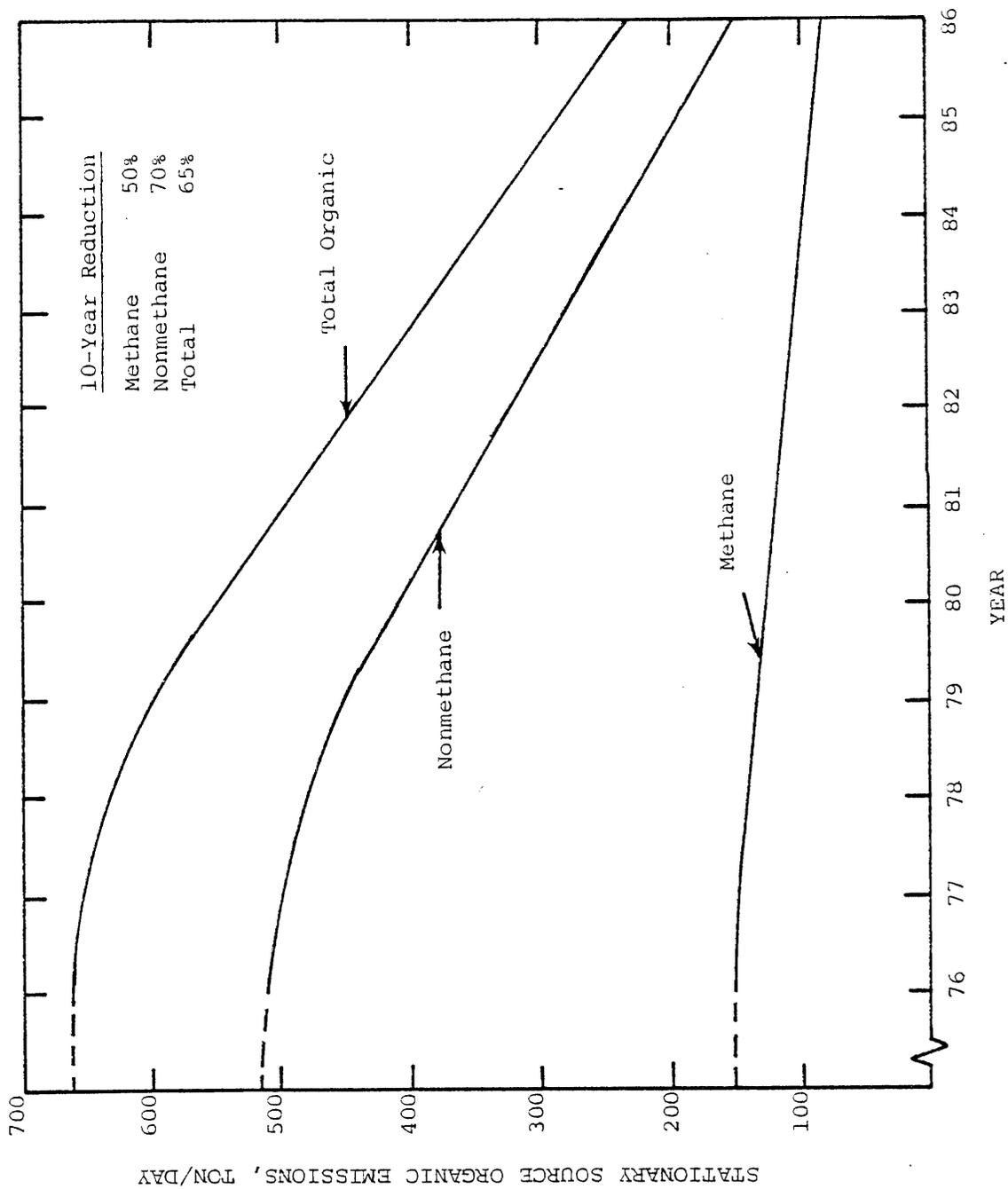


Figure 5-1. Anthropogenic stationary source organic emissions projection, 1976-1986.

REFERENCES FOR SECTION 5.0

- 5-1. "Emissions and Air Quality Assessment," California Air Resources Board Technical Resources Unit/Land Use Planning Program Evaluation and Planning, Sacramento, CA, April 1976, Appendix B.
- 5-2. Sherwood, A., Letter to Tim Sonnichsen of KVB, Inc., July 19, 1977. Enclosing production indices and gross product projections by county.



## SECTION 6.0

### ABBREVIATION LIST

ACFM	- Actual Cubic Feet per Minute
AP-42	- Emission Factor Publication (see Reference 2.3)
APCD	- Air Pollution Control District
API	- American Petroleum Institute
AQCR	- Air Quality Control Region
ARB	- California Air Resources Board
ARCO	- Atlantic Richfield Corporation
ARLI	- Analytical Research Laboratories, Inc. of Monrovia, CA
AV	- AeroVironment, Inc. of Pasadena, CA (consultants)
AVQUAL	- Designation given to a plume dispersion model
C2, C3, etc.	- General hydrocarbon formula (aliphatic) indicating number of carbon atoms in the molecule
CARB	- California Air Resources Board (usually just ARB)
CEC	- Consolidated Electrodynamics Corp.
EIS/P&R	- Emission Inventory Subsystem/Permit and Registration
EPA	- Environmental Protection Agency
ESS	- Eco Science System, Riverside, CA (consultants)
FCC	- Fluidized-bed Catalytic Cracker, refining equipment
FID	- Flame Ionization Detector
FM	- Fire Marshall (as in FM approved)
GC	- Gas Chromatograph
GC/FID	- Gas Chromatograph with a Flame Ionization Detector
GC/MS	- Gas Chromatography/Mass Spectrometry
GM	- General Motors
HC	- Hydrocarbon
HP	- Horsepower
IBM	- International Business Machines
IC	- Internal Combustion
ID	- Identification
LA	- Los Angeles
LEL	- Lower Explosion Limit
M.E.K.	- Methyl Ethyl Ketone
MIBK	- Methyl Isobutyl Ketone
MMBtu	- Million British Thermal Units
M.W.	- Molecular Weight
Mwt	- Molecular Weight
NBS	- National Bureau of Standards
NC	- No (emission) Control

Continued

ABBREVIATION LIST (continued)

OPR	- California Governor's Office of Planning and Research
PD	- Positive Displacement
ppm	- Parts per Million
P/V	- Pressure/Volume
PVC	- Polyvinyl Chloride
QC	- Quality Control
RETA	- Ryckman, Edgerley, Tomlinson & Associates, Consultants in St. Louis, MO
RVP	- Reid Vapor Pressure
SAROAD	- Storage and Retrieval of Aerometric Data (A Coding System for Aerometric Data)
SBAPCD	- Santa Barbara Air Pollution Control District
SCAB	- South Coast Air Basin (often just Basin)
SCAG	- Southern California Association of Governments
SCAPCD	- Southern California Air Pollution Control District (predecessor to SCAQMD)
SCAQMD	- South Coast Air Quality Maintenance District
SCC	- Source Classification Code
SDAPCD	- San Diego Air Pollution Control District
SIC	- Standard Industrial Code
SKC	- SKC, West Fullerton, CA (Chemical Equipment Supplies)
SOHIO	- Standard Oil of Ohio
TLV	- Total Level; Designation for Bacharach Total Hydrocarbon Sniffer
TOC	- Total Organic Content
UCR	- University of California at Riverside
UTM	- Universal Transverse Mercator
UV/VIS	- Ultraviolet, Visual Range
VAPCD	- Ventura Air Pollution Control District
VW	- Volkswagen
WOGA	- Western Oil and Gas Association
XAD-2	- Designation for a sorbent material, i.e., chromasorb XAD-2