AD-A242 110

ESL-TR-90-33

Degreaser System Pollution Prevention Evaluation

M.F. SZABO, M.T. NUTTER

PEI ASSOCIATES, INC.
11499 CHESTER ROAD
CINCINNATI, OHIO 45246

SEPTEMBER 1990

FINAL REPORT
NOVEMBER 1989 - SEPTEMBER 1990

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

AEERL

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
PROJECT OFFICER: CHARLES H. DARVIN

AFESC

ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403
PROJECT OFFICER: DR. JOSEPH WANDER

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFESC/RD (ENGINEERING AND SERVICES LABORATORY). ADDITIONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5285 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release Distribution Unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) ESL-TR-90-33
6a. NAME OF PERFORMING ORGANIZATION PEI Associates, Inc. Air Engineering and Measurement 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Air Force Engineering Services Center
6c. ADDRESS (City, State, and ZIP Code) 11499 Chester Road Cincinnati, OH 45246	7b. ADDRESS (City, State, and ZIP Code) HQ AFESC/RDVS Tyndall AFB FL 34403-6001
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 64708F; PROJECT NO. 3788; TASK NO. 30; WORK UNIT ACCESSION NO. 68

11. TITLE (Include Security Classification)

Degreaser System Pollution Prevention Evaluation

12. PERSONAL AUTHOR(S)

Szabo, Michael Francis; Nutter, Mark Thomas

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 11/89 TO 9/90	September 1, 1990	

16. SUPPLEMENTARY NOTATION

Availability of this report is specified on the reverse of the front cover

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Vapor degreaser, trichloroethane, TCA, air pollution, industrial hygiene,

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this project was to investigate the capability of various engineering changes to an existing vapor degreaser to reduce solvent emissions to the atmosphere while remaining within the established Air Force exposure limits for 1,1,1-trichloroethane (TCA). A 1970 vintage vapor degreasing system serving the USAF's 4950 TW/AMFSM metal fabrication shop had been converted from trichloroethylene to TCA and fitted with a lip vent exhaust system to decrease worker exposure. Solvent consumption with this configuration was two to three 55-gallon drums weekly, all presumed to be emmited to the atmosphere via the lip vent. In sequence, various modifica- tions to the degreaser and operating procedures were instituted to define their capability to reduce emissions and comply with exposure limit requirement. They include decrease and elimination of lip vent suction, a freeboard extension, add-on chiller, and a freeboard extension plus add-on chiller.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. Joseph Wander	22b. TELEPHONE (Include Area Code) (904) 283-4234 — 22c. OFFICE SYMBOL RDVS

DD Form 1473, JUN 86 — Previous editions are obsolete — SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. Abstract (continued)

Whereas the lip vent was shown to lower workplace concentrations, it also resulted in greatly increased TCA emission rates. The elimination of the lip vent with the simultaneous addition of a freeboard extension plus add-on chiller provided approximately equivalent workplace concentrations of TCA but with a decreased discharge rate of TCA. The rate of consumption of TCA was reduced by approximately 75 percent with this configuration while the same degree of worker safety was maintained as with the lip vent

EXECUTIVE SUMMARY

A. OBJECTIVE:

The purpose of this project was to investigate the technical and economic feasibility of applying a range of solvent conservation options to a vapor degreaser located at Wright Patterson Air Force Base (WPAFB-4950 TW/AMFSM) while keeping worker breathing zone concentrations at U.S. Air Force engineering targets of 25 percent of Occupational Safety and Health Administration (OSHA) action limits of 43 ppm for an 8-hour time-weighted average (TWA) and a short-term exposure limit (STEL) of 56 ppm for TCA. The degreaser uses 1,1,1-trichloroethane (TCA) as a solvent.

B. BACKGROUND:

The U.S. Environmental Protection Agency Air and Energy Engineering Research Laboratory (EPA-AEERL) and the U.S. Air Force Headquarters Air Force Engineering and Services Center (AFESC) are involved in a joint program to identify methods of reducing pollution from USAF Depot facilities throughout the U.S. The vapor degreaser being studied was inspected and chosen as a test candidate for reducing emissions of TCA through various pollution prevention options. The degreaser utilizes a lip vent suction system that results in excessive loss of TCA. Since TCA will be phased out of use over the next 10 years, its cost will rise in the interim period, increasing the incentive for the implementation of solvent conservation options.

C. SCOPE:

The scope of the project included baseline degreaser measurements, effects of ventilation patterns on solvent loss/worker exposure, and a series of physical modifications to the degreaser system, such as reducing exhaust fan speed, increasing freeboard area, and installing a freeboard chiller. The physical modifications were designed to systematically reduce solvent consumption at increasing cost levels.

D. METHODOLOGY:

Solvent loss and worker exposure measurements were taken during each test. A portable infrared analyzer (Miran 1A) and charcoal tubes were used for the solvent loss/exposure measurements. Various other ancillary parameters such as exhaust duct air flow, atmospheric pressure, degreaser temperature, and solvent level were measured during each test. Both winter and summer operating conditions were tested.

E. TEST DESCRIPTION:

An initial series of four test options was performed during the winter and spring from February to April 1990. A second series of tests was conducted in late May/early June 1990 to represent summer conditions. Both sets of tests included baseline testing at full fan speed, reduced fan speed, and an increase in freeboard height. The summer tests included

the use of a chiller both alone and in conjunction with the freeboard extension, and ventilation patterns were altered to isolate the degreaser room.

F. RESULTS:

Five test options controlled worst-case personal exposure to levels (at degreaser midpoint) that achieved, or slightly exceeded, the Air Force Engineering Target Levels: (1) baseline, (2) reduced lip vent suction, (3) fan off with freeboard extension, (4) chiller without fan or freeboard extension, and (5) chiller with freeboard extension. One test option did not reduce worst-case personal exposure to meet the Air Force Engineering Target Levels: fan off with existing freeboard. Two test options achieved acceptable control from a worker comfort standpoint: (1) baseline operation and (2) chiller with freeboard extension. The use of a chiller with freeboard extension resulted in a maximum reduction in solvent consumption of 72 percent.

G. CONCLUSIONS:

Very significant reductions in solvent use are achievable from the WPAFB degreaser using the chiller plus freeboard option, while simultaneously keeping worker exposure below Air Force engineering targets, and with worker acceptance and support of the physical modifications to the degreaser.

The installation of the chiller plus freeboard is technically feasible, requiring only a few days of down time. The economic payback for this degreaser is less than 1 year, based on solvent and heat loss savings.

H. RECOMMENDATIONS:

The degreaser should be operated with the chiller and freeboard extension (no fan) on a permanent basis. Continued isolation of the degreaser room with more permanent materials is also necessary to maintain current levels of worker exposure. Leaks in the degreaser system should be repaired and will likely reduce worker exposure even further. Better recordkeeping on degreaser operation and solvent use would help in identifying causes of excessive solvent consumption.

PREFACE

This report was prepared by PEI Associates, Inc., Cincinnati, Ohio, under Environmental Protection Agency (EPA) Contract No. 68-02-4284, funded by the Air Force Engineering and Services Center, Engineering and Services Laboratory (AFESC/RDVS), Tyndall Air Force Base, Florida 32403-6001.

This report summarizes work done between November 1989 and September 1990, by James Boiano and Robert Schraft under the direction of Michael Szabo and Avinash Patkar, and in cooperation with Mark Nutter, all of PEI Associates. The EPA work assignment officer was Charles H. Darvin, Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina. Dr. Joseph D. Wander was the Air Force project officer for this contract.

Support and assistance provided by personnel of 4950 TW/AMFS, Wright Patterson AFB, Ohio, is gratefully acknowledged. Jack Fluty and Roger Guernsey provided access to the facility in which this study was executed, and Robert Howell wore sampling equipment for several days during the course of performing his job duties. Ultrakool, Inc., Gilbertsville, Pennsylvania, provided a freeboard chiller at a substantially reduced cost in support of this research effort.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for public release.

JOSEPH D. WANDER
Project Officer

MICHAEL L. SHELLEY, Maj, USAF, BSC
Chief, Environics Division

WAYNE P. CHEPREN, Capt, USAF
Chief, Environmental Compliance
R&D Branch

FRANK P. GALLAGHER III, Colonel, USAF
Director, Engineering and
Services Laboratory

A-1

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(Concluded)

LIST OF FIGURES

LIST OF FIGURES
(Concluded)

LIST OF TABLES

CONVERSION FACTORS AND EQUIVALENTS

1 atmosphere = 14.7 lb/in^2 = 29.92 in.Hg = 760 millimeter (mm) Hg

1 British Thermal Unit (Btu) = 2.928×10^{-4} kilowatt-hours (kWh)

T° Centigrade = (T° Fahrenheit - 32)/l.8

1 cubic foot (ft^3) = 0.02832 cubic meter

1 gallon (gal) = 3.785 liters

1 horsepower (hp) = 0.75 kilowatt

1 inch (in) = 2.540 centimeters

1 liter = 1.057 quarts (U.S.,liquid) = 0.03531 cubic feet (ft^3)

1 meter (m) = 3.281 feet (ft) = 39.37 inches (in)

1 millimeter (mm) Hg = l.36 cm of H_2O

l pound (lb) = 453.6 grams = 0.454 kilogram

1 pound/square foot (lb/ft^2) = 1.488 kilograms/square meter

1 square foot (ft^2) = 0.0929 square meter (m^2)

1 square inch (in^2) = 6.452 square centimeters (cm^2)

(The reverse of this page is blank)

SECTION I

INTRODUCTION

A. OBJECTIVE

The purpose of this project was to investigate the technical and economic feasibility of applying a range of TCA solvent conservation options to the Wright - Patterson AFB (WPAFB), degreaser while keeping worker breathing zone concentrations at 25 percent of Occupational Safety and Health Administration (OSHA) action limits for 43 ppm or an 8-hour time-weighted average (TWA) and a short-term exposure limit (STEL) of 56 ppm.

B. BACKGROUND

The U.S. Environmental Protection Agency Air and Energy Engineering Research Laboratory (EPA-AEERL) and the U.S. Air Force, Headquarters Air Force Engineering and Services Center (AFESC), are involved in a joint program to identify methods of reducing pollution from USAF Depot facilities throughout the U.S. A vapor degreaser located in Wright-Patterson Air Force Base (WPAFB), Building 5, Area B, was inspected and chosen as a test candidate for reducing emissions of its solvent, 1,1,1-trichloroethane (TCA), through various pollution prevention options. The degreaser utilizes a lip vent suction system to remove TCA vapors and prevent them from entering the workers' breathing zone. While this is effective, the lip vent also results in excessive loss of TCA. It is estimated that the degreaser uses about 100 barrels of solvent per year. Since TCA may be phased out of use over the next 10 years, and its cost will most certainly rise in the interim period, there is more incentive for the implementation of solvent conservation options. Previous degreaser studies over the past 15 years have demonstrated that a number of physical modifications and worker operating procedures can significantly reduce solvent consumption in vapor degreasers. A major study sponsored by EPA-IERL-Cin, in 1980[1] investigated the impact of variables such as cover utilization, freeboard height, refrigerated chiller, lip exhaust vents, hoist system speed, load cross sectional area and solvent type on vapor degreasers under carefully controlled conditions of temperature, humidity, airflow and barometric pressure. An increase in freeboard ratio from 50 to 100 percent resulted in a 50 percent reduction in solvent consumption. With the addition of a freeboard chiller, an additional reduction of 44 percent was achieved at a freeboard ratio of 100 percent. Use of machine covers resulted in solvent loss reductions of 40-60 percent for nonboiling and boiling operation respectively. Other studies conducted in the 1970's and 1980's have confirmed the results obtained in the 1980 EPA study.[2-9]

C. SCOPE

The scope of the project included baseline degreaser measurements, effects of ventilation patterns on solvent loss/worker exposure, and a series of physical modifications to the degreaser system, such as reducing exhaust fan speed, increasing freeboard area, and installing a freeboard chiller. The physical modifications were designed to systematically reduce solvent consumption at increasing cost levels.

Solvent loss and worker exposure measurements were taken during each test. A portable infrared analyzer (Miran 1A) and charcoal tubes were used for the solvent loss/exposure measurements. Various other ancillary parameters such as exhaust duct air flow, atmospheric pressure, degreaser temperature, and solvent level were measured during each test. Both winter and summer operating conditions were tested.

Section 2 of this report provides an overview of the test program by presenting the degreaser and site description, a discussion of the conservation options studied, the industrial hygiene targets for worker exposure, and the project schedule.

Section 3 presents the sampling and analysis procedures utilized during the study, including descriptions of all sampling equipment, sampling procedures, and quality assurance (QA) objectives.

Section 4 presents the study results by describing the tests performed in chronological order over the 5-month test period; a technical/economic evaluation of each test option is also presented, as well as the industrial hygiene implications of each test option.

Section 5 provides conclusions and recommendations. Appendices include the various test logs accumulated throughout the project, selected photographs of the degreaser and test equipment, and QA summaries for charcoal tube data.

The results of this report can be utilized by a wide audience of users who operate older vapor degreasers which are not equipped with the types of solvent use minimization devices investigated in this study. The tests were conducted under actual operating conditions and the results reflect the variability inherent in the operation of any vapor degreaser. Users of this document can determine 1) the importance of proper control of ventilation patterns to reduce cross drafts, 2) monitoring techniques necessary to document changes in operator breathing zone concentrations, 3) changes in breathing zone and area concentrations as a function of physical modifications to the degreaser, and 4) reductions in solvent usage as a function of the various options tested.

SECTION II

OVERVIEW OF TEST PROGRAM

A. SITE/DEGREASER DESCRIPTION

The vapor degreaser studied during this project is located at WPAFB Area B, Building 5 (Figure 1). Although the degreaser is located in its own room, it was subject at the start of this study to significant cross drafts across its open top because the degreaser room is under negative pressure. Next to the degreaser room is a plating shop with a large centrifugal fan that exhausts all of the hoods over the plating baths. This fan causes a negative pressure differential in the degreaser room. Other activities in Building 5 also affect degreaser emissions; these activities are discussed in Section 4.

The degreaser was manufactured by Phillips Manufacturing Co., Chicago, Illinois, and has been in operation since 1979. The solvent originally used in the degreaser was trichloroethylene (TCE). The company switched to TCA 3 years ago because of worker exposure concerns. About 95 percent of the parts degreased are aluminum. Parts are degreased both manually and (for larger parts) with the aid of an overhead hoist and conveyor located 4 feet above the top of the degreaser. Following are pertinent degreaser specifications:

- Model: Phillips T156S
- Solvent: 1,1,1-Trichloroethane (TCA)
- Solvent use rate: 100 drums/year
- Total dimensions: L = 180 inches, W = 30 inches, H = 96 inches
- Working dimensions: L = 156 inches, W = 24 inches, H = 96 inches
- Basket height: 18 inches
- Conveyor height: 4 feet from hook top of degreaser
- Height to water jacket centerline: 78 inches
- Present freeboard ratio requirements: 75 percent
- Freeboard height (water jacket center line to top): 15 inches
- OSHA permissible emission limits: 350 ppm (8-hour TWA), 450 ppm (STEL)
- Present breathing zone level: 10 ppm

1. Description of Operation

The vapor degreaser operates on the same principle as all vapor degreasers: steam coils located at the bottom of the sump heat the TCA

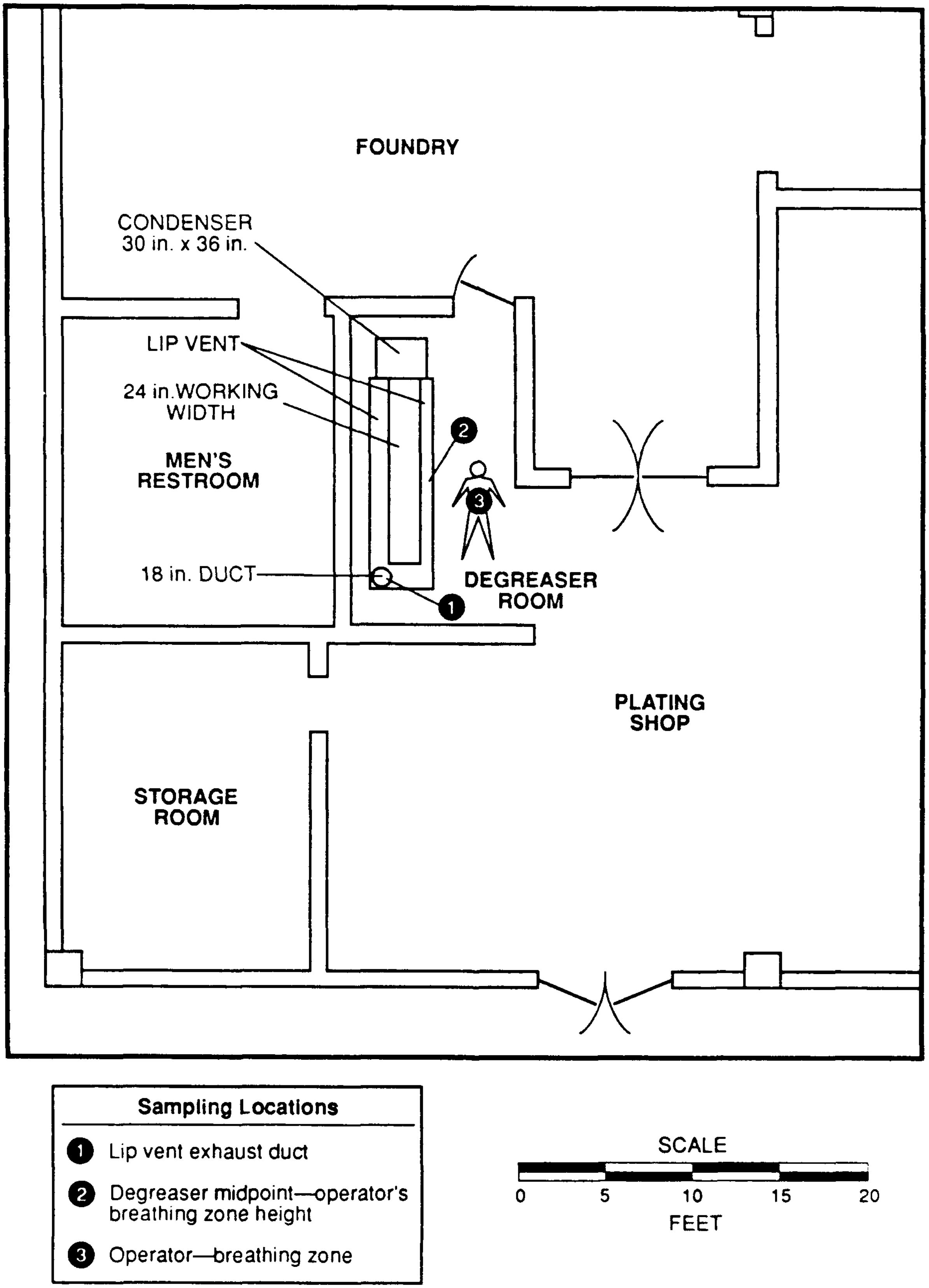


Figure 1. Overview of Building 5 project area showing Degreaser Room and sampling locations.

contained in the main tank. The solvent boils and generates vapors used to clean the aluminum parts. The height of the vapors is controlled by the water jacket located along three sides of the main tank and the condenser coils located only in the auxiliary tank, not around the entire main tank perimeter. The water jacket helps to maintain a vapor line by not allowing the freeboard walls to transfer heat from the hotter wall surface below the freeboard. Solvent and moisture condensed on the coils fall onto a stainless steel pan that drains to an end trough. The outlet flow from this trough empties into a solvent/water separator. The heavier solvent is returned to the auxiliary tank and the lighter water evaporates or overflows through a relief tube if the level is high enough.

The freeboard section of the degreaser is measured from the top of the vapor line (about three-quarters of the height of the water jacket) to the lip of the suction vent. This freeboard area is designed to permit drying of parts before they are lifted out of the degreaser and to minimize vapor disturbance from air movement. Freeboard ratio is defined as the distance from the top of the vapor line to the lip suction vent (freeboard) divided by the width across the open top of the degreaser.

Lip suction vents located on each side of the degreaser keep solvent vapors away from workers by exhausting them to a stack located at one end of the degreaser. The freeboard ratio was increased to 75 percent 3 years ago by extending the lip suction vent out about 6 inches along the side of the degreaser closest to the exhaust stack. This was done in response to a local air pollution control agency request.

The main degreaser chamber holds up to 150 gallons of solvent, and capacity of the auxiliary condenser chamber is 250 gallons. In normal operation, the solvent in both chambers is balanced and only 250 gallons is utilized. The auxiliary chamber is located under the condensing coils on the opposite end of the stack and does not have a lip suction vent. Safety features on the degreaser include low solvent level/steam shut-off, water jacket circulation/steam shut-off, solvent temperature/steam shut-off, and exhaust airflow/steam shutoff.

It is estimated that about 100 drums per year of solvent are used in the degreaser. Less than one drum (55 gallons) of waste solvent is shipped out each year. The rest is lost in evaporation and dragout.

2. Degreaser Deficiencies

A number of deficiencies were noted in the operation of the degreaser during the course of the project. The most important was that the water/ solvent separator was not functioning properly. This occurred because there was no cooling loop installed in the separator to decrease the solvent/water mixture temperature to about 155°F to allow the separation of solvent and water to occur. A new water/solvent separator was installed by Ultralkool during the latter part of the project.

In addition, the drain pan under the condenser coils was missing. This meant that only the solvent/water mixture condensed from the coils located over the top of the end drain trough (less than 10 percent of total) was being routed through the water/solvent separator. The remaining solvent/water mixture (greater than 90 percent) was draining directly back into the auxiliary sump. A new drain pan was purchased by PEI and installed by WPAFB during the latter part of the project.

The third mechanical problem noted is the presence of vapor leaks around the sight glass and a number of other pipe entrances into the degreaser. These leaks were suspected and verified during the latter part of the tests. The leaks were left as is, and thus contribute to the breathing zone concentrations.

B. BASELINE TESTING AND WASTE MINIMIZATION OPTIONS

The individual reconfigurations that were evaluated during this study are as follows:

- Baseline testing (including worker operating practice observations and qualitative airflow study)
- Modification of area ventilation (roof fan and temporary curtains)
- Reduction of vent suction
- Cessation of induced-draft fan use
- Increase in freeboard height
- Installation of secondary strap-on chiller

These items are presented in the order in which they were evaluated, and represent a progressive increase in complexity and cost. A description of the rationale behind each of these options is presented in the following paragraphs.

1. Baseline Testing

The baseline testing consisted of measuring the stack and area concentrations of TCA with the system operating "as is." In addition, worker operating practices were videotaped and studied to determine how they might affect solvent loss through the exhaust stack and worker exposure. Videotaping was continued during most of the tests.

A qualitative airflow study of the air currents in the degreaser room was conducted. Ventilation smoke tubes were used to visualize the air currents over the degreaser with the existing ceiling-mounted axial-flow fan on. Capture velocity at the lip vents and air velocity in the stack were measured. Static pressure was measured to determine whether the degreaser room was under positive or negative pressure.

2. Modify Area Ventilation

The results of the baseline testing in February 1990 indicated that there was not a significant cross-draft problem in the degreaser room. Thus, temporary curtains were not installed to isolate the degreaser room from cross draft. Later, during the test period in April, test results indicated that ventislation patterns had changed (presumably due to seasonal effects), and curtains were installed in the doorway leading out of the degreaser room. Plastic sheeting was also installed above the curtains, and air passages into the room at higher elevations were sealed to further isolate the degreaser room and reduce cross drafts. Other modifications to operating procedures in Building 5 were also necessary to reduce cross drafts and are discussed in Section IV of this report.

3. Reduction of Lip Vent Suction

This simple modification lowered collection velocity by decreasing the speed of the induced-draft fan that exhausts the solvent vapors to the atmosphere. This was done by substituting a larger pulley on the fly wheel and decreasing the motor pulley diameter. Otherwise, the system was left "as is" to measure solvent emissions and worker exposure.

4. Cessation of Induced-Draft Fan Use

For this option, the induced-draft fan was turned completely off and the system left "as is" to measure solvent emissions and worker exposure.

5. Increase in Freeboard Height

This option resulted in an increase in existing freeboard from 15 to 24 inches through the installation of a 9-in. 20-gauge metal extension mounted directly on top of the existing lip suction vent (see Appendix C). This resulted in a freeboard ratio of approximately 100 percent. A movable flap was installed on one side of the freeboard extension so that workers could more easily insert and remove parts. A temporary 6-inch step was also installed in front of the degreaser so that parts could be inserted easily without lowering the movable flap.

6. Use of Freeboard Chiller

A freeboard chiller was purchased at a heavily discounted price of $6000 for research purposes. The chiller was supplied and installed by Ultra Kool, Inc., Gilbertsville, Pennsylvania. The freeboard chiller consisted of copper-finned nickel-plated refrigeration lines placed around the inside perimeter of the main degreasing chamber, directly above the water jacket. The chiller operates at sub-zero refrigerant temperature (-20°F), and creates a cold-air blanket that settles on the top of the solvent vapor zone. The cold-air blanket intercepts the rising heated solvent fumes, suppressing the evaporation, increasing the saturation level of the solvent vapors, and causing the fumes to form droplets and fall back into the sump.

The temperature of the cold-air blanket is kept at about 115°F below the boiling point of the TCA (165°F), at about 50°F. Parts being degreased will not disturb the blanket enough to disrupt the vapor zone, provided they are properly inserted into and extracted from the degreaser.

Solvent fumes and some moisture will condense on the cold coils of the chiller. Once each hour, the refrigeration cycle is reversed for several minutes and warm gas flows through the refrigerant tubes to melt the condensed frost on the coils. The liquid solvent/water mixture falls into a trough below each coil and flows to the end of the degreaser and onto the drip pan for the condenser coils in the auxiliary tank. This mixture is then routed through the solvent/water separator.

C. INDUSTRIAL HYGIENE TARGETS

The operator breathing zone concentration targets for the study originated with OSHA Permissible Exposure Limits (PELs) and action levels (i.e., 50 percent of the OSHA PELs) for TCA. For this study, however, the target breathing zone targets were based on the United States Air Force (USAF) engineering control limit, which is 25 percent of the OSHA action level. These limits for TCA are as follows:

OSHA PEL	OSHA action limit, ppm	Study target limit, ppm[c]
350 ppm - 8-h TWA[a]	175 ppm	43 ppm
450 ppm - STEL[b]	225 ppm	56 ppm

[a] 8-h time-weighted average expressed in parts per millon (ppm).
[b] 15-minute short-term exposure limit.
[c] USAF engineering control limit.

Thus, the goal of the study was to keep the average area and personal breathing zone concentrations of TCA at or below 43 ppm (8-h TWA) and 56 ppm (STEL), while decreasing solvent consumption as much as possible.

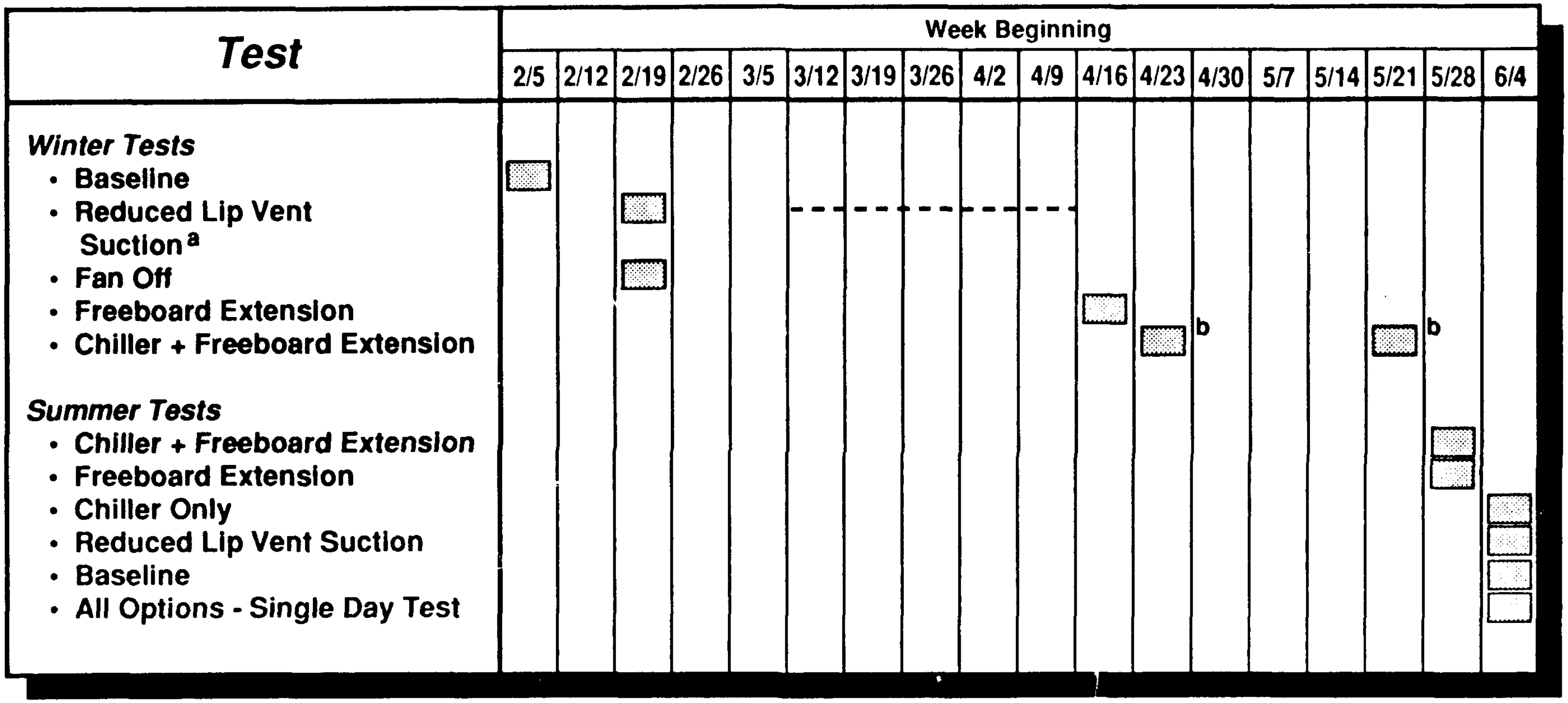
D. PROJECT SCHEDULE

Testing of various options was classified as winter or summer depending on the month it was conducted. The winter set of tests began in February 1990, when baseline reduced fan speed, and fan-off tests were completed. Additional operation of the degreaser from mid-March to early April was monitored periodically, but no formal testing was conducted. After installation of the additional freeboard height (9 inches) in mid-April, a test with the new freeboard was conducted to complete the winter tests.

The freeboard chiller was installed in late April. A failed test of the chiller immediately after its installation and a second failed test in May because the steam supply was shut down delayed the summer set of tests until the last day of May; testing continued into the second week in June. These tests include: chiller with freeboard extension, freeboard extension only, chiller without freeboard extension, reduced fan speed, and baseline.

A final test of all options in one day was conducted on 8 June. The degreaser was then set up to run with the fan off and the secondary chiller operating with the freeboard extension to test the impact or solvent use over at least one month of operation.

Figure 2 summarizes the schedule followed for testing the various TCA emission minimization options.



[a] Dashed line represents periodic checks

[b] Failed test

Figure 2. Summary of Schedule for Vapor Degreaser.

SECTION III

SAMPLING AND ANALYTICAL PROCEDURES

A. SAMPLING EQUIPMENT

Three types of data were collected for this study: continuous real-time measurement of TCA, full-shift charcoal tube air samples, and gas bag samples (full shift and STEL). In addition, various instruments were used to perform system measurement during the test periods. A brief description of the types of equipment used and their testing configurations is presented in the following subsections.

1. Real-Time Measurement

A Miran 1A™ General Purpose Gas Analyzer was used to measure the real-time concentration of TCA at the degreaser during each test event. The Miran 1A is a single-beam, portable infrared spectrometer with a variable path-length gas cell. The analyzer consists of a radiation source, a mirror system, a pyroelectric detector, a meter that provides absorbance and percent-transmission scales, and a 0- to 1-volt output for a strip-chart recorder. Data from the Miran were continuously logged on a strip-chart recorder and stored on a Foxboro DL-332F Datalogger™. The DL-332F is a microcomputer-based single-channel data logger which measures analog voltages supplied by the Miran 1A, computes statistics based on programmed input parameters, and stores up to 3180 values. Metrosonics MS-931F LoggerSoft™ software interfaced with the Datalogger to create a database for the real-time measurements.

2. Full-Shift Air Sampling

Sorbent tubes containing activated charcoal were used to collect full-shift (8-hour) air samples. Quadruple-head sorbent tube holders (SKC No. 224-26-04) were used to collect four air samples simultaneously at each sampling location. Large charcoal tubes containing a 400-milligram front section and 200-milligram backup charcoal sections were used to sample air streams containing 300 to 400 ppm of TCA. Small charcoal tubes containing 100-milligram front/50-milligram backup charcoal sections were used to sample air streams of 1 to 100 ppm TCA. DuPont Alpha 1™ and P4LC™ constant-flow air-sampling pumps collected the air for the sorbent tubes at a rate of approximately 0.06 liter per minute (Lpm) per tube. Sampling pumps were calibrated before and after the shift with a primary standard for air flow calibration, a Gilibrator™ manufactured by Gilian Corporation.

When sampling was completed, the charcoal tube samples were stored at 40°F until they were analyzed by International Technology Analytical Services (ITAS) in Cincinnati. The charcoal tubes were desorbed in carbon disulfide and analyzed by gas chromatography and flame ionization detection, in accordance with National Institute for Occupational Safety and Health (NIOSH) Method 1003 for halogenated hydrocarbons (revision 1: 8/15/87). Certificates of Analysis for the sorbent tube samples are included in Appendix A for reference.

3. Short-Term Exposure-Limit Sampling

DuPont Alpha 1 air samplers configured in the bag-filling mode were used to collect gas bag samples for STEL determinations. Filling rates for 25-liter TedlarR bags (SKC No. 232-15) were 0.04 Lpm for full-shift samples and 1.6 Lpm for 15-minute STEL determinations. The bags were purged prior to use with ultra-zero air. At the end of the work shift, the bag samples were read out on the Miran 1A to determine the concentration of TCA for the period sampled.

4. System Measurement

Several instruments were used to periodically check system performance during each solvent loss reduction test. A Kurz Model 441™ Air Velocity Meter was used to determine the airflow rate at the lip vent and in the exhaust stack. Ventilation smoke tubes (MSA No. 458481) were used to characterize general area airflow patterns, vapor-blanket stability inside the degreaser, and airflow into the degreaser room and the degreaser itself. A digital multimeter manufactured by Extech Instruments was used to record the temperature and relative humidity in the degreaser room, as well as the vapor temperature and mid-line chiller temperature inside the degreaser tank. Finally, a Neotronics EPM201 pressure meter was used to measure the static pressure differential between the plating shop and outside Building 5. Records of the system measurements are included in Appendix B.

B. SAMPLING PROCEDURES

1. Stack Measurement

The exhaust stack of the degreaser lip vent was sampled to estimate the pounds/day solvent loss through the ventilation system in configurations that required use of the induced draft fan, i.e., during baseline testing and reduced fan operation. Multiple charcoal tube samples in the stack provided an 8- to 9-hour time-weighted average concentration of TCA exhausted during degreaser operation. Continuous (air stream) sample extraction analyzed by the Miran 1A provided a real-time TCA concentration that was averaged by the Datalogger™ for the testing period. The degreaser ventilation stack was sampled with charcoal tubes at four points located equidistant along the circumference of the exhaust stack (at 90° relative to one another). The charcoal tubes were positioned in a vertical attitude to prevent channeling of TCA around the charcoal; 4-inch lengths of plastic tubing were taped into the exhaust stack and positioned horizontally, or perpendicular to the air flow, inside the exhaust stack to sample the air stream. The Miran sampling port was located below charcoal tube sampling points on the exhaust duct. Photographs that show the relative positions of the Miran and charcoal tube stack samples are presented in Appendix C.

2. Degreaser Midpoint Measurement

Air samples located at a worker's breathing zone height beside the degreaser were collected throughout the day (including lunchtime and breaks) to estimate the worst-case exposure for the degreaser operator. Charcoal tubes and sampling hoses (i.e., Miran and STEL bag-filling hoses) were positioned at the degreaser midpoint at a height of 5 feet (1.5 meters) above the floor level [approximately 1.5 feet (0.5 meters) above the lip vent of the degreaser tank] on a post that was placed at the same point throughout the study. Three types of samples were collected at the degreaser midpoint: full-shift charcoal tubes (4), a full-shift Tedlar® 25-liter bag sample, and two to four 15-minute STEL samples, also collected in Tedlar® bags.

3. Breathing Zone Measurements

The degreaser operator wore personal air samplers in his breathing zone for the duration of the work shift. One sampling manifold with four charcoal tubes was clipped to the shirt collar, and the hose for the bag-filling STEL sample (when being collected) was placed as close as possible to the operator's chin. The full-shift charcoal tube samples were turned off during lunch, typically between 1100 and 1200 hours.

4. System and Environmental Measurements

System performance and environmental conditions were evaluated by measuring several key parameters, including room and degreaser temperatures, room static pressure, and exhaust ventilation rate (when the fan was operating). For all tests involving the ID fan, capture velocity along the lip suction vent and air velocity in the annular exhaust or duct were measured using a thermal anemometer. Twenty air velocity measurements were made at multiple traverse points in centers of equal annular area in the exhaust duct. The arithmetic average of the 20 velocity measurements was converted into a volumetric air flow rate (cubic feet per minute) using the duct cross-sectional area. In addition, 50 traverse points were measured at the centerline (25 along each side) of the lip suction vent, averaged and converted into volumetric flow rate. For reasons that could not be determined, the flow rate calculated from the average duct velocity was always greater than that determined by measurements at the lip suction vent (consistently about 20 percent higher). However, system in-leakage most likely accounts for the difference between the calculated flow rates. A digital electronic multimeter was used to measure degreaser room temperature and relative humidity, chiller mid-line temperature, and degreaser vapor temperature. Static pressure differential between the degreaser room and ambient outdoor pressure was measured with a digital pressure meter (Neotronics EPM201).

5. Solvent Use Measurements

A record of solvent use maintained by the degreaser operator dating back to 1986 was consulted to determine average annual consumption of TCA. Reportedly, the degreaser uses 120 to 150 drums of solvent per year; however, the degreaser operator's record for previous years indicated approximately 95 drums per year were used. Solvent use differed greatly in some periods on this record when comparison was made between similar months in consecutive years. For example, in the 3-month period October-to-November

1988, 23 drums were used; for the same period in 1989, only 9 drums were used. These inconsistencies imply under-reporting on the solvent use record-the workers may have forgotten to enter the solvent data. Other possibilities exist: the degreaser may have been used infrequently due to budgetary constraints or the work in-house predominantly did not require part degreasing during this period.

For this study, the solvent level in the degreaser was considered a variable that could potentially affect degreaser emissions and, therefore, was maintained at approximately the same level for each set of measurements. Sight glass on the side of the degreaser indicates the solvent level in the main tank; however, the level indicated fluctuates depending on the temperature of the solvent in the degreaser as well as in the sight glass. The solvent level was marked on the sight glass during the baseline test in February 1990 and checked during each test. The solvent level was best controlled by filling the tank up to a protective metal screen that covers the steam coils inside the main solvent tank.

6. QA Objectives

a. Miran 1A Analyzer

The Miran portable analyzer was operated in accordance with the manufacturer's instructions. The sampling team calibrated the unit before and after each work shift for the majority of the experiment. During the last series of tests in early June, the Miran ran continuously and required only periodic zero adjustment for electronic drift. Each time the Miran was zero-adjusted, the team made a single mid-range injection to check calibration fit. Calibration curves and continuous data were logged on a strip-chart recorder to compare readings with calibration points, detect periodic shifts in baseline readings, and serve as a backup to the DL332F Datalogger™.

Tedlar® bag samples were prepared at known concentrations to test/verify the bag sampling method. Samples were prepared by direct microliter injection of liquid TCA into the bag and dilution with ultra-zero (hydrocarbon and particulate-free) air to a known volume using constant-flow air sampling pumps. Samples prepared in this manner typically read 20 percent below their theoretical concentration. A similar effect was seen with comparison of the real-time data with charcoal tube results. Possible reasons for this will be discussed at the end of this section.

b. Charcoal tube samples

Four charcoal tubes were collected simultaneously at each sampling location. Each tube on the sampling manifold was calibrated before and after the work shift to determine the average flow rate or verify that the flow was consistent (i.e., ± 5%) for the sampling pump. Start and stop times were logged on a sampling data sheet. Comments pertaining to sampling anomalies, if any, were also logged on the data sheet. Calculations for air sample volume and TCA concentrations were checked by a second person.

Desorption efficiency of the charcoal tube analytical method was studied independently from the sampling tests. Several charcoal tubes from each size and lot used in the study were analyzed after spiking the tubes with known amounts of TCA. Analyst-injected spikes and "blind" spikes (prepared by the laboratory QA officer) were prepared and analyzed in addition to routine method blanks. Based on the results of this study, 100 percent desorption efficiency was assumed for all subsequent analyses and calculations. Analyst spikes were periodically prepared during the study to verify desorption efficiency. Laboratory reports for the desorption efficiency study (work Order XO-02-140 reported 28 February 1990) are included in Appendix A.

c. Discrepancies

A discrepancy between the Miran data and the charcoal tube data was noted at the completion of the study; the Miran data were consistently 10-25 percent lower than charcoal tube readings throughout the study. Despite the difference in absolute values, the two sets of data have a correlation coefficient of 0.98. This discrepancy cannot be attributed to equipment used for the study because the effect can be seen from the start of the study to finish despite the fact that two Miran 1A analyzers, two sets of syringes, and three calibration curves were utilized. This fact should have eliminated systematic equipment error, and control for systematic bias due to setup parameters for the machine.

A series of analyses of Tedlar^R bags prepared at known concentrations was performed to determine the cause for the discrepancy. Two sources of systematic error were identified: pressure differential in the Miran cell and injection error when using microliter syringes. Two sets of Tedlar bags were prepared at 51.5 ppm TCA, with different syringes, and one set of three Tedlar bags was prepared at 309 ppm. No significant difference in results was noted between the two sets of low concentration samples (i.e., no effect from different syringes).

Reportedly, static pressure inside the Miran infrared cell is critical to accurate measurement of ambient chemical concentrations in the workplace. When the Miran is calibrated in a closed-loop configuration, the cell is near ambient pressure due to the balanced flow (cell inlet and outlet pressure) afforded by the external pump. However, when the analyzer was used to measure workplace concentrations, the external pump was placed on the cell outlet and 25 feet of polyethylene tubing was placed before the cell inlet. The Miran was operated in a remote location and the tubing was run to the degreaser to sample the ambient air (at atmospheric pressure). Negative pressure inside the Miran resulted from the sampling configuration used. Because the sampled air was at reduced pressure inside the Miran cell, the molar volume of the gas was smaller, transmittance to the Miran detector was greater and the resulting real-time concentration readings were lower. This sampling anomaly could account for a large portion of the difference between charcoal tube and real-time Miran data.

After the study was completed it was observed that, typically, residual solvent in the syringe needles was injected with the measured amount of TCA during closed-loop calibration injections. An additional 0.05 to 0.15 μL was injected into the Miran at each calibration point. Based on injection volumes of 2.4 μL, this injection error would produce 2 to 6 percent systematic bias in the calibration curve, causing the calibration points to be higher than calculated; field samples analyzed against this calibration curve would have read lower than actual.

Other systematic error, such as adsorption of TCA onto the Tedlar^R of the sample bags (and others as yet undetermined), may have caused cumulative error that biased sampling results of the Miran 1A^{TM}. Because systematic bias in the Miran data has been identified, charcoal tube data have been the primary source for solvent loss reduction calculations in this report. This is the most prudent choice for reliable data because the charcoal tube samples were collected and analyzed by a standard NIOSH method that has been previously field-validated.

SECTION IV

STUDY RESULTS

A. OVERVIEW OF TESTING SERIES

Measurements were made in an initial series of four tests during the winter and spring from February to May 1990. All solvent vapor control evaluations were successfully completed except for the last option, freeboard extension with secondary chiller. This test had failed twice because of changes in onsite conditions (primarily airflow patterns) and loss of steam supply in the Plating Shop. The first four options completed compared well in terms of anticipated decreases of solvent loss. Stack concentrations between baseline and reduced fan speed were statistically different in the first series of tests but not in the second series, and breathing zone concentrations between "fan-off" and freeboard extension differed significantly.

After considering the results of the first series of tests, seasonal variability indicated in records of solvent use and inherent day-to-day and week-to-week variability of the degreasing process, it was decided that the series of tests--all options--should be repeated within a short time span (i.e., one week) to eliminate seasonal and week-to-week variability. Four full-shift tests were completed in early summer from 31 May to 5 June 1990. A repeat test of "fan-off" without freeboard extension was not performed in light of the unacceptable worker exposures monitored in the first series. Finally, to eliminate day-to-day variability, a third series of tests was performed during a single shift (90 minutes per test option) 8 June 1990.

In the second (full-shift) series of tests, a control option not previously shown in the work plan was evaluated: secondary chiller operation without freeboard extension. This test was performed because future operation of the degreaser in this configuration was likely. The degreaser operators proposed eliminating the freeboard extension because it reduced clearance between the tank and overhead hoist, which limited access for parts, and required the use of a platform (and bending further over) to hang or recover parts inside the degreaser. Evaluation of degreaser operation with the secondary chiller in operation and without the freeboard extension was tested on 6 June 1990.

Data summary tables for the project tests are presented in the following subsections. Data are organized in three sections according to the source/-collection point for the data, i.e., exhaust duct, degreaser midpoint, or degreaser operator. Average concentrations in parts per million (ppm) TCA are presented for the monitored periods. With the exceptions of overnight and STEL data, the monitoring results represent 8- to 9-hour samples collected over the duration of the work shift, typically from 0700 to 1000. Operator breathing zone (OBZ) personal samples started when the degreaser operator entered the Plating Shop, stopped over lunch break, and terminated at the end of the work shift. No corrections were made to the OBZ data for zero exposure periods (lunch and other unsampled portions of the work shift). The STEL data represent the average concentration of TCA for 15-minute periods of peak activity. Overnight data are averages for 14-hour periods, beginning approximately 1600 and ending at 0600 the following morning.

1. Initial Series of Tests (Winter Season)

Before testing baseline conditions, the airflow currents in the degreaser room were evaluated with ventilation smoke tubes and a thermal anemometer to evaluate the effect of directional airflow near the degreaser on the vapor-line stability inside the tank. Strong directional airflow through the double doors next to the degreaser room was identified as a potential source of vapor-line disturbance. When the double doors were closed, however, cross-drafts in the degreaser room were eliminated. As a result, the first control option, installation of temporary curtains in the degreaser doorway, was bypassed.

During this initial survey, the sight glass for the main solvent holding tank was cleaned of deposits and marked at the solvent level present during the baseline monitoring. When TCA was added the following week, observations were made of the level attained when one 55-gallon drum was added. In general, the desired solvent level was attained by adding one 55-gallon drum of TCA after the solvent reached the steam coils and the tank required filling. After the tank was filled, the TCA was slightly below the protective screen inside the tank. The solvent level in the tank during all subsequent tests was maintained within 2 inches (25 gallons) of the baseline mark on the sight glass.

Baseline measurements of the air velocity at the lip vent indicated that the local exhaust system operated between 2442 and 2600 cubic feet per minute. For the second test, the lip vent suction was reduced by installing a 10-inch pulley on the fan drive. Reducing fan speed by 50 percent lowered the actual cubic feet per minute exhausted by the system by only 30 percent. Further reduction was achieved by decreasing the effective diameter of the motor pulley; the sides of this pulley are independent and can be screwed together or apart to vary the pulley diameter. The final flow rate achieved during the reduced fan speed test was approximately 1400 cubic feet per minute, 56 percent of the baseline ventilation flow rate (44 percent reduction).

Table 1 presents results of the initial series of tests conducted in February and April 1990. Charcoal tube results for the first two induced-draft fan test arrived on the same date and confirmed what had been indicated by the Miran 1A data: concentrations at the degreaser are slightly lower at reduced lip vent suction. It should be noted that the difference between the baseline and reduced suction tests is statistically significant at the 90 percent confidence interval (alpha = 0.10). When the induced draft fan was turned off TCA levels were significantly higher statistically, and exceeded the TCA concentration limits for the study, 43 ppm TWA and 56 ppm STEL.

Based on the results of the first three tests, it was decided to operate the degreaser system with reduced lip vent suction to evaluate solvent use for a one-month period. (During this time, freeboard testing was put on hold pending equipment procurement.)

While the degreaser was in the reduced-lip-vent-suction configuration, operating conditions were periodically checked to ensure that TCA levels were within the project's engineering targets. Periodic checks were performed on 13, 22, and 30 March and 13 April. The TCA concentrations at the operator's breathing zone over 2-hour periods or during STEL sampling were typically between 10 and 25 ppm, levels slightly higher than those measured during the first two tests, but within the engineering targets for the project. Interestingly, lip-vent-exhaust-duct TCA concentrations increased throughout the month of March. TCA duct concentrations averaged 260 ppm on 13 March, 440 ppm on 22 March, and 560 ppm on 30 March. These observations verify the previously reported increase in solvent use experienced during summer months.

TABLE 1. DATA SUMMARY FOR INITIAL SERIES OF TESTS (FEB. TO MAY 1990)

SAMPLE TYPE/location	Average Concentration (ppm) of 1,1,1-TCA with Control Option			
	2/9/90 Baseline	2/21/90 Reduced lip vent suction	2/22/90 Fan off	4/19/90 Freeboard extension
CHARCOAL TUBE SAMPLES				
Lip Vent Exhaust Duct	391.1	329.5	NS[a] (fan off)	NS (fan off)
Degreaser midpoint	15.1	11.4	86.4	28.1
Operator	1.5	1.4	12.1	4.8
MIRAN 1A/REAL-TIME DATA				
Lip Vent Exhaust Duct – day shift	264.4	242.4	NS	NS
– overnight	37.5	39.4	NS	NS
Degreaser midpoint – day shift	NS	NS	42.2	13.5
– overnight	NS	NS	13.2	11.7
TEDLAR BAG SAMPLES				
Full Shift – Degreaser midpoint	NS	9.2	48.9	45.5
STEL Average – Degreaser midpoint	17.1	8.5	33.5	43.2
– Operator	5.2	<1.0	46.4	27.7
STEL #1 – Degreaser	15.7	5.0	10.0	71.5
– Operator	5.7	<1.0	40.0	41.2
STEL #2 – Degreaser	21.0	17.5	9.1	31.9
– Operator	3.7	<1.0	18.9	17.2
STEL #3 – Degreaser	14.5	4.5	69.6	26.2
– Operator	6.3	<1.0	61.7	24.8
STEL #4 – Degreaser	NS	7.0	45.2	NS
– Operator	NS	1.6	65.1	NS

[a]Not sampled.

Two days before the final periodic check, the freeboard extension was installed. The exhaust duct concentration averaged 370 ppm with freeboard extension in place and induced fan operating.

Although TCA levels at the degreaser were within engineering limits overall for the fan operating at reduced speed, personal comfort was adversely affected; operators also reported generally stronger TCA odor around the degreaser and frequent headaches. In response to employee concerns, the fan was returned to its original setting at approximately 2400 cubic feet per minute on 13 April 1990.

The degreaser was tested with the third control option, increased freeboard ratio, on 19 April 1990. Again, the lip vent exhaust fan was turned off during this test. Time-weighted average TCA levels at the degreaser mid-point and the degreaser operator's breathing zone were well within the engineering targets for the study and showed a marked improvement over the previous test option (fan off without freeboard extension). Breathing-zone TCA levels during the freeboard extension test, however, were higher than both the baseline and reduced-fan tests and caused discomfort to the workers operating the degreaser. Upon completion of the freeboard test, the induced-draft fan was turned on and operated at reduced flow (1400 cfm) in conjunction with the freeboard extension. After a few days, however, the fan was not operated at night because the freeboard covers were located above the lip unit, which caused large amounts of solvent to be exhausted during the degreaser cool-down period.

2. Second Series of Tests (Summer Season)

Table 2 summarizes the five tests performed in late May and early June 1990. Contrary to the first series of tests, the test options using the induced-draft fan, baseline, and reduced speed did not show a significant statistical difference in the duct concentrations. The breathing zone results, however, confirmed observations made by the degreaser operators during the periodic checks in March: levels were higher with the degreaser operating at reduced lip vent suction.

With the exhaust fan off, addition of the freeboard extension or secondary chiller achieved ambient TCA levels that met or only slightly exceeded the engineering targets for the study. With both options (freeboard

TABLE 2. DATA SUMMARY FOR SECOND SERIES OF TESTS (SUMMER TESTING)

SAMPLE TYPE/location	Average Concentration (ppm) of 1,1,1-TCA with Control Option				
	6/5/90 Baseline	6/4/90 Reduce lip vent suction	6/1/90 Freeboard extension	6/6/90 2° Chiller w/o extension	5/31/90 2° Chiller w/ extension
CHARCOAL TUBE SAMPLES					
Lip Vent Exhaust Duct	347.4	350.0	NS[a] (fan off)	NS (fan off)	NS (fan off)
Degreaser midpoint	21.3	44.5	39.7	NA[b]	32.0
Operator	0.4	0.8	3.3	NA	4.0
MIRAN 1A/REAL-TIME DATA					
Lip Vent Exhaust Duct – day shift	279.1	312.2	NS	NS	NS
– overnight	NS	47.1	NS	NS	NS
Degreaser midpoint – day shift	NS	NS	43.0	45.6	29.2
– overnight	NS	NS	NS	25.7	NS
TEDLAR BAG SAMPLES					
Full Shift – Degreaser	15.7	36.0	38.8	41.2	27.2
STEL Average – Degreaser	14.8	30.8	64.3	43.4	23.9
– Operator	1.3	6.1	7.4	5.7	5.8
STEL #1 – Degreaser	13.1	30.9	60.1	43.2	28.6
– Operator	1.7	7.9	5.5	4.4	9.9
STEL #2 – Degreaser	15.6	30.7	85.5	43.5	21.8
– Operator	1.4	4.3	10.6	6.9	5.5
STEL #3 – Degreaser	14.2	NS	47.2	NS	21.3
– Operator	1.2	NS	6.1	NS	1.9
STEL #4 – Degreaser	16.1	NS	NS	NS	NS
– Operator	1.0	NS	NS	NS	NS

[a]Not sampled.
[b]Not analyzed.

extension in place and secondary chiller operating), the degreaser performed well within the engineering targets. Operation in this mode effectively reduced ambient levels of TCA by approximately 25 percent, and the degreaser operators reacted positively; no ill effects were noted. As a result, the degreaser was left in this configuration after testing was completed. Solvent usage has been closely monitored since that time.

Overall, TCA levels in the breathing zone during the summer testing were higher than levels measured during the winter season. This effect was evident in comparison of baselines, reduced lip vent suction, and freeboard extension tests. Degreasing activity was minimal during the April freeboard test; therefore, the increase in ambient levels during the summer is attributable to increased activity and to the higher temperature in the degreaser room.

The extra test performed (secondary chiller without freeboard extension) showed results similar to the freeboard extension test and above the exposure limits for the study. The degreaser operators complained of discomfort when the unit was operated in this mode without the freeboard extension or lip vent suction.

The summer testing was performed with temporary curtains in place at the degreaser room threshold because of changes in the airflow patterns around the degreaser. Directional airflow caused by a draft entering the Plating Shop above the double doors (see photograph C-9 in Appendix C) disturbed the vapor-line inside the degreaser tank during two previous attempts to test the secondary chiller with freeboard extension. The TCA levels were consistently above 70 ppm at the degreaser midpoint with the secondary chiller and freeboard extension in place and lip vent suction shut down. In addition to temporary curtains, polyethylene sheeting was secured above the curtains to keep air from entering the degreaser room above the hoist. With the temporary curtains and polyethylene sheeting in place, the double doors next to the degreaser room were left open to facilitate part movement.

Ventilation in the Plating Shop was modified to lessen air- flow through the double doors next to the degreaser room. The Plating Shop contains approximately 20 dip tanks equipped with local exhaust ventilation (LEV). A large air-handling unit exhausts 25,000 cubic feet per minute to maintain air flow for the LEV. Slowing this fan to one-third speed reduced the draft through the double doors and thereby improved the effectiveness of the temporary curtains.

During an overnight test in the spring, elevated concentrations of TCA were found below the floor grating beside the degreaser. On the morning of 27 April, the sampling tube for the degreaser midpoint detached from the 5-foot high post and fell to the floor grating; the monitoring equipment immediately detected an increase in TCA levels from 50 to 250 ppm. Levels 2 feet below the grating, beside the main tank sight glass, were 425 ppm when measured the next day. Ultimately, the Miran was used to identify sources (leaks) in the outer case of the degreaser that caused the high TCA levels.

It is believed that leaks in the tank below the grating and diffusion through the breathing zone at the degreaser midpoint decreased sensitivity of the measurements between each control option. Essentially, ambient levels of 10 to 20 ppm TCA in the degreaser room resulting from leaks made it difficult to measure small changes in fugitive emissions from one test to the next, particularly at breathing zone height near the degreaser midpoint. Leaks could not be repaired for the study because of the heavy work load in the shop at that time.

3. Consecutive Tests in an 8-Hour Period (8 June 1990)

Table 3 presents a data summary of the consecutive testing performed over an 8-hour work shift. Unlike the first two series of tests, the data collected on the same day showed a much smaller difference between each option for samples collected at the degreaser midpoint. Samples for the consecutive day had a standard deviation s = 2.8 ppm; for the other two series, excluding the "extra" test, s = 14.9 ppm. Also, average concentrations measured at the degreaser midpoint were lower overall in comparison with the Miran data for the other two series of tests. Despite the data's smaller statistical variation (possibly caused by the short sampling time), the consecutive test data correlate well with data from the other sets in terms of overall ranking of control options. In terms of fugitive emissions at the degreaser midpoint, secondary chiller with freeboard extension performed very well, but not quite as effectively as the induced draft fan tests. Fugitive emissions were highest for the freeboard test. All four test options studied

TABLE 3. DATA SUMMARY FOR CONSECUTIVE TESTING (JUNE 8, 1990)

Sample type/location	Average concentration[a] (ppm) of 1,1,1-TCA with Control Option			
	Baseline	Reduced lip vent suction	Freeboard extension	Secondary chiller w/extension[b]
MIRAN 1A/REAL-TIME DATA				
Degreasers midpoint	20.0	21.5	26.9	23.4
TEDLAR BAG SAMPLES				
Lip vent exhaust duct	240.8	360.6	-	-
Degreaser midpoint	16.0	20.7	22.6	19.6

[a] Results shown are 90-minute averages for each control option.

[b] Exhaust fan was turned off for these options.

performed below the engineering targets for personal exposure (43 ppm TWA and 56 ppm STEL).

Concentrations in the lip vent exhaust duct between the baseline and reduced-lip-vent-suction tests were quite different. During the reduced-lip-vent-suction test, it was noted that excursions at the degreaser midpoint (i.e., during part removal from the tank) did not occur when the induced-draft fan was in operation; excursions, or TCA spikes, were observed during both the freeboard and secondary chiller tests. Apparently, the draft into the lip vent was very effective in capturing solvent because no deflection from baseline was noted even when parts were rapidly pulled from the tank. Unfortunately, the part-removal challenge was repeated numerous times, which caused extremely high TCA levels in the lip vent exhaust duct. For this reason, the disparity in duct concentrations between the baseline and reduced-fan-speed tests is considered artifactual; TCA levels at the degreaser midpoint, however, should not have been affected.

B. INDUSTRIAL HYGIENE IMPLICATIONS OF WASTE MINIMIZATION OPTIONS

1. Study Objectives

The purpose of this study was to evaluate a range of engineering options for controlling (reducing) emissions of TCA while, as a condition of successful control, assuring that personal exposures to employees operating the degreaser would be no more than the Air Force engineering control limit, 25 percent of the OSHA action level, or 12 percent of the permissible exposure limit (PEL), (43 ppm 8-hour TWA and 56 ppm STEL). Throughout the study, levels of TCA were maintained at less than one-half the OSHA action level. Samples collected overnight and in the lip vent exhaust duct served to estimate the amount of solvent loss over a 24-hour period; they are not part of this discussion. In this section, measurements performed at the degreaser operator's breathing zone (OBZ) and the degreaser midpoint (at 5 feet, breathing zone height) will be used to evaluate industrial hygiene implications.

2. Personal Exposure Data

Personal exposure to TCA was determined by two methods: charcoal tube samples collected in the OBZ for the full work shift, and Tedlar® bag samples collected for STEL determinations. None of the samples collected exceeded the OSHA PEL or action level; in fact, only 2 of 60 personal samples, both of which were STEL samples, exceeded the Air Force engineering target limits. The TWA exposure (full shift) was typically less than 10 ppm; the operator's TWA during the fan-off test (the only exposure over 10) was 12 ppm. The degreaser operator's STEL exposures tended to be less than 10 ppm in all but two of the tests performed--fan-off and the winter freeboard test. The STEL exposure during the fan-off test ranged from 20 to 70 ppm TCA. During the winter freeboard test, STEL exposure ranged from 15 to 45 ppm TCA. Because of the potential for employee discomfort, neither test option where samples exceeded STEL engineering targets is considered a usable long-term configuration at the Building 5 degreaser.

3. Degreaser Midpoint Data

Samples collected at the degreaser midpoint represent the "worst-case" exposure for the degreaser operators. In all three series of tests, the baseline and secondary chiller with extension options met the TWA and STEL engineering control targets for the study. The reduced-lip-vent-suction test failed during the summer series but was under the limits and performed very well during the winter series. The fan-off without freeboard extension (winter test) failed; the TWA and STEL measurements were above 43 and 56 ppm, respectively. The summer tests with the freeboard extension and secondary chiller without extension failed to meet the criteria.

4. Reducing Worker Exposure

Employee exposure to TCA could be further reduced by 1) repairing leaks in the degreaser near the steam line entry and sight glass, 2) replacing gaskets around the condenser unit, 3) examining work practices to ensure that parts are being dried in the freeboard zone before removal from the degreaser, and 4) modifying the degreaser room general ventilation. Measurements made in April indicate that TCA vapor leaking into the pit causes high concentrations below the floor grating. A thermal draft beside the degreaser created by hot steam lines pulls TCA through the workers' breathing zones when they are in the room. Repairing leaks around the steam lines, the sight glass, and the condenser would eliminate a significant portion of current employee exposure to TCA. Work practices should be examined to ensure that workers pause when removing parts from the degreaser to allow sufficient time for parts to dry before removal from the bath. This minimizes drag-out of TCA during part removal. For evaluation of the effect of TCA drag-out, real-time measurements of TCA peak concentrations were made at the degreaser midpoint during the removal of parts. Parts were held in the freeboard zone at four time increments--0, 2, 5, and 10 seconds-- before removal from the degreaser. Consistent reduction in solvent drag-out was noted with each increase in time spent in the freeboard zone. The data are summarized here.

Free-board time, s	No. of tests	Concentration range, ppm TCA	Mean concentration, ppm	Reduction, percent	Incremental difference, percent
0	4	39.6-146.0	73.6	-	-
2	12	9.9-181.0	54.3	26	26
5	7	20.8-95.7	42.1	43	17
10	6	18.5-50.2	32.3	56	13

Finally, modification of the degreaser room general ventilation could also reduce personal exposure. Exhaust ventilation mounted on the south wall of the degreaser room (using the existing induced-draft fan or a separate exhaust fan) would pull air across the degreaser and dilute TCA emissions above the unit. Replacement (supply) air mounted on the north wall and directed at the degreaser operator may reduce breathing zone concentrations of TCA even further. After system leaks are repaired, background concentration of TCA in the degreaser room should be checked to determine the need for or benefit from modifications to room ventilation.

C. STATISTICAL MANIPULATION OF MIRAN AND CHARCOAL TUBE TEST DATA

1. Miran 1A Real-Time Data

For each TCA control option, a single estimated concentration was obtained for each hour of sampling by calculating the arithmetic mean of the individual minute-by-minute concentrations determined by the Miran 1A/Data Logger. This provided one measurement for each 60-minute period of sampling. A student's T-test was then performed on the hourly averages to determine whether significant differences occurred when comparing different control options and between seasons for each control option. Only day-shift data were used for statistical comparisons. All statistical comparisons were performed at the 0.10 significance level (90 percent confidence level). A summary of the results of these comparisons is presented in Table 4. The data indicate that the baseline and reduced fan duct concentrations are not significantly different for both sets of tests. With the exception of the summer freeboard/secondary chiller without freeboard extension comparison, all other comparisons of concentrations of TCA measured under differing control requirements are significantly different. With the singular exception of the baseline tests, all of the seasonal comparisons were significantly different.

2. Charcoal Tube Data

Duplicate charcoal tube samples (usually four) from full-shift daytime testing were compared in the same manner as the Miran 1A real-time data discussed in the previous section. The results of the charcoal tube data matched all but two of the Miran 1A statistical analyses, i.e., charcoal tube data indicated that the 19 February baseline and 21 February reduced-lip vent suction tests were significantly different and the 21 February and 4 June reduced-lip-vent suction tests were not significantly different. Seasonal effects between identical tests (baseline, reduced-lip-vent-suction and freeboard-extension) were noted at higher degreaser midpoint levels of TCA, but operator exposures were actually lower than for the winter tests. Duct concentrations for baseline were lower in the summer, and summer/winter values for reduced lip-vent suction were equal.

TABLE 4. STATISTICAL COMPARISON OF MIRAN 1A MONITORING VALUES

Control option	t-value	Probability level (P)	Significantly different at 0.1 significance level?
° 2/9 baseline - 2/21 reduced lip vent suction	0.59	0.5611	No
° 2/22 fan off - 4/19 freeboard extension	4.28	0.0007	Yes
° 6/5 baseline - 6/4 reduction lip vent suction	1.45	0.1684	No
° 2/9 baseline duct - 6/5 baseline duct	0.95	0.3598	No
° 2/21 reduced lip vent suction (duct) - 6/4 reduced lip vent suction (duct)	2.16	0.0472	Yes
° 4/19 freeboard extension (duct) - 6/1 freeboard extension	4.37	0.0005	Yes
° Chiller with freeboard extension - chiller without freeboard extension	6.22	0.0001	Yes
° 6/1 freeboard extension - chiller with freeboard extension	1.91	0.0759	Yes
° 6/1 freeboard extension - secondary chiller without freeboard extension	0.79	0.4394	No

Comparisons between different control options (i.e., baseline vs. reduced-lip-vent suction) showed opposite effects for winter and summer. In winter, the duct, degreaser mid-point, and operator levels were lower for reduced lip-vent suction than for the baseline. In summer, reduced lip-vent-suction duct concentrations were equal to baseline, but degreaser mid-point and operator levels were significantly higher than the baseline. A summary of the results of these comparisons is presented in Table 5.

D. SOLVENT USE REDUCTION ESTIMATES

Preliminary estimates of solvent use reductions attributable to each control option tested were performed using a combination of measured solvent concentrations in the duct and at the breathing zone and monitored use of solvent. These data were used to calculate emission factors for the baseline and various control options.

Baseline emission estimates were calculated based on 1) measured duct concentrations of TCA and estimated operating hours per year, and 2) ambient emissions of TCA, which were derived by subtracting the amount of solvent loss through the exhaust duct from total estimated yearly solvent usage. A review of solvent-use logs provided by WPAFB resulted in the data shown in Table 6. Data for all years except 1988 are incomplete. An estimate of 100 drums per year (or an average of two drums per week) was established as the baseline solvent use for the present set of emission calculations. The calculated emission factors are presented in Table 7. Duct and/or degreaser emissions factors are presented in pounds per square foot per hour for baseline conditions and all control options. Overall and incremental reductions in emissions are also displayed.

All degreaser ambient emission estimates other than the baseline estimates in Table 8 are based on percentage differences between charcoal tube data for the various control options measured at the degreaser midpoint for the summer tests (see Table 2). Reduction in fan speed resulted in an estimated 35 percent lowering of total TCA emissions. Turning off the fan completely reduced total emissions by another 20 percent. Addition of increased freeboard extension on the secondary chiller decreases TCA emissions by another 33 percent. The combination of chiller and increased freeboard decreased emissions by another 21 percent. Overall, it is estimated that

TABLE 5. STATISTICAL ANALYSIS OF CHARCOAL TUBE SAMPLES

Comparison	t-value	Probability level (P)	Significantly different at 0.1 significance limit
2/9 Baseline - 2/21 reduced lip-vent suction			
- Duct	4.27	0.005	Yes
- Degreaser midpoint	4.88	0.005	Yes
- Operator	0.51	0.627	No
2/22 Fan off - 4/19 freeboard extension			
- Degreaser midpoint	33.51	<0.001	Yes
- Operators	9.06	<0.001	Yes
6/5 Baseline - 6/4 reduced lip-vent suction			
- Duct	-0.10	0.921	No
- Degreaser midpoint	14.68	<0.001	Yes
- Operator	16.70	<0.001	Yes
2/9 Baseline - 6/5 baseline			
- Duct	2.67	0.37	No
- Degreaser midpoint	6.52	<0.001	Yes
- Operator	110.62	<0.001	Yes
2/21 Reduced lip-vent suction - 6/4 reduced lip vent suction			
- Duct	-0.88	0.415	No
- Degreaser midpoint	24.86	<0.001	Yes
- Operator	10.40	<0.001	Yes
4/19 Freeboard extension - 6/1 freeboard extension			
- Degreaser midpoint	6.76	<0.001	Yes
- Operator	7.06	<0.001	Yes

TABLE 6. SOLVENT CONSUMPTION IN DRUMS BY MONTH FROM WPAFB RECORDS

	Year						
Month	86	87	88	89	90	Avg.	Comments
January		6	6	8	6	6.5	
February		10	6	8	7[b]	7.75	
March		5	10	9	9	8.25	Only 2 drums used in last two weeks with reduced fan speed
April		4[a]	5	-	9[b,d]	5	Used 6 drums in April 90, for avg.
May		-	6[b]	-	6[b,d]	6	
June		-	10	15	3[d]	12.5	Excludes June '90
July		-	7	13		10	
August		-	13	14		13.5	
September	9	4[a]	10	6		7.25	
October	7	10	9	3		7.25	
November	9	6	4	3		5.5	
December	6	5	9	3		5.75	
Total	31	50	95	82	39		
Avg./Mo.	7.75	6.25	7.91	8.2	6.5		

[a] Partial months.

[b] Tank cleaned.

[c] Solvent lost because of improper use of covers.

[d] Partial chiller operation.

TABLE 7. ESTIMATED EMISSION FACTORS FOR DEGREASER BASELINE AND CONTROL OPTIONS (pounds/square foot/hour)

Condition	Duct	Degreaser	Total	Reduction from Baseline (percent)	Incremental reductions (percent)
Baseline	0.60[a]	0.09[b]	0.69[d]	-	-
Reduced fan (60%)	0.36	0.18[c]	0.45	35	35
No fan	-	0.36[c]	0.36	47	20
Freeboard extension (no fan)	-	0.24[c]	0.24	65	33
Chiller only (no fan)	-	0.24[c]	0.24	65	33
Chiller/freeboard extension (no fan)	-	0.19[c]	0.19[c]	72	21

[a] Direct measured concentrations in the exhaust duct.

[b] Derived by difference based on total annual solvent consumption.

[c] Based on differences in charcoal tube concentrations at the degreaser. (See Table 2.)

[d] Corresponds to 2 drums/week of solvent use (average).

[e] Corresponds to 0.56 drums/week of solvent use (average).

Option	Capital cost	Annual O&M savings	Annual solvent cost savings, $[a]	Payback, years	Technical applica-bility	Priority rating[b]
Reduced fan	500[c]	1,000[d]	12,250	<1 month	Good[e]	3
Fan off	500[c]	1,990[d]	7,000 (16,450)[f]	<1 month (<1 month)	Poor[g]	h
Chiller (fan off)	14,500	1,850[d,i]	10,500 (22,750)[f]	1.2 0.6	Good[e]	2
Freeboard extension (fan off)	1,500	1,990[d]	10,500 (22,750)[f]	1 month (<1 month)	Good[e]	2
Chiller + freeboard extension (fan-off)	15,500	1,850[d,i]	12,950 (25,200)[f]	1 (0.6)	Excellent[j]	1

[a] Based on solvent cost of $350/drum (55 gallons).

[b] Recommended priority for permanent installation at WPAFB.

[c] Baseline capital cost applied to all options to account for ventilation modifications (plastic curtains and plastic sheeting at degreaser room doorway).

[d] Savings from not having to heat exhaust air to 70°F, 24 hours/day, 180 days/year at $2.50/million British Thermal Units of natural gas plus reduced or total elimination of fan horsepower at 5 cents/kilowatt-hour.

[e] Meets or slightly exceeds engineering limits for breathing zone concentrations; reduced-fan-speed option, however, still results in significant solvent loss through the exhaust stack.

[f] Savings calculated from original baseline instead of reduced-fan-speed option as baseline.

[g] Does not meet industrial hygiene target limits for breathing zone concentrations.

[h] Not recommended as a solvent use minimization option, unless combined with freeboard extension and chiller.

[i] Chiller electricity costs of $140/year are more than offset by savings in fan horsepower.

[j] Meets all engineering target limits for breathing zone concentrations.

operation with the chiller plus increased freeboard option in conjunction with no exhaust fan has lowered TCA emissions by about 72 percent from the baseline condition.

The 0.19-pound per square foot per hour estimate for the chiller/-increased freeboard/no fan option corresponds to 0.56 drum/week of solvent based on the estimated operating schedule of the degreaser. Solvent consumption was monitored with the degreaser operating under these conditions from 9 June to 14 September, 1990, and 5 drums of TCA were consumed. This calculates to 5 drums in 14 weeks or 0.4 drum/week. This indicates that the 72 percent reduction estimate for the chiller/increased freeboard/no fan option is conservative.

Although solvent consumption has been verified only for the most stringent set of control options, it would be a simple matter to run the degreaser for 2 to 4 weeks under any other set(s) of operating conditions to verify emission factor(s) contained in Table 7.

E. TECHNICAL/ECONOMIC EVALUATION

A technical economic evaluation of the various control options was undertaken to compare their feasibility and cost-effectiveness. The control options evaluated were reduced fan speed, fan off, increased freeboard with no fan, chiller with fan off, and chiller with increased freeboard and fan off. In Table 8, the comparison of capital and operating costs for each option with the annual cost savings shows simple payback (years to recover the capital investment), the applicability of each option based on its ability to maintain breathing zone concentrations below industrial hygiene targets, and the recommended priority for permanent installation on the degreaser. A baseline capital cost of $500 was applied to all of the options to account for curtains and plastic sheeting installed in the doorway of the degreaser room to reduce cross drafts and stabilize air flow in the vapor zone. Annual solvent cost savings are shown at two levels: 1) from a reduced fan baseline (a conservative incremental savings level), and 2) from the original baseline (a best case estimate of solvent savings). Each control option is briefly discussed below.

1. Reduced Fan Speed

The reduced-fan-speed option has a negligible additional capital cost (new fan pulley) an estimated annual cost savings of $12,250 in TCA. An additional savings of approximately $620 is estimated from not having to heat the ambient air being exhausted from the stack to 70°F for 6 months out of the year. Reduction in fan horsepower provides an additional $380 savings. Payback for this option is less than 1 month. All industrial hygiene breathing zone targets are met; however, a significant portion of TCA is still exhausted to the stack. Therefore, this option has a low priority for permanent use on the degreaser. The degreaser is currently set to run on reduced fan speed if such is needed to reduce breathing zone concentrations in case of an emergency, and this configuration can stay "as is."

2. Fan-Off

This option involves no additional capital tool or operating costs, and it offers $16,450 in TCA savings per year, heat less savings of $1500 and fan horsepower savings of $490. Payback is less than 1 month. It is not an acceptable option by itself, however, because breathing zone concentrations of TCA are substantially above the industrial hygiene targets. Therefore, it is recommended as an option only in conjunction with the freeboard and/or chiller options.

3. Chiller

Capital cost to install a freeboard chiller is an additional $14,000. Annual operating costs for electricity are only about $140/year, and these are offset by the fan horsepower savings of $490. Heat loss savings of $1500 are also obtained. The TCA savings will be $22,750, and payback will be 0.6 year. Industrial hygiene targets are met or slightly exceeded, and this modification is rated second only to the chiller-plus-freeboard-extension option for permanent installation. Installation of the chiller requires about 3 days and can usually be done during shutdown for cleaning of the degreaser.

4. Freeboard Extension

Fabricated locally, the freeboard extension was at an additional capital cost of $1000. The extension has a fold-down section to assist in lowering difficult parts into the degreaser. The extension is also easy to remove (requires only a few minutes). Annual O&M costs are zero, and payback is achieved in less than 1 month, TCA savings being equivalent to the chiller-only option, $22,750 plus $1500 in heat loss savings and $490 in power to operate the fan. The freeboard extension is rated second only to the chiller plus-freeboard-extension option in terms of permanent installation. It meets all of the industrial hygiene breathing zone concentration targets.

5. Chiller Plus Freeboard Extension

This option has the highest additional capital cost ($15,000 with annual operating costs of $140), which are offset by fan horsepower savings of $490, that result in zero annual operation costs. Heat loss savings of $1500/yr are also obtained. Solvent loss savings are the highest of all options, $25,200. The 0.6 year payback is excellent. All industrial hygiene targets are easily met, and this option has the highest recommendation for permanent installation on the degreaser. Operators using the degreaser with this configuration expressed no complaints regarding TCA odors and have observed an obvious decrease in solvent consumption.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

A review of the results of this study to reduce TCA solvent consumption in the vapor degreaser at Wright Patterson Air Force Base Area B, Building 5, has led to the following conclusions and recommendations:

A. CONCLUSIONS

1. Option Effectiveness/Industrial Hygiene Considerations

- All solvent loss-reduction-option tests controlled degreaser operator personal exposure below the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL), 350 ppm as an 8-hour time-weighted average (TWA), and short-term exposure limit (STEL), 450 ppm during 15-minute periods of peak activity.

- All test options control degreaser operator exposure to levels that achieved (or slightly exceeded) the Air Force engineering target levels (25 percent of OSHA action level) of 43 ppm 8-hour TWA, and 56 ppm STEL.

- All test options controlled worst-case personal exposure to levels (at degreaser midpoint) below the OSHA PEL and STEL.

- Five test options controlled worst-case personal exposure to levels (at degreaser midpoint) that achieved (or slightly exceeded) the Air Force Engineering target levels: (1) baseline, (2) reduced lip-vent suction, (3) fan off with freeboard extension, (4) chiller without fan or freeboard extension, and (5) secondary chiller with freeboard extension.

- One test option did not reduce worst-case personal exposure to meet the Air Force engineering target levels: fan-off with existing freeboard.

- Two test options achieved acceptable control from a worker comfort standpoint: (1) baseline operation, and (2) secondary chiller with freeboard extension.

2. External and Degreaser Operating Conditions

- Definite seasonal effects were noted with regard to (1) temperature, which increased breathing zone levels in summer over those in winter for the reduced-lip-vent-suction and freeboard-extension tests; and (2) ventilation patterns in which cross-drafts in the degreaser room during the summer tests caused vapor-line instability and increased breathing zone levels. Mitigation of the disruptive ventilation patterns tended to lower breathing zone levels.

- The 1,1,1-trichloroethane (TCA) leaks at the main solvent tank sight glass, steam-line junctions, and condenser tank contributed to background levels of TCA in the degreaser room, which resulted in reduced sensitivity of degreaser emission measurement in the 10 to 20 ppm range and increased breathing zone concentrations.

- A nonfunctioning water/solvent separator and lack of a drip pan to direct solvent/water condensation from the primary condenser tubes to the water-solvent separator have contributed to solvent contamination and degradation and increased solvent use. These conditions were rectified during the study.

- The lack of full water circulation through the degreaser water jacket during startup until after the TCA solvent was boiling is an operational problem that caused elevated levels of TCA during the first 25 to 30 minutes of operation during each day of testing. This affected testing of another theory--that additional solvent savings might have been possible if, during the day when parts were not being degreased, all degreaser covers were left on with the steam turned off. It would not have been possible, however, to keep water circulating through the jacket with no heat being applied to the degreaser. Tests with two of four covers on the degreaser during operation resulted in higher breathing zone levels than with all covers off because of the buildup of heat and pressure under the covers. Thus, tests other than baseline and reduced-fan-speed were conducted with all covers off.

3. Solvent Use Reduction

- The calculated emission factors, which reflect the baseline condition and emission/solvent reductions attributable to each control option, are considered to be the best estimates possible given the existing operating data. These numbers could be verified by additional monitoring of solvent consumption over 2 to 4-week periods with each option. Consumption of approximately 0.5 drum per week with the chiller plus freeboard extension in place, however, is considered to be an accurate estimate of future operation of the degreaser. This corresponds to an approximate 75-percent reduction in solvent consumption over the baseline condition (from two to about one-half drum per week). As a result, the chiller-plus-freeboard-extension option provides the greatest amount of TCA reduction in addition to the lowest feasible worker exposure level without lip-vent suction.

4. Technical/Economic Feasibility

- The application of all of the control options was considered technically feasible; the most difficult option was installation of the freeboard chiller, which disrupted operation for about 3 days. Practical feasibility, however, determined by breathing zone targets and operator comfort, is considered limited to the chiller-plus-freeboard-extension option.

- The use of the chiller/freeboard control option is considered to be a viable method of satisfying pollution control requirements without the need for add-on controls at the exhaust stack. Add-on control equipment would need to be sized to control about 2500 cubic feet per minute of gas flow. This would considerably increase the cost and complexity of reducing TCA use over the use of the controls used in this study. The use of the driller/freeboard control option not only obviates the need for add-on controls but also accomplishes pollution prevention without adversely affecting worker breathing zone concentrations of TCA.

- All of the control options tested in this study are considered applicable to vapor degreasers in general, not just the WPAFB degreaser.

- Economically, the payback periods for all of the options ranged from less than 1 month to only 1.2 years. The savings in solvent use, primarily, plus heat-loss savings and fan horsepower savings (which offset chiller operation costs) were the reasons for the almost negligible payback periods. Thus, expenditures for the chiller plus freeboard extension, the most expensive and effective control option, can be easily justified.

B. RECOMMENDATIONS

- The degreaser should be operated permanently with the chiller-plus-freeboard-extension options installed as they are now. The lip-vent exhaust stack should be fitted with a positive displacement damper if the degreaser is to be continuously operated in this configuration. An interlock system should be installed where the lipvent exhaust fan would automatically activate if the chiller should become inoperative while the degreaser is operating.

- The degreaser water jacket circulation valving should be examined and modified so that full water circulation through the jacket occurs before the steam heat for the degreaser is activated.

- A followup evaluation should be conducted in several months (i.e., before winter) to ensure that engineering controls in place are performing properly and worker exposures are within acceptable limits. If it is deemed necessary for estimated solvent use reductions for individual control options to be further verified, solvent consumption (and worker exposure and comfort) should be monitored for a 2- to 4-week period for each option (i.e., the length of time required to consume 1 drum of solvent).

- After leaks in the degreaser system are repaired, background levels of TCA in the degreaser room should be characterized to determine their impact on worker safety and to further evaluate the results of this study.

- Ventilation patterns around the degreaser must be periodically checked and cross-drafts eliminated to maintain acceptable levels of TCA in the vicinity of the degreaser. Replacement of the plastic sheeting above the plastic curtains with other permanent material to isolate the degreaser room is recommended. The plating-shop ventilation fan should also be left at one-third speed to help eliminate channeling of air into the degreaser room through the double doors.

- As an added safety feature, additional ventilation could be added to the degreaser room. This would consist of an air inlet plenum placed across or below the degreaser and designed to pull air away from the operator breathing zone and out through a roof exhaust vent. A replacement air plenum would be located behind the operator.

- Recordkeeping in terms of TCA consumption, degreaser operating hours, cleaning, and other operating changes or incidents of note should be ritualized by developing a form that is religiously filled out by the operators. This would help track solvent use and help to identify operating conditions that result in excessive consumption.

- As new operators are hired, training should be conducted to hold parts in the freeboard long enough for adhesive TCA to evaporate completely.

REFERENCES

1. Gerstle, R. W., Katari, V. S., and Schindler, E.S., Evaluation of Solvent Loss From Vapor Degreaser System, EPA-600/2-81-042, (NTIS PB81-176398) March 1981.

2. Staheli, A.H., "Throwing a Cold Blanket on the Vapor Degreasing Problem," Mechanical Engineering, Vol. 45, pp 83-86, 8, August 1973.

3. Wolf, C., "Reducing Solvent Losses in Degreasers," Metal Finishing, Vol. 87, pp 45-46, 3 March 1989.

4. Burstein, E., "A Step-by-Step Guide to Controlling Solvent Emissions," Metal Finishing, Vol. 126, pp. 15-16, August 1989.

5. Nylen, G.C., and Osterman, H. F. "Cool It to Cut Degreasing Cost," American Machinist, Vol. 127(ii), pp. 140-141, 11 November 1982.

6. Gerard D.R, "Solving Air Pollution by Reducing Emission Losses From Solvent Vapor Cleaning Systems," Journal of Testing and Evaluation, Vol. 17, No. 2, March 1989. pp. 106-177.

7. Polhamus, R.L., "Solvent Emission Reduction and Conservation Techniques Using Available Technology" Proceedings 35th Annual Technical Meeting, Institute of Environmental Sciences (Anaheim, CA), pp. 292-293, 1989.

8. Wadden, R.A., Scheff, P.A., and Franke J. E., "Emission Factors for Trichloroethylene Vapor Degreasers," American Industrial Hygiene Association Journal, Vol. 50, pp. 496-500, September 1989.

9. Wiess, R.C., "Reducing Energy Costs in Vapor Degreasing System," Plant Engineering, pp. 66-67, March 28, 1985.

(The reverse of this page is blank)

APPENDIX A

ANALYTICAL LABORATORY CERTIFICATES OF ANALYSIS

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Degreaser System Pollution Prevention Evaluation Date: February 28, 1990

Attn: Mr. Mark Nutter (PEI)

Job Number PN 3758-9

This is the Certificate of Analysis for the following samples:

Client Project ID:	Degreaser System Pollution Prevention Evaluation
Date Received by Lab:	February 13, 1990
Work Order:	X0-02-110
Number of Samples:	18
Sample Type:	Charcoal Tubes

I. Introduction

Eighteen charcoal tube samples arrived at ITAS Cincinnati on February 13, 1990. The samples were sent for analytical work in support of monitoring work for the Degreaser System Pollution Prevention Evaluation project. The samples were labeled as follows:

Charcoal Tube # 2-09-P-A	Charcoal Tube # 2-09-P-G	Charcoal Tube # 2-09-S-B
Charcoal Tube # 2-09-P-B	Charcoal Tube # 2-09-G-A	Charcoal Tube # 2-09-S-C
Charcoal Tube # 2-09-P-C	Charcoal Tube # 2-09-G-B	Charcoal Tube # 2-09-S-D
Charcoal Tube # 2-09-P-D	Charcoal Tube # 2-09-G-C	Charcoal Tube # 2-09-S-E
Charcoal Tube # 2-09-P-E	Charcoal Tube # 2-09-G-D	Charcoal Tube # 2-09-S-F
Charcoal Tube # 2-09-P-F	Charcoal Tube # 2-09-S-A	Charcoal Tube # 2-09-S-G

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analysis requested was 1,1,1-Trichloroethane.

Reviewed and Approved by:

Lawrence D. Anderson

Lawrence D. Anderson
GC Group Leader
002110 X0-02-110

II. Analytical Results/Methodology (cont.)

The charcoal tube samples were desorbed with carbon disulfide and analyzed by Gas Chromatography with Flame Ionization Detection.

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Client: Degreaser System Pollution Prevention Evaluation
Work Order: X0-02-110
00211002

IT ANALYTICAL SERVICES
CINCINNATI, OH

1,1,1-Trichloroethane Concentrati

Client Sample ID	Lab No.	ug Front	ug Back	Total
Charcoal Tube # 2-09-P-A	110-01	200	ND	20
Charcoal Tube # 2-09-P-B	110-02	190	ND	19
Charcoal Tube # 2-09-P-C	110-03	190	ND	19
Charcoal Tube # 2-09-P-D	110-04	190	ND	19
Charcoal Tube # 2-09-P-E	110-05	ND	ND	<
Charcoal Tube # 2-09-P-F	110-06	ND	ND	<
Charcoal Tube # 2-09-P-G	110-07	ND	ND	<
Charcoal Tube # 2-09-G-A	110-08	2600	ND	260
Charcoal Tube # 2-09-G-B	110-09	2400	ND	240
Charcoal Tube # 2-09-G-C	110-10	2300	ND	230
Charcoal Tube # 2-09-G-D	110-11	2400	ND	240
Charcoal Tube # 2-09-S-A	110-12	21,000	ND	21,00
Charcoal Tube # 2-09-S-B	110-13	21,000	ND	21,00
Charcoal Tube # 2-09-S-C	110-14	22,000	ND	22,00
Charcoal Tube # 2-09-S-D	110-15	22,000	ND	22,00
Charcoal Tube # 2-09-S-E	110-16	ND	ND	<
Charcoal Tube # 2-09-S-F	110-17	ND	ND	<
Charcoal Tube # 2-09-S-G	110-18	ND	ND	<
Method Blank		ND	ND	<

ND = Not Detected (<4 ug/Sample, Samples 1 - 11)
(<8 ug/Sample, Samples 12 - 18)

Client: Degreaser System Pollution Prevention Evaluation
Work Order: X0-02-110
00211003

IT ANALYTICAL SERVICES
CINCINNATI, OH

Standard Reference Material

Analyte	Theoretical Value	Value Obtained	Percent Recovery
1,1,1-Trichloroethane	1337	1505	112

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Degreaser System Pollution Prevention Evaluation   Date: February 28, 1990

Attn: Mr. Mark Nutter (PEI)

Job Number PN 3758-9

This is the Certificate of Analysis for the following samples:

Client Project ID:	Degreaser System Pollution Prevention Evaluation
Date Received by Lab:	February 16, 1990
Work Order:	X0-02-140
Number of Samples:	9
Sample Type:	Charcoal Tubes

I. Introduction

Nine charcoal tube samples arrived at ITAS Cincinnati on February 16, 1990. The samples were sent for analytical work in support of monitoring work for the Degreaser System Pollution Prevention Evaluation project. The samples were labeled as follows:

Large Tube # 1	Small Tube # 1	Small Tube # 4
Large Tube # 2	Small Tube # 2	Small Tube # 5
Large Tube # 3	Small Tube # 3	Small Tube # 6

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analysis requested was 1,1,1-Trichloroethane.

Reviewed and Approved by:

Lawrence D. Anderson

Lawrence D. Anderson
GC Group Leader
002140 X0-02-140

IT Analytical Services • 11499 Chester Road • Cincinnati, OH 45246 • 513-782-4600

II. Analytical Results/Methodology (cont.)

The charcoal tube samples were desorbed with carbon disulfide and analyzed by Gas Chromatography with Flame Ionization Detection.

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

As requested, the samples were spiked at various levels, these levels and the desorption efficiencies are reported on the following page. The blind spikes were spiked by the GC Group Leader.

Desorption Efficiency Study,
1,1,1-Trichloroethane

Client Sample ID	Lab No.	mg Added	mg Recovered	Percent Recovery
Large Tube #1	140-01	16.7	14.9	89
Large Tube #2	140-02	16.7	16.0	96
Large Tube #3	140-03	16.7	15.9	95
Small Tube #1	140-04	1.67	1.65	99
Small Tube #2	140-05	1.67	1.65	99
Small Tube #3	140-06	1.67	1.64	98
Small Tube #4 (1)	140-07	3.34	3.67	110
Small Tube #5 (1)	140-08	8.36	8.61	103
Small Tube #6 (1)	140-09	10.0	10.1	101

(1) These are blind spikes.

Standard Reference Material

Analyte	Theoretical Value	Value Obtained	Percent Recovery
1,1,1-Trichloroethane	1337	1505	112

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Degreaser

Date: March 15, 1990

Attn: Mr. Mark Nutter (PEI)

Job Number PN 3758-9

This is the Certificate of Analysis for the following samples:

Client Project ID:	Degreaser
Date Received by Lab:	February 26, 1990
Work Order:	X0-02-211
Number of Samples:	29
Sample Type:	Charcoal Tube

I. Introduction

Twenty-nine charcoal tube samples arrived at ITAS Cincinnati on February 26, 1990. The samples were sent for analytical work in support of monitoring work on the Degreaser Project. The samples were labeled as follows:

Charcoal Tube #2-21-S-A	Charcoal Tube #2-21-G-A
Charcoal Tube #2-21-S-B	Charcoal Tube #2-21-G-B
Charcoal Tube #2-21-S-C	Charcoal Tube #2-21-G-C
Charcoal Tube #2-21-S-D	Charcoal Tube #2-21-G-D
Charcoal Tube #2-21-S-E	Charcoal Tube #2-22-G-A
Charcoal Tube #2-21-S-F	Charcoal Tube #2-22-G-B
Charcoal Tube #2-21-S-G	Charcoal Tube #2-22-G-C
	Charcoal Tube #2-22-G-D
Charcoal Tube #2-21-P-A	Charcoal Tube #2-22-P-A
Charcoal Tube #2-21-P-B	Charcoal Tube #2-22-P-B
Charcoal Tube #2-21-P-C	Charcoal Tube #2-22-P-C
Charcoal Tube #2-21-P-D	Charcoal Tube #2-22-P-D
Charcoal Tube #2-21-P-E	Charcoal Tube #2-22-P-E
Charcoal Tube #2-21-P-F	Charcoal Tube #2-22-P-F
Charcoal Tube #2-21-P-G	Charcoal Tube #2-22-P-G

Reviewed and Approved by:

Lawrence D. Anderson

Lawrence D. Anderson
GC Group Leader
002211 X0-02-211

IT Analytical Services • 11499 Chester Road • Cincinnati, OH 45246 • 513-782-4600

Client: Degreaser
Work Order: X0-02-211
00221103

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration, ug/Tube

Client Sample ID	Lab No.	1,1,1-Trichloroethane Front	Back	Total
Charcoal Tube #2-21-S-A	01	19,000	ND	19,000
Charcoal Tube #2-21-S-B	02	19,600	ND	19,600
Charcoal Tube #2-21-S-C	03	22,000	ND	22,000
Charcoal Tube #2-21-S-D	04	22,200	ND	22,000
Charcoal Tube #2-21-S-E	05	1600	ND	1600
Charcoal Tube #2-21-S-F	06	ND	ND	ND
Charcoal Tube #2-21-S-G	07	ND	ND	ND
Charcoal Tube #2-21-P-A	08	180	ND	180
Charcoal Tube #2-21-P-B	09	200	ND	200
Charcoal Tube #2-21-P-C	10	200	ND	200
Charcoal Tube #2-21-P-D	11	200	ND	200
Charcoal Tube #2-21-P-E	12	1100	ND	1100
Charcoal Tube #2-21-P-F	13	ND	ND	ND
Charcoal Tube #2-21-P-G	14	ND	ND	ND
Charcoal Tube #2-21-G-A	15	1800	ND	1800
Charcoal Tube #2-21-G-B	16	1700	ND	1700
Charcoal Tube #2-21-G-C	17	1800	ND	1800
Charcoal Tube #2-21-G-D	18	1600	ND	1600
Charcoal Tube #2-22-P-A	19	1600	ND	1600
Charcoal Tube #2-22-P-B	20	1200	ND	1200
Charcoal Tube #2-22-P-C	21	1900	ND	1900
Charcoal Tube #2-22-P-D	22	2000	ND	2000
Charcoal Tube #2-22-P-E	23	40	ND	40
Charcoal Tube #2-22-P-F	24	1300	ND	1300
Charcoal Tube #2-22-P-G	25	ND	ND	ND
Charcoal Tube #2-22-G-A	26	15,000	ND	15,000
Charcoal Tube #2-22-G-B	27	13,000	ND	13,000
Charcoal Tube #2-22-G-C	28	15,000	ND	15,000
Charcoal Tube #2-22-G-D	29	14,000	ND	14,000

ND = Not Detected

Detection Limit = 10 ug/Tube

Spike Recovery, 1,1,1-Trichloroethane

Client Sample ID	Theoretical Value	Percent Recovery
Charcoal Tube #2-21-S-E	1.34	122
Charcoal Tube #2-21-P-E	1.34	84
Charcoal Tube #2-22-P-F	1.34	96

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyte requested was 1,1,1-Trichloroethane.

The charcoal tube samples were desorbed with carbon disulfide, and analyzed by Gas Chromatography with Flame Ionization Detection.

III. Quality Control

As requested, samples #2-21-S-E, #2-21-P-E and #2-22-P-F were spiked with 1.34 mg of 1,1,1-Trichloroethane. The results are included in this report.

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Degreaser System Pollution Prevention Evaluation

Date:Ma y 4, 1990

Attn: Mark Nutter (PEI)

Job Number PN 3758-9

This is the Certificate of Analysis for the following samples:

Client Project ID: Degreaser System Pollution Prevention Evaluation
Date Received: April 23, 1990
Work Order: X0-04-186
Number of Samples: 10
Sample Type: Charcoal Tubes

I. Introduction

Ten charcoal tube samples arrived at ITAS Cincinnati on April 23, 1990. The samples were se t for analytical work in support of monitoring work for the Degreaser System Pollution Prevention Evaluation. The samples were labeled as follows:

WP-01	WP-03	WP-05	WP-07	WP-09
WP-02	WP-04	WP-06	WP-08	WP-10

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analysis requested was 1,1,1 - Trichloroethane.

Reviewed and Approved by:

(for LDA)

Lawrence D. Anderson
GC Group Leader

II. Analytical Results/Methodology (cont'd)

The charcoal tube samples were desorbed with carbon disulfide and analyzed by Gas Chromatography with Flame Ionization Detection by NIOSH Method 1003.

Client: Degreaser System Pollution
Work Order: X0-04-186
00418602

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration,ug/tube

Client Sample ID	Lab No.	1,1,1-Trichloroethane (1)
Charcoal # WP-01	01	690
Charcoal # WP-02	02	650
Charcoal # WP-03	03	730
Charcoal # WP-04	04	640
Charcoal # WP-05	05	4700
Charcoal # WP-06	06	4200
Charcoal # WP-07	07	4100
Charcoal # WP-08	08	3900
Charcoal # WP-09	09	3.5
Charcoal # WP-10	10	ND
Method Blank		ND
Detection Limit		2

ND = Not Detected

(1) All Back Halves = Not Detected

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Degreaser
Prevention Evaluation

Date: June 26, 1990

Attn: Mr. Mark Nutter (PEI)

Job Number PN 3758-9

This is the Certificate of Analysis for the following samples:

Client Project ID:	Degreaser System Pollution Prevention Evaluation
Date Received:	June 14, 1990
Work Order:	X0-06-141, X0-06-142, X0-06-143 and X0-06-144
Number of Samples:	52
Sample Type:	Charcoal Tubes

I. Introduction

Fifty-two charcoal tube samples arrived at ITAS Cincinnati on June 14, 1990. The samples were sent for analytical work in support of monitoring work for the Degreaser System Pollution Prevention Evaluation. The samples were labeled as follows:

Tube # 64-D1	Tube # 64-P2	Tube # 61-G1	Tube # 65-D4
Tube # 64-D2	Tube # 64-P3	Tube # 61-G2	Tube # 65-D5
Tube # 64-D3	Tube # 64-P4	Tube # 61-G3	Tube # 65-D6
Tube # 64-D4	Tube # 531-G1	Tube # 61-G4	Tube # 65-G1
Tube # 64-D5	Tube # 531-G2	Tube # 61-G5	Tube # 65-G2
Tube # 64-D6	Tube # 531-G3	Tube # 61-G6	Tube # 65-G3
Tube # 64-G1	Tube # 531-G4	Tube # 61-P1	Tube # 65-G4
Tube # 64-G2	Tube # 531-G5	Tube # 61-P2	Tube # 65-G5
Tube # 64-G3	Tube # 531-G6	Tube # 61-P3	Tube # 65-G6
Tube # 64-G4	Tube # 531-P1	Tube # 61-P4	Tube # 65-P1
Tube # 64-G5	Tube # 531-P2	Tube # 65-D1	Tube # 65-P2
Tube # 64-G6	Tube # 531-P3	Tube # 65-D2	Tube # 65-P3
Tube # 64-P1	Tube # 531-P4	Tube # 65-D3	Tube # 65-P4

Reviewed and Approved by:

Lawrence D. Anderson

Lawrence D. Anderson
GC Group Leader
006141

IT Analytical Services • 11499 Chester Road • Cincinnati, OH 45246 • 513-782-4600

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analysis requested was 1,1,1-Trichloroethane.

The charcoal tubes were desorbed with Carbon Disulfide and analyzed by Gas Chromatography with Flame Ionization Detection.

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Tubes # 64-D5, 64-G5, 531-G5, 61-G5, 65-D5, and 65-G5 were indicated for spiking. The recoveries for these tubes are included in this report.

Client: Degreaser System Pollution Prevention Evaluation
Work Order: X0-06-141
006141A

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration, ug/tube

Client Sample ID	Lab No.	1,1,1-Trichloroethane Front	Back	Total
Tube # 64-D1	141-01	11,000	13	11,000
Tube # 64-D2	141-02	8400	31	8400
Tube # 64-D3	141-03	8800	15	8800
Tube # 64-D4	141-04	9600	20	9600
Tube # 64-D6	141-06	5.0	ND	5.0
Tube # 64-G1	141-07	6500	ND	6500
Tube # 64-G2	141-08	6200	ND	6200
Tube # 64-G3	141-09	6500	ND	6500
Tube # 64-G4	141-10	5800	ND	5800
Tube # 64-G6	141-12	4.2	ND	4.2
Tube # 64-P1	141-13	60	ND	60
Tube # 64-P2	141-14	62	ND	62
Tube # 64-P3	141-15	53	ND	53
Tube # 64-P4	141-16	58	ND	58
Method Blank		ND	ND	ND
Detection Limit				2

ND = Not Detected

Client: Degreaser System Pollution Prevention Evaluation
Work Order: X0-06-142
006141B

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration, ug/tube

		1,1,1-Trichloroethane		
Client Sample ID	Lab No.	Front	Back	Total
Tube # 531-G1	142-01	4100	ND	4100
Tube # 531-G2	142-02	3600	2.2	3600
Tube # 531-G3	142-03	3900	2.3	3900
Tube # 531-G4	142-04	3500	2.2	3500
Tube # 531-G6	142-06	3.6	ND	3.6
Tube # 531-P1	142-07	380	2.4	380
Tube # 531-P2	142-08	230	2.2	230
Tube # 531-P3	142-09	410	ND	410
Tube # 531-P4	142-10	450	2.5	450

Detection Limit 2

ND = Not Detected

Client: Degreaser System Pollution Prevention Evaluation

Work Order: X0-06-143

006141C

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration, ug/tube

Client Sample ID	Lab No.	1,1,1-Trichloroethane Front	Back	Total
Tube # 61-G1	143-01	6000	ND	6000
Tube # 61-G2	143-02	6400	ND	6400
Tube # 61-G3	143-03	5900	ND	5900
Tube # 61-G4	143-04	5100	ND	5100
Tube # 61-G6	143-06	4.3	ND	4.3
Tube # 61-P1	143-07	190	ND	190
Tube # 61-P2	143-08	230	ND	230
Tube # 61-P3	143-09	200	ND	200
Tube # 61-P4	143-10	210	ND	210
Detection Limit				2

ND = Not Detected

Client: Degreaser System Pollution
PrevePrevention Evaluation
Work Order: X0-06-144
006141D

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analyte Concentration, ug/tube

Client Sample ID	Lab No.	1,1,1-Trichloroethane Front	Back	Total
Tube # 65-D1	144-01	33,000	ND	33,000
Tube # 65-D2	144-02	33,000	ND	33,000
Tube # 65-D3	144-03	29,000	14	29,000
Tube # 65-D4	144-04	32,000	ND	32,000
Tube # 65-D6	144-06	28	ND	28
Tube # 65-G1	144-07	2500	ND	2500
Tube # 65-G2	144-08	2400	ND	2400
Tube # 65-G3	144-09	2500	ND	2500
Tube # 65-G4	144-10	2200	ND	2200
Tube # 65-G6	144-12	5.4	ND	5.4
Tube # 65-P1	144-13 (1)	2.3	ND	2.3
Tube # 65-P2	144-14	55	ND	55
Tube # 65-P3	144-15	50	ND	50
Tube # 65-P4	144-16 (1)	48	ND	48
Detection Limit				2

ND = Not Detected

(1) These samples or extracts may have been switched. There is no way to trace the possible error.

Quality Control
Matrix Spikes

Client Sample ID	Lab No.	Theoretical Value, ug	Percent Recovery
Tube # 64-D5	X0-06-141-05	200	101
Tube # 64-G5	X0-06-141-11	400	109
Tube #531-G5	X0-06-142-05	200	117
Tube # 61-G5	X0-06-143-05	100	119
Tube # 65-D5	X0-06-144-05	268	104
Tube # 65-G5	X0-06-144-11	268	89

APPENDIX B

SYSTEM MEASUREMENT
DATA SHEETS

Baseline Test

Date 2/08/90	Time 15:23 ~~PM~~	Operator Boraso / Hutton

Dry Bulb Temperature (Ambient)	78	°F
Vapor Degreaser Temperature	164	°F
Humidity (Ambient)	35	%
Static Pressure in Duct	-0.335	in. H2O

Comments DB temp of 78°F measured at north side of degreaser at worker position. Corresponding RH = 35%

DB temp of 161°F measured inside degreaser below vapor level (in vapor cloud)

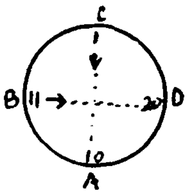
Temp in duct 75°F

Static Pressure meas in duct $\underset{-0.36}{A}$ $\underset{-0.36}{B}$ $\underset{-0.30}{C}$ $\underset{-0.32}{D}$ $\bar{x}$ = 0.335 "H_2O

Date 2/8/90	Time 3 PM	Operator BOTANO, NUTTER

Exhaust Duct Measurements, ft/min			
1	1250	11	1350
2	1350	12	1400
3	1450	13	1400
4	1450	14	1400
5	1350	15	1350
6	1100	16	850 ✓
7	1500	17	1350
8	1600	18	1500
9	1550	19	1550
10	1500	20	1500

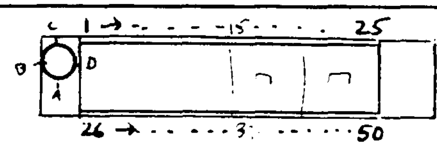
Comments



VELOCITY Average: ~~[illegible]~~ 1387.5 ft/min
FLOWRATE (CFM) = 1387.5 ft/min × 1.76 ft^2 = 2442

Lip Vent Measurements, ft/min									
1	1400	11	900	21	650	31	1000	41	700
2	1000	12	800	22	600	32	1000	42	750
3	900	13	750	23	600	33	1000	43	600
4	850	14	700	24	550	34	1050	44	650
5	800	15	800*	25	500	35	1000	45	600
6	900	16	750	26	1400	36	1000	46	600
7	950	17	750	27	1100	37	850	47	500
8	950	18	750	28	900	38	800	48	500
9	900	19	700	29	850	39	750*	49	500
10	850	20	600	30	750	40	700	50	450

Comments

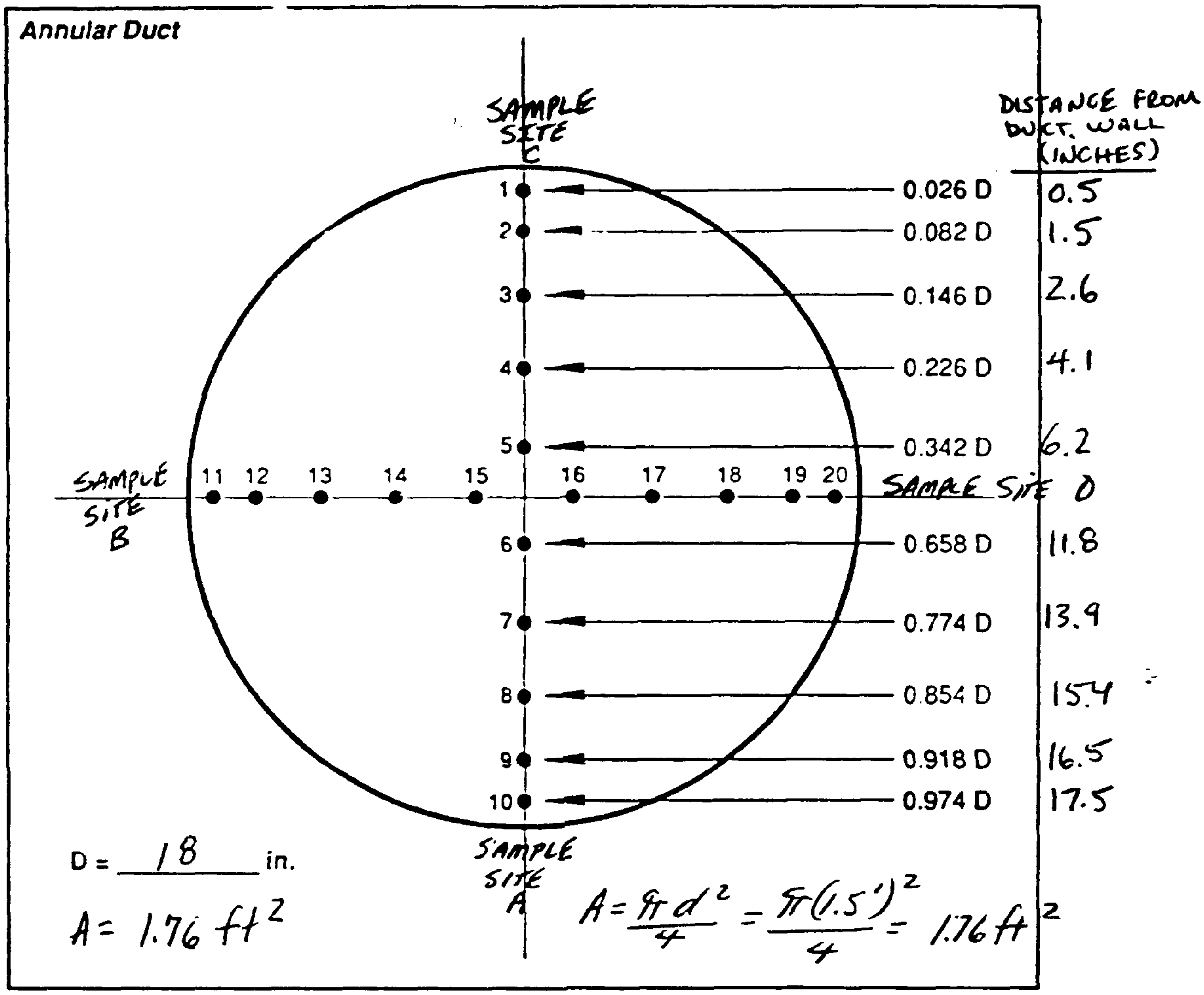


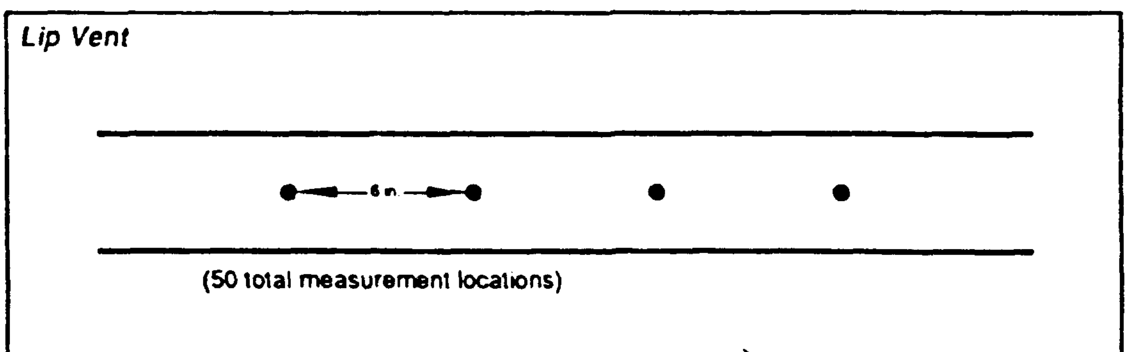
During velocity measurements of lip vent 2 of 4 lids were positioned on degreaser. Therefore, measurements taken at points 15 to 25 and 39 to 50 were made with the covers on. Velocity measurement 1 to 15 and 26 to 39 were made with the lids off

Velocity Average: 798 ft/min
FLOWRATE (CFM) = 798 ft/min × 2.21 ft^2

= ~~1596~~ 1763 CFM

$\frac{1763}{[illegible]} = 72\%$





LIP VENT DIMENSIONS $2\left(\underline{1}'' \times \underline{159}''\right) = \underline{318}\ in^2$ or $\underline{2.21} ft^2$

TOTAL AREA OF LIP VENT $= 2.21\ ft^2$

Figure 3-2. Locations of air velocity measurements in the degreaser exhaust duct and lip vent.

Date 02-09-90	Time 6:50 AM	Operator Bolano, Nutter

Dry Bulb Temperature	75.	°F	
Vapor Degreaser Temperature	161	°F	in tank
Humidity	46	%	
Static Pressure	0.38	in. H2O	

Comments S.P. = A = -0.39 ; B = -0.36 ; C = -0.39 ; D = -0.39

$\bar{x}$ = -0.38 in lip vent exhaust duct.

DB temp of 75°F measured at north side of degreaser at worker position center of degreaser adjacent to GA sample

Temp in duct - 80F

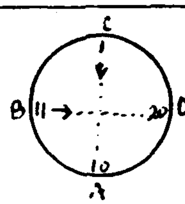
Temp in degreaser 161°F

Ventilation (velocity) measurements taken with a calibrated Kurz Air Velocity Meter Model 441 SN PCE-33131 Calibrated 7/11/89

Date 2/9/90	Time 6:36 AM	Operator Boiano, Nutter
	8:45 Am	

Exhaust Duct Measurements, ft/min			
1	1350	11	1500
2	1450	12	1400
3	1450	13	1500
4	1500	14	1500
5	1450	15	1550
6	1400	16	850
7	1650	17	1450
8	1650	18	1550
9	1600	19	1600
10	1600	20	1550

Comments



Sp A = -0.38
B = -0.36
C = -0.39
D = -0.39

Measurements made at start of test.

Both the double & single doors were shut

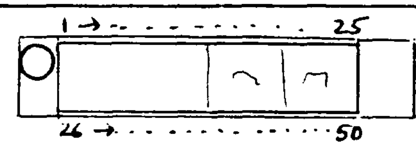
VELOCITY Average: 1478 ft/min

FLOWRATE (CFM) = 1478 ft/min x 1.76 ft^2 = 2600

Lip Vent Measurements, ft/min									
1	1200	11	900	21	650	31	1000	41	650
2	1350	12	850	22	650	32	950	42	700
3	1300	13	750	23	675	33	1100	43	650
4	1300	14	675*	24	650	34	1000	44	650
5	1300	15	800	25	550	35	850	45	650
6	800	16	750	26	1350	36	1000	46	650
7	850	17	750	27	1150	37	800	47	500
8	875	18	750	28	800	38	800	48	500
9	950	19	675	29	800	39	800	49	500
10	900	20	675	30	1150	40	700	50	450

→ LIP VENT NOT BALANCED

Comments



Measurements made at 8:45A

2 lids on as shown. Therefore velocity measurements at points 15 to 25 and from 39 → 50 were made w/ covers on

(Both double & single door were shut

Velocity Average: 835 ft/min

FLOWRATE (CFM) = 835 ft/min x 2.21 ft^2

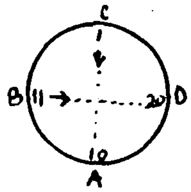
= ~~[illegible]~~ 1845 CFM

$\frac{1845}{\ }$ = 71%

Date 2/20/90	Time 1547 ☐ AM ☒ PM	Operator M. Nutter

Exhaust Duct Measurements, ft/min	
1 1200	11 1250
2 1400	12 [illegible]
3 1500	13 1550
4 1350	14 1600
5 1200	15 1500
6 1200	16 400
7 1500	17 500
8 1700	18 300
9 1800	19 250
10 1200	20 1200

Comments



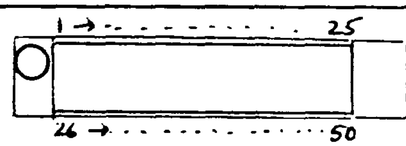
24100 ÷ 20 = 1205

VELOCITY Average: 1205 ft/min

FLOWRATE (CFM) = ft/min × 1.76 ft^2 = 2120.8

Lip Vent Measurements, ft/min				
1 1000	11 [illegible]	21 [illegible]	31 1000	41 750
2 [illegible]	12 [illegible]	22 675	32 1100	42 800
3 8[illegible]	13 750	23 650	33 1100	43 650
4 800	14 650	24 600	34 1150	44 700
5 850	15 750	25 550	35 1050	45 700
6 800	16 750	26 1500	36 1050	46 500
7 850	17 800	27 1000	37 850	47 475
8 800	18 750	28 1000	38 800	48 500
9 800	19 700	29 900	39 750	49 500
10 750	20 650	30 800	40 700	50 450
9300	7350	7725	9550	6025

Comments



1764.5 CFM

Velocity Average: 799 ft/min

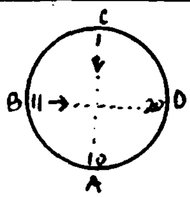
FLOWRATE (CFM) = 799 ft/min × 2.2 ft^2

Date 2/20/90	Time 2215 ☐ AM ☒ PM	Operator M. Nutter

Exhaust Duct Measurements, ft/min

1 950	11 700
2 1100	12 1100
3 [illegible]	13 1100
4 [illegible]	14 1100
5 1000	15 1100
6 500	16 450
7 200	17 900
8 1200	18 1150
9 1350	19 1200
10 1050	20 1000

Comments



Put on 10" pulley to cut [illegible] LESS [illegible]

[illegible] IN [illegible]

CFM

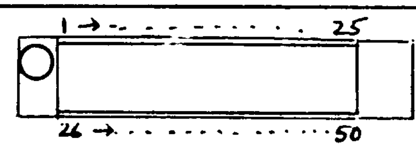
Δ 669
Δ 27%

VELOCITY Average: 20150 ft/min
FLOWRATE (CFM) = ft/min x 1.76 ft^2 = 1773.3

Lip Vent Measurements, ft/min

1 1000	11 650	21 450	31 700	41 550
2 700	12 550	22 500	32 750	42 [illegible]
3 700	13 600	23 450	33 750	43 450
4 650	14 600	24 450	34 750	44 500
5 700	15 650	25 425	35 650	45 450
6 675	16 600	26 1100	36 700	46 450
7 675	17 600	27 800	37 600	47 350
8 750	18 600	28 700	38 550	48 350
9 700	19 550	29 650	39 550	49 375
10 700	20 500	30 550	40 500	50 325

Comments



Δ 566.86
Δ 29%

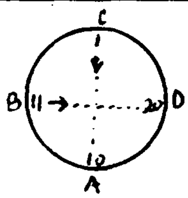
1257.64 CFM

Velocity Average: 569.5 ft/min
FLOWRATE (CFM) 569.5 ft/min x 2.21 ft^2

Date 2/20/90	Time 2330 ◯AM ⬤PM	Operator M. Nutter

Exhaust Duct Measurements, ft/min	
1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

Comments



Rel Humid - 26%
Temp - 78°

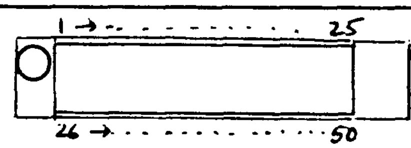
1035 · 1.376

1484 CFM

VELOCITY Average: ________ ft/min
FLOWRATE (CFM) = ft/min x 1.76 ft² =

Lip Vent Measurements, ft/min				
1 [illegible]	11 525	21 400	31 500	41 400
2 600	12 500	22 400	32 500	42 375
3 550	13 500	23 375	33 525	43 300
4 500	14 500	24 350	34 575	44 350
5 550	15 500	25 350	35 500	45 350
6 500	16 500	26 800	36 500	46 375
7 575	17 475	27 600	37 400	47 275
8 600	18 475	28 500	38 400	48 300
9 600	19 500	29 500	39 425	49 250
10 550	20 450	30 400	40 450	50 250
5825	4925	4675	4775	3225

Comments

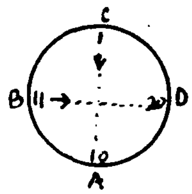


1034.6 CFM

23425.

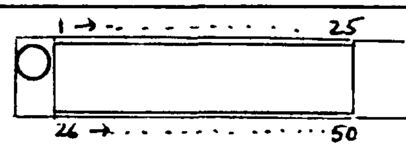
VELOCITY Average: 468.5 ft/min
FLOWRATE (CFM) = 468.5 ft/min x 2.21 ft²

Date 2/21/90	Time 0950 ☒AM ☐PM	Operator M. Nutter / R Schraft

Exhaust Duct Measurements, ft/min		Comments
1	11	 REDUCED FAN TEST
2	12	
3	13	
4	14	
5	15	1002 · 1.376
6	16	1379 CFM
7	17	
8	18	
9	19	VELOCITY Average: ______ ft/min
10	20	FLOWRATE (CFM) = ft/min x 1.76 ft² =

Lip Vent Measurements, ft/min				
1 500	11 500	21 350	31 [illegible]	41 400
2 575	12 425	22 375	32 550	42 400
3 [illegible]	13 425	23 [illegible]	33 [illegible]	43 [illegible]
4 500	14 375	24 350	34 650	44 400
5 450	15 450	25 300	35 600	45 375
6 450	16 400	26 800	36 550	46 350
7 450	17 400	27 600	37 500	47 300
8 425	18 400	28 450	38 450	48 275
9 600	19 375	29 400	39 500	49 300
10 550	20 375	30 450	40 425	50 350
5300	4125	4425	5425	3400

Comments



2 Pass [illegible]

1002.235 CFM

Velocity Average: 453.5 ft/min
FLOWRATE (CFM) = 4535 ft/min x 2.21 ft²

ate 2/29/90	Time 1430	☐ AM ☐ PM	Operator	M. Natt—	
ry Bulb Temperature	79	°F			
apor Degreaser Temperature		°F			
lumidity	15.8	%			
tatic Pressure	−0.18	in. H2O	→ Plating Shop ⇐ Outdoors		

omments Fan operating at reduced speed.

Two lids on degreaser. Double doors + single door closed.

0940 78°F 21% r.h. in degreaser room

Date 2/22/90	Time 0745 AM	Operator Nutter

Dry Bulb Temperature	71 °F	Outdoors: 59°F Rain
Vapor Degreaser Temperature	165 °F	
Humidity	37.4 %	
Static Pressure	in. H2O	

Comments Fan OFF. High concentration when the degreaser started up. Had to cover the duct at top of deg. rm. because NP inside degreaser room pulled air down stack + into degreaser (yesterday). Stack covered w/ cardboard and garbage bags (duct-taped).

2 covers on degreaser. Double doors closed.

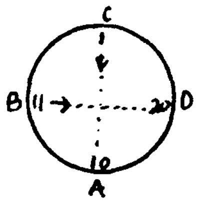
Bob H. has a headache.

1800: Tank level 1" above mark made 2/9/9[illegible]

Date 3/21/90	Time 6 PM	Operator M. Nutter

Exhaust Duct Measurements, ft/min			
1	650	11	800
2	900	12	900
3	750	13	900
4	800	14	900
5	800	15	900
6	750	16	500
7	925	17	800
8	950	18	950
9	950	19	950
10	850	20	850

Comments

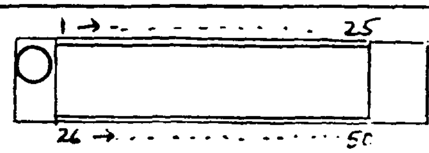


1476 CFM

VELOCITY Average: 838.75 ft/min
FLOWRATE (CFM) = 839 ft/min x 1.76 ft^2 =

Lip Vent Measurements, ft/min									
1	675	11	500	21	425	31	700	41	450
2	525	12	475	22	400	32	750	42	475
3	500	13	450	23	400	33	750	43	450
4	450	14	450	24	375	34	775	44	475
5	475	15	450	25	375	35	650	45	375
6	500	16	450	26	700	36	525	46	350
7	575	17	450	27	700	37	475	47	325
8	600	18	425	28	600	38	500	48	325
9	575	19	475	29	525	39	450	49	350
10	500	20	425	30	600	40	475	50	325

Comments



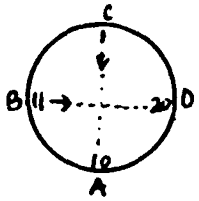
1104 CFM

VELOCITY Average: 499.5 ft/min
FLOWRATE (CFM) = 500 ft/min x 2.21 ft^2

Date 3/30/90	Time 3:15 PM	Operator M. Nutter

6000 Scale Exhaust Duct Measurements, ft/min			
1	750	11	750
2	800	12	800
3	800	13	900
4	800	14	800
5	800	15	700
6	650	16	600
7	700	17	700
8	850	18	850
9	900	19	900
10	900	20	850

Comments



Degreaser temp = 170°F at spray bar

Deg. Rm = 80°F 40.7% Rh

3/30 → ~~Fan~~ Motor pulley spread to reduce dia. + slow fan.

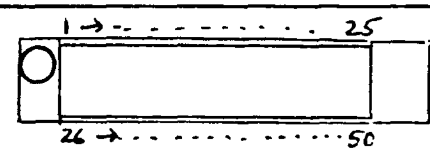
1390 CFM

VELOCITY Average: 790 ft/min

FLOWRATE (CFM) = 750 ft/min x 1.76 ft^2 = 1,390

1250 Scale Lip Vent Measurements, ft/min				
1 725	11 525	21 425	31 525	41 425
2 550	12 440	22 400	32 625	42 475
3 450	13 400	23 400	33 550	43 400
4 510	14 425	24 400	34 550	44 375
5 500	15 450	25 350	35 525	45 375
6 500	16 450	26 625	36 400	46 300
7 575	17 475	27 575	37 450	47 325
8 560	18 450	28 475	38 400	48 300
9 515	19 450	29 500	39 400	49 290
10 510	20 450	30 425	40 450	50 290

Comments



Measurements made w/ all lids on.

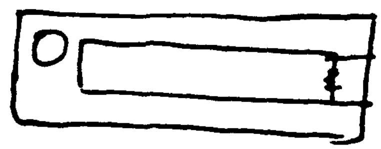
1,013 CFM

Velocity Average: 458.3 ft/min

FLOWRATE (CFM) = 458.3 ft/min x 2.21 ft^2

Date 4/19/90	Time 1100	Operator Nutter

Dry Bulb Temperature	74	°F
Vapor Degreaser Temperature	165	°F
Humidity	20.6	%
Static Pressure	− 0.15	in. H2O



NO COVERS

Comments

Freeboard extension installed.
flap fixed up
platform in place

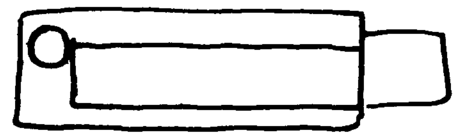
Double doors closed
Single door closed, not taped shut.

No covers on dgr.

Fan off
Stack covered + taped off at roof.

Date 5/31/90	Time 0745 AM PM	Operator Nutter

Dry Bulb Temperature	68	°F
Vapor Degreaser Temperature	162	°F
Humidity		%
Static Pressure		in. H2O



No covers

Comments Chiller midpoint temperature 50°F 0750

Troughs on dgr leak-tested: poor.

Curtains in place. Double doors open. Plating Shop fan at 1/3 speed.

Freeboard + platform in place. 2° Chiller operating.

Date 6/1/90	Time 1350 ~~AM~~ PM	Operator Nutter
Dry Bulb Temperature	83 °F	
Vapor Degreaser Temperature	167 °F	
Humidity	%	
Static Pressure	- 0.04 in. H2O →	Plating Shop ⇆ outdoors

Comments Freeboard test repeat.

No covers. No chiller.

Curtains in place w/ plastic above. Taped configuration w/ video camera.

Double doors open.

Date 6/4/92	Time 1010 AM	Operator Nutter

Dry Bulb Temperature	75 °F	Overcast and cool outdoors.
Vapor Degreaser Temperature	164 °F	
Humidity	%	
Static Pressure	in. H2O	

Comments Reduced fan test.

No freeboard or chiller in use other than existing water jacket.

Curtains in place. Double doors open. Single door shut but not taped.

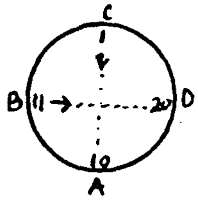
Fan at approx. 1100 CFM at lip vent.

Date 6/4/90	Time 8:30 AM	Operator Nutter, Schraft

Exhaust Duct Measurements, ft/min

1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

Comments



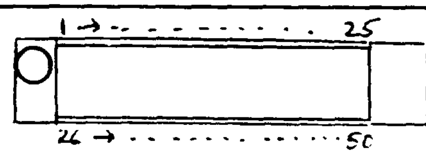
1st attempt at fan adjustment to provide reduced fan speed flow.

VELOCITY Average: ________ ft/min
FLOWRATE (CFM) = ft/min x 1.71 ft^2 =

Lip Vent Measurements, ft/min

1 1200	11 750	21 550	31 850	41 700
2 900	12 600	22 500	32 850	42 650
3 800	13 550	23 475	33 950	43 600
4 700	14 525	24 475	34 950	44 575
5 750	15 675	25 425	35 850	45 550
6 750	16 600	26 950	36 650	46 475
7 800	17 625	27 950	37 700	47 475
8 850	18 650	28 850	38 650	48 450
9 800	19 600	29 750	39 700	49 450
10 700	20 550	30 700	40 700	50 450

Comments



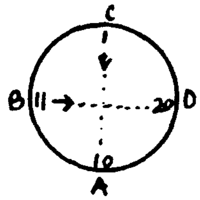
1,513 CFM

Velocity Average: 684.5 ft/min
FLOWRATE (CFM) = ft/min x 2.21 ft^2

Date 6/4/90	Time 8:45 AM	Operator Nutter, Schraft

Exhaust Duct Measurements, ft/min	
1	11
2	12
3	13
4	14
5	15
6	16
7	17
8	18
9	19
10	20

Comments



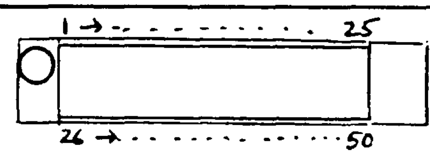
2ND attempt at reduced fan.

VELOCITY Average: ________ ft/min
FLOWRATE (CFM) = ft/min x 1.76 ft² =

Lip Vent Measurements, ft/min				
1 750	11 425	21 350	31 550	41 450
2 500	12 375	22 325	32 600	42 400
3 475	13 350	23 325	33 550	43 400
4 425	14 300	24 250	34 550	44 400
5 425	15 375	25 250	35 500	45 325
6 475	16 375	26 600	36 450	46 325
7 475	17 375	27 600	37 450	47 300
8 500	18 400	28 475	38 425	48 280
9 475	19 375	29 475	39 425	49 280
10 425	20 350	30 425	40 475	50 250

#2

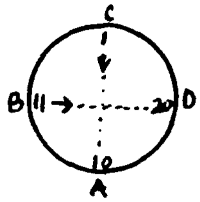
Comments

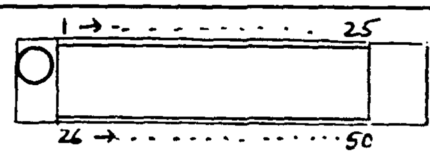


932 CFM

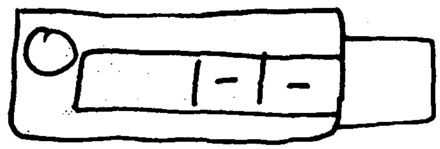
VELOCITY Average: 421.7 ft/min
FLOWRATE (CFM) = 421.7 ft/min x 2.21 ft²

Date 6/4/90	Time 9 AM / PM	Operator Nutter, Schraft

Exhaust Duct Measurements, ft/min				Comments
1	700	11	800	 ~~BA~~ REDUCED FAN RETEST
2	850	12	900	
3	900	13	850	
4	850	14	900	
5	850	15	850	
6	800	16	400	
7	900	17	650	1452 CFM
8	950	18	850	1452/1401.5 = 104%
9	950	19	950	VELOCITY Average: 825.0 ft/min
10	800	20	800	FLOWRATE (CFM) = ft/min x 1.76 ft^2 =

Lip Vent Measurements, ft/min										Comments
1	750	11	450	21	375	31	600	41	500	
2	550	12	400	22	375	32	600	42	475	
3	500	13	400	23	325	33	625	43	425	
4	500	14	375	24	240	34	625	44	425	
5	500	15	450	25	240	35	550	45	325	
6	500	16	425	26	725	36	500	46	300	1,009 CFM
7	525	17	425	27	625	37	475	47	290	
8	525	18	425	28	525	38	475	48	310	1009/1018 = 99%
9	500	19	400	29	500	39	450	49	290	Velocity Average: 456.6 ft/min
10	450	20	375	30	550	40	500	50	270	FLOWRATE (CFM) = ft/min x 2.2 ft^2

Date 6/5/90	Time 0840	Operator Nutter

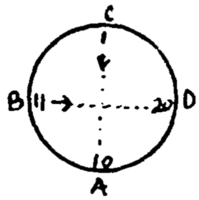
Dry Bulb Temperature	66 °F	 2 covers
Vapor Degreaser Temperature	163 °F	
Humidity	%	
Static Pressure	in. H2O	

Comments Baseline retest.

Date 6/5/90	Time 8:15 AM	Operator Natter, Schraft

Exhaust Duct Measurements, ft/min			
1	1200	11	~~1600~~/1100
2	1500	12	~~1800~~/1500
3	1500	13	~~1800~~/1400
4	1600	14	~~1900~~ 1500
5	1500	15	~~1400~~ 1500
6	~~700~~ 700	16	~~350~~ 700
7	~~2000~~ 1000	17	1500
8	~~2200~~ 1700	18	1700
9	~~2100~~ 1500	19	1700
10	~~1700~~ 1500	20	1300

Comments



BASELINE RETEST

2429 CFM

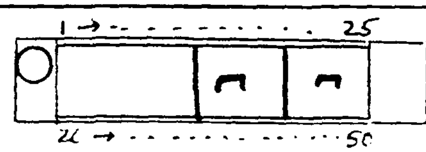
2429/2442 = 99.5%

VELOCITY Average: 1380 ft/min

FLOWRATE (CFM) = ft/min x 1.76 ft² = 2428

Lip Vent Measurements, ft/min				
1 1300	11 750	21 650	31 900	41 700
2 1400	12 800	22 700	32 1000	42 750
3 1000	13 750	23 575	33 950	43 650
4 900	14 700	24 600	34 900	44 625
5 850	15 700	25 550	35 875	45 600
6 800	16 750	26 1000	36 800	46 500
7 850	17 750	27 1100	37 95 900	47 500
8 900	18 750	28 800	38 725	48 500
9 950	19 800	29 800	39 700	49 525
10 1000	20 800	30 800	40 700	50 [illegible]75

Comments



1739.3 CFM

1739/1763 = 99%

Velocity Average: 787 ft/min

FLOWRATE (CFM) = 787 ft/min x 2.21 ft²

Date 6/8/90	Time 1555	Operator Nutter

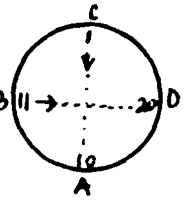
Dry Bulb Temperature	84 °F	All options tested • Chiller + freeboard ext. • Freeboard ext. w/o chiller • Baseline • Reduced fan
Vapor Degreaser Temperature	165 °F	
Humidity	%	
Static Pressure	in. H2O	

Comments Consecutive Day testing

Date 6/8/90	Time 3:00 PM	Operator SCHRAFT / Szabo

Exhaust Duct Measurements, ft/min			
1	~~650~~ 1700	11	~~800~~ 1300
2	~~850~~ 1400	12	~~900~~ 1500
3	~~900~~ 1500	13	~~900~~ 1400
4	~~900~~ 1500	14	~~900~~ 1600
5	~~900~~ 1500	15	~~900~~ 1600
6	~~900~~ 1500	16	~~650~~ 750
7	~~850~~ 1700	17	~~880~~ 1300
8	~~850~~ 1800	18	~~1000~~ 1500
9	~~900~~ 1700	19	~~1000~~ 1500
10	~~[illegible]~~ 1500	20	~~925~~ 1900

Comments



BASELINE TEST
SINGLE DAY CONSEC.

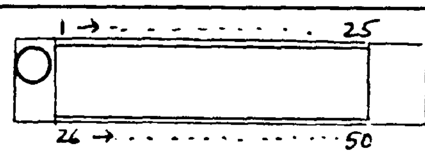
2556 CFM

VELOCITY Average: 1452.5 ft/min

FLOWRATE (CFM) = ft/min x 1.76 ft^2 = ~~1551~~

Lip Vent Measurements, ft/min									
1	1400	11	850	21	600	31	1000	41	700
2	1350	12	800	22	650	32	950	42	700
3	900	13	750	23	600	33	900	43	700
4	900	14	700	24	650	34	1000	44	650
5	850	15	650	25	550	35	1000	45	650
6	800	16	700	26	1000	36	800	46	500
7	900	17	700	27	1000	37	800	47	500
8	950	18	750	28	900	38	800	48	500
9	950	19	750	29	900	39	700	49	550
10	900	20	650	30	800	40	750	50	500

Comments



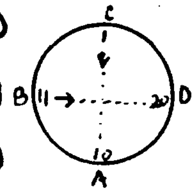
1746 CFM

VELOCITY Average: 790 ft/min

FLOWRATE (CFM) = ft/min x 2.21 ft^2

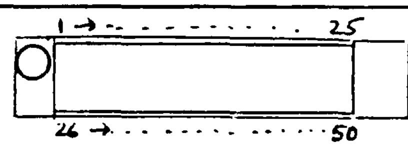
Date 6/8/90	Time 11:45 AM	Operator SCHRAFT / Szabo

Exhaust Duct Measurements, ft/min				Comments
1	~~700~~ 650	11	~~750~~ 700	REDUCED FAN TEST SINGLE DAY 80NSEC.
2	~~900~~ 800	12	~~800~~ 750	
3	~~800~~ 750	13	~~1000~~ 900	
4	~~1000~~ 800	14	~~900~~ 950	
5	~~900~~ 750	15	~~900~~ 800	
6	~~800~~ 800	16	~~650~~ 550	
7	~~900~~ 800	17	~~1000~~ 750	1386 CFM
8	~~1000~~ 850	18	~~1000~~ 900	
9	~~1100~~ 950	19	~~1000~~ 900	VELOCITY Average: ______ ft/min
10	~~1000~~ 900	20	~~700~~ 900	FLOWRATE (CFM) = 787.5 ft/min x 1.76 ft^2 = 1386



Lip Vent Measurements, ft/min				
1 650	11 500	21 450	31 500	41 400
2 700	12 400	22 400	32 600	42 450
3 500	13 400	23 350	33 600	43 400
4 500	14 375	24 300	34 500	44 400
5 500	15 400	25 300	35 500	45 350
6 500	16 400	26 ~~[illegible]~~	36 450	46 300
7 450	17 450	27 600	37 450	47 350
8 550	18 400	28 500	38 400	48 250
9 600	19 450	29 500	39 450	49 300
10 500	20 500	30 500	40 450	50 250

Comments



1033

VELOCITY Average: 467.5 ft/min
FLOWRATE (CFM) = 467.5 ft/min x 2.21 ft^2

APPENDIX C

PHOTOGRAPHS OF OPERATIONS

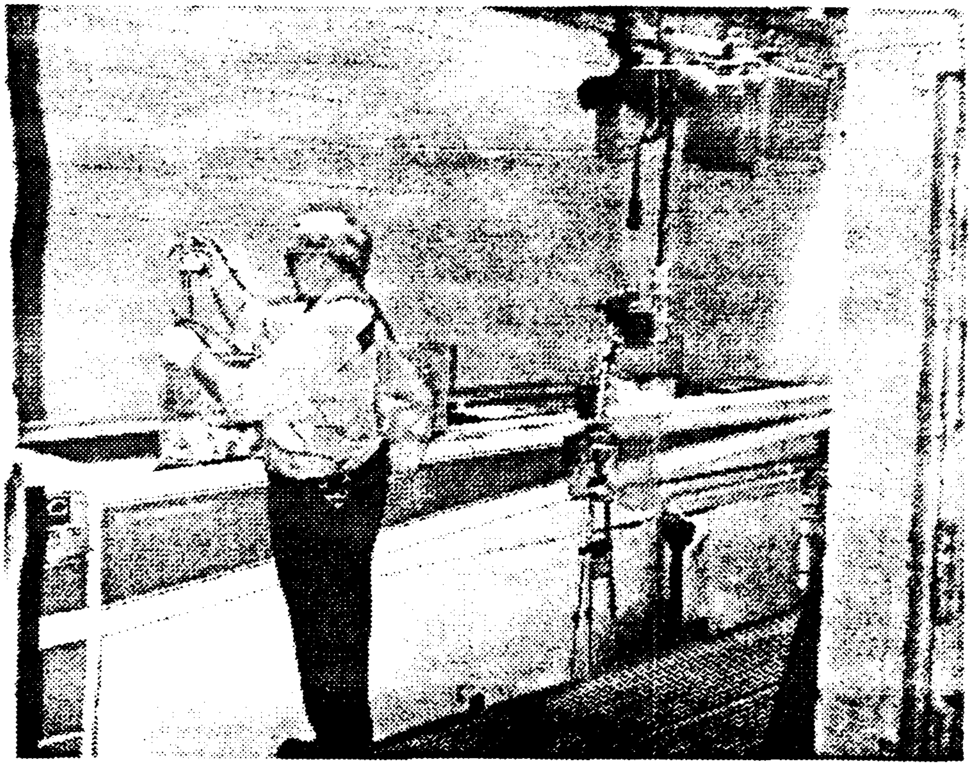


Figure C-1. Operator loading parts into vapor degreaser.

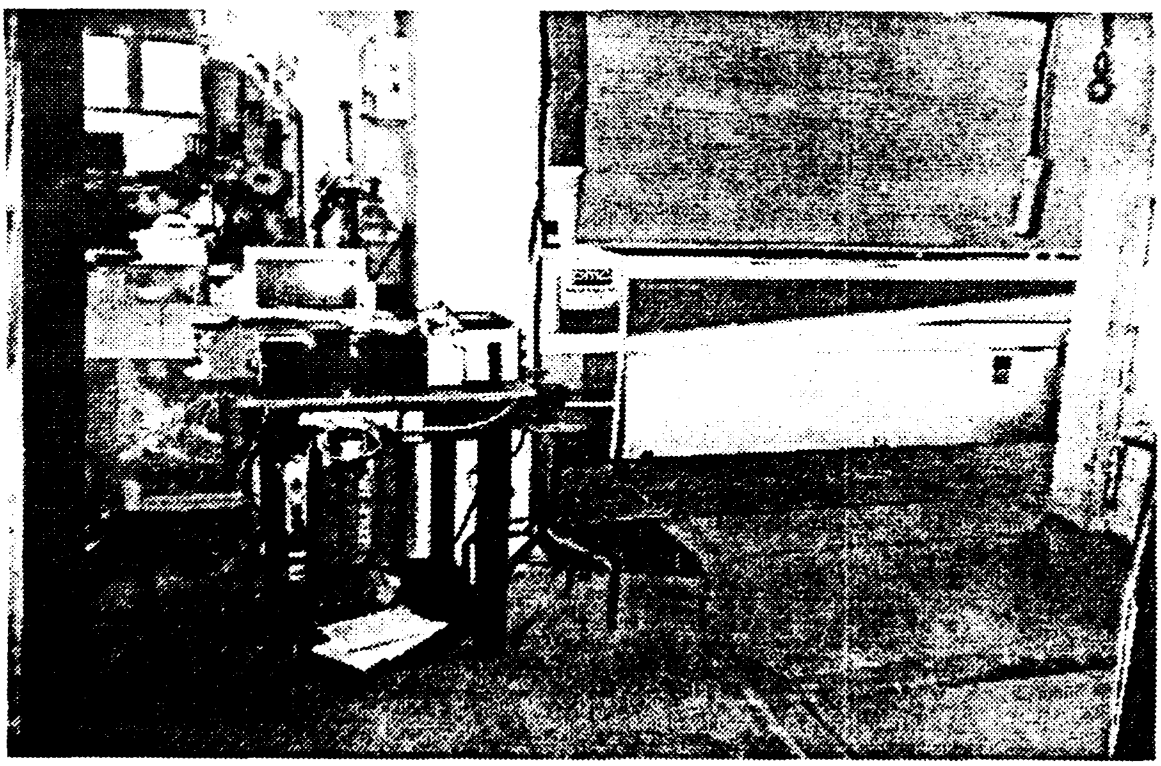


Figure C-2. Vapor degreaser and remote monitoring station.

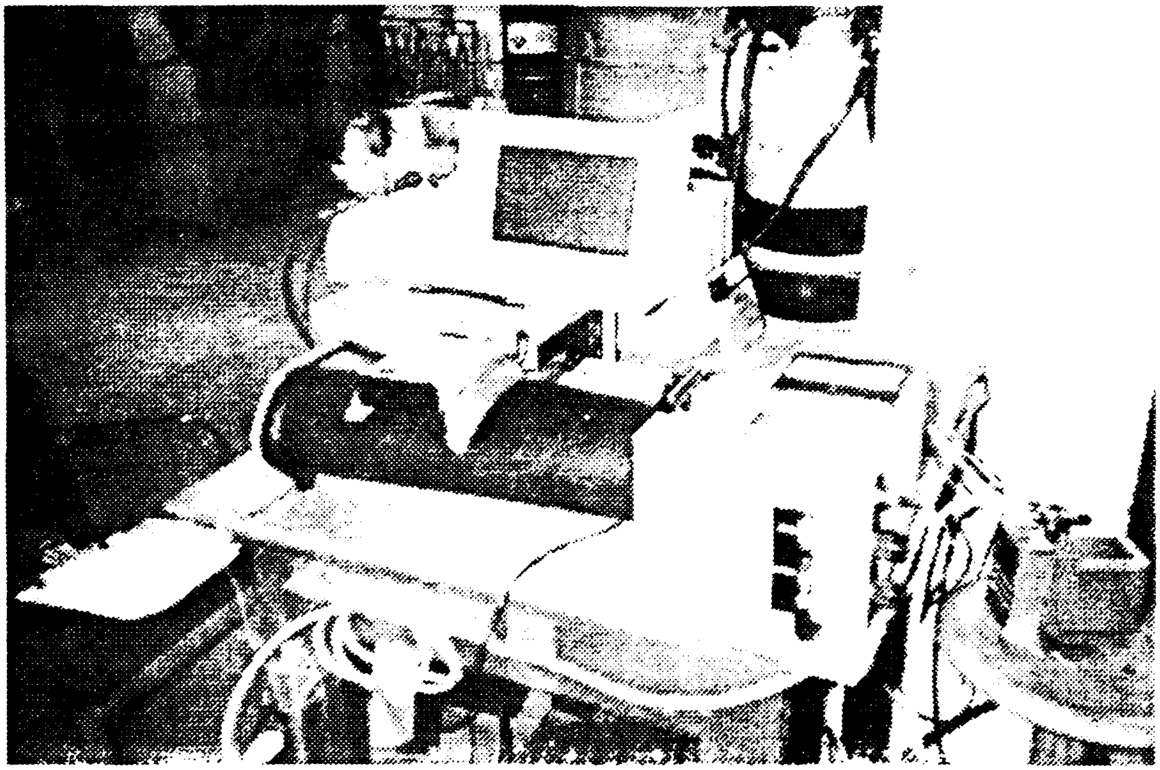


Figure C-3. Remote monitoring station showing Miran 1A, DL332F data logger, strip-chart recorder and portable computer for real-time display of monitoring data.

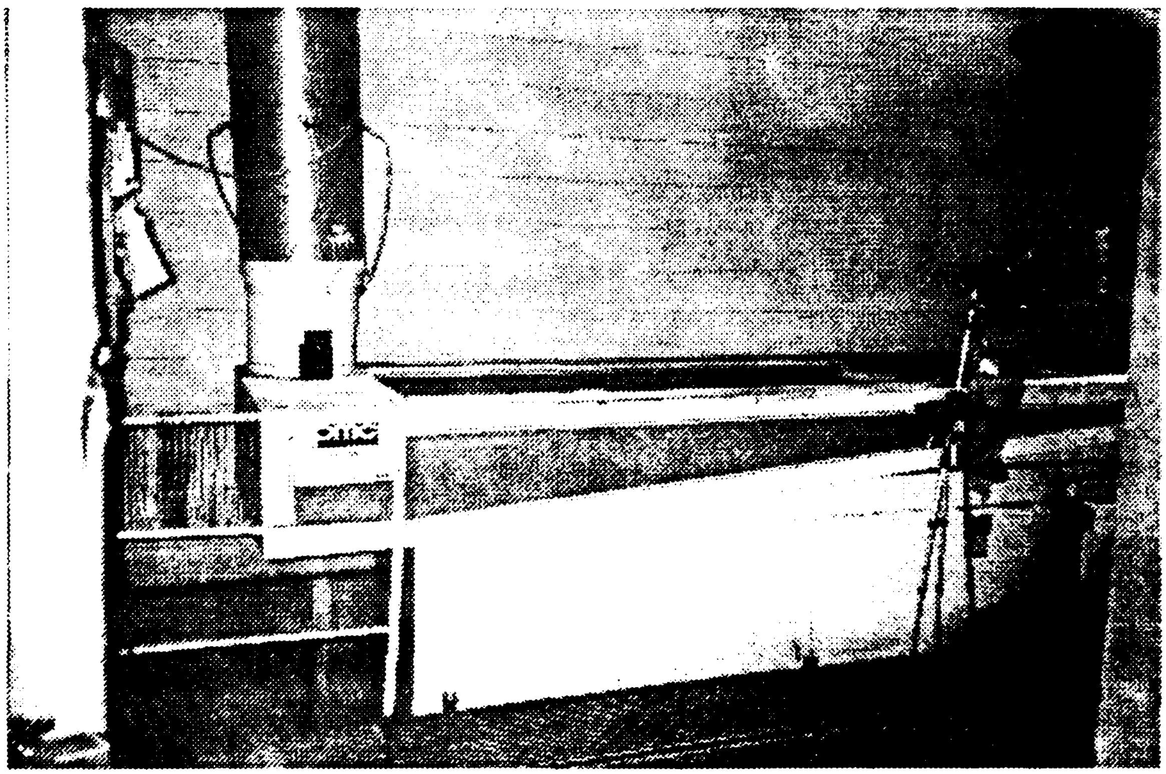


Figure C-4. Monitoring locations at vapor degreaser: lip vent exhaust duct (charcoal tubes and Miran 1A port) and degreaser midpoint (charcoal tubes and Tedlar® bag sample).

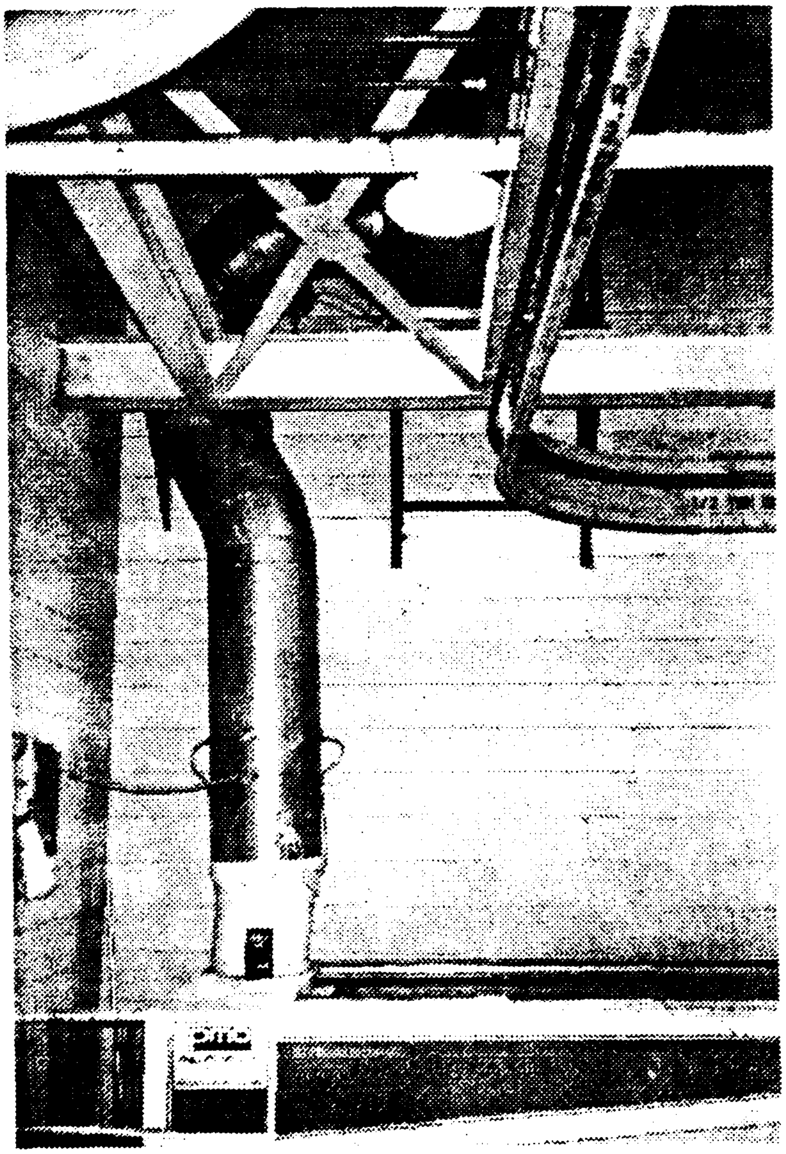


Figure C-5. Closeup of lip vent exhaust duct sampling configuration.

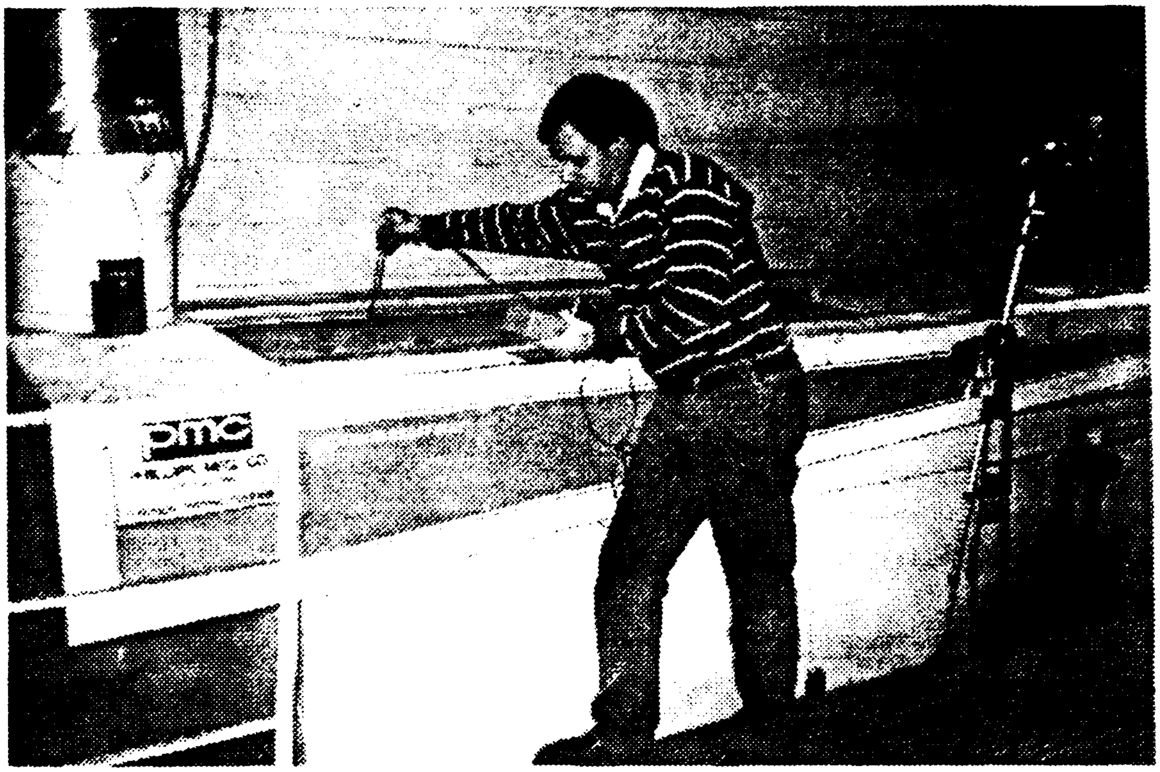


Figure C-6. Air velocity measurement at degreaser lip vent.

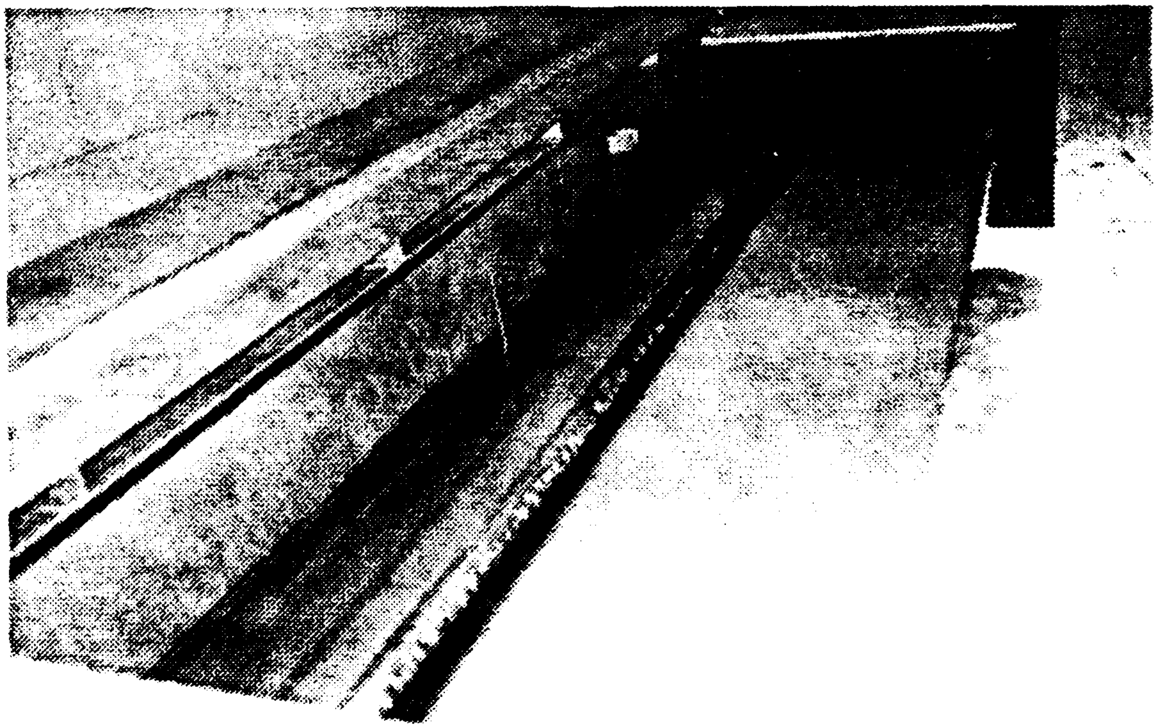


Figure C-7. Closeup of vapor line inside degreaser, 3/4 up water jacket.

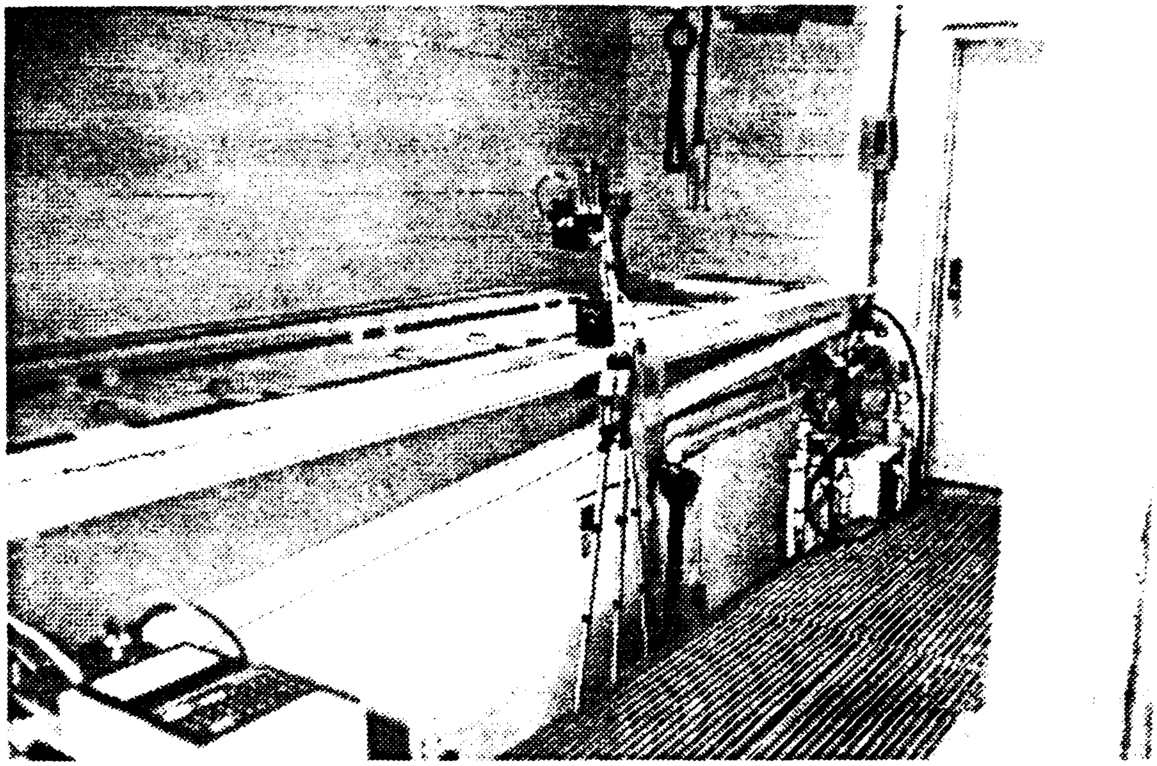


Figure C-8. Monitoring location at degreaser midpoint showing charcoal tube and Tedlar® bag sample.

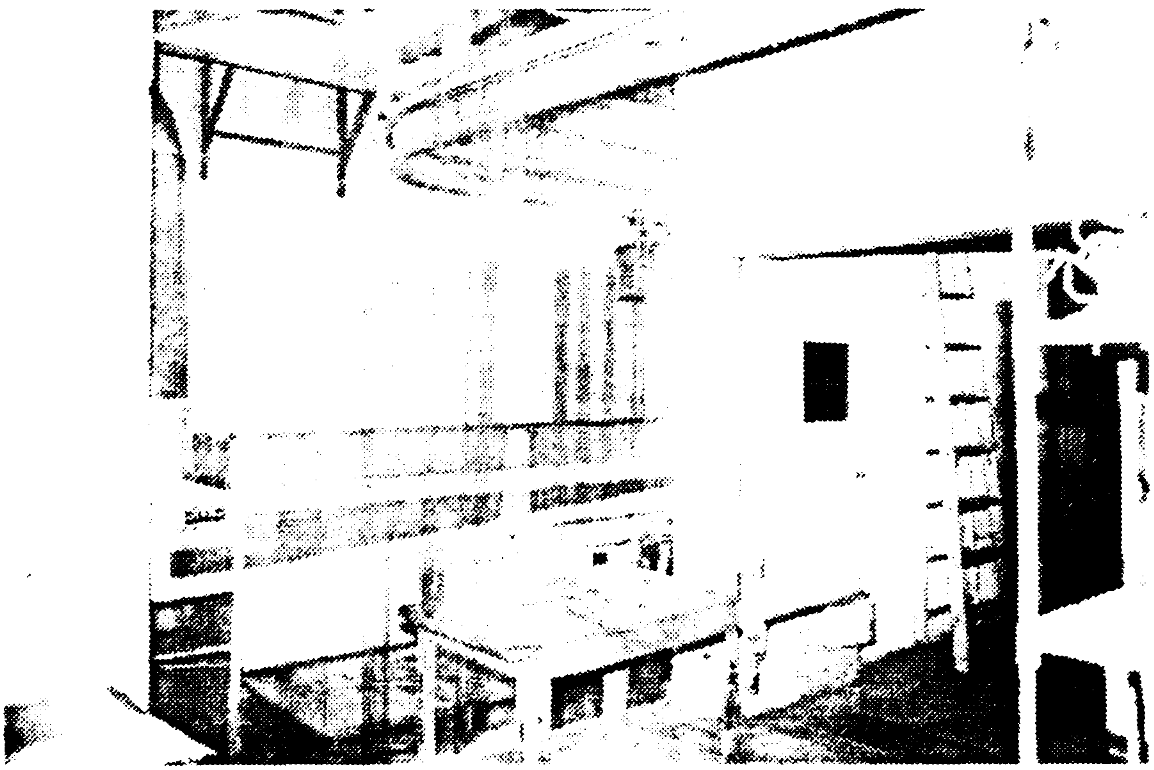


Figure C-9. Temporary curtains in place at degreaser room threshold to control cross drafts.

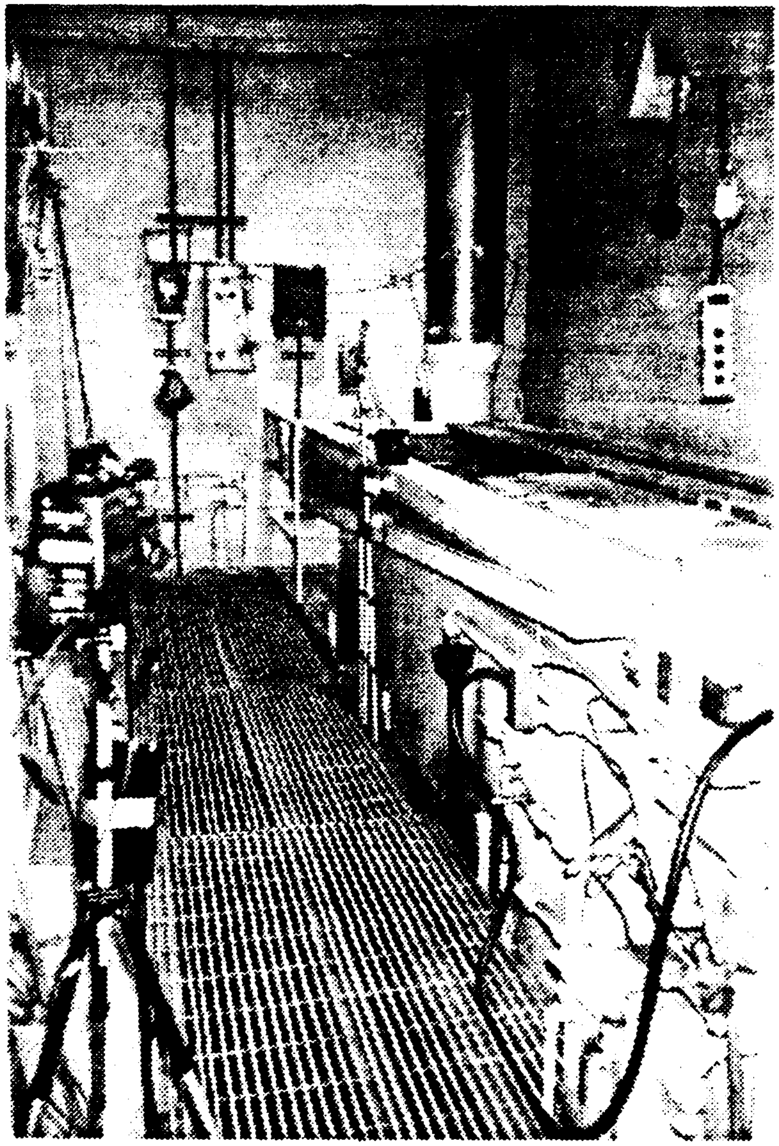


Figure C-10. Camera location for continuous recording of degreaser activity (left foreground).

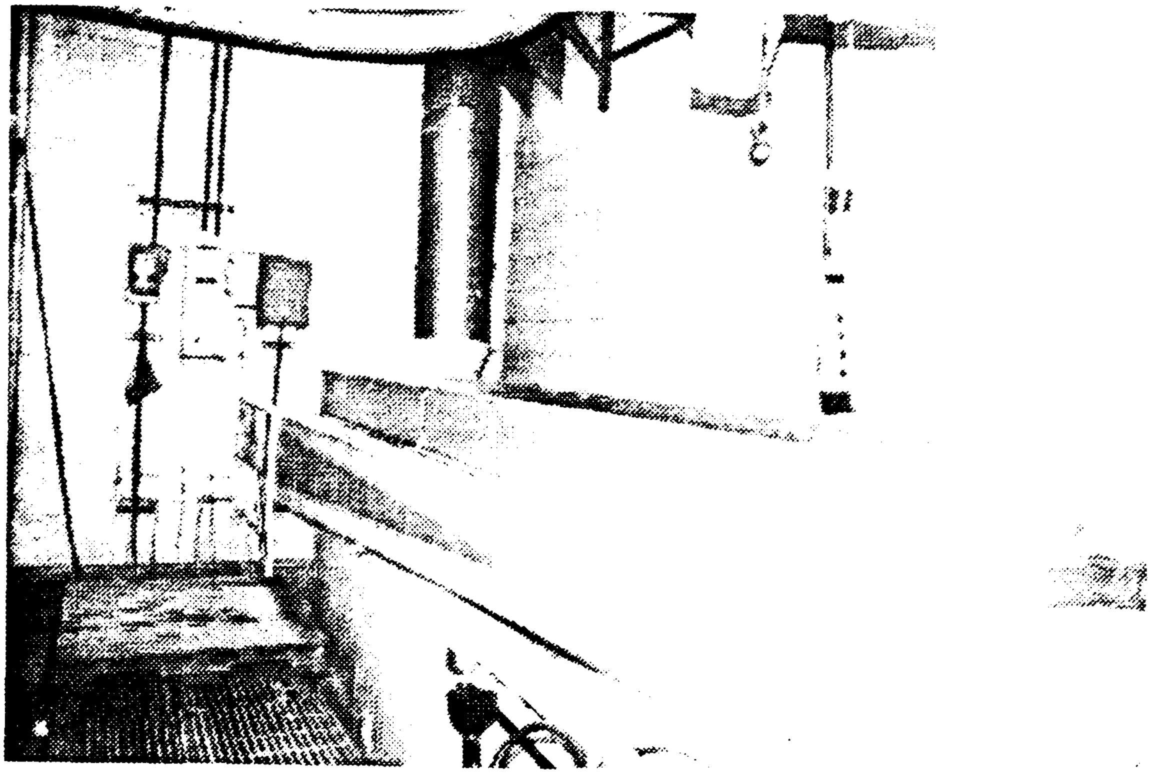


Figure C-11. Degreaser configuration for freeboard extension tests showing 20-gauge sheet metal extension and work platform (on floor grating).

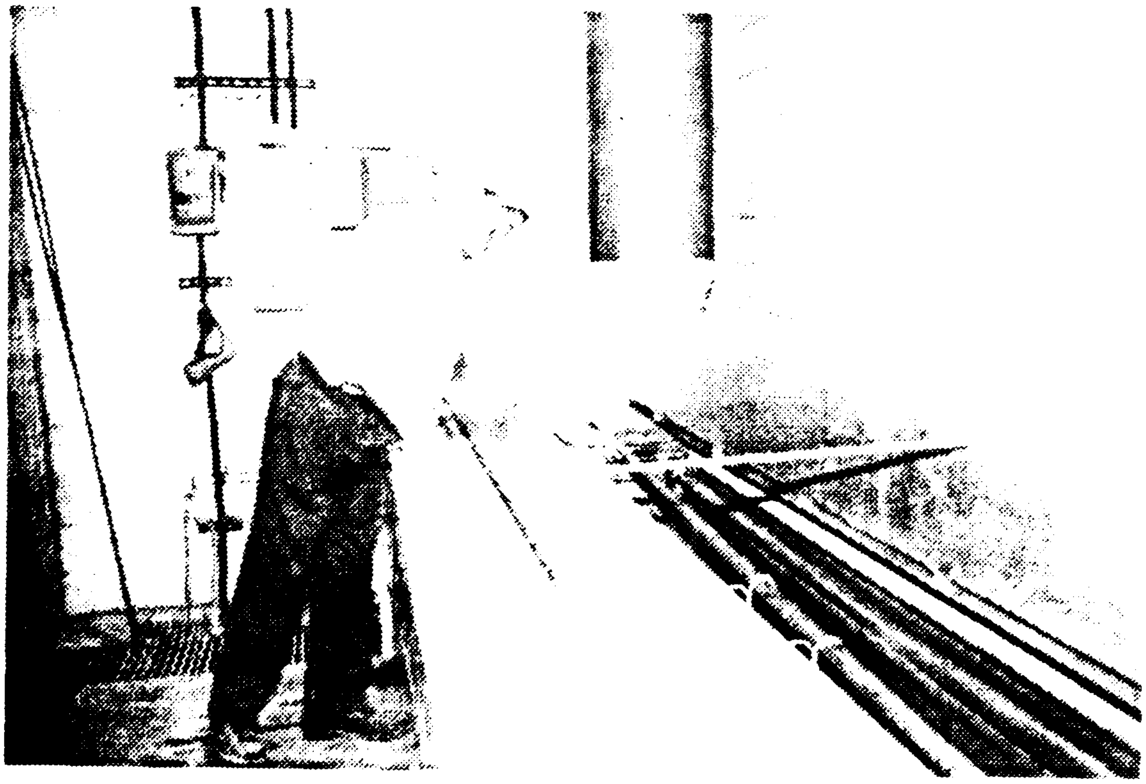


Figure C-12. Operator loading parts into degreaser with extension in place

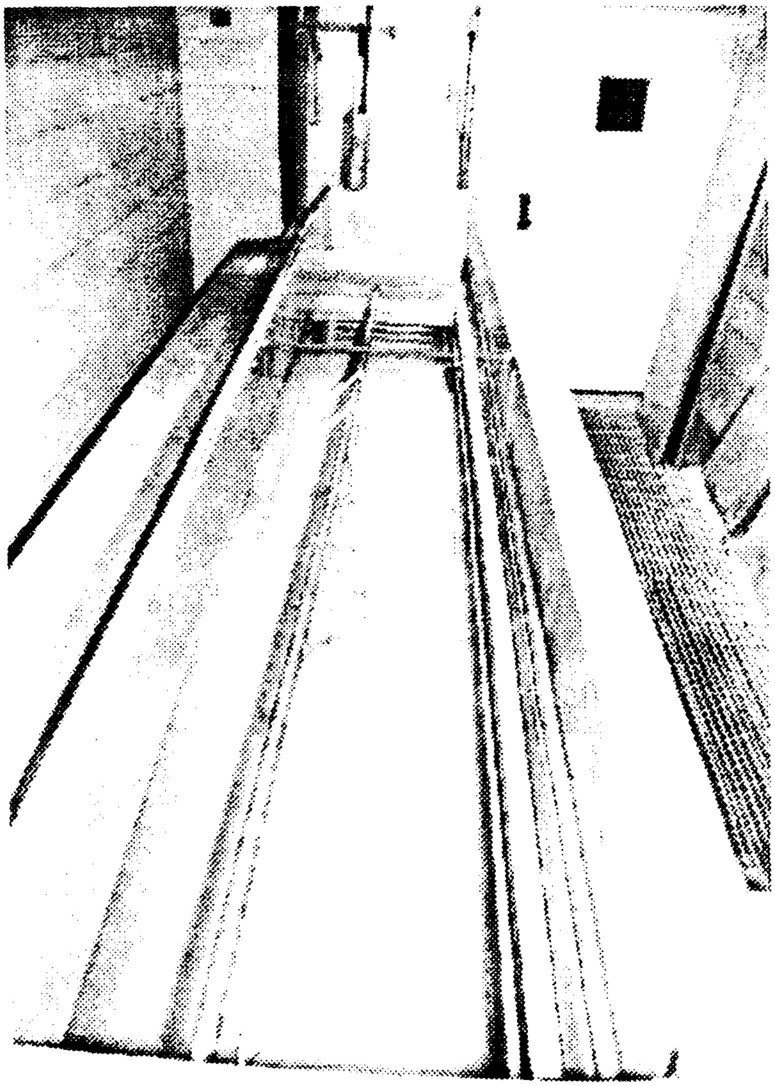


Figure C-13. Parts inside vapor degreaser with freeboard extension in place.

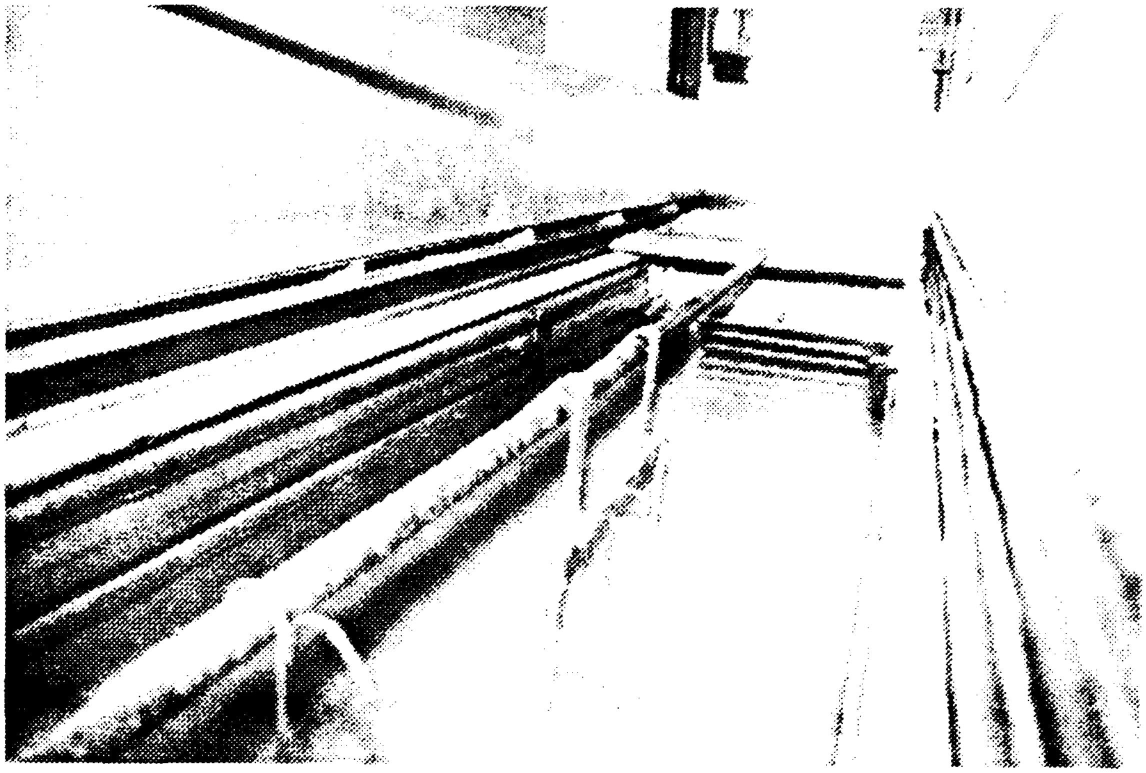


Figure C-14. Secondary chiller coils inside vapor degreaser.Upper coils are covered with TCA frost. Note location of lip vent below freeboard extension.

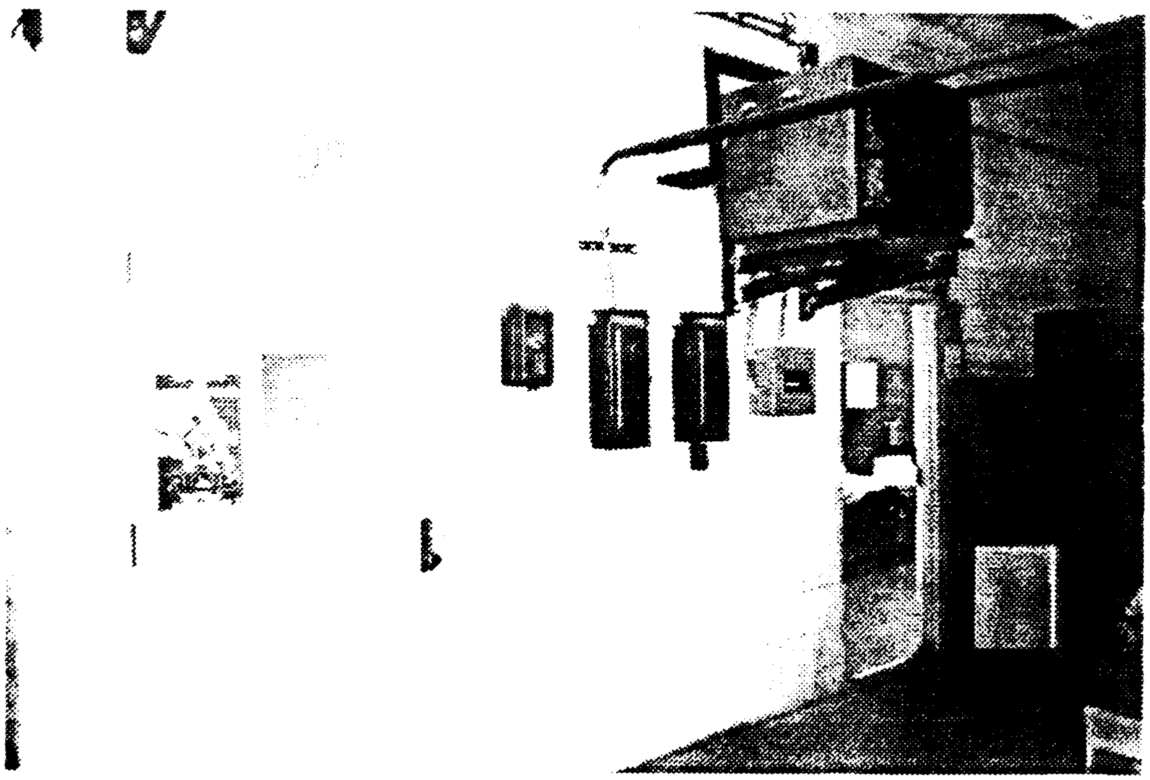


Figure C-15. Compressor for secondary chiller mounted outside degreaser room.

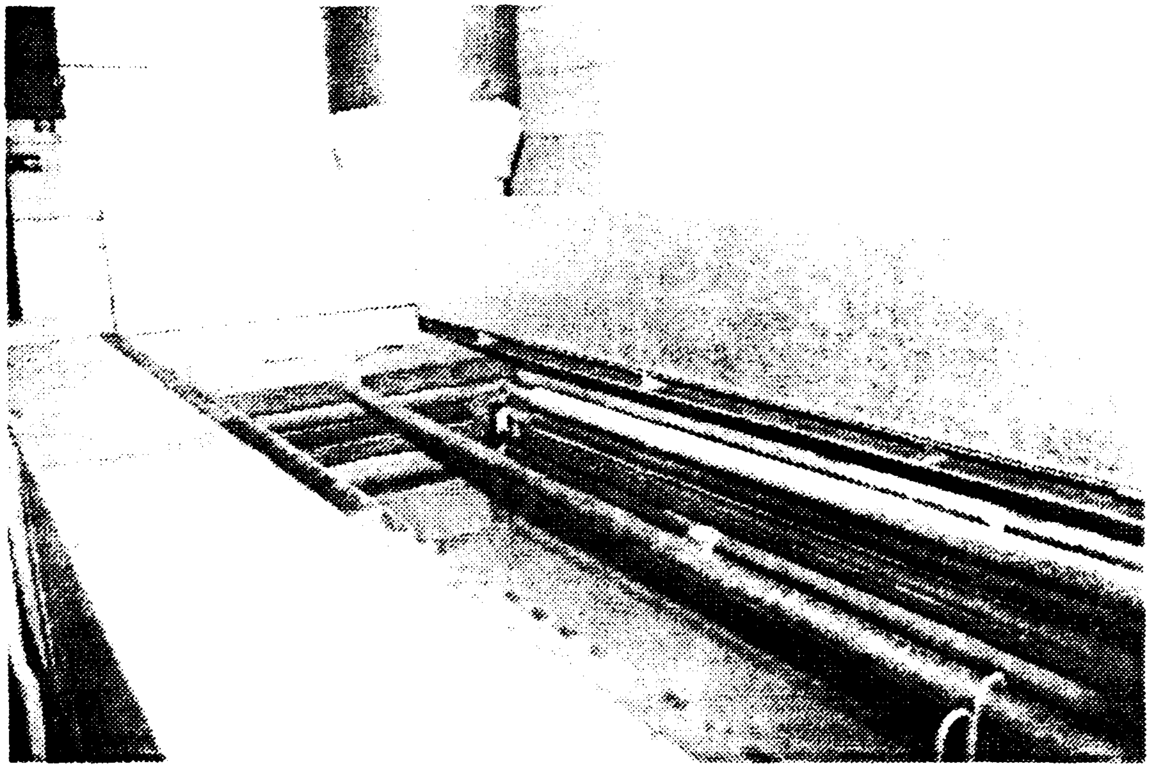


Figure C-16. Closeup of secondary chiller coils inside degreaser.

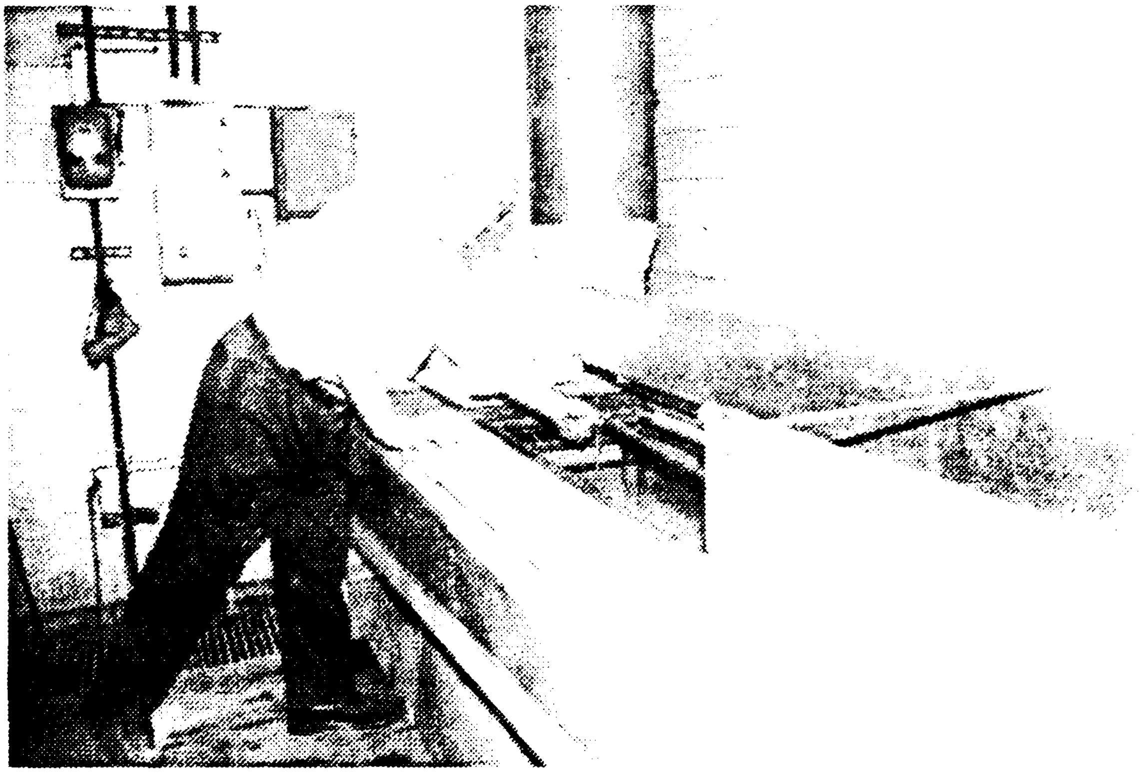


Figure C-17. Post-study use of vapor degreaser using freeboard extension flap for better access.

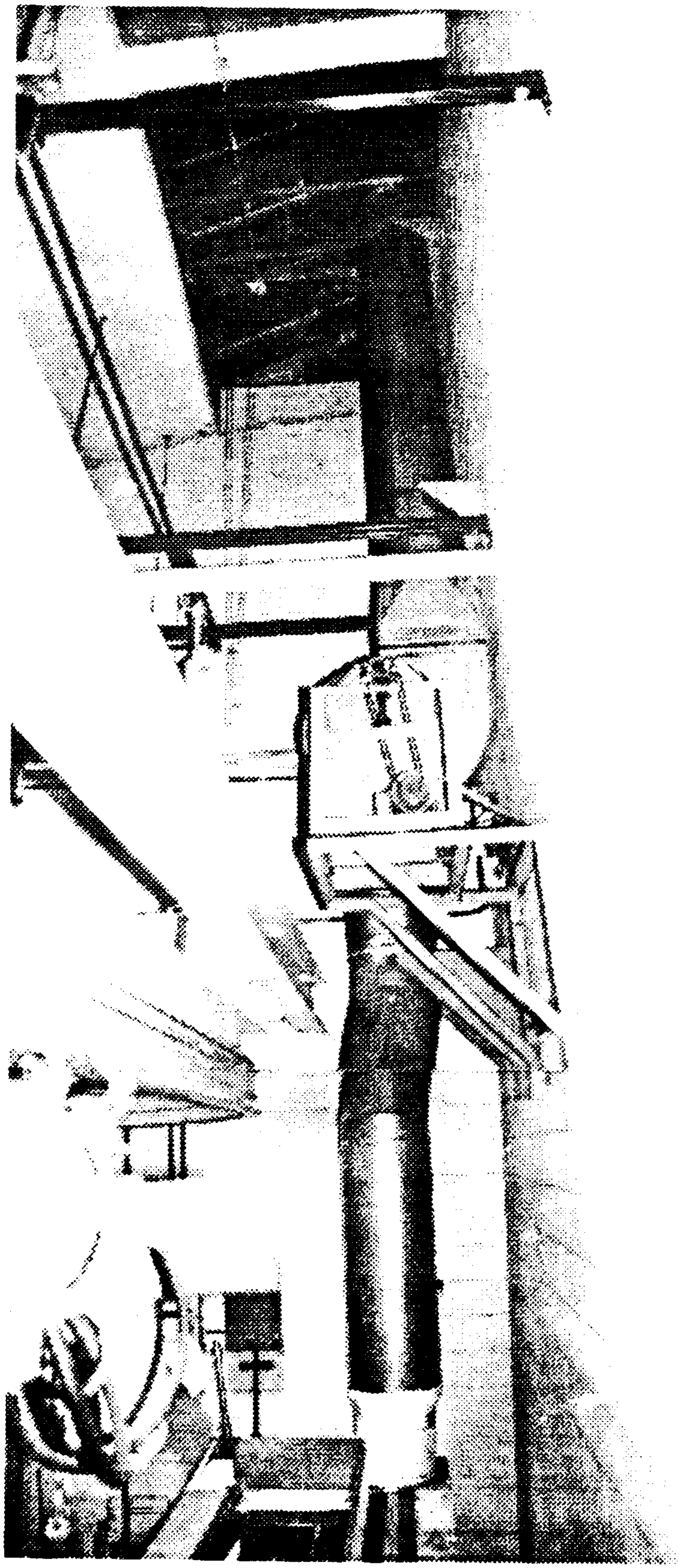


Figure C-18. Composite photo showing lip vent exhaust system in baseline configuration with 5 inch fan pulley.