

Lilly RACT Enclosures

Ex. 1

ELI LILLY AND COMPANY
LILLY TECHNOLOGY CENTER
INDIANAPOLIS, INDIANA
BUILDING 110

Summary Description

Eli Lilly and Company (Lilly) is a research based corporation which develops, manufactures, and markets human and animal medicines. As a research company, one of its most important functions is to conduct research and development of new pharmaceutical products. Building 110, located at Lilly Technology Center in Indianapolis, contains the Chemical Process Research and Development Pilot Plant. It has two purposes: to produce pharmaceutical and animal health products for toxicological studies and clinical trials, and to conduct process development and scale-up of chemical synthesis. B110 is an existing pilot plant which is currently subject to a site specific RACT plan issued by IDEM on July 27, 1994 and modified on February 20, 1996.

Lilly proposes to install four additional portable tanks in B110. Lilly is submitting this permit application to obtain a federally enforceable construction permit which authorizes the equipment listed in this application to operate under the site-specific B110 RACT plan, and thereby exempting it from the requirements of 326 IAC 8-5-3(b)(1). The equipment listed in this permit application is potentially subject to the requirements of 328 IAC 8-5-3, the synthesized pharmaceutical manufacturing RACT rule, since the B110 equipment is capable of emitting on any given day more the 15 lbs/day of VOC emissions. The additional B110 equipment will not increase the building allowable emissions of 19.01 tons/year.

PROCESS DESCRIPTION

The Building 110 pilot plant is used primarily for developing chemical processes for pharmaceutical products, and for producing small quantities of pharmaceutical compounds used in toxicology studies and clinical trials research.

Typical pharmaceutical processes begin with a chemical reaction, followed by various unit operations such as extraction, distillation, crystallization, filtration and drying. Major process equipment used in the pilot plant includes reactor vessels, dryers, filters/centrifuges, and portable tanks in various combinations.

PROCESS EQUIPMENT

A pilot plant, by nature, is a dynamic facility. It must be multipurpose to meet changing research and development activities. Building 110 utilizes stationary and portable, non-dedicated equipment for the numerous batch operations it performs.

Lilly is submitting this permit application to obtain a federally enforceable construction permit which authorizes the equipment listed in this application to operate under the site-specific B110 RACT plan. Table 1 lists the tanks covered by this permit application. Each tank has a potential to emit of 15 pounds/day or more.

TABLE 1: EQUIPMENT LIST

UNIT DESCRIPTION	WING/MODULE	EQUIPMENT NUMBER
16 Gallon Hastelloy Tank	Portable	PH9124
16 Gallon Hastelloy Tank	Portable	PH9125
16 Gallon Hastelloy Tank	Portable	PH9126
16 Gallon Hastelloy Tank	Portable	PH9127

EMISSION CONTROLS

The site-specific B110 RACT plan will exempt the equipment from the requirements of 326 IAC 8-5-3(b)(1). Building 110 will comply with the other emission control requirements of 326 IAC 8-5-3. The emission control devices and work practices used to reduce VOC emissions are described on pages 61 through 63 and summarized in Table 11.1 on page 73 of the revised petition for a site-specific RACT plan. Appendix A contains the revised petition for a site-specific RACT plan submitted on December 9, 1993.

EMISSION ESTIMATES

Lilly is submitting this construction permit application to include additional equipment in the B110 site-specific RACT plan without increasing the building emission limit of 19.01 tons/year. Although Building 110 processes are on pilot scale with capacities significantly less than commercial pharmaceutical production facilities, volatile organic compound (VOC) emissions can exceed the de minimis level in 326 IAC 8-5-3 (15 lbs/day).

In general, the emissions calculated for this facility in the B110 site-specific RACT plan are based on historical mass balance analysis and calculations. Pages 42 through 48 of the revised petition for a site-specific RACT plan describes the general method used to estimate pre-control potential VOC emission from the Building. The new equipment will not increase reactor capacity, and therefore has no effect on the potential to emit totals for the building. The HAP potential to emit will also not be effected, and therefore, forms Y1 - Y5 (air toxic pollutants) have not been submitted with this application.

RULES COMPLIANCE SUMMARY

Building 110 equipment will be exempted from the requirements of 326 IAC 8-5-3(b)(1) with federally enforceable permit conditions which authorize Building 110 to operate under the site-specific RACT plan.

The addition of equipment in Building 110 will not increase the building allowable emissions of 19.01 tons/year. Thus, the facility is not subject to the requirements of 326 IAC 2.2 Prevention of Significant Deterioration.

The product of this plant is not listed as a Synthetic Organic Chemical under 40 CFR Parts 60, New Source Performance Standards.

None of the materials or processes used at this facility is listed under 40 CFR Part 61 and Part 63, National Emissions Standards for Hazardous Air Pollutants

ELI LILLY AND COMPANY
LILLY TECHNOLOGY CENTER-SOUTH
INDIANAPOLIS, INDIANA

BUILDING 110

APPENDIX A

PETITION FOR A SITE-SPECIFIC RACT PLAN
DECEMBER 9, 1993



Eli Lilly and Company

Lilly Corporate Center
Indianapolis, Indiana 46285
(317) 276-2000

December 9, 1993

Mr. Trip Sinha
Office of Air Management
Indiana Department of Environmental Management
100 North Senate Avenue
PO Box 6015
Indianapolis, Indiana 46206

Re: Eli Lilly and Company
Building 110 Site-Specific RACT Plan
Additional Information and Revisions

Dear Mr. Sinha:

Based on the questions you have posed and the information you have requested, Eli Lilly and Company (Lilly) is submitting a revision to the Petition for a Site-Specific RACT Plan that Lilly submitted on September 23, 1993. Included with this letter are three copies of the revised petition. Please note that this submittal replaces the original petition rather than serving as a supplement. Most of the information in this submittal, however, is identical to the September 23rd Petition. For your convenience, I have noted the revised portions of the petition with flags and highlighter.

Also included in this submittal is a list of all portable and stationary emitting equipment in both the existing Building 110 and the proposed expansion to Building 110. The list includes an estimate of *potential uncontrolled* VOC emissions (in lb/day) from each piece of equipment. If the *potential uncontrolled* emissions from any one piece of equipment could be greater than 15 lb/day (due to the nature of batch operations), the emissions are being stated as ">15 lb/day". In general, most equipment in Building 110 could possibly emit more than 15 lb/day of VOC on any given day.

The petition has been revised to address the following issues:

1. The September 23rd petition did not include an analysis of the costs of meeting the CTG RACT requirements found in 326 IAC 8-5-3(b)(1) for centrifuges (use of vent condensers that achieve a -25 degree C outlet gas temperature). There will be one centrifuge in all of Building 110. Because the unit is portable, it could be used for liquid/solids separation in any of the modules in Building 110. The revised Petition shows that compliance with the portion of the CTG RACT requiring vent condensers for centrifuges is not cost-effective, nor is any other control strategy. The proposed RACT for centrifuges in Building 110, therefore, is no controls. The centrifuge, however, is a closed unit and will comply with 326 IAC 8-5-3(b)(4).
2. The September 23rd petition did not include an analysis of the costs of meeting the CTG RACT requirements found in 326 IAC 8-5-3(b)(2)(B) for filters (reduce emissions to less than 33 lb/day if the filter is equipped with "production equipment exhaust systems"). Filter emissions in Building 110 occur through two routes. First, when the solvent liquid is separated from the solid material, the filtrate is sent to a receiving vessel (reactor tank). Any VOC fumes would exit the system through the reactor vent. As noted in the petition, compliance with 326 IAC 8-5-3 for reactors is not cost-effective. The reactors, however, will

be equipped with primary condensers that operate with a -10 degree C cooling medium (when freezing of the condensate is not a concern).

The second source of filter emissions is when the filter is opened to remove the filter cake for placement in the dryer. The filter is opened under a walk-in hood. This hood is considered a "production equipment exhaust system", and 326 IAC 8-5-3(b)(2)(B) limits VOC emissions to 33 lb/day. 326 IAC 8-5-3(b)(2), however, allows the commissioner to waive this requirement if the owner can show that meeting the 33 lb/day emission rate is not practical because of dilution of the exhaust gas with large quantities of air. The walk-in hoods operate with a high face velocity to remove fumes away from the work area when the filter is opened. The result is a dilute concentration of VOC fumes in an exhaust system designed to operate at 4000 cfm and measured at 3800 cfm. Because of the high air flow and low solvent concentrations associated with the exhaust system, controls for this system would be less cost-effective than CTG RACT level controls on equipment such as reactors which operate at a much lower air flow rate and with a saturated exhaust and which were already shown not to be cost-effective.

Therefore, no controls are proposed as RACT for the production equipment exhaust systems. The filters are, however, closed units and will comply with 326 IAC 8-5-3(b)(4).

3. The September 23rd petition stated that the emissions from dryers located in the C-Wing expansion were *deminimis*. Upon closer examination, Lilly estimates that one of the dryers in C-Wing, the rotary vacuum dryer, has *potential uncontrolled* VOC emissions greater than 15 lb/day. The revision includes new emission estimates for the dryers in C-Wing – the emissions for these dryers are now calculated using the same methodology as in the other modules (based on reactor capacity). The total emissions from C-Wing sources does not increase from 1.94 ton/yr; only the allocation of the total emissions among the equipment has changed.
4. Also included in this revised petition (in Sections 11.5.2 and 11.6.2) are descriptions of the impact of the costs of the proposed RACT and the CTG RACT on Lilly. These elements are required by 326 IAC 8-1-5 and were mistakenly omitted from the September 23rd submittal.

If you have any questions or comments about this submittal, please call me at 278-0331.

Sincerely,



Bernie Paul
Technical Group Leader
Environmental Affairs Division

Attachments

cc: Paul Dubenetzkyy w/o attachments

**Petition for a Site-Specific
Reasonably Available Control
Technology Plan**

*Eli Lilly and Company
Lilly Technology Center - South
Building 110 Chemical Process Research and Process
Development Pilot Plant*

ERM-Midwest, Inc.
307 N. Hurstbourne Parkway, Suite 250
Louisville, Kentucky 40222

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Petition for a Site-Specific Reasonably Available Control Technology Plan

*Eli Lilly and Company
Lilly Technology Center - South
Building 110 Chemical Process Research and Process
Development Pilot Plant*

November 29, 1993

ERM-Midwest, Inc.
307 N. Hurstbourne Parkway, Suite 250
Louisville, Kentucky 40222

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(IDEM) OZONE MAINTENANCE PLAN*

EXECUTIVE SUMMARY

Eli Lilly and Company (Lilly) is submitting this petition to propose site-specific volatile organic compound (VOC) Reasonably Available Control Technology (RACT) for its Building 110 pilot plant located at the Lilly Technology Center-South in Indianapolis. This document demonstrates that the generalized guidelines described in the USEPA's Control Technology Guideline (CTG) *Control of Volatile Organic Emissions from Synthesized Pharmaceutical Products*, December 1978, and 326 IAC 8-5-3 (b)(1) are not RACT for Building 110.

Building 110 currently consists of six batch pilot production areas or 'modules'. A proposed expansion will increase the number of modules to nine. Pilot production modules are used primarily for development of chemical processes for the manufacture of small quantities of pharmaceutical compounds used in toxicological studies and clinical trial research.

Building 110 facilities are smaller and more flexible operations than those found at commercial pharmaceutical manufacturing plants. Process equipment capacities and batch sizes are much smaller and product mix and process variability is much greater.

Although Building 110 process capacities are significantly less than commercial pharmaceutical production facilities, VOC emissions can exceed *de minimis* levels in 326 IAC 8-5-3 (15 lb/day). Based on potential to emit, existing and proposed Building 110 emissions sources are subject to RACT requirements. Generalized RACT requirements, as outlined in the USEPA's CTG, appear in 326 IAC 8-5-3 of the Indiana SIP.

USEPA CTG states that, "control requirements be imposed after considering local air quality, the mass rate of emissions, control cost estimates, and plant safety effects." The USEPA CTG lists generalized control program guidelines if the above approach is not practical. CTG generalized guidelines apply to reactors, centrifuges, filters, vacuum dryers, air dryers, storage tanks, process tanks, and equipment leaks.

326 IAC 8-1-5 allows an owner or operator of a source to satisfy RACT requirements by either:

- implementing generalized CTG guidelines as described in 326 IAC 8-5-3, or
- submitting a petition to the commissioner requesting a site-specific RACT plan.

Due to relatively low emissions from Building 110 pilot equipment, the general guidelines have been determined not to be RACT for Building 110. Therefore this petition for an alternative RACT plan is being submitted.

The USEPA CTG describes RACT as follows:

"RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility."

To determine RACT, the technical feasibility of applying condensation, incineration, flares, absorption (scrubbing), carbon adsorption, and carbon adsorption/oxidation control technologies to Building 110 emissions streams was evaluated. Only scrubbing and condensation were determined to be technically feasible.

The economic feasibility of condensation and scrubbing control technologies were evaluated using guidelines in the USEPA's *Control Technologies for Hazardous Air Pollutants*, June 1991. Because of the relatively small emissions from pilot-scale equipment, neither control technology was considered economically feasible. The cost effectiveness of adding condensation VOC controls to a pilot production module ranged from \$15,500 to \$191,900 per ton VOC removed. The cost effectiveness of adding scrubbing VOC controls ranged from \$20,100 to \$249,800 per ton VOC removed.

Based on the Indiana permitting experience of two ERM-Midwest employees, Timothy Jones and David Jordan, VOC RACT is considered to be between \$2,000 and \$5,000 per ton controlled; VOC BACT cost effectiveness is considered to be between \$5,000 and \$12,000 per ton controlled. The cost effectiveness for condensation and scrubbing far exceed what is widely accepted as VOC RACT. Furthermore, the cost effectiveness of condensation and scrubbing exceed BACT (more stringent than RACT) thresholds.

In lieu of complying with the RACT requirements of 326 IAC 8-5-3, Lilly proposes the following control strategy as an alternative RACT plan:

- 1) Building 110 will comply with the requirements of 326 IAC 8-5-3 (b)(2) through (b)(6).
- 2) As an alternative to complying with the vent condenser requirements of 326 IAC 8-5-3 (b)(1), Building 110 will utilize primary condensers on process reactors to reduce emissions.

Total pre-control VOC emissions from existing and proposed Building 110 sources are estimated to be 29.34 TPY. The site-specific RACT proposed for Building 110 would reduce VOC emissions by 10.61 TPY VOC; applying generalized RACT guidelines in 326 IAC 8-5-3 would reduce emissions by 17.23 TPY. The incremental cost effectiveness of applying generalized CTG RACT over the proposed RACT is \$88,735/ton VOC removed.

The proposed RACT for Building 110 will not significantly affect Marion County's ability to attain and maintain compliance with the NAAQs for ozone. Building 110 comprises only a small portion of the Marion County VOC emissions inventory. The difference between the proposed RACT and the CTG RACT (0.018 actual tons/day) is 0.009% of 1990 base year VOC emissions of 204.633 tons/day, 0.010% of the Marion County Draft Maintenance Plan projected 2006 VOC emission target of 175.496 tons/day, and 0.057% of the projected point source total by the year 2006 of 31.256 tons/day. The difference also would account for 0.352% of projected point source emissions growth from the Draft Maintenance Plan of 5.063 tons/day.

Given the small relative share of the attainment plan targeted emission level for VOCs in Marion County, it is not expected that approval of a SIP revision for this site-specific RACT will generate any significant impacts that would interfere with attainment or maintenance of the ozone NAAQS.

This petition contains the required elements of a site-specific RACT plan as described in 326 IAC 8-1-5. An 326 IAC 8-5-1 compliance demonstration is contained in Section 11 of this petition.

Eli Lilly and Company (Lilly) is a research-based corporation which develops, manufactures and markets human medicines, agricultural products, medical instrument systems and diagnostic products. As a research company, one of its most important functions is to conduct research and development of new pharmaceutical products.

Research and development in the pharmaceutical industry is a lengthy and financially risky process. On average, it takes ten years from the time a compound is identified as a potential medicine to bring it to the market for sale. Moreover, only 1 in 10,000 compounds receive Food and Drug Administration (FDA) approval and make a profit for the company.

After research scientists identify a chemical compound for its potential therapeutic value, the company must develop the manufacturing process for the compound. The first attempts at synthesizing a compound occur in laboratories. After potential routes for synthesizing the chemical have been identified, development of the process shifts to process development facilities also known as pilot plants.

At a typical pilot plant, the goal of the chemists and engineers conducting the process development is to devise a process which delivers the highest yield of the compound in the most cost effective manner, while constantly taking into account safety and environmental issues. In a year's time, the researchers may conduct several different trials on hundreds of different compounds. The trials, usually conducted in batches, involve a variety of solvents and equipment, which are difficult to predict.

In addition to process development for new products, pilot plants will also manufacture small quantities of medicines for use in clinical trials. During the clinical trials, hospitals and other medical research organizations test the product for safety and effectiveness in order to obtain approval from the FDA. Sometimes a pilot plant will also manufacture *de minimis* quantities of products intended for commercial sale.

Building 110, located at the Lilly Technology Center - South (LTC-S) at 1555 South Kentucky Avenue in Indianapolis, contains the Chemical Process Research and Development Pilot Plant. It has two purposes: to produce pharmaceuticals and animal health products for toxicological studies and clinical trials and to conduct process development and scale-up of chemical syntheses.

The Indianapolis Air Pollution Control Section (IAPCS) issued a final installation permit for Building 110 on August 7, 1987. The installation permit allowed construction of the following:

- Batch pilot plant Modules A, B, C, and D
- Batch pilot plant 30 Gallon Modules A and B
- Batch pilot plant High Bay Module
- A fluidized bed dryer (since removed)

In addition, IAPCS issued an installation permit on January 2, 1992 for the following Building 110 equipment additions :

- A Zwag portable agitated filter/dryer
- Batch pilot plant Solids Containment Area

These modules are described in greater detail in section 3.0.

The permit established an allowable VOC emission limit of 850 pound/day and 18.9 ton/year. The permit did not require the use of add-on pollution control equipment, nor did it require Lilly to comply with the emission control requirements of the Reasonably Available Control Technology (RACT) Control Technology Guideline (CTG) for synthesized pharmaceutical manufacturing. The requirements of this CTG can be found in Indiana regulations at 326 IAC 8-5-3 and in Indianapolis regulations at Regulation IV-3.7. The facility is subject to those rules.

In February of 1993, Lilly submitted a permit application to the IAPCS for an expansion to Building 110. The expansion includes the following:

- Adding batch pilot plant Modules E and F
- Upgrading the 30 Gallon Modules
- Adding equipment to the C-Wing
- Adding a portable Rosenmund agitated filter/dryer

The IAPCS issued the installation permit for the expansion to Building 110 on July 16, 1993. The permit addressed compliance with the synthesized pharmaceutical manufacturing RACT rule by requiring Lilly to meet one of three conditions:

1. Operating the equipment pursuant to 326 IAC 8-1-1(b), which exempts a source from a RACT rule if its actual emissions from each piece of equipment before add-on controls are less than 15 lb/day and if detailed records of solvent usage and emissions are kept. This condition applied only until either the second or third conditions were met.

2. Complying with the RACT rule through the use of add-on controls required by the rule.
3. Obtaining approval of a Site-Specific RACT Plan pursuant to 326 IAC 8-1-5. The RACT Plan would specify the required controls (if any) based on a detailed analysis of the cost effectiveness of various control options.

Because of the small size of the equipment in a pharmaceutical pilot plant, the highly variable emission rates and the overall low emission rates, the generalized RACT CTG for synthesized pharmaceutical manufacturing does not constitute Reasonably Available Control Technology for the Building 110 pilot processes. In general, the cost-effectiveness of complying with the RACT rule for both the existing Building 110 and the planned expansion far exceeds what is generally accepted as RACT. Therefore, Lilly is submitting, pursuant to 326 IAC 8-1-5, a petition for a Site-Specific RACT Plan for the existing Building 110 and the planned expansion. The remainder of this document provides the detailed elements required by 326 IAC 8-1-5.

This petition is being submitted by:

Mr. Bernard O. Paul
Eli Lilly and Company
Lilly Corporate Center
Indianapolis, Indiana 46285
(317) 276-0331

Signature: Bernard O. Paul
Date: 12/9/93

Lilly is requesting approval of a petition for a Site-Specific Reasonably Available Control Technology Plan for Building 110, the Chemical Process Research and Process Development Pilot Plant. Building 110 is located at the Lilly Technology Center South (LTC-S). A site layout of LTC-S is presented in Figure 2.1. Building 110 is involved in chemical process research and development for pharmaceutical products. Though Building 110 processes are primarily batch, continuous pilot plant operations can also be conducted. Building 110 processes are currently organized into independent pilot processes or 'modules'.

Building 110 pilot processes are used primarily for development of chemical processes for pharmaceutical products manufacture and for production of very small quantities of pharmaceutical compounds used in toxicology studies and clinical trial research. Occasionally Building 110 processes may produce very small quantities of product for commercial sale. The present situation is highly unusual in that product for commercial sale represents approximately 10% of total Building 110 annual production. Under normal operating conditions product for commercial sale represents much less than 10% of Building 110 annual production.

Building 110 currently is divided into four sections:

- The A-Wing contains laboratories.
- The B-Wing is used primarily for material storage.
- The C-Wing is the site of the small amount of continuous process research and development.
- The D-Wing is used for batch process research and development. Existing D-Wing modules are A, B, C, D, two modules referred to as the 30 Gallon Modules, and the Solids Containment Area.

A recently permitted modification would result in construction of two additional modules, E and F, in the D-Wing and equipment additions to C-Wing and 30 Gallon Modules. Additionally, a portable Rosenmund agitated filter will be purchased and utilized where needed in Building 110. The details of the proposed expansion are described in Section 3.0 of this plan.

The Building 110 plot plan is presented in Figure 2.2.

NORTH



LOT 11
VISITOR &
INTERPLANT
PARKING

KENTUCKY AVE.

BLDG. 101
STEEL
WORKS
BUILDING

HARDING STREET

LOT 12

LOT 14

LOT 13

LOT 15

No Scale

RAYMOND STREET

FIGURE 2.1
LTC-S Site Layout

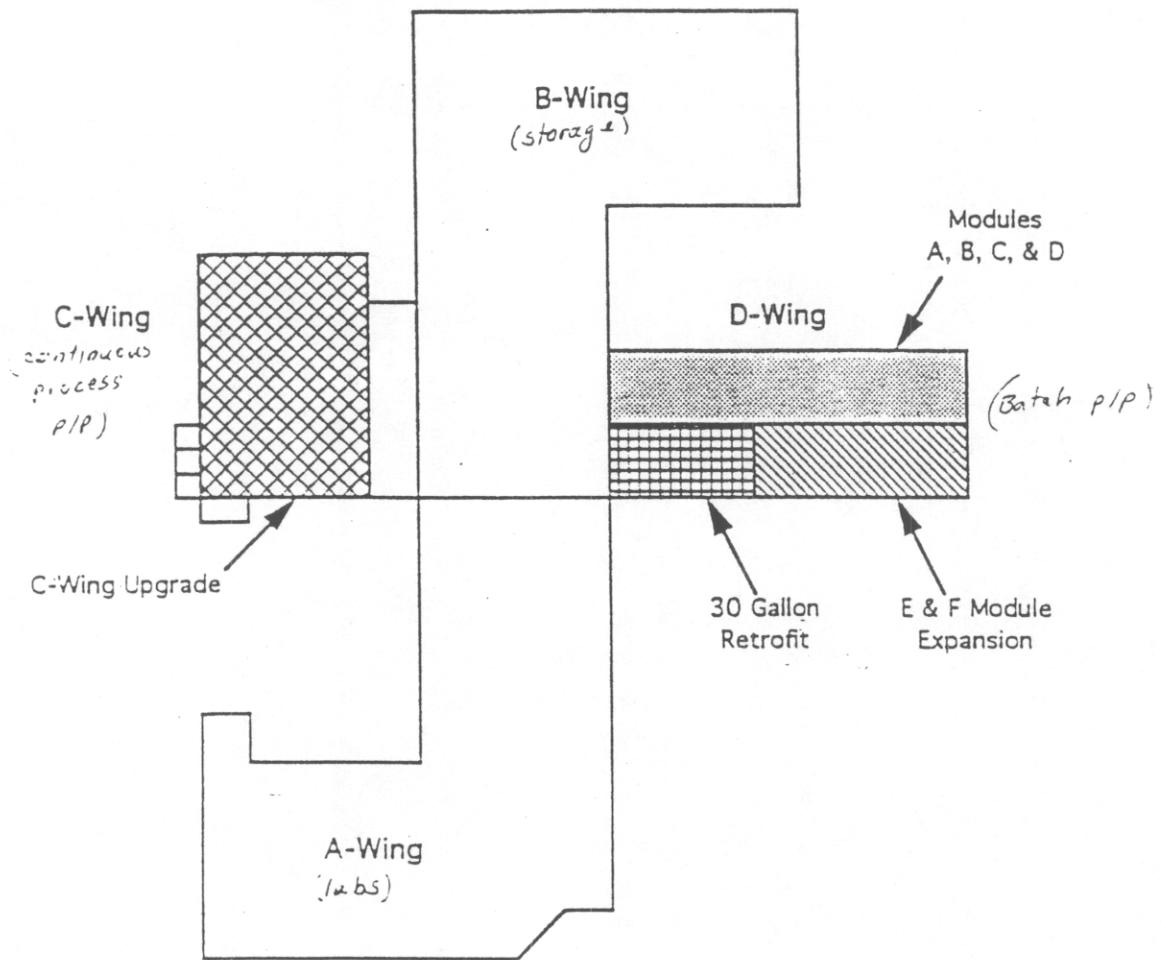
Provided by: Eli Lilly and Company
Date: 07/13/93
Revised by:
Date:

Checked by /
Date:
Checked by /
Date:



ERM

North



No Scale

FIGURE 2.2

Bldg 110 Plot Plan

Provided by: JRG

Date: 08/05/93

Revised by /

Date:

Checked by: SSC

Date: 08/06/93

Checked by /

Date:



ERM

Both the existing and proposed Building 110 facilities are smaller and more flexible operations than those found at commercial pharmaceutical manufacturing plants. Process equipment capacities and batch sizes are much smaller and product mix and process variability is much greater. The remainder of this section describes Building 110 proposed and existing process equipment and the additional complexities of pilot plant pharmaceutical production.

3.1

BUILDING 110 PROCESSES

Building 110 is a chemical process research and development facility. The facility is organized into process 'modules'. A module consists of all the various process equipment units required to produce a product. Each module is an independent production unit.

The following activities take place in Building 110 modules:

- Batch process research and development occurs in Modules A, B, C, and D.
- Very small batch process research and development is conducted in the two 30-Gallon Modules.
- After the proposed expansion, C-Wing will be primarily used for small batch research and development with some capacity for small scale continuous process research and development.
- The Solids Containment Area is used to dry, mill, and blend material produced in other modules when a uniform product consistency is required.

Process flow within a module is generally from reaction to drying. However, because of the research oriented nature of Building 110 processes, process flow from component to component is usually complicated and varies from batch to batch. For that reason all process equipment within a module is arranged and installed for maximum flexibility. All filters and some dryers are portable and are used where needed within Building 110. Very few 'hard pipe' connections exist between process equipment components within a module. Connections are made using flexible, easily reconfigured hose.

Due to the high variability in products and corresponding process flows, it is not possible to produce a precise flow diagram. However, based on historical information, a process block diagram for a typical process that is

representative of Building 110 pilot processes has been developed and is presented in Figure 3.1. The representative batch process description is presented in Table 3.1.

Building 110 processes are used for pilot production of small quantities of pharmaceuticals, therefore, the capacity of individual units of process equipment is small compared to the capacity of similar equipment used in commercial production of pharmaceuticals. Correspondingly, VOC emissions from Building 110 pilot processes are significantly less and more variable than emissions from commercial pharmaceutical processes. The USEPA's Office of Air Quality Planning and Standards (OAQPS) Guideline Series, *Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products*, December 1978, states:

"The typical batch reactor is glass lined or stainless steel and has a capacity of 2,000 to 11,000 liters (500-3,000 gallons)."

The capacity of vessels used in Building 110 processes ranges from 5 to 500 gallons.

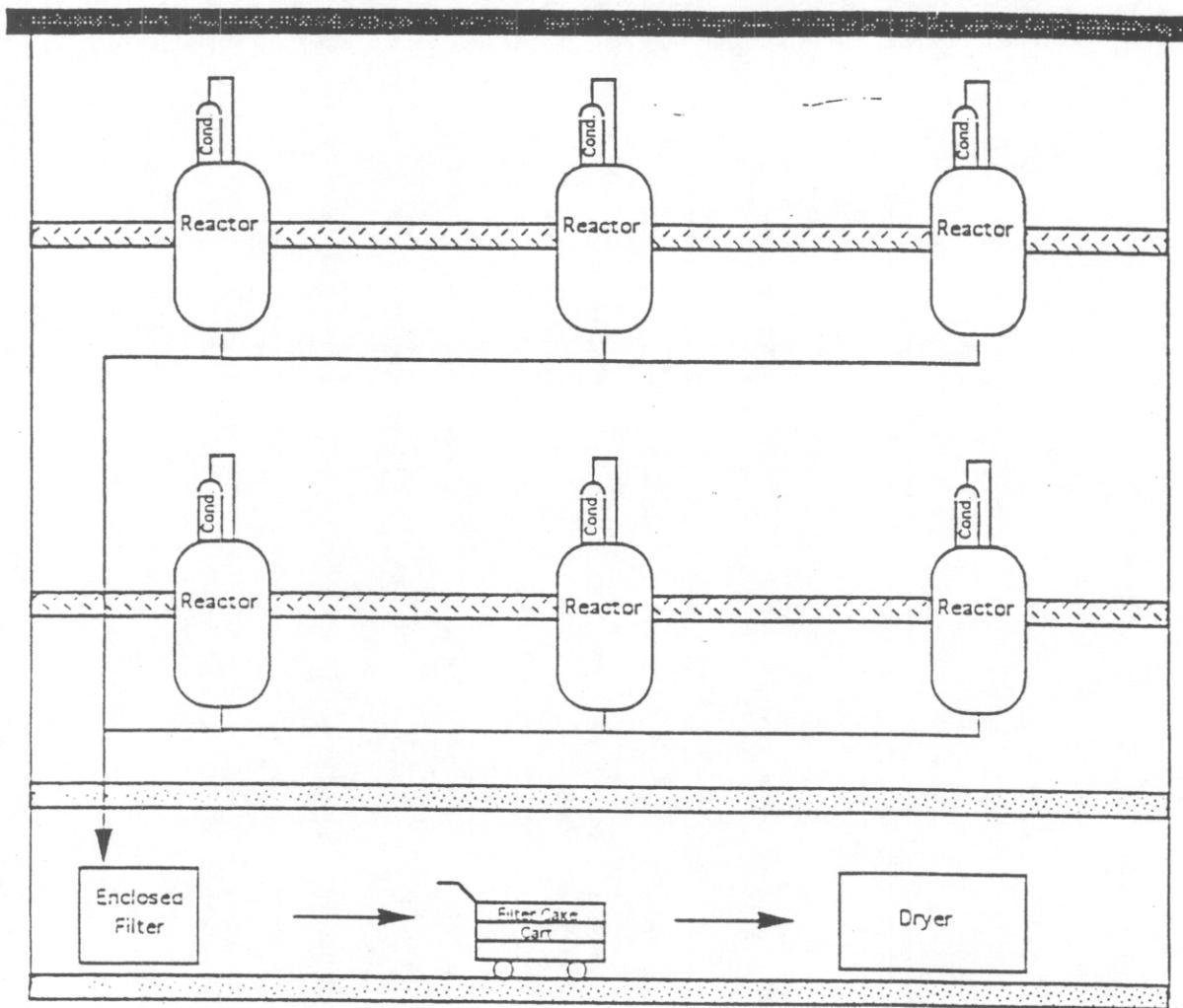
Though the capacities of Building 110 processes are generally much smaller than commercial processes, unit operations are similar. Typical Building 110 process flow begins with chemical reaction, followed by various unit operations such as extraction, distillation, crystallization, filtration, and drying. Major process equipment used in these processes include reactor vessels, filters, centrifuges, and dryers in various combinations. Reactor vessels are utilized for distillations, crystallizations, and extractions, in addition to reactions. Various volatile organic compounds (VOCs) are used primarily as solvents in each unit operation. Small quantities of VOCs are emitted during each unit operation.

Existing and proposed process equipment is described in the following sections.

3.2

EXISTING BUILDING 110 PROCESS EQUIPMENT

Existing scale-up equipment are located in C and D wings of Building 110. Modules A, B, C, D, the two Thirty Gallon Modules, and the Solids Containment Area are located in D-Wing. The Solids Containment Area can be used for drying materials produced in other modules. Emissions from the Solids Containment Area are accounted for in the drying process of each production module. Highbay Module equipment operates in conjunction with C Module processes. Major process equipment used



No Scale

FIGURE 3.1
Representative
Batch Process

Drawn by: JRG
Date: 08/05/93
Revised by /
Date:

Checked by: SSC
Date: 08/06/93
Checked by /
Date:



END TIME (hour/min)	REACTOR 1	REACTOR 2	REACTOR 3	REACTOR 4	REACTOR 5	REACTOR 6	COMMENTS
15:36-15:49	500 gallon N2 to waste	300 gallon	200 gallon	100 gallon	100 gallon Add 300l Hex. N2 to 15psig	100 gallon Add 300l MeOH N2 to 15psig Transfer to R2 Vent to atm.	Mixture of hexanes
15:49-15:50							
16:05		Heat to 40C					Stir to solution
16:26		Seed					
18:25		Cool to 0C					Add through manway
18:30		Drop on filter					
20:30		N2 thru filter to R1					
20:31							
21:00							
19:55-19:56							
10:58-20:04							
20:04-20:14							
20:14-20:15							
20:15-20:30							
21:30							
22:00		Vent to atm.					Thru -15C condensor
23:30							Blow wet cake dry, -15C
24:30							Transfer in walk in hood
24:40							Weigh
30:40							Dry @50C & FV, weigh
P0:01							
P0:09							
P0:10							
P0:30							
P0:50							
P1:00							

Table 3.1 (continued)
Representative Process Description

Drawn by /
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Revised by /
Date:

Checked by /
Date:

Checked by /
Date:



in these processes include reactor vessels equipped with primary condensers, dryers, and filters. Although the main function of the primary condensers is process control, the condensers can reduce VOC emissions. Reactors range in capacity from 30 to 300 gallons and are primarily utilized for reactions, distillations, crystallizations, and extractions.

C-Wing, which has been used for small-scale continuous pilot trials, is not currently equipped for batch pilot production. The equipment proposed for the C-Wing expansion will be subject to the RACT CTG. Proposed C-Wing equipment subject to the CTG is described in Section 3.3 of this analysis. Existing process equipment subject to the CTG is summarized in the following tables.

Table 3.2

Module A Equipment

Quantity	Description
3	100 gallon reactor
2	200 gallon reactor
1	300 gallon reactor
1	Vacuum shelf dryer
2	Air tray dryer

Table 3.3

Module B Equipment

Quantity	Description
2	50 gallon reactor
2	100 gallon reactor
2	200 gallon reactor
1	Vacuum shelf dryer
2	Air tray dryer

Table 3.4

Module C Equipment

Quantity	Description
1	50 gallon reactor
2	100 gallon reactor
3	200 gallon reactor
1	Vacuum shelf dryer
2	Air tray dryer

Table 3.5

Module D Equipment

Quantity	Description
1	100 gallon reactor
2	200 gallon reactor
3	300 gallon reactor
1	Vacuum shelf dryer
2	Air tray dryer
1	Portable agitated filter/dryer*

Table 3.6

30 Gallon-A Module Equipment

Quantity	Description
2	30 gallon reactor
1	13 gallon evaporator
1	Vacuum shelf dryer

* When the portable agitated filter is used for vacuum drying, a vacuum shelf dryer is temporarily disconnected and its vacuum system used for the agitated filter/dryer.

Table 3.7

30 Gallon-B Module Equipment

Quantity	Description
1	30 gallon reactor
1	40 gallon reactor
1	Vacuum shelf dryer

Table 3.8

Solids Containment Area

Quantity	Description
1	Vacuum shelf dryer

Table 3.9

Bulk VOC Storage Tanks

Quantity	Description
1	4,000 gallon acetone storage tank
1	7,500 gallon waste solvent tank

3.3

PROPOSED BUILDING 110 PROCESS EQUIPMENT

The proposed Building 110 expansion consists of five components: addition of Module E, addition of Module F, 30 Gallon Modules Upgrade Project, C-Wing Equipment Project, and the Rosenmund agitated filter. Proposed reactors will be equipped with primary condensers.

3.3.1

Modules E and F

Modules E and F will be new batch pilot plant modules. Module E will be installed in place of the existing High-Bay Module (High-Bay Module equipment will be removed). Chilled water condensers will be installed on Module E, F, and 30 Gallon vacuum dryer lines for the purposes of obtaining condensation data. These units will be used for experimental

~~summarized~~ and are not considered VOC control devices. The following tables summarize the equipment to be installed in Module E and F pilot plant modules.

Table 3.10

Module E Equipment

Quantity	Description
1	500 gallon glass reactor
1	300 gallon glass reactor
1	200 gallon Hastelloy reactor
1	100 gallon Hastelloy reactor
2	100 gallon removable glass reactor
2	Vacuum shelf dryer
1	Portable agitated filter/dryer*
1	Pressure safety element (PSE) catch tank
1	Portable clean-in-place (CIP) system
1	Portable mill
1	Portable blender
4	Vacuum pump
1	Floor collection tank (common to E and F)

* When the portable agitated filter is used for vacuum drying, a vacuum shelf dryer is temporarily disconnected and its vacuum system used for the agitated filter/dryer.

Table 3.11

Module F Equipment

Quantity	Description
1	500 gallon glass reactor
1	300 gallon glass reactor
1	200 gallon Hastelloy reactor
1	100 gallon Hastelloy reactor
2	100 gallon removable glass reactor
2	Vacuum shelf dryer
1	Portable agitated filter/dryer *
1	Pressure safety element (PSE) catch tank
1	Portable clean-in-place (CIP) system
4	Vacuum pump

3.3.2

30 Gallon Modules Upgrade Project

Lilly proposes to upgrade the two existing 30 Gallon Modules by adding two 50 gallon reactor vessels and by replacing the existing 40 gallon reactor with a 30 gallon reactor. The equipment additions are summarized in Table 3-11.

Table 3.12

30 Gallon Modules Upgrade

Quantity	Description
2	50 gallon Hastelloy conical bottom reactor
1	30 gallon glass reactor
2	16" Hastelloy filter
1	Vacuum pump
1	13 gallon evaporator

* See note on preceding page.

Lilly proposes to improve the capability of C-Wing pilot plant processes. Additional equipment required for the project is summarized in Table 3-12.

Table 3.13

C-Wing Equipment Project

Quantity	Description
3	50 gallon portable Hastelloy reactor
3	50 gallon portable glass reactor
3	30 gallon portable Hastelloy reactor
3	30 gallon portable glass reactor
3	5 gallon portable Hastelloy reactor
3	5 gallon portable glass reactor
6	Vacuum shelf dryer
1	Rotary vacuum dryer
1	Centrifuge
4	16" Hastelloy filter

3.3.4

Rosenmund Agitated Filter Dryer

Lilly proposes to purchase a portable Rosenmund agitated filter dryer. The filter dryer will be utilized throughout Building 110 as required by specific process unit operations.

Table 3.14

Rosenmund Agitated Filter Dryer

Quantity	Description
1	Rosenmund agitated filter/dryer *

* See note on page 15

Although Building 110 processes are pilot processes with capacities significantly less than commercial pharmaceutical production facilities, VOC emissions can exceed the *de minimis* levels in 326 IAC 8-5-3 (15 lb/day). Based on potential to emit, existing and proposed emissions sources resulting from the Building 110 expansion are subject to RACT requirements. RACT control requirements are outlined in USEPA's Control Technology Guideline (CTG) entitled *Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products*. Generalized RACT requirements, as outlined in USEPA's CTG, appear in 326 IAC 8-5-3 of the Indiana SIP.

The remainder of this section describes the generalized VOC emissions control requirements contained in the synthesized pharmaceutical RACT CTG.

4.1

RACT DEFINITION

The USEPA's pharmaceutical CTG describes RACT as follows:

"RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility."

Technological feasibility evaluation requires determining if a particular control technology could effectively and reliably reduce emissions from a particular source without introducing property damage risks or jeopardizing the health and safety of employees. After the technological feasibility of a particular control device has been determined, economic feasibility is determined.

Economic feasibility evaluation involves estimating the annual cost of operating a control device (including capital recovery) and calculating the emissions reduction resulting from application of the control device. Comparing the ratio of annual operating cost to the resulting emissions reduction is the measure of economic feasibility. This ratio is usually expressed in dollars per ton of emissions. In Indiana, based on the permitting experience of two ERM-Midwest employees, Timothy Jones and David Jordan, VOC RACT cost effectiveness is considered to be between \$2,000 and \$5,000 per ton controlled.

USEPA does not define economic feasibility as affordability. In a memo dated June 19, 1985, John Calcagni, then chief of the USEPA Economic Analysis Branch, states:

"We would advise avoiding any decision criteria or tests for "affordability". There is no basis in economic theory to support rewarding an inefficient firm to the detriment of the efficient solely because the inefficient firm cannot afford its fair degree of control which is being implemented by other companies."

USEPA's OAQPS draft document, *Evaluation of Technological and Economic Infeasibility Demonstrations in VOC Site-Specific RACT Reviews*, September 1990, states:

"The agency does not believe that less efficient firms should be rewarded solely because they cannot "afford" the degree of control being implemented by other areas in related areas of production."

It is clear, that to be considered RACT, a particular control technology must be determined to be technically feasible for a particular application *and* must be determined to be economically feasible as measured by the ratio of annual operating cost to tons per year of resulting emissions reductions.

4.2

POTENTIAL VOC CONTROL TECHNOLOGY

Existing and proposed Building 110 VOC emissions sources potentially subject to the synthesized pharmaceutical CTG include reactors, dryers, filters, centrifuges, and storage vessels. According to the USEPA CTG, reasonably available controls for these sources include condensers, scrubbers, and carbon adsorbers. Incinerators are expected to have limited application but may be effective for certain situations. Storage and transfer emissions can be controlled by vapor return lines, vent condensers, conservation vents, vent scrubbers, pressure tanks, and carbon adsorbers.

The USEPA CTG recommends that, "control requirements be imposed after considering local air quality, the mass rate of emissions, control cost estimates, and plant safety effects." The USEPA CTG lists generalized control program guidelines if the above approach is not practical.

326 IAC 8-1-5 allows an owner or operator of a source to satisfy RACT requirements by either:

- implementing generalized CTG guidelines as described in 326 IAC 8-5-3, or
- submitting a petition to the commissioner requesting a site-specific RACT plan.

Due to relatively low emissions from Building 110 pilot equipment, the general guidelines have been determined not to be RACT for Building 110. Therefore this petition for an alternative RACT plan has been submitted.

USEPA CTG generalized guidelines which may apply to Building 110 are summarized below. These potential requirements also appear in 326 IAC 8-5-3.

- 1) Each vent from reactors, centrifuges, and vacuum dryers that emit 15 pounds VOC/day or more require surface condensers from which outlet gas temperatures do not exceed -25°C to 25°C , dependent upon the vapor pressure of the VOC controlled. Variability of the solvents used in Building 110 would require condenser outlet gas temperatures to be maintained at -25°C to insure compliance for all solvents used.
- 2) Air dryers and production equipment exhaust systems that emit more than 330 lb/day must control air emissions by 90%. Air dryers and production equipment exhaust systems that emit less than 330 pounds VOC/day require emission reduction to 33 lb/day.
- 3) Storage tanks of 2,000 gallon or more capacity, storing VOC with a vapor pressure greater than 4.1 psia at 20°C are required to be equipped with a vapor balance system that is at least 90% effective in reducing VOC emissions from truck or railcar deliveries.
- 4) For tanks storing VOC with a vapor pressure greater than 1.5 psia require pressure/vacuum vents set at ± 0.03 psia.
- 5) Enclose all centrifuges containing VOCs, rotary vacuum filters processing liquid containing VOC, and any other filters having an exposed liquid surface where the liquid contains VOCs. This applies to liquids exerting a total VOC vapor pressure of 0.5 psia or more at 20°C .
- 6) All in-process tanks shall have covers. Covers should be closed when possible.

- 7) All leaks in which VOC containing liquid can be observed to be running or dripping from vessels and equipment (pumps, valves, flanges) should be repaired as soon as practical.

It is made clear in the USEPA CTG, that control technologies summarized above are general guidelines only and should be applied only if, upon technical and economic evaluation, they are considered to be RACT. The technical and economic feasibility of the above guidelines are evaluated later in this analysis.

This section discusses the available control technologies and their technical feasibility to control various VOC emissions streams from existing and proposed Building 110 process equipment. The sources of information presented in this section are from the OAQPS's *Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products* and the USEPA's *Control Technologies for Hazardous Air Pollutants*, June 1991.

VOC control technologies can be divided into three categories: combustion devices, reclamation devices, and prevention devices.

Combustion refers to exposing VOCs to temperatures sufficient to cause VOC destruction and formation of carbon dioxide and water vapor. Incinerators are a combustion device.

Reclamation refers to the capture of the VOCs for reuse or disposal. Condensers, scrubbers, and carbon adsorbers are reclamation devices.

Prevention refers to procedures and equipment that prevent VOCs from becoming an emission. Vapor return lines and pressure conservation tank vents are examples of prevention devices.

5.1

COMBUSTION CONTROL METHODS

Organic compounds are usually oxidized at temperatures ranging from 1200° F to 2200° F, depending on their chemical composition and the desired destruction efficiency. Halogenated organic compounds usually require combustion temperatures greater than 2000 °F. When complete combustion is achieved, carbon dioxide and water vapor result as products. Turbulent mixing and combustion chamber retention times of 0.5 to 1.0 seconds are necessary to obtain high destruction efficiencies.

Normally, natural gas is used to fuel the combustion chamber and maintain the required temperatures, but fuel oil is substituted in some cases. Concentrated VOC streams having high heat contents require less supplementary fuel than dilute VOC streams. In some cases, the VOC streams have high enough heat content to be self-sustaining.

Combustion control technologies include: recuperative thermal incineration, regenerative thermal incineration, recuperative catalytic incineration, regenerative catalytic incineration and flares.

5.1.1

Recuperative Thermal Incineration

Thermal incineration is commonly used to control VOC emissions via combustion and is considered a potential reasonably available control technology for Building 110. In comparison to other control techniques, thermal incineration is much less dependent on emission stream chemical characteristics. Destruction efficiencies in excess of 99% are possible. Recuperative thermal incineration recovers, and re-uses, up to 70% of the heat of combustion using a gas-to-gas heat exchanger.

As illustrated in Figure 5.1, the pollutant gas stream enters the incinerator and is preheated by the gas-to-gas heat exchanger. The preheated stream is then further heated by the burner to the incineration temperature causing combustion of the VOCs. The resulting "hot exhaust gas" is passed back through the gas-to-gas heat exchanger to preheat the incoming pollutant gas stream and then is vented to the stack.

Thermal incineration is recommended for emission streams containing a minimum of 20 ppm_v of combustible VOCs but less than 25% of the lower explosive limit (LEL) of the pollutant. If high concentrations are present, additional air, otherwise known as dilution air, may be required to eliminate the explosive hazard.

Thermal incinerators are simple to operate and require relatively minimal maintenance time. Fuel costs, however, can be expensive depending on the volume and heat content contribution of the VOC-laden stream to be incinerated. Also, thermal incinerators do not efficiently adjust to highly variable process exhaust flow rates due to poor mixing and varying residence times. Varying concentrations may also cause wide fluctuations of the combustion chamber temperature, adversely affecting the destruction efficiency. The incineration of halogenated organic compounds may cause corrosion problems within the incinerator and its exhaust stack. Scrubbing may be required to remove remaining halogenated emissions from the exhaust stream.

Emissions stream flow rates and concentrations from Building 110 are highly variable, making application of recuperative thermal incineration technically infeasible. Therefore, the economic viability of recuperative thermal incineration was not evaluated in this analysis.

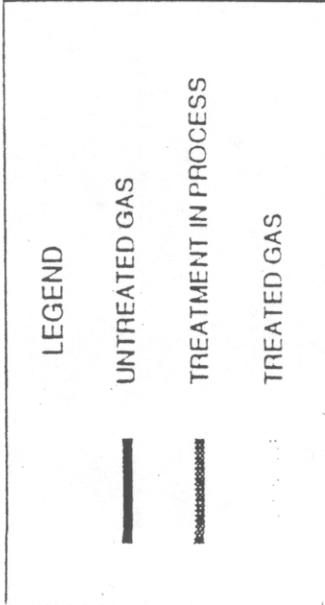
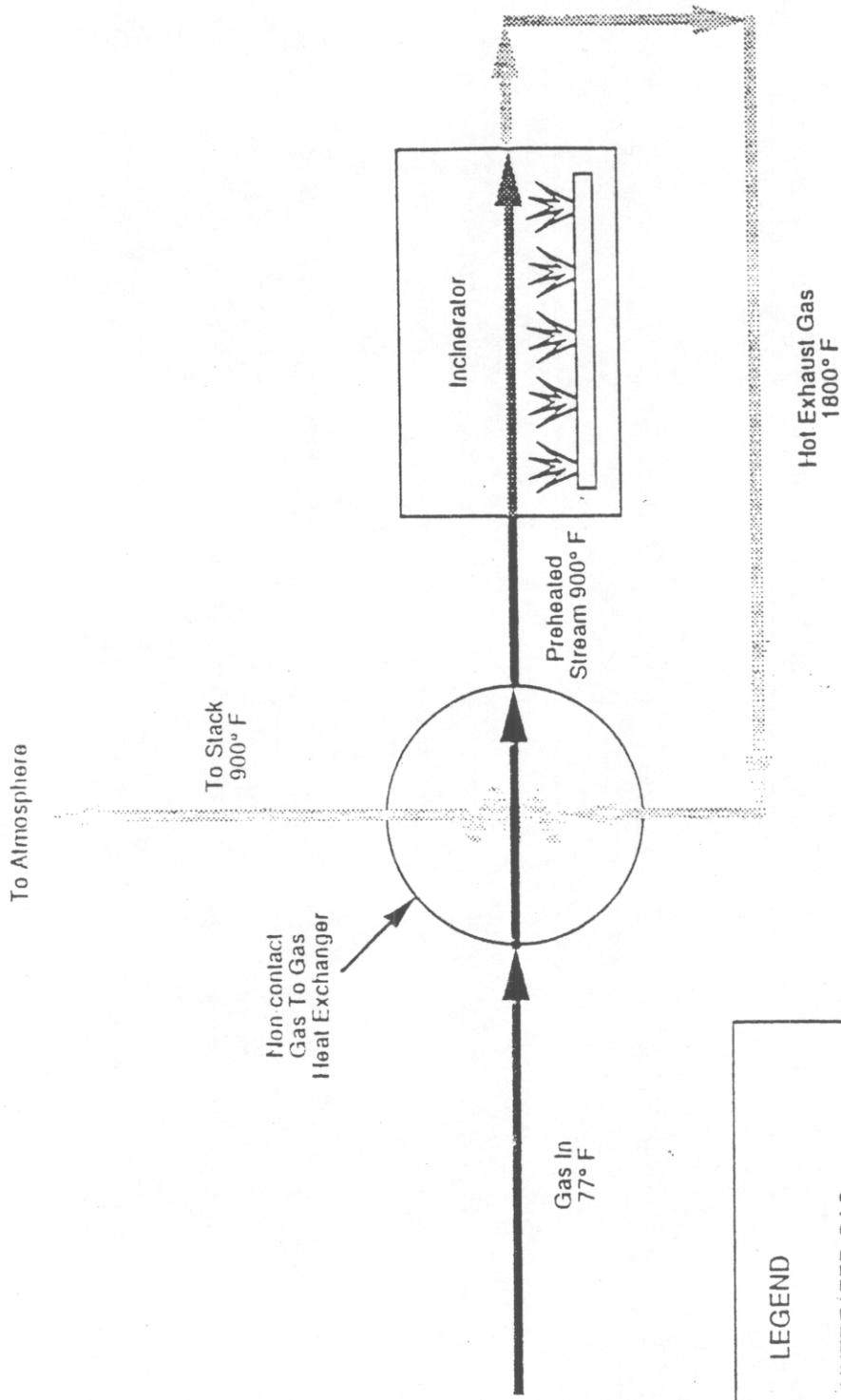


Figure 5.1
Recuperative Thermal Incineration

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Date: RAZ 12/4/92

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Date:

Checked by /
Date: MTD 12/4/92

Checked by /
Date:



Regenerative Thermal Incineration

Regenerative thermal incineration operates similarly to recuperative thermal incineration. The one difference is the method of preheating the pollutant stream before it enters the combustion chamber. Regenerative thermal incineration utilizes heat recovery chambers filled with irregularly shaped ceramic material as a heat transfer medium as compared to a gas-to-gas heat exchanger commonly found in recuperative thermal incineration systems. In Figures 5.2 and 5.3, the pollutant stream enters heat recovery chamber I and is preheated by the ceramic material. After destruction, the high temperature exhaust from the combustion chamber flows to heat recovery chamber II to heat its ceramic material. After the ceramic is sufficiently heated by the exhaust stream, the flow is reversed so that the pollutant stream enters heat recovery chamber II and is preheated before destruction. After destruction the high temperature exhaust flows through heat recovery chamber I and heats its ceramic material.

Regenerative thermal incineration is applicable over the same range of concentrations as recuperative thermal incineration and has the same LEL requirements.

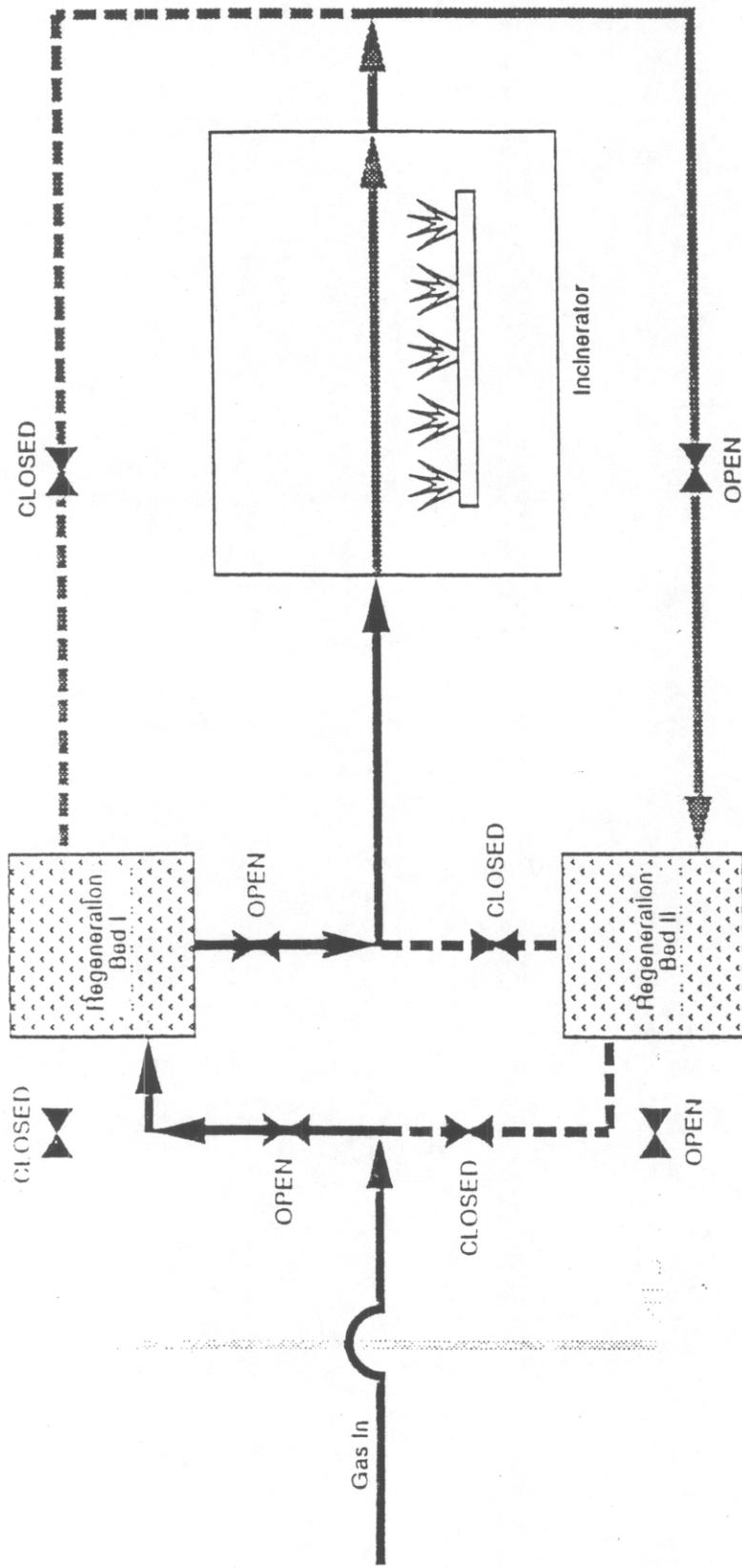
Regenerative thermal incineration has a higher capital cost than recuperative thermal incineration. This may be offset by the fuel savings since regenerative thermal incineration recovers up to 95% of the heat while recuperative thermal incineration recovers up to 70%.

As discussed earlier, emissions stream flow rates and concentrations from Building 110 are highly variable, making application of regenerative thermal incineration technically infeasible. For this reason, the economic feasibility of regenerative thermal incineration was not evaluated.

Recuperative Catalytic Incineration

Recuperative catalytic incineration operates similarly to recuperative thermal incineration in that it recovers the hot exhaust gas heat using a gas-to-gas heat exchanger. The difference between catalytic and thermal incineration is the presence of the catalyst in the combustion chamber. The presence of the catalyst enhances the destruction of the VOCs and allows for a much lower destruction temperature within the chamber.

To Atmosphere



LEGEND

- UNTREATED GAS
- TREATED GAS
- - - TREATMENT IN PROCESS
- CLOSED LINE - NO FLOW

Figure 5.2
Regenerative Thermal Incineration
Flow Path A

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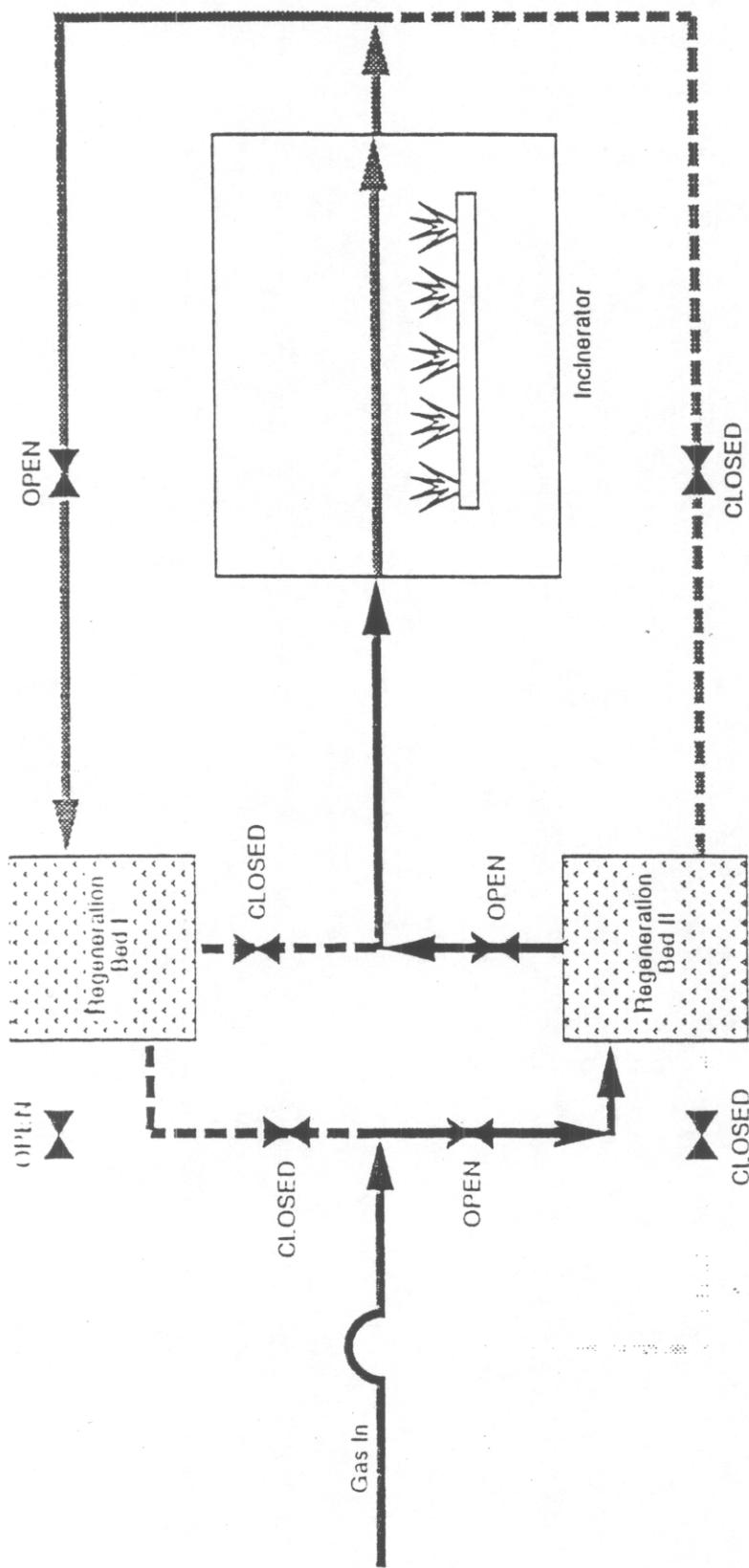
As illustrated in Figure 5.4, the pollutant gas stream enters the incinerator and is preheated by the gas-to-gas heat exchanger. The preheated stream is then further heated by the burner to the incineration temperature. The gas then passes through the catalyst which enhances the destruction of the VOCs by decreasing the amount of energy required for incineration and thereby, lowering the necessary auxiliary fuel requirement. The resulting "hot exhaust gas" is passed back through the gas-to-gas heat exchanger to preheat the incoming pollutant gas stream and then is vented to the stack.

Recuperative catalytic incineration is recommended for emission streams containing a minimum of 50 ppm_v of combustible VOCs but less than 25% of the LEL of the pollutant. High concentrations may require dilution air to eliminate the explosive hazard.

Recuperative catalytic incinerators are simple to operate and require minimal maintenance. The main advantage catalytic incineration has over other thermal incineration options is the decreased combustion chamber temperature requirement (1800 °F vs. 900 °F in some cases) which results in lower fuel costs. This savings may be offset depending on catalyst replacement cost and frequency. Catalyst costs from \$775/ft³ for units sized for base metal oxides to \$3,000/ft³ for units sized for precious metal oxides, and need replacing every two to five years. However, because the required amount of precious metal catalyst may be only one third or less than that for base metal catalyst for the same conditions, the ultimate costs are similar. Catalyst selection depends on the constituents of the pollutant stream. The effectiveness of any catalyst may be greatly reduced or even eliminated if the emission stream contains constituents, such as halogenated compounds, which coat the surface of the catalyst and allow the emission stream to pass unaffected. This phenomena is known as "blinding" or "poisoning". Thermal aging or erosion of the catalyst will cause catalyst failure.

Halogenated VOC containing solvents (see Table 5.1) are used in Building 110 processes. Furthermore, future research activities may require the pilot testing of new halogenated solvents. Due to the wide variation in VOC solvent usage and catalyst blinding problems created by the presence of halogenated compounds in the existing and proposed Building 110 process equipment emissions stream, recuperative catalytic incineration is not considered a feasible VOC control technology. Therefore, it is not included in the control technology economic evaluation in this analysis.

To Atmosphere



LEGEND

— UNTREATED GAS

- - - TREATED GAS

· · · CLOSURE LINE - NO FLOW

Figure 5.3
Regenerative Thermal Incineration
Flow Path B

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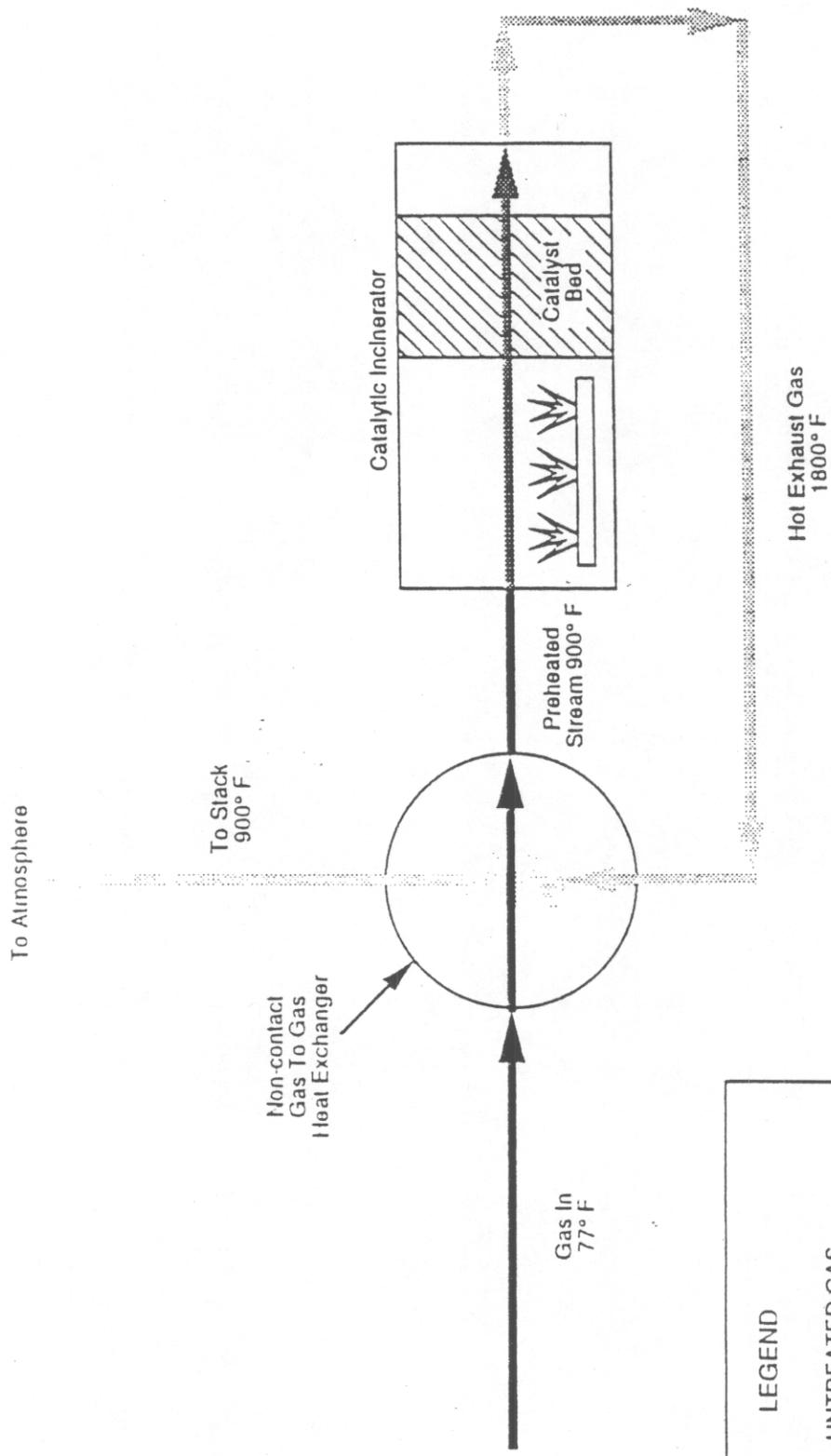
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Table 5.1 Historical Top 10 Building 110 VOC Containing Solvents

Solvent (VOC)	1992 Usage (%)
Acetone	23.8%
Methanol	8.7%
Methylene Chloride *	11.9%
Ethyl Acetate	5.2%
Toluene	8.9%
Chloroform	3.2%
Methyl tert-Butyl Ether (MTBE)	5.8%
Isopropyl Alcohol	6.3%
Ethanol	5.0%
Heptane	4.4%
Other	16.8%
	100.0%

* Not legally defined as a VOC



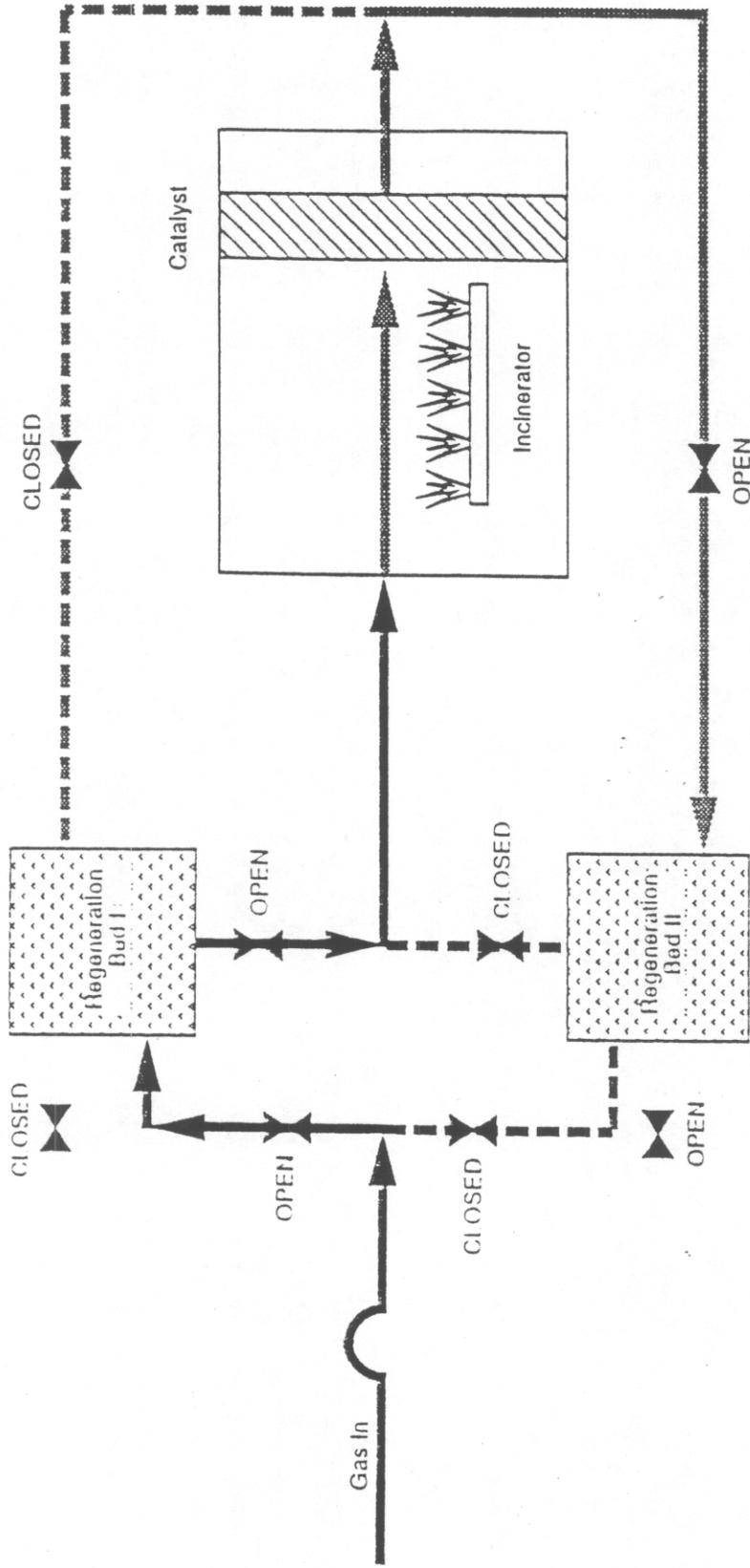
LEGEND

—	UNTREATED GAS
- - -	TREATMENT IN PROCESS
—	TREATED GAS

Figure 5.4
Recuperative Catalytic Incineration

Drawn by / Date:	RAZ 12/4/92	Checked by / Date:	MTD 12/4/92
Revised by / Date:		Checked by / Date:	

To Atmosphere



LEGEND

- UNTREATED GAS
- - - TREATED GAS
- TREATMENT IN PROCESS
- - - CLOSED LINE - NO FLOW

Figure 5.5
Regenerative Catalytic Incineration
Flow Path A

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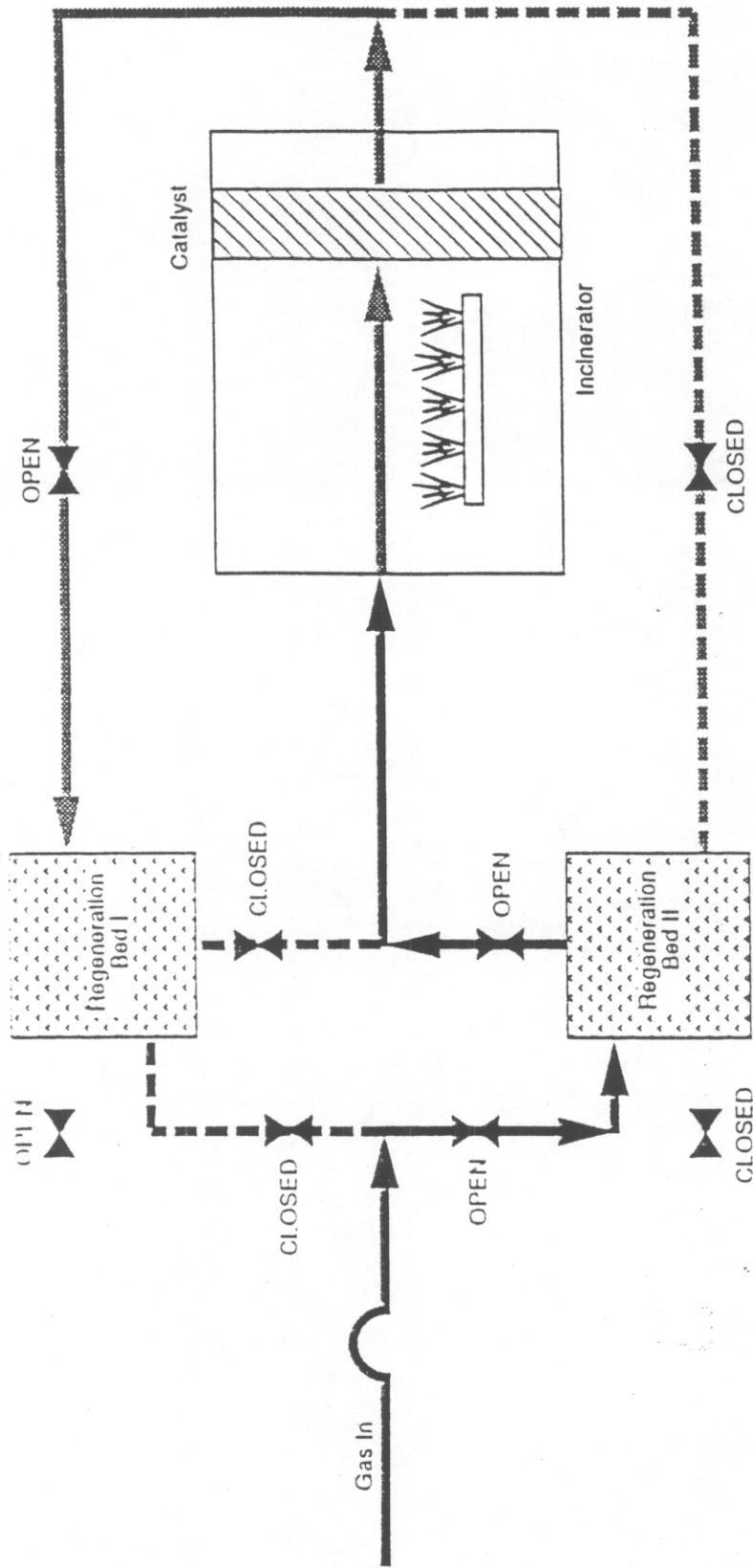
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Date:

Revised by /
Date:

Checked by /
Date:



To Atmosphere



LEGEND

- UNTREATED GAS
- - - TREATED GAS
- TREATMENT IN PROCESS
- CLOSED LINE - NO FLOW

Figure 5.6
Regenerative Catalytic Incineration
Flow Path B

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Date:

Checked by / MTD 12/4/92
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Regenerative catalytic incineration utilizes the same method of heat recovery as does regenerative thermal incineration. In Figures 5.5 and 5.6, the pollutant stream enters heat recovery chamber I and is preheated by the ceramic material. After destruction, the high temperature exhaust from the combustion chamber flows to heat recovery chamber II to heat its ceramic material. After the ceramic is sufficiently heated by the exhaust stream, the flow is reversed so that the pollutant stream enters heat recovery chamber II and is preheated before destruction. After destruction the high temperature exhaust flows through heat recovery chamber I and heats its ceramic material.

Regenerative catalytic incineration systems are uncommon in the United States. Only a few vendors offer regenerative catalytic incinerators. All manufacturers of these incinerators are currently European companies. Two United States based company, however, are working on prototype models of regenerative catalytic Incinerators. Neither of these U.S. companies have sold or proven a unit in the field as of the date of this document.

Due to similar problems with emissions stream variation and catalyst blinding described in Section 5.1.3 regarding recuperative catalytic incineration, regenerative catalytic incineration is not considered a feasible VOC control technology and is not included in the control technology economic evaluation in this analysis.

Flares are open flames used to combust emissions streams resulting from normal or upset process conditions. Flares are typically applied when the heat content of the emission stream is greater than 300 btu/scf and when the value of any recovered product is negligible.

The emission stream enters the flare stack and encounters the pilot burners which ignite the VOCs. The emission stream destruction efficiency achieved with flaring depends on factors such as flare gas exit velocity, emission stream heating value, residence time in the combustion zone, emissions stream/oxygen mixing and flame temperature.

If mixing of the emission stream is desirable, steam or compressed air is sometimes introduced to cause turbulence. If the heating value of the emission stream is not high enough to sustain a high enough temperature, supplementary fuel (usually natural gas) is necessary. Properly employed, the efficiency of a flare can be 98% or better.

A flare system is not considered a feasible VOC control method for Building 110 equipment. The heating value for the emissions stream studied is significantly lower than the minimum heating value of 300 btu/scf recommended by the USEPA in the handbook *Control Technologies for Hazardous Air Pollutants*. This differential would require an excessive amount of supplementary fuel to sustain an adequate destruction efficiency. Therefore, a flaring system was not included in the control technology economic evaluation in this analysis.

5.2 RECLAMATION CONTROL METHODS

Organic compounds may be reclaimed by one of three possible methods: carbon adsorption, absorption (scrubbing) or condensation. In general, the organic compounds are separated from the emission stream and reclaimed for reuse or disposal. Depending on the inlet concentration of the emission stream, efficiencies of 99% may be obtained.

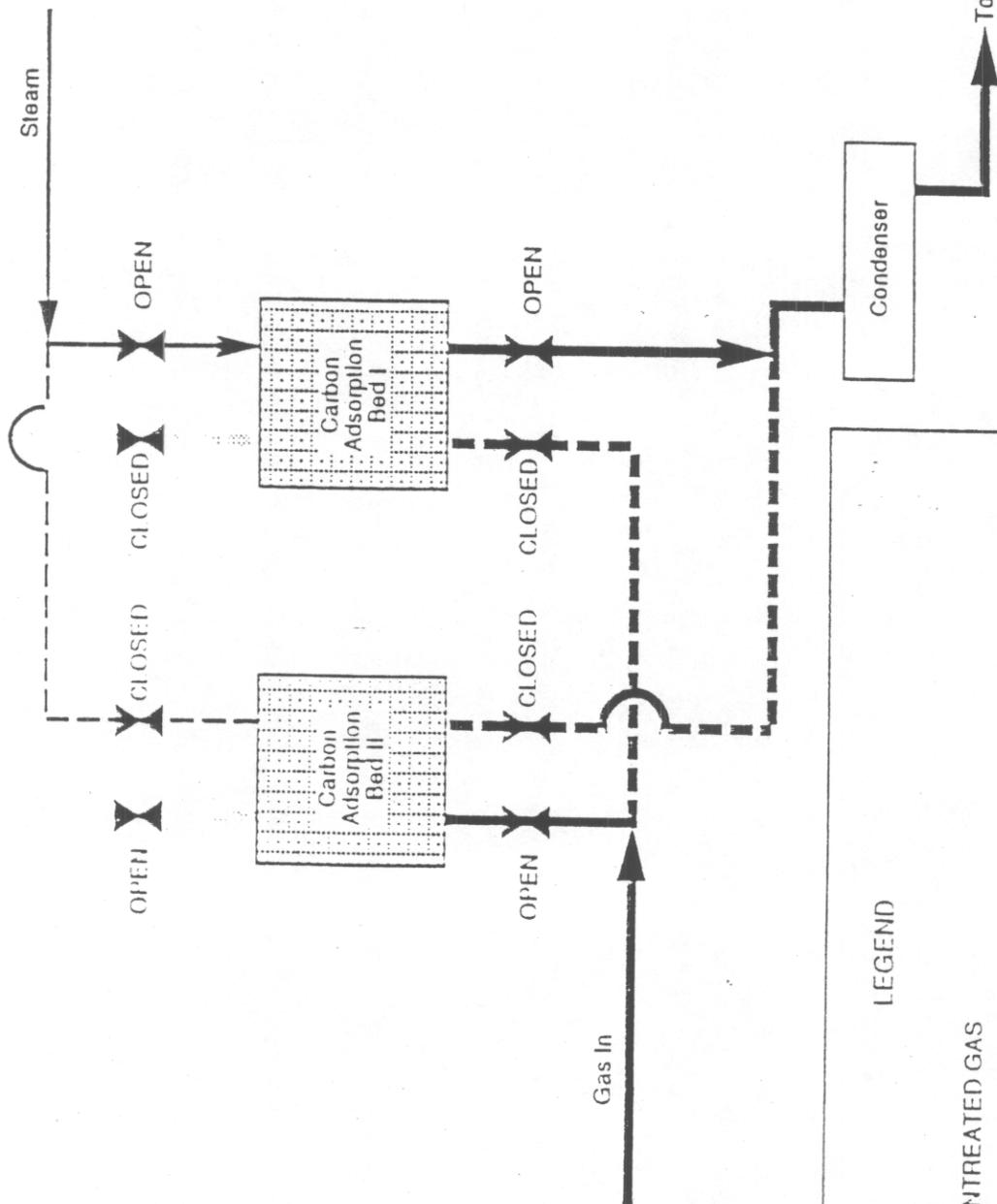
5.2.1 Carbon Adsorption

Carbon adsorption utilizes a bed of activated carbon to adsorb VOCs from an emission stream. The VOCs attach themselves to the surface of the carbon as a result of the intermolecular attraction between the carbon and the VOC molecules. The carbon and the VOC are both chemically intact after the adsorption and the VOCs may be desorbed from the carbon and reclaimed. As the process continues, the adsorption rate declines until the carbon bed is saturated and is no longer able to adsorb VOCs efficiently. At this point "break through" is said to occur and VOCs pass untreated. For this reason, dual carbon beds are normally utilized so that the active bed can be on-line controlling VOC emissions, while the saturated bed is being regenerated by high temperature air stripping, vacuum or steam stripping. Steam is the most common method of regeneration.

As illustrated in Figures 5.7 and 5.8, the emission stream enters carbon bed II, the VOCs are adsorbed and then the stream continues to the stack. Carbon bed I is being desorbed by steam injection countercurrent to normal emission stream flow. The steam, now laden with desorbed VOCs, then passes to the condenser. After carbon bed II has become saturated the emission stream is rerouted to the recently regenerated carbon bed I and then to the stack while carbon bed II is regenerated by steam injection.

Carbon adsorption systems are most effective on emission streams containing 700 to 10,000 ppm, VOC concentration but less than 25% of the

To Atmosphere



LEGEND

— UNTREATED GAS

- - - TREATED GAS

— CLOSED LINE - NO FLOW

Figure 5.7
Carbon Adsorption - Flow Path A

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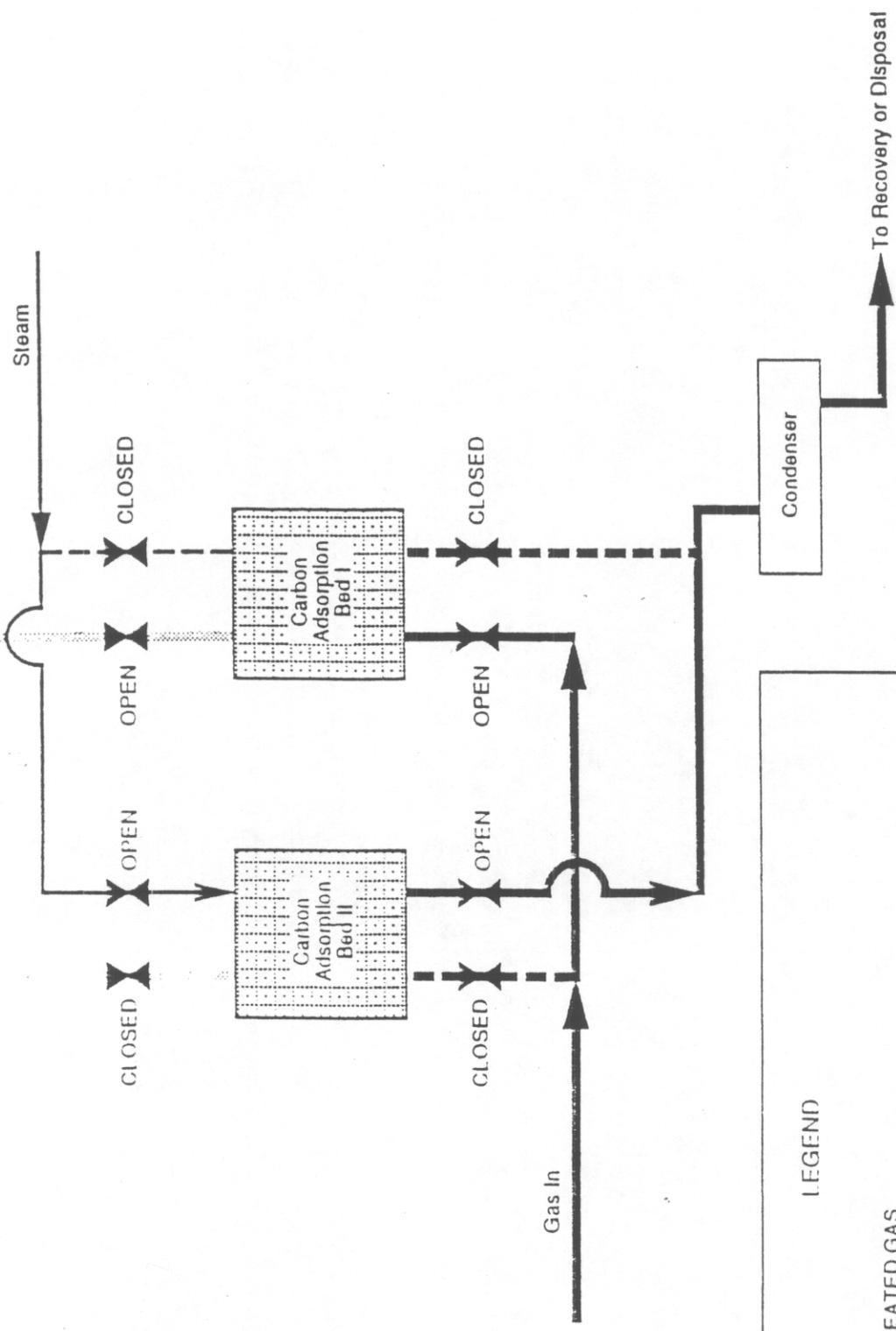
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ERM

To Atmosphere



LEGEND

- UNTREATED GAS
- - - TREATED GAS
- - - - - CLOSED LINE - NO FLOW

Figure 5.8
Carbon Adsorption - Flow Path B

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LEL per the USEPA Handbook, *Control Technologies for Hazardous Air Pollutants*, June 1991. Carbon adsorption is sensitive to emissions stream conditions. The presence of liquid or solid particles or high boiling organics will require pretreatment procedures (such as filtration) to minimize bed plugging. A carbon adsorber system may have difficulties when controlling emission streams containing ketones (e.g. acetone, methyl ethyl ketone). Ketones exothermically polymerize on the carbon, clogging the pores on the surface of the carbon which reduces the effective amount of carbon contained in the vessel. This in turn, decreases the system efficiency. Also, dehumidification is usually necessary if the emissions stream has a relative humidity greater than 50%, and cooling may be required if the emission stream temperature exceeds 120 °F.

Carbon adsorption systems are advantageous when the emission stream contains a chemical that may be reused. They are relatively inexpensive to operate if steam or another regeneration method is readily available. If the collected solvent does not have commercial value, waste disposal cost increase dramatically and may cause carbon adsorption to become economically infeasible.

Due to the high acetone (a ketone) usage in Building 110, carbon adsorption is not considered a technically feasible VOC control alternative and is not included in the economic feasibility section of this analysis.

5.2.2

Absorption (Scrubbing)

Absorption, or scrubbing as it will be referred to, is an operation where gas is transferred to a nonvolatile liquid, usually water. The liquid contains less than the equilibrium concentration of the gas and the difference between the actual concentration and the equilibrium concentration provides the driving force for absorption. There are several types of scrubbers including packed beds, plate or tray towers, spray chambers and venturi scrubbers. Packed beds are common in air pollution control, and therefore will be the main focus of this discussion.

Scrubbing is a process for removing one or more components (i.e., VOCs and/or particulates) from an emissions stream by passing it upward and usually countercurrent to, and in intimate contact with, a stream of descending liquid. The liquid is chosen for its ability to absorb the desired components only. The emissions stream may be broken into fine bubbles upon entering a tower filled with liquid, but more frequently the tower is filled with a packing material (ceramic saddles, broken stone, etc.) over which the liquid flows while exposing a relatively large surface to the rising gas or vapor from the emission stream. The liquid is then sent to a waste water facility for processing or disposal.

Scrubbing is recommended for emission streams containing 250 to 10,000 ppm_v that are readily soluble in water or another solvent.

Building 110 processes use a variety of solvents, some of which are not readily soluble in water. In addition, Building 110 does not operate a wastewater pretreatment plant. Scrubber effluent would require off-site disposal, greatly increasing the cost of operating this control technology.

Depending on the VOC emissions controlled, scrubbing could be an economically viable control technology. Therefore, the economic feasibility of scrubbing is evaluated later in this analysis.

5.2.3

Condensation

Condensation is the separation of VOCs from an emission stream by either increasing the system pressure or lowering the system temperature below the dew point of the VOC vapor. When condensers are used for air pollution control, they usually operate at the pressure of the emission stream, and a refrigeration unit may be required depending on the temperature necessary to condense the VOCs from the emission stream.

The emission stream enters a heat exchanger, usually of shell and tube design, and encounters the cold surface of the tube carrying the refrigerant. The emission stream temperature drops to the dew point of its VOC constituents. The VOC liquefies and drops out of the emission stream. The "cleaned" emission stream is then vented to the stack while the condensed solvent is collected for reuse or disposal.

Condensation systems are recommended for emission streams containing between 5,000 and 10,000 ppm_v. Condensation is affected significantly by the number and nature of the constituents in the emission stream. The greater the variance of components, the greater the range of temperatures that must be maintained to achieve condensation.

Condenser freezing can occur if the temperature of the condenser surface is less than the freezing point of at least one constituent in the emissions stream. Although approximately 20% of Building 110 solvents are aqueous and will cause condenser freezing, condensation is considered a technically feasible VOC control technology for Building 110 equipment. A condensation economic feasibility evaluation that takes into consideration the technical limitations of condensation for Building 110 emissions streams is presented later in this analysis.

In some cases, a combination of control technologies results in the most efficient and cost effective VOC control method. Presently, a combination of carbon adsorption and oxidation (incineration) has had good results on low concentration emission streams.

5.3.1

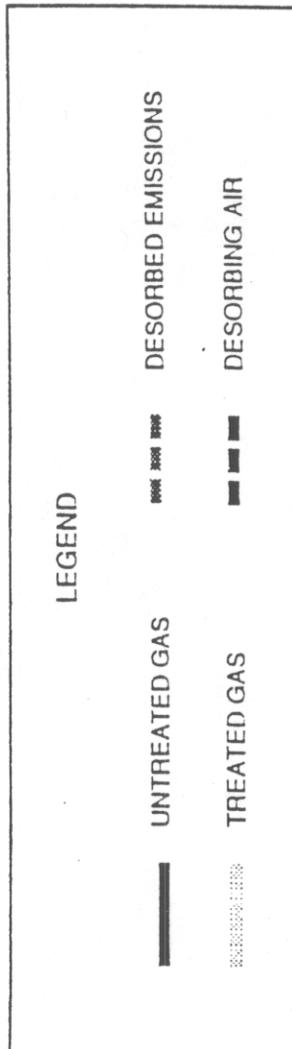
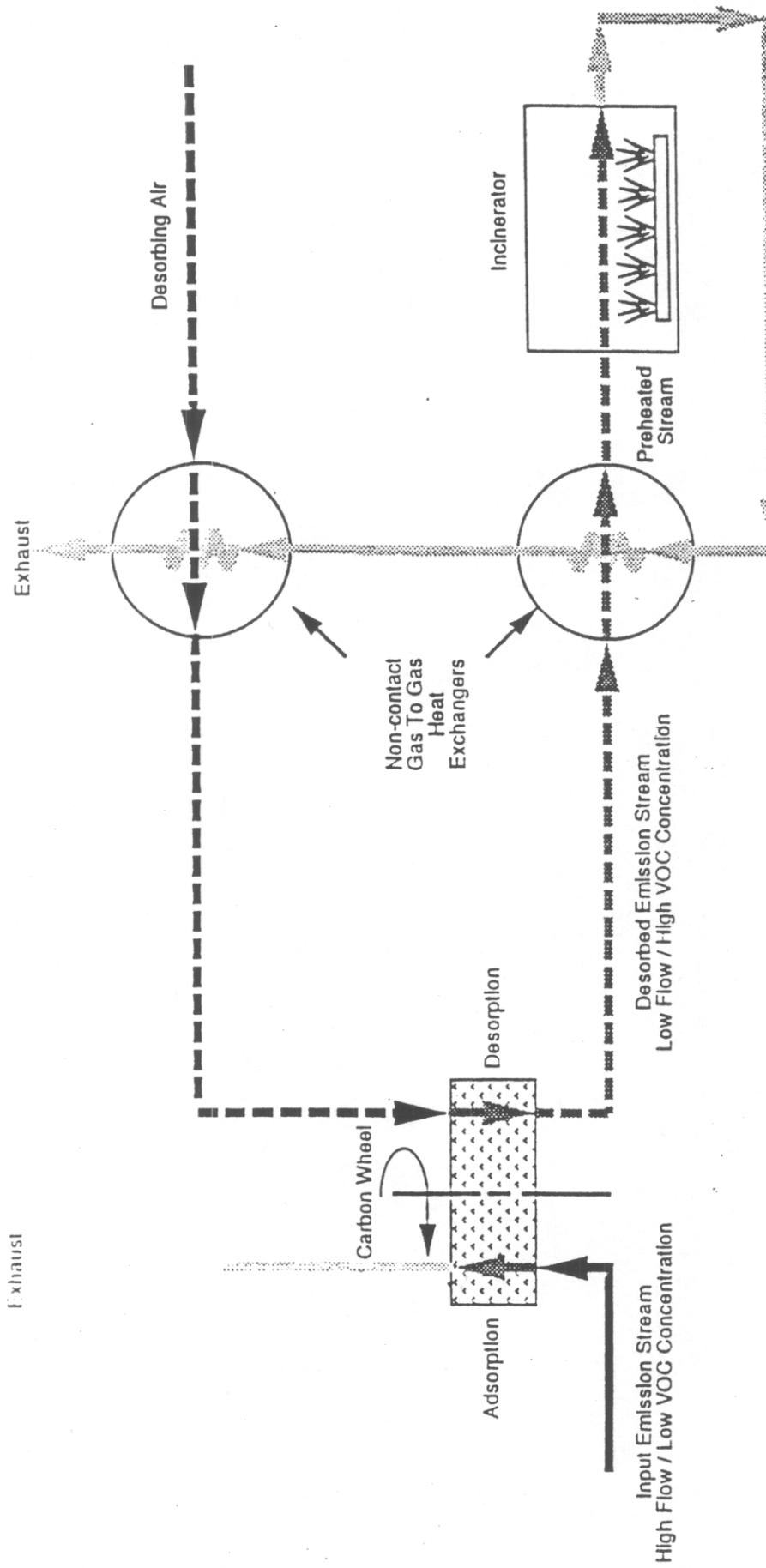
Carbon Adsorption/Oxidation

Carbon adsorption/oxidation combines a carbon adsorption system and a recuperative thermal incineration system for capture and incineration of VOCs. This system concentrates the VOC stream by using carbon adsorption to first remove low concentration VOCs from large gas flows and then uses much lower gas flows to regenerate the carbon. The gas stream coming from the regeneration process contains much higher concentrations of VOCs which are then sent to a thermal incinerator for a more efficient destruction.

The carbon adsorption system is usually configured as a rotating wheel. During rotation, most of the wheel is utilized for adsorbing VOCs while approximately 10% of the wheel is being regenerated using high temperature air. A typical system is illustrated in Figure 5.9. The low concentration emission stream passes through the carbon adsorption system where up to 95% of the VOCs are captured. High temperature air from a gas-to-gas heat exchanger flows counter-current to the flow of the emission stream desorbing the carbon wheel. This desorbing air flow may be only as one-tenth of the original emission stream flow. The desorbing air, now laden with a high concentration of VOCs, goes to a recuperative thermal incinerator where the VOCs are destroyed at up to 99% efficiency.

This system concentrates and reduces the air flow of the emission stream thereby decreasing the size and fuel requirement of the thermal incinerator. Substantial operating savings may be realized with this type of system. Capital cost is significantly higher than that of either a carbon adsorption system or a recuperative thermal incinerator alone.

As discussed earlier in the carbon adsorption control technology section, ketones can exothermically polymerize on the carbon bed, clogging the pores on the surface of the carbon which reduces the effective amount of carbon contained in the vessel. This in turn, decreased the system efficiency. Due to the high acetone usage in Building 110, carbon adsorption/oxidation is not considered a technically feasible VOC control alternative and is not included in the economic feasibility section of this analysis.



<p>Figure 5.9 Carbon Adsorption / Oxidation</p>		Drawn by / Date:	RAZ 12/4/92	Checked by / Date:	MTD 12/4/92
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Preventative control methods that are applicable to the Building 110 process are vapor return lines and pressure conservation vents. These methods are used to control emissions from resulting from VOC storage and transfer.

5.4.1 *Pressure Conservation Vents*

Pressure conservation vents are pressure control devices for VOC storage vessels. A conservation vent maintains tank pressure within preset limits. Thus, vapor emissions from small volume and temperature changes are reduced.

Both of Building 110 bulk VOC storage tanks (waste solvent and acetone) are equipped with pressure conservation vents, therefore, additional feasibility and cost-effectiveness calculations will not be needed for this demonstration.

5.4.2 *Vapor Return Lines*

Vapor return lines connect vessels that are transferring materials to each other. During a transfer operation, vapor displaced from the head space of the vessel being filled flows through the vapor return line into the vessel that from which the material is being transferred. Using this method, pressure is equalized between the vessels and no material is emitted.

Building 110 operates an acetone bulk storage tank that accepts tank truck deliveries of acetone. This tank is currently equipped with a vapor return system, therefore, additional feasibility and cost-effectiveness calculations will not be needed for this demonstration.

Building 110 is primarily a research and development facility. It is not possible to precisely forecast the product mix, production schedule, and exact number and type of emitting equipment associated with each batch. Therefore, the most reliable approach to developing emissions estimates is to identify a batch process sequence of events that is 'representative' of the typical Building 110 process.

As a result of the research and development orientation of Building 110 processes, material consumption is well documented. Reliable records of material use allow for accurate mass balance calculations. In view of these factors, mass balances were determined to be the most reliable method of estimating emissions from Building 110 equipment.

The potential emissions associated with existing and proposed equipment are based on historical data collected during similar operations conducted on similar process equipment. A description of the historical information and assumptions associated with each type of process equipment is presented in the following sections.

6.1 EMISSIONS DATABASE

Appendix A includes a more detailed discussion and the supporting documentation for the following calculations. This section is intended to provide an overview of the calculation methods used.

In 1990, Building 110 initiated a program to account for all solvents associated with the processing in the research and development areas. This new program was an extension of the accounting system used for tracking dryer emissions, which began with the start-up of Building 110 in 1987. The accounting system requires the collection of data based on a process or protocol ticket. Data is collected on each batch produced in Building 110. This information identifies, for each solvent, the points of entrance and exit from the process module on a batch basis. Solvent generally leaves Building 110 by a combination of routes: recovered for reuse, consumed in the reaction, collected for disposal, emitted as fugitive emissions, or emitted as point source emissions. Solvent emission numbers from each process are entered into a database and totaled. For pilot plant facilities, this mass balance approach yields more accurate emissions information than the calculation methods used to estimate emissions from a full scale production facility.

1991 actual mass balance data was used as the basis for estimating the potential emissions from equipment associated with the proposed expansion.

6.2

EMISSIONS ESTIMATION BASIS

Total pilot plant emissions are a function of batch size, number of batches run, and the quantity of unrecovered solvent for each batch. Emissions calculations are based on these parameters. Reactor capacity determines the maximum batch size. The number of batches processed is obtained from historical data and, using statistical analyses, is the basis for projecting future operations. Solvent usage information is obtained from Building 110 process mass balances and is used, in combination with the anticipated batch size and number of batches run, to estimate future emissions.

It is also important to recognize the operating practices of the pilot plant facility when calculating potential emissions. Normally, one batch at a time is processed in a module. All operations associated with a batch are carried out in one module (i.e. batches are not typically transferred between modules). The module essentially becomes a dedicated, independent facility for a specific batch. Compounds produced in the reactors are typically filtered or centrifuged, then dried. Filtration/centrifugation may occur in one or more pieces of equipment. The same is true for drying operations.

Since the function of a pilot plant is to develop the production process from lab scale equipment, its operation involves evaluating various types of equipment for production of the same compound. To have a valid basis for comparison, an evaluation must be run on the same batch.

For a module, the amount of product generated in reactors is the maximum amount of material that can be filtered/centrifuged, then dried. Emissions from the filtering/centrifuging and drying operations may come from one or several pieces of equipment but will be limited by the reactor capacity. The following steps were chosen to estimate actual batch pilot plant VOC emissions for 1991. See Appendix A for details.

1. Determine the total reactor capacity of each existing batch pilot plant *module* and the number of batches produced in each module during 1991.

Table 6.1

Production Summary

Module	Reactor Capacity (gallons)	Batches
A	1,000	29
B	700	25
C	850	35
D	1,400	35

2. Calculate the total amount of solvent emitted to the air during 1991 through chemical processing and equipment cleaning as a percentage of total usage.

Approximately 3%

3. Based on the four major existing modules A, B, C, D, and the number of batches processed in each of these modules in 1991, calculate the gross solvent usage per batch per gallon of reactor capacity.

$$\frac{3.37 \text{ lb gross annual solvent usage}}{(\text{batch})(\text{gallon of reactor capacity})}$$

4. Based on the percent solvent emitted and the gross solvent usage, calculate the total amount of solvent emitted to the air per batch per gallon of reactor capacity.

$$Total = \frac{0.101 \text{ lb solvent emitted to the air annually}}{(\text{batch})(\text{gallon of reactor capacity})}$$

5. Calculate the solvent emitted to the air annually for each module.
6. Based on historical information, allocate the total VOCs emitted to the air for each type of equipment in each module.

Dryers:

0.00894 lb annual emissions from each dryer vent
(batch)(gallon of reactor capacity)

Filtration/Centrifugation:

10 lb annual emissions from each filter / centrifuge vent
(batch)

Note: The filtration/centrifugation calculations apply per module

Fugitive Emissions:

Fugitive emissions were estimated using emission factors in the USEPA's *Protocols for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and VHAP*. The number of each type of fugitive emission source (valves, flanges, pump seals, etc.) in each module was estimated. Equipment estimates were then multiplied by the appropriate emission factor in Table 2-1 of the protocol. Fugitive emissions calculations are summarized on the worksheets in Appendix B of the report.

Reactor Emissions:

Reactor emissions = (Total emissions - dryer emissions - filtration emissions - fugitive emissions)

6.3

EMISSIONS CALCULATIONS FOR EXISTING AND PROPOSED PROCESS EQUIPMENT

The calculation methodology presented in Section 6.2 was applied to existing and proposed equipment with the following assumptions:

1. Similar chemical processing, unit operations and equipment utilization are expected for all batch pilot plant areas.
2. The maximum available reactor capacity for existing and proposed process equipment is summarized in Table 6.2.

Table 6.2 Maximum Reactor Capacity

Module	Maximum Capacity
Module A	1,000 gallons
Module B	700 gallons
Module C	850 gallons
Module D	1,400 gallons
Module E	1,300 gallons
Module F	1,300 gallons
30 Gallon-A Upgrade ^a	123 gallons
30 Gallon-B Upgrade ^a	110 gallons
C-Wing Equipment ^b	480 gallons

Notes to Table 6.2:

- a. For the 30 gallon upgrade project, the 50 liter (13 gallon) evaporator is treated as a reactor vessel. Additionally, the expansion, unlike Modules E and F and C-Wing, expands existing capacity. Upon completion of this project, total 30 gallon module capacity will be 233 gallons. The filter emissions will be prorated to account for the increase in emissions due to the increase in batch size.
 - b. Based on the largest 12 reactor vessel combination that can be utilized at any one time.
3. Based on the amount of material to be processed in portable mills and blenders, it is not anticipated that potential particulate emissions will exceed 5 lb/hr or 25 lb/day.
 4. The vacuum shelf dryers and the rotary vacuum dryer included in the C-Wing Expansion are lab sized equipment.

5. The maximum number of batches capable of being processed per module in the pilot plant facility is based on 1990, 1991, and the first half of 1992 throughput data. Batches processed for the last half of 1992 were extrapolated from the January through July data for that year. A statistical analysis of the data assuming a normal distribution was done. The average batches run per module totaled 38 with a standard deviation of 11.8 batches. For a confidence interval in excess of 99%, the maximum number of batches processed is estimated at 73 (mean plus 3 standard deviations). To ensure that this confidence interval provides a sufficient margin to enable Building 110 to make the campaign changeovers necessary, the emissions estimates assume a maximum capability of 80 batches/year per module.
6. Fugitive emissions are calculated for each module using emission factors in the USEPA's *Protocols for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and VHAP*.

These assumptions were incorporated into the calculation methodology developed in Section 6.2. Sample calculations are provided in Appendix B. Table 6.3 summarizes the potential VOC emissions from existing and proposed process equipment.

Table 6.3 Summary of Pre-Control Potential Emissions (TPY) from Existing and Proposed Building 110 Process Equipment

Module	Reactor Emissions	Dryer Emissions	Filter & Centrifuge Emissions	Fugitive ¹ Emissions	Total
A	2.26	0.36	0.40	1.02	4.04
B	1.16	0.25	0.40	1.02	2.83
C	1.71	0.30	0.40	1.02	3.43
D	3.73	0.50	0.40	1.02	5.65
E	3.36	0.46	0.40	1.02	5.24
F	3.36	0.46	0.40	1.02	5.24
30 Gallon-A	0.11	0.04 ²	0.20 ³	0.14	0.49
30 Gallon-B	0.10	0.04 ²	0.20 ³	0.11	0.45
C-Wing	0.79	0.18	0.40	0.57	1.94
Total	16.58	2.59	3.20	6.94	29.31

Notes to Table 6.3:

1. Estimated using USEPA emission factors.
2. For the vacuum pump associated with existing dryer VDS-696.
3. Emission factor adjusted for small batch size.

Based upon the determination of VOC control technical feasibility discussed in Section 5, two VOC control technologies have been economically evaluated for each emissions source. These technologies are condensation at -25° C (-25° C is the general RACT CTG) and absorption (scrubbing). The cost effectiveness of each VOC control method is estimated using quotations from equipment vendors and the USEPA Handbook *Control Technologies for Hazardous Air Pollutants*, June 1991 (the HAP Manual). Capital costs were estimated using the guidelines found in the same reference.

The general RACT CTG is -25° C condensation (or equivalent) on VOC emissions streams from reactors, centrifuges, and vacuum dryers. Building 110 pilot processes currently use filters, not centrifuges, for solids separation. However, a portable centrifuge is a component of equipment proposed for the C-Wing module. Although filters will most often be used for solids separation, it is possible that the C-Wing centrifuge could be used for solids separation in any Building 110 module. For this reason, the effectiveness and cost of applying controls to VOC emissions from filters/ centrifuges (solids separation) have been calculated. Because most solid separations will be achieved through filtration (general CTG does not require control equipment on filters), the VOC emissions reductions predicted by the application of general RACT CTG controls is overstated (conservative).

All cost effectiveness calculations are based on 100% capture efficiency in order to yield the most conservative (lowest) cost per ton ratio. It should be noted that VOCs may escape from the emissions stream area and, in practice, 100% capture is highly unlikely.

The cost of installing extensive ductwork to convey emissions from reactors, filter/ centrifuges, and vacuum dryers to a control device was conservatively estimated to be \$25,000 for each module. Reactors in modules A, B, C, and D are currently equipped with steam ejectors. Installation of add-on VOC controls would require replacing steam ejectors with vacuum pumps, at a cost of \$79,500 per module. These costs are included in the auxiliary equipment category detailed in Appendix C.

Approximately 20% of the solvents used in Building 110 processes are aqueous solutions. Emissions from these solutions will freeze on condenser surfaces, preventing flow through the condenser. For this

reason, condensation is a technically feasible control technology for 80% of VOC emissions from Building 110.

The cost effectiveness of condensation and absorption were calculated, considering the technical limitations of each. Condensation VOC control technology was determined to be more cost effective than scrubbing control technology. This is due primarily to the cost of disposing of the scrubber effluent. In addition, the varying solubility of Building 110 VOCs reduced the overall scrubbing VOC removal efficiency. For these reasons, condensation was determined to be the most effective VOC control technology.

7.1

EMISSIONS STREAM IDENTIFICATION AND CHARACTERIZATION

The first step in estimating the cost of controlling emissions is identifying and characterizing each emissions stream. Individual components of process equipment within a module are small emissions sources. Average VOC emissions from individual reactors during a batch are approximately 0.61 lb/hr; from individual filter/centrifuges, 5.00 lb/hr; from individual dryers, 1.99 lb/hr. Installing dedicated VOC emissions control technology on individual pieces of process equipment would be less cost effective than installing one control device and collection system in each module. Installation of add-on VOC controls on Building 110 processes would be most cost-effective for combined emissions streams, even though Building 110 processes are very sensitive to cross-contamination. To eliminate the possibility of cross-contamination, each module would ideally require a dedicated, independent control device.

For purposes of this study combined emission stream flow rates and VOC contents were calculated for each module. The source, identification, and relevant parameters of each emissions stream are summarized in Table 7.1.

Table 7.1 Pre-Control Point Source Emissions Stream Characterization Summary (lb/hr)

Module	Average Reactor Emissions	Average Dryer Emissions	Average Filter & Centrifuge Emissions	Minimum Flow Rate (acfm)	Maximum Flow Rate (acfm)
A	2.35	1.49	5.00	0.71	10.00
B	1.20	1.04	5.00	0.50	10.00
C	1.78	1.27	5.00	0.60	10.00
D	3.89	2.09	5.00	0.99	10.00
E	3.51	1.94	5.00	0.92	10.00
F	3.51	1.94	5.00	0.92	10.00
30 Gallon-A	0.12	0.18	2.50	0.06	10.00
30 Gallon-B	0.10	0.16	2.50	0.05	10.00
C-Wing	0.82	0.73	5.00	0.35	10.00

Average VOC emission rates are based on mass balance procedures described in Chapter 6 and USEPA emission factors. The emissions in lb/hr are calculated from emissions in tons per year, using 80 batches per year, 24 hours reaction time per batch, 6 hours drying time per batch, and two solids separations (via filtration or centrifugation) per batch, each requiring one hour.

Emission stream minimum flow rate is the minimum flow required to transport the VOC mass at the rate shown in Table 7.1, assuming emission stream saturation with VOC and ideal gas behavior. The maximum flow rate is based on vacuum pump ratings. Fugitive emissions from valves, flanges, etc. were not included in determination of condenser or scrubber cost-effectiveness calculations because they are not emitted through vents.

The emission stream may contain several different VOC components. These components will vary with time and specific emission source. For purposes of evaluating the cost and effectiveness of control technologies, representative values of HAP vapor pressure and molecular weight were calculated.

The methods for calculating representative values are shown in Table 7.2. A usage-weighted molecular weight of 70.87 was calculated based on the molecular weight and 1992 usage of each VOC.

Vapor pressure parameters are the temperature at which the substance has a vapor pressure of 1 mm Hg, and the temperature for 100 mm Hg-vapor pressure. These parameters are available in Table 3-8 of Chemical Engineer's Handbook (Perry and Chilton, 1973), and are used to derive the vapor pressure-temperature relationship shown in Figure 4.8-2 of the HAP manual. Usage weighted temperatures for both 1 mm partial pressure and 100 mm partial pressure are calculated in Table 7.2. This provides a vapor pressure-temperature relationship which is representative of the behavior of the various VOCs potentially present in the emission stream.

The emission stream is assumed to be saturated with VOC. The usage weighted average vapor pressure of VOC is 2.73 psia at the emission stream temperature of 20 Degrees C (Table 7.2). This yields a saturated VOC concentration of $2.73 \text{ psia} / 14.7 \text{ psia} = 0.185034 = 185,034 \text{ ppm}_v$.

It is possible that emissions from a particular source at certain times may contain vapor at a concentration greater than 185,034 ppm_v. If, for instance, a tank contained pure acetone, the equilibrium concentration would be 237,000 ppm_v. However, these occasions will be more than offset by concentration which are expected to be much less than 185,034 ppm_v for most of the operating hours.

It is assumed that the concentration of VOC is 185,034 ppm_v during all operating hours. In a condensation system, this parameter is used for evaluating the removal efficiency of the condenser at a given condensation temperature. The higher the VOC concentration, the higher the removal efficiency of the condenser. Therefore, using a relatively high value for VOC concentration tends to underestimate the cost of adding VOC controls per ton removed.

In the case of a scrubber system, the VOC concentration is used for sizing the pollution control equipment and volume of solvent (water) flow. The pollution control equipment must be sized to handle the maximum expected concentration, so the average saturation value of 185,034 ppm_v is reasonable.

The controllable emissions from each module consist of vapor displaced from vessels during filling, purging, and distillation and from dryers during drying operations. Emissions stream flow will vary from 0 acfm to approximately 10 acfm at times, reflecting the operating limits of the vacuum pumps.

TABLE 7.2

USAGE WEIGHTED AVERAGE VAPOR PRESSURE AND MOLECULAR WEIGHT

Solvent (VOC)	Mol. Weight	Vapor Pressure (psia @ 20 C)	Temp 1 mm Hg	Temp 100 mm Hg	Vapor Pressure (mm Hg @ 20 C)	1992 Usage (lb)	1992 Usage (%)
Acetone	58.1	3.5	-59.4	7.7	181.7	95,546	23.8%
Methanol	32.1	1.9	-44	21.2	97.3	34,917	8.7%
Methylene Chloride *	84.9	6.9	-70	-6.3	355	47,616	11.9%
Ethyl Acetate	88.1	1.4	-43.4	27	72.8	20,670	5.2%
Toluene	92.1	0.4	-26.7	51.9	21	35,814	8.9%
Chloroform	119.4	3.1	-58	10.4	160	12,683	3.2%
Methyl tert-Butyl Ether (MTBE)	88.17	2.1	-44	21.2	110	23,203	5.8%
Isopropyl Alcohol	60.1	0.6	-26.1	39.5	33	25,145	6.3%
Ethanol	46.7	0.9	-31.3	34.9	48	19,877	5.0%
Heptane	100.2	0.7	-34	41.8	38	17,601	4.4%
Other							
Total						333,072	100.0%
Usage Weighted Average	70.87	2.73	-48.13	19.93			

* Though not technically classified as a VOC, emissions would be reduced

The methods provided in the HAP Manual for calculating equipment and operating costs are based on steady state flow. In this case, it is assumed that the emission stream flow rate is 10 acfm, a reasonable maximum value. The maximum value is important because this parameter is used for sizing VOC control equipment. The equipment must be sized to handle the maximum expected flow.

Other emission stream parameters required for VOC control technology cost effectiveness analysis are summarized below:

- Operating schedule of 2,560 hours per year (80 batches X 32 hours/batch)
- Temperature of 77 °F

After the removal efficiency and the pollution control costs are calculated, the cost per ton is evaluated based on the projected actual maximum VOC emissions in tons per year for the module. For example, adding a low-temperature condenser in accordance with CTG guidelines to Module E will result in an annual cost of \$50,450, including capital recovery. This is divided by 3.25 tons VOC removed, for a cost of \$15,500 per ton.

The performance and costs for implementing condenser systems for each module are in Table 7.3. The performance and costs for implementing absorber systems for each module are in Table 7.4.

Sample calculations of pollution control removal efficiency and cost for Module E are included in Appendix C. These calculations are conducted in the manner specified for condenser and scrubber systems in the HAP manual.

7.2 CONDENSATION CALCULATIONS

The following subsections describe the procedure for estimating the capital, direct and indirect annual costs, and the cost effectiveness of applying condensation control technology to point emission streams.

7.2.1 Condensation System Specifications

Once emissions stream characteristics have been defined, condensation operating specifications can be developed. The RACT general guideline requires a -25° C operating temperature for VOCs with vapor pressures greater than 5.8 psia. Because of the variety of solvents used in the pilot plant, the condensation system must be designed to comply with all temperature requirements in the RACT rule.

TABLE 7.3

CONDENSATION CONTROL TECHNOLOGY PERFORMANCE SUMMARY

MIXTURE	EMISSIONS (TPY)							CAPITAL COST (\$)	ANNUAL COST (\$)	COST PER TON CONTROLLED
	REACTOR/B	FLYER/ CENTRIFUGE	DRYER	FUGITIVE	TOTAL					
A	Pre-control Emissions	2.28	0.40	0.36	1.02	4.04				
	Post-Control Emissions	0.02	0.08	0.08	1.02	1.71				
	VOC Removed	1.74	0.31	0.28	0.00	2.33	\$293,838	\$44,048	\$38,123	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.58				
B	Pre-control Emissions	1.18	0.40	0.25	1.02	2.83				
	Post-Control Emissions	0.27	0.08	0.08	1.02	1.44				
	VOC Removed	0.68	0.31	0.18	0.00	1.38	\$293,838	\$43,968	\$60,220	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.48				
C	Pre-control Emissions	1.71	0.40	0.30	1.02	3.43				
	Post-Control Emissions	0.38	0.08	0.07	1.02	1.87				
	VOC Removed	1.32	0.31	0.23	0.00	1.88	\$293,838	\$44,018	\$48,281	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.84				
D	Pre-control Emissions	3.73	0.40	0.60	1.02	6.66				
	Post-Control Emissions	0.84	0.08	0.11	1.02	2.08				
	VOC Removed	2.87	0.31	0.38	0.00	3.57	\$293,838	\$44,124	\$23,544	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.63				
E	Pre-control Emissions	3.36	0.40	0.48	1.02	6.24				
	Post-Control Emissions	0.77	0.08	0.11	1.02	1.98				
	VOC Removed	2.58	0.31	0.38	0.00	3.25	\$127,842	\$60,460	\$18,818	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.82				
F	Pre-control Emissions	3.36	0.40	0.48	1.02	6.24				
	Post-Control Emissions	0.77	0.08	0.11	1.02	1.98				
	VOC Removed	2.58	0.31	0.38	0.00	3.25	\$127,842	\$60,460	\$18,818	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.82				
30 Gal. A	Pre-control Emissions	0.11	0.20	0.04	0.14	0.49				
	Post-Control Emissions	0.03	0.05	0.01	0.14	0.22				
	VOC Removed	0.08	0.18	0.03	0.00	0.27	\$127,842	\$60,268	\$188,263	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.55				
30 Gal. B	Pre-control Emissions	0.10	0.20	0.04	0.11	0.45				
	Post-Control Emissions	0.02	0.05	0.01	0.11	0.19				
	VOC Removed	0.08	0.15	0.03	0.00	0.26	\$127,842	\$60,268	\$181,871	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.58				
C Wing	Pre-control Emissions	0.78	0.40	0.18	0.87	1.84				
	Post-Control Emissions	0.18	0.08	0.04	0.87	0.85				
	VOC Removed	0.81	0.31	0.14	0.00	1.08	\$127,842	\$60,308	\$47,888	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.84				
TOTAL	Pre-control Emissions	18.98	3.20	2.88	8.84	28.31				
	Post-Control Emissions	3.81	0.73	0.68	8.84	12.08				
	VOC Removed	12.77	2.47	2.00	0.00	17.23	\$1,818,482	\$657,888	\$34,113	
	VOC Removal Efficiency	0.77	0.77	0.77	0.00	0.88				

Condenser cost and performance is based on -25 Deg C condenser, which has a 99.3% removal efficiency.

Reactor emissions stream removal efficiency is based on 99.3% VOC removal from 80% of emissions streams.
20% of annual emissions are from aqueous (> 1% water) solutions that cannot be controlled by low temperature condensation due to freezing problems.

TABLE 7.4

ABSORPTION CONTROL TECHNOLOGY PERFORMANCE SUMMARY

MODULE	EMISSIONS (TPY)						TOTAL	CAPITAL COST (\$)	ANNUAL COST (\$)	COST PER TON CONTROLLED
	REACTORS	FILTER/ CENTRIFUGE	DRYER	FUGITIVE						
A	Pre-control Emissions	2.26	0.40	0.30	1.02		4.04	\$290,220	\$62,492	\$62,096
	Post-Control Emissions	0.93	0.16	0.15	1.02		2.26			
	VOC Removed	1.33	0.24	0.21	0.00		1.78			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.44			
B	Pre-control Emissions	1.16	0.40	0.25	1.02		2.83	\$290,220	\$62,492	\$60,906
	Post-Control Emissions	0.48	0.16	0.10	1.02		1.77			
	VOC Removed	0.66	0.24	0.15	0.00		1.06			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.36			
C	Pre-control Emissions	1.71	0.40	0.30	1.02		3.43	\$290,220	\$62,492	\$65,209
	Post-Control Emissions	0.70	0.16	0.12	1.02		2.01			
	VOC Removed	1.01	0.24	0.18	0.00		1.42			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.41			
D	Pre-control Emissions	3.73	0.40	0.50	1.02		5.65	\$290,220	\$62,492	\$33,974
	Post-Control Emissions	1.54	0.16	0.21	1.02		2.93			
	VOC Removed	2.19	0.24	0.29	0.00		2.72			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.48			
E	Pre-control Emissions	3.36	0.40	0.48	1.02		5.24	\$79,340	\$49,940	\$20,126
	Post-Control Emissions	1.36	0.16	0.19	1.02		2.78			
	VOC Removed	1.98	0.24	0.27	0.00		2.48			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.47			
F	Pre-control Emissions	3.36	0.40	0.48	1.02		5.24	\$79,340	\$49,940	\$20,126
	Post-Control Emissions	1.36	0.16	0.19	1.02		2.78			
	VOC Removed	1.98	0.24	0.27	0.00		2.48			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.47			
30 Gal-A	Pre-control Emissions	0.11	0.20	0.04	0.14		0.49	\$79,340	\$49,940	\$242,663
	Post-Control Emissions	0.05	0.08	0.02	0.14		0.28			
	VOC Removed	0.06	0.12	0.02	0.00		0.21			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.42			
30 Gal-B	Pre-control Emissions	0.10	0.20	0.04	0.11		0.45	\$79,340	\$49,940	\$249,500
	Post-Control Emissions	0.04	0.08	0.02	0.11		0.25			
	VOC Removed	0.06	0.12	0.02	0.00		0.20			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.44			
C-Wing	Pre-control Emissions	0.79	0.40	0.18	0.57		1.94	\$79,340	\$49,940	\$61,994
	Post-Control Emissions	0.33	0.16	0.07	0.57		1.13			
	VOC Removed	0.46	0.24	0.11	0.00		0.81			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.42			
TOTAL	Pre-control Emissions	16.58	3.20	2.59	6.94		29.31	\$1,553,660	\$619,668	\$47,110
	Post-Control Emissions	6.83	1.32	1.07	6.94		16.16			
	VOC Removed	9.75	1.88	1.52	0.00		13.15			
	VOC Removal Efficiency	0.59	0.59	0.59	0.00		0.45			

The total capital cost of a condensation system consists of the cost of the condenser, refrigeration unit, auxiliary equipment, sales tax, freight, engineering, installation, and start-up. Because condensers cannot be used where steam jets provide vacuum, auxiliary equipment for modules A, B, C, and D, include vacuum pumps to replace the existing steam ejectors used to provide vacuum on reactor vessels.

First, the temperature of condensation is determined for the stated removal efficiency, using Figure 4.8-2 in the HAP Manual. This, plus additional parameters including the stream flow rate, HAP heat of vaporization, and HAP specific heat, will yield calculated values for condenser heat load (Equation 4.8-7), condenser area (Equation 4.8-9), coolant flow rate (Equation 4.8-10), and refrigeration capacity (Equation 4.8-11).

Equipment costs for the condenser is a function of condenser area (Equation 4.8-3). Equipment costs for the refrigeration unit is a function of condensation temperature and refrigeration capacity (Table 4.8-2 of the HAP Manual).

Purchased equipment cost includes the condenser, refrigeration unit, auxiliary equipment, instrumentation, sales tax, and freight. From Table 4.8-5 of the HAP Manual, instrumentation, sales tax, and freight are estimated as 20% of the sum of the cost of the condenser and auxiliary equipment. Indiana state sales tax of 5% is used instead of the 3% listed in this table.

Direct installation costs are 43% of the purchased equipment cost, plus the building cost and site preparation cost. Site preparation costs are set to zero in this study, although for some installations these costs could be considerable. Building cost is set at 6% of the purchased equipment cost.

7.2.3

Condensation Direct Annual Cost

Direct annual costs include electricity, maintenance, labor, and the cost of disposing recovered VOC. Direct annual costs can then be estimated using the equations in Table 4.8-6 of the HAP Manual. In this study, the refrigerant cost was conservatively set to zero.

7.2.4

Condensation Indirect Annual Cost

Indirect annual cost includes overhead, property taxes, insurance, administration, and capital recovery. These costs are estimated using the

equations in Table 4.8-6 of the HAP Manual. The capital recovery cost factor is based on a 10 year useful life at a 10% interest rate.

7.2.5 *Condensation Total Annual Cost and Cost Effectiveness*

Direct and indirect annual costs are summed to obtain the total annual cost of operating a condensation system. Total VOCs controlled by the system is obtained by multiplying the emission rate by the system's VOC removal efficiency. Dividing the total annual cost of operating the system by the tons of VOC controlled yields the system's cost effectiveness in terms of dollars per ton of pollutant controlled. Approximately 20% of the solvents used in Building 110 are aqueous solutions and, due to condenser freezing, can not be controlled through condensation control technology. This technical limitation is factored into the cost effectiveness calculations. Condensation emission stream and cost-effectiveness, based on the above assumptions is summarized in Table 7.3.

7.3 *ABSORPTION (SCRUBBING) CALCULATIONS*

The following subsections describe the procedures for estimating the capital, direct and indirect annual costs, and the cost effectiveness of applying scrubber control technology to an emissions stream.

7.3.1 *Scrubber System Specifications*

After emissions stream characteristics have been defined, scrubber operating specifications can be developed. Typical scrubber VOC removal efficiency is 95%. The calculations were based on a conservative removal efficiency of 100% for soluble VOCs. Because 41.2% of the solvents (usage weighted average) used in Building 110 are not soluble in water, the effective annual removal efficiency for scrubbing is 58.8%.

7.3.2 *Scrubber System Capital Cost*

Total capital cost of a scrubber system consists of the cost of the scrubber, packing material, auxiliary equipment, sales tax, freight, direct installation costs, and indirect installation costs.

First, the liquid flow rate is calculated based on emission stream rate and the slope of the equilibrium curve for the HAP in the solvent, using equations 4.7-1 through 4.7-5. Then, the absorber column diameter is calculated using Equations 4.7-6 through 4.7-11 and Figure 4.7-2. The height of the column is calculated in equations 4.7-12 through 4.7-19. Additional parameters for the column height calculation are the Schmidt

numbers for the HAP in air and in the solvent, and packing constants for the packing material used in the absorber column. The cost of the absorber column is a function of column diameter, as shown in Figure 4.7-4.

Purchased equipment cost includes the absorber, packing material, auxiliary equipment, instrumentation, sales tax, and freight. Using Table 4.7-3 of the HAP Manual, instrumentation, sales tax, and freight are estimated as 20% of the sum of the cost of the incinerator and auxiliary equipment. Indiana state sales tax of 5% is used instead of the 3% listed in this table.

Direct installation costs are 85% of the purchased equipment cost, plus the building cost and site preparation cost. Site preparation costs are set to zero in this study, although for some installations these costs could be considerable. Building cost is set at 6% of the purchased equipment cost.

Indirect Installation Costs, based on Table 4.7-3 of the HAP manual, are 35% of the purchased equipment cost.

7.3.3 *Scrubber System Direct Annual Costs*

Direct annual costs include, electricity, maintenance, and labor. These costs are estimated using the equations in Table 4.7-4 of the HAP manual.

7.3.4 *Scrubber System Indirect Annual Costs*

Indirect annual cost includes overhead, property taxes, insurance, administration, and capital recovery. These costs are estimated using the equations in Table 4.7-4 of the HAP Manual. The capital recovery cost factor is based on a 10 year useful life at a 10% interest rate.

7.3.5 *Scrubber System Total Annual Costs and Cost Effectiveness*

Direct and indirect annual costs are summed to obtain the total annual cost of operating a scrubber system. Total VOCs controlled by the system is obtained by multiplying the emission rate by the system's VOC removal efficiency. Dividing the total annual cost of operating the system by the tons of VOC controlled yields the system's cost effectiveness in terms of dollars per ton of pollutant controlled. Condensation emission stream and cost-effectiveness, based on the above assumptions is summarized in Table 7-4.

In all cases, the cost per ton for a scrubber system was found to be higher than for a condensation system at -25 Degrees C. In each module, a

scrubber system also has a lower removal efficiency than a condenser system. Therefore, a scrubber system was not evaluated further.

7.4

CONCLUSION - COST ESTIMATES

Based on the Indiana permitting experience of two ERM-Midwest employees, Timothy Jones and David Jordan, VOC RACT cost effectiveness is considered to be between \$2,000 and \$5,000 per ton controlled; VOC BACT cost effectiveness is considered to be between \$5,000 and \$12,000 per ton controlled. Condensation cost effectiveness of \$15,518 to \$191,871 per ton VOC controlled exceeds generally accepted cost per ton RACT thresholds. Condensation cost effectiveness also exceeds typical BACT (more stringent than RACT) cost per ton thresholds.

Scrubbing cost effectiveness of \$20,126 to \$249,800 per ton VOC controlled also exceeds generally accepted RACT and BACT thresholds.

Lilly has already incorporated into Building 110 control technologies and operating practices that effectively reduce VOC emissions. Proposed additional equipment for the expansion will also include VOC emissions control technologies. The existing and proposed control technologies and operating practices are described in the following sections. Lilly proposes that these VOC emissions control technologies and operating practices be considered Building 110 site-specific RACT.

Unit operation specific proposed VOC RACT on existing and proposed equipment are described in the following sections.

8.1

REACTORS

Each reactor vessel (with the exception of a 100 gallon high pressure hydrogenation reactor in module A that due to extremely high pressure operating conditions is not equipped with a condenser) in Building 110 is directly connected to a primary condenser. The temperature of the working fluid at the inlet of these condensers is -10°C or colder. Although the main purpose of the condensers is process control, they act as air pollution control devices and reduce VOC emissions. The condensers are operated whenever the reactors are venting. When venting aqueous/VOC mixtures or other mixtures which will freeze at -10°C , the condensers are operated at a warmer temperature to prevent ice from forming in the condenser.

Operating the primary condensers at -10°C during material transfer and venting will reduce Building 110 pre-control reactor VOC emissions of 16.58 TPY by approximately 10.72 TPY.

Lilly proposes as RACT for reactor vessels to use primary condensers with a working fluid inlet temperature of -10°C or colder for mixtures that will not freeze at -10°C (includes most non-aqueous streams). The condensers will operate during reactor venting, material transfer, and distillation. Lilly will record the working fluid temperature at the inlet and outlet of the condenser while condensers are in operation and vented.

8.2

EXPOSED LIQUID CENTRIFUGES AND FILTERS

Lilly will enclose all Building 110 centrifuges and filters having an exposed liquid surface containing VOC.

8.3 *VACUUM DRYERS*

Maximum VOC emissions from any one vacuum dryer are estimated to be 0.50 tons per year. Adding VOC controls for this small quantity of emissions would not be economically feasible, and consequently would not be RACT. The proposed alternate RACT for Building 110 vacuum dryers is no control.

8.4 *AIR DRYERS*

Each Building 110 air dryer will emit less than 33 pounds VOC per day.

8.5 *STORAGE TANKS*

Building 110 does not operate storage tanks of capacity greater than 2,000 gallons, receiving deliveries from trucks or railcars, storing VOC with a vapor pressure greater than 4.1 psia. A 4,200 gallon acetone (vapor pressure of 3.5 psia) storage tank is a component of Building 110 processes. The acetone tank is equipped with a vapor balancing system that is 90% effective in reducing emissions during deliveries. The acetone tank vapor recovery system will reduce VOC emissions by 0.03 TPY more than is required by general RACT guidelines for storage tanks. Calculations of acetone storage tank emissions are in Appendix B. All storage tanks for VOCs with a vapor pressure greater than 0.5 psia at 20° C are equipped with pressure/vacuum conservation vents set at a minimum of +/- 0.03 psia.

8.6 *IN-PROCESS TANKS*

All in-process tanks containing VOCs are equipped with tight fitting covers. These covers are closed at all times unless production, sampling, inspection, or maintenance activities require access to the tank.

8.7 *EQUIPMENT LEAKS*

Building 110 standard operating procedure is to repair all visible equipment leaks as soon as possible. During module operation, process operators inspect vessels and equipment (valves, flanges, etc.) for visible indications of leaks. Any leaks are repaired as soon as the leaking component is off-line for a period of time long enough to complete the repair.