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Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency

U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Center for Environmental Research Information
Cincinnati, Ohio

NOTICE

The U.S. Environmental Protection Agency through its Office of Research and Development funded and managed the research described here under Contract #68-C7-0011, Work Assignment 21, to Science Applications International Corporation. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director

ACKNOWLEDGMENTS

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Science Applications International Corporation, (SAIC), of Hampton and Reston, Virginia, revised the original document,

ABSTRACT

This document presents an overview of industrial assessments and the general framework for conducting an assessment. It describes combined assessments for pollution prevention and energy, "industrial assessments", providing guidance to those performing assessments at industrial or other commercial facilities. In addition, basic information about waste generating industrial operations and energy consuming equipment is provided. This guide can be used by both facility personnel to conduct in-house assessments of operations and by third parties who are interested in providing industrial assessments.

Traditionally, assessments have been performed on singular problem areas, focusing on either pollution prevention or energy. An interagency agreement between the USEPA and the Department of Energy combined pollution prevention and energy assessments into industrial assessments, looking at both areas for small and medium size facilities in SIC codes 20-39. A first draft of a training manual describing this industrial assessment methodology was prepared by Rutgers, The State University of New Jersey, in December of 1995.

This **Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency** is organized into four basic sections:

Basic Concepts, Chapters 1- 4.	Assessment methodology, fundamentals of an assessment, and evaluation of pollution prevention and energy conservation opportunities.
Specific Waste Generation Information, Chapter 5.	Industrial operations, waste generated from each operation, and pollution prevention opportunities.
Specific Energy Consumption, **Information**, Chapters 6-10.	Types of energy consuming equipment including electrical equipment, heat generating equipment like boilers, and furnaces, prime movers of energy, thermal applications, and HVAC.
References and Case Studies,	Materials to be used repeatedly such as references, sources of information, and pollution prevention and energy conservation case studies.

This guide is an effort by EPA to contribute to an understanding of both pollution prevention and energy assessments at commercial facilities. Companies from large to small, and government at all levels, as well as assistance providers, could find the information contained in this directory useful.

This report was submitted in fulfillment of Contract #68-C7-0011, Work Assignment 21, by Science Applications International Corporation, under the sponsorship of the U.S. Environmental Protection Agency. This work covers a period from May to September, 1998.

Table of Contents

.... 74 ....
4.4.1.4 Hazardous Waste4.4.1.4 Hazardous Waste4.4.1.4 Hazav
4.4.1.3 Solid Waste..... Waste 7
4.4.1.3 Solid Waste................................

List of Exhibits

Notes

Notes

E.2.1 Planning and Organization

The planning and organization of an industrial assessment is important to obtain the desired results. The assessment team should decide on a data collection format for the assessment. The team may use standard worksheets provided in EPA's Facility Pollution Prevention Guide or may develop their own assessment worksheets, questionnaires, or checklists. The team should prepare an assessment agenda and schedule the assessment in advance to coincide with a particular operation of interest

E.2.2 Assessment Phase

The second phase is the assessment phase. This phase can be broken down into two parts: the pre-assessment and the actual assessment.

E.2.2.1 Pre-Assessment

Prior to the assessment it is a good idea to collect information, allowing the assessment team to review and prepare additional questions. Information that should be collected includes: a facility description, a process description, a process flow diagram, major energy consuming equipment, raw material information, and energy and waste data collection. The team should collect information for a 12-month period and all information should be for the same 12-month period. The energy information should be converted to a standard unit of measure such as the British Thermal Unit (BTU) and graphed to view energy usage trends. Waste data can be summarized in a table format for review and reference. Collection of this data prior to the assessment will also give the assessment team an idea of where its attention should be focused during the actual assessment.

E.2.2.2 Assessment

During the actual assessment, the team should begin with a review of operations and data collected prior to the assessment with persons who work in the area on a day-to-day basis. After the team has discussed the operations, the team should take a walk-through the facility to observe actual operations. During the walk-through team members should talk with personnel to confirm operational procedures and information collected prior to the assessment. After the walk-through, the team members should brain storm ideas for energy conservation and pollution prevention. This is the point where the team will generate a list of ideas without regard to cost or feasibility. Once the list of ideas has been generated, the team can collect information that it needs to complete a feasibility analysis.

E.2.3 Feasibility Analysis Phase

The third phase of the assessment is the feasibility analysis. This portion of the assessment is usually completed over several days after the assessment and will include both a technical feasibility analysis and an economic feasibility analysis.

The feasibility analysis should begin with a prioritization of the identified opportunities. Because of time and resource constraints many facilities will have to choose among opportunities for implementation. The team can develop a relative ranking of opportunities using a tool know as the decision matrix. The decision matrix tool can be used to rank the identified opportunities using a list of critical factors that are important to the facility allowing an "apples-to-apples" comparison of the options.

The feasibility analysis should be documented for presentation to other facility personnel or to management. This documentation should include a clear description of current operations and practices, a description of the opportunity, the benefits of that would result from implementation of the opportunity, as well as a technical and economic evaluation of the opportunity. The detail of the technical and economic evaluations will vary depending on facility requirements and the complexity of the opportunity.

E.2.3.1 Technical Feasibility

The technical feasibility analysis can include:

- Calculation of energy consumption and waste generation reductions,
- Determination of how much labor will be involved with the changes in operations or equipment,

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- Evaluation of space constraints,
- Evaluation of safety and health aspects for employees,
- Compatibility with current operations and materials, and
- Changes in annual operating and maintenance costs.

There are many other factors that can be included in a technical evaluation. All of the factors listed above may not apply to every opportunity. The team should determine what criteria are applicable to a specific opportunity based on the complexity and applicability of implementation and impact on operations.

E.2.3.2 Economic Feasibility

An economic feasibility analysis is a process in which financial costs, revenues, and savings are evaluated for a particular project. This analysis is necessary to evaluate the economic advantages of competing projects and is used to determine how to allocate limited resources. Three methods of comparison are currently is widespread use: Payback Period, Net Present Value, and Internal Rate of Return. The method of economic eval disposal. Regulations such as the Clean Air Act (CAA) and the National Pollutant Discharge Elimination System (NPDES) require facilities to apply for and obtain permits to discharge pollutants from their operations. The limits placed on a facility as a result of their discharge permits may impact a facility's

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efficiently; the opportunity for energy savings with motors rests primarily in selection and use. The most direct power savings can be obtained by shutting off idling motors, eliminating no-load losses.

Often motors have a greater rating than required, operating at partial load. Reasons for oversized motors include:

- Personnel may not know the actual load; and to be conservative, select a motor larger than necessary.
- The designer or supplier wants to ensure that the unit will have ample power.
- The correct motor rating is not available when a replacement is needed.

Newer technologies have made motors more efficient and allow flexibility in motor loads such as reduce speed/variable drives and variable frequency AC motors.

Many lighting systems that represented good practice in the past are inefficient in view of today's higher electrical costs. A lighting conservation program not only saves energy but is a highly visible indication of management's interest in conserving energy in general. The importance of lighting conservation, therefore, should be considered not only for its dollar savings but also for its psychological effect on the facility's entire conservation program. Opportunities for conservation include:

- Using task specific lighting levels,
- Turning off unneeded lighting,
- Using lighting specifically designed for high ceiling area, and
- Using energy efficient lamps.

E.5.2 Heat

Boilers are common throughout industry to provide steam for applications as well as heat. A boiler system is comprised of four main parts: a boiler, a steam distribution system, steam traps and a condensate return system. There are several factors that can impact a boiler's efficiency. These include adjustment of air/fuel ratio for fuel combustion, make-up water pre-heat, frequency and amount of blowdown to clean the system of excess solids, percentage of condensate return, and maintenance of the system for leaks and proper operation. Many opportunities for increasing efficiency can be realized through simple maintenance of the system through cleaning, repair of leaks, and periodic adjustment of the air/fuel ratio for combustion.

Heating systems are an integral part of industry today. They are used for process heating, drying and comfort/space heating. The main purpose of industrial space heating is to provide a comfortable work environment for its employees. Destratification fans are used to push warm air that has risen to the ceiling back down to personnel level. This allows the air to mix and reduces the heating requirements for the facility.

in the form of thermal discharges to the atmosphere. Industrial plants with cogeneration facilities can use the rejected steam in their plant process and thereby achieve a thermal efficiency as high as 80 percent.

Thermoenergy storage systems are used to take advantage of lower cost electrical rates with nighttime operation to provide daytime thermal needs. There must be a significant difference between night

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E.5.4 Thermal Applications

The most common types of cooling towers dissipate heat by evaporation of water that is trickling from different levels of the tower. Cooling towers conserve water, prevent discharge of heated water into natural streams and avoid treating large amounts of make-up water. Opportunities for energy reduction in cooling tower operations include adjustment of condenser water temperature, adjustment of chilled water supply temperature, installation of variable speed motors for cooling tower fans, and use of hot gas defrost for air cooler coils.

Absorption and mechanical chillers are used to produce chilled liquid for air conditioning and industrial refrigeration processes. These chillers are usually powered by low-pressure steam or hot water, which can be supplied by the plant boiler or by waste heat from a process. When prime energy is needed, mechanical refrigeration is usually preferable. Air leakage can be a serious operating 083 3/m for absorptio

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than can be supplied. A facility can minimize the impact of ventilation during winter months by balancing airflow and recovering heat for reuse.

E.6 References and Resources

This guide is intended to be a starting point for those interested in increasing a facility's efficient use of materials and energy. References used in compilation of this document are listed for more in-depth information. Industry specific guides available from the U.S. EPA and other sources are also listed.

There are many agencies and organizations that are available to provide assistance to industrial and

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CHAPTER 1. INTRODUCTION

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This document is intended to provide guidance to those who are interested in performing industrial assessments at industrial or commercial facilities. This document is not intended to be an all-encompassing guide to industrial assessments but a general reference for performing industrial assessments. This

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assessment provides useful information for facility personnel to evaluate a particular operation or the entire facility. Benefits resulting from industrial assessments include economics and establishing a pollution prevention program. A program is simply an organized, comprehensive, and continual effort to systematically reduce or eliminate pollution and wastes.

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There are four basic elements of a pollution prevention program.

1. Management Support
2. Characterization of Energy Usage and Waste Generation
3. Conducting Industrial Assessments
4. Review of Effectiveness

These elements provide the framework to obtaining effective results from industrial assessment efforts.

1.5.1 Management Support

A successful pollution prevention program begins with management support. Visible management support is important to ensure that employees understand that pollution prevention is a priority. This commitment can be demonstrated using several techniques including:

1. Written company policy,
2. Setting goals for reducing energy consumption and waste reductions,
3. Designating program coordinators or a working group,
4. Publicizing and rewarding successes, and
5. Providing employee training.

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The data elements identified and discussed below are some examples of information that could be regularly compiled (if applicable) and reviewed by the environmental office or an appointed environmental head. For each of these components, large uses should be identified and improved upon.

- *Toxic Release Inventory (TRI) Releases* – track the usage of TRI chemicals to provide data for identifying reduction opportunities. Material substitution and process changes can reduce TRI chemical usage.
- *Hazardous Waste Generation* – track and record hazardous waste generation for each group/process within the facility. The group's progress toward hazardous waste reduction should be reported.
- *Non-Hazardous Solid Waste* – track and record waste generation for each group within the facility. The group's progress towards reducing the amount of municipal solid waste generated should be reported.
- *Alternative-Fueled Vehicles* – document and promote use of alternatively fueled vehicles.
- *Pesticide Management* – track pesticide management practices. The information can be utilized to produce a baseline for a goal of pesticide reduction.
- *Ozone Depleting Chemicals* – track the purchase and usage of ozone depleting chemicals. A formal reduction plan can be formulated to eliminate the use of all ozone depleting substances.
- *EPA 17 Industrial Toxics* – tracking can identifying high volume uses of EPA 17 industrial toxics, and pollution prevention opportunity assessments can be conducted specifically targeting those products/chemicals.
- *Affirmative Procurement* – track procurement of materials, including the amounts of recycled content products purchased by the facility. To do this, office personnel can utilize the EPA Affirmative Procurement Guideline Items to identify particular products.
- *Energy Conservation* – track energy consumption sources (e.g., #2 and #6 fuel oil, natural gas, propane, electricity). This information should be utilized to track progress toward pollution prevention goals.
- *Water Conservation* – track water usage on a monthly basis to gauge progress toward pollution prevention goals. Water use data should be distributed to all involved groups.

goals

CHAPTER 2. ENERGY AND POLLUTION PREVENTION ASSESSMENTS

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The assessment process begins with the recognition for the need for pollution prevention and energy conservation. Facility personnel have many pieces of information available to them to evaluatecarry PE.go Pollution Prevention informa

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Industrial assessments are an in-depth review of existing operations to increase efficiency of the operation through pollution prevention and energy conservation. Assessments can be divided into three types: energy, waste (hazardous and non-hazardous) or a combination of the two. It is very important to remember that the goal of an industrial assessment is increased operation efficiency and that the assessments are not focused on environmental or safety compliance issues although improved compliance can be a benefit of the assessment. If a facility has particular issues it would like to resolve, the Assessment Team can choose to focus on that particular area. For example

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Once the Assessment Team is established, you will need to meet to discuss the assessment strategy prior to the assessment. The Team should determine:

- **What** processes will be assessed.
- **Who** will be involved with the assessment (i.e., Team members and shop staff).
- **When** will the assessment occur.
- **How** will the Team approach the assessment.

An important part of planning is piecing together knowledge about the selected process to begin building an understanding of what may be involved in the assessment phase. Team members should contribute what they know about the process, especially those who work directly with the process. The Team should also obtain pollution prevention case studies, model shop descriptions, and other resources that can provide pollution prevention ideas for processes that are similar to the one being assessed.

The Team should decide on a data collection format for the assessment. The format can be a standard format, such as the worksheets provided in EPA's Facility Pollution Prevention Guide (EPA/600/R-92/088). Alternatively, the Team may want to develop their own assessment worksheets, questionnaires, or checklists that may be used to collect data and observations during the site visit. Examples of types of information to collect in worksheets, questionnaires, or checklists include the following items.

- Process descriptions/flow diagrams
- Energy consumption
- Input materials
- Waste streams
  - Air
  - Water
  - Hazardous waste
  - Solid waste
- General questions/observations
  - Material handling techniques
  - Storage procedures
  - Housekeeping
- Process specific questions/observations
  - Developed for the individual process
- List of major energy consuming and waste generating equipment

The Team should prepare an assessment agenda and schedule the assessment in advance to coincide with a particular operation of interest. Depending on the operation, multiple walk-throughs may need to be scheduled, particularly if there are several shifts. The Team may also want to conduct a pre-assessment whereby Team members begin collecting preliminary information about the process, such as process descriptions and flow diagrams.

2.2.2 Assessment Phase

The second phase is the assessment phase. This phase is broken in to two parts: pre-assessment and assessment.

2.2.2.1 Pre-Assessment Activities

It is a good idea to obtain information prior to the assessment. This will allow the Team to study the information and prepare additional questions. This part of the assessment is called pre-assessment activities.

Pre-assessment data collection should include general information about the facility. This information should include a facility description, a process description, a process flow diagram, and energy and waste data collection. The Assessment Team should collect data for a twelve-month period. Utility costs, raw material and waste generation data should be for the same 12-month period. The Team should be cautious about collecting data that is not necessary to complete the assess

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Facility Description

A facility description should include the following basic items: point of contact (if applicable), annual business volume, annual business sales, the number of employees, previous energy conservation and pollution prevention efforts, operational schedule, and general characteristics of plant facilities. This information will provide scale of operation and comparison for energy consumption and waste generation versus production. In addition, a general layout of the facility is helpful to provide orientation and scale of facility operations. A simplified drawing of the facility is helpful in determining measurements and logistical aspects of potential opportunities. An example facility description and facility layout is provided in Section 2.3.

Process Description

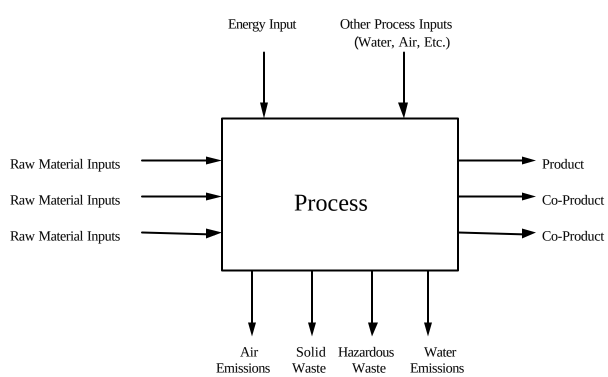
The process description is a very important part of the information collection process as it will provide the basic information needed to generate process flow diagrams and for opportunity analysis. A process description should include the following elements:

- Description of the products produced (i.e., tooth brushes, decals, blue jeans),
- Description or brief list of raw materials,
- Step-by-step description of unit operations from the beginning of the product manufacture following through to the finished product, and
- Notations of any energy consuming equipment ratings (i.e., ovens at 500°F, steam at 75 psi) and wastes generated (these can be made in the description or can be noted on the flow diagram).

Process Flow Diagram

Developing a flow diagram from scratch may require team members to discuss the process with the supervisor along with multiple members of the staff. The Team will need to visually observe the process and obtain an adequately detailed description of each step in the process in order to sketch a flow diagram. Block flow diagrams are useful tools for the assessment. A model block diagram is provided below in Exhibit 2.3.

Exhibit 2.3: Block Diagram Model



A flow diagram is simply a series of block diagrams that visually describe the process or flow of materials. For each block in the flow diagram, the Team should obtain data including raw material input, waste stream output, utilities, products, and co-products. All data should be based on the same time unit, e.g. annual, quarterly, or monthly. At a minimum, the Team should collect the data elements above.

In addition to the basic raw material and waste stream information described above, you should note other information pertinent to the assessment. For example, you should identify the following.

- Co-

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- Pollution control devices.
- Routine and non-routine input materials and waste streams.
- Environmental fate of waste stream (e.g., landfill, recycle, hazardous waste, etc.).
- Temperature settings of any operation that requires heat or cooling.
- Pressure settings for compressed air and requirements at the point of use.
- Pressure requirements for steam and actual steam generation pressure.

Example flow diagrams are given in Section 2.3. These diagrams should follow the process description and will visually illustrate the flow of materials and energy usage for specific operations. These diagrams can be used to determine where energy is being consumed and wastes are being generated.

Energy and Waste Data Collection

Information obtained prior to the assessment can become a springboard in the determination of possible energy consery.4te4 -0.1095 Tc eTc 0.05 /F2 9.7 npringboard in te( ) Tj -139.5 u,0.109p

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- Material safety data sheets (MSDSs),
- Product composition and batch sheets,
- Electric, natural gas, and/or fuel oil bills, and
- Standard operating procedures (SOPs).

Analysis of Energy Information

The Team should collect utility usage and cost data for the previous 12-month period prior to the assessment to allow the data to be summarized and graphed. There are three reasons for collecting energy information prior to the assessment: (1) to determine how much energy is consumed, (2) how much it costs, and (3) what are the trends in energy usage. Energy bills yield information that may provide recommendations before the assessment such as energy demand rescheduling, avoidance of late payment penalties, and energy ratcheting errors.

Once information for each energy source is collected the Team must convert the different energy types to BTUs to allow comparison and overall trending of energy usage. Presentation and reference to this information is usually done in a table and graphical format. Examples of energy usage information are presented in Section 2.3.

For electric utilities; the Team should collect the following key pieces of information.

- Electricity Usage
- Energy Charge
- Peak Demand
- Demand Cost
- Other Costs
- Reactive Costs
- Total Electric Cost
- Unit Electric Cost (calculated average)

Review of electricity and other utility use will enable the Assessment Team to determine trends for the heating season, the cooling season and possible seasonal trends in manufacturing.

The Assessment Team should collect natural gas usage information for the same 12-month period as for other energy sources. Examination of natural gas usage can reveal the following types of potential problems.

- Leaking Fuel Lines
- Faulty Temperature Measuring Devices
- Faulty Relief Valves
- Excessive Burner Cycling
- Warped Furnace Doors
- Deteriorating Furnace Insulation

Natural gas supplied to industrial operations is usually done on an interruptible basis. This allows the facility to obtain lower rates for their natural gas use. Interruption of gas service is done to meet demands for heating private homes during winter months. Facilities that have an interruptible gas supply must maintain a back-up fuel supply such as fuel oil.

The Assessment Team should collect fuel oil usage information for the same 12-month period as for other energy sources. In the United States three types of fuel are available. The most expensive oil is No. 2, 138,000 Btu/gallon. A little cheaper option is No. 4, 142,000 to 145,000 Btu/gallon and the cheapest is No 6, 149,690 Btu/gallon. It is important to keep in mind that the fuels are not interchangeable because the combustion equipment is designed for only one type of fuel. If a facility uses more than one type of fuel oil, the Team should make separate tables and graphs for each type of fuel.

Graphical representation of the data subsequently provides the Team the next logical step in the energy usage analysis progression. Experience indicates that graphical summaries are easily read and understood indicators of relative proportions. Usage patterns normalized for comparison to regional and like industries may indicate abnormalities worthy of investigation. A graph for each energy source and a summary graph with all energy sources should be prepared with the unit of measure for energy in BTUs

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versus each month. It is important when comparing different energy types to use the same unit of measure. The type of graphs listed below will aid in trend analysis.

- Monthly Electric Usage
- Monthly Natural Gas Usage
- Monthly Fuel Oil Costs (make separate graphs for multiple types of fuel oil)
- Monthly Fuel Oil Usage (make separate graphs for multiple types of fuel oil)
- Monthly Itemized Electric Costs
- Monthly Natural Gas Costs
- Monthly Total Electric Costs
- Summary Cost Graph (with all energy types)
- Summary Graph (with all energy types

Raw Material and Waste Generation Data

Prior to the actual assessment, the Team should also collect raw material and waste generation data. Collection of this information will permit the assessment Team to become familiar with the types of materials used in the facility and the resulting waste streams that are generated. The Team should review this data prior to the actual assessment to begin generating additional questions. In addition to the basic raw material and waste stream information described above, other types of information pertinent to the assessment should be identified.

- Co-products that are recycled back into the process.
- Pollution control devices.
- Routine and non-routine input materials and waste streams.
- Environmental fate of waste stream (e.g., landfill, recycle, hazardous waste, etc.).

Raw materials can be provided in advance of the assessment in a table or can be provided in the flow diagrams. All material information collected should be for the same 12-month period. Facility personnel will find that collecting raw material information will be simpler using the table format and then use this information to break raw material information down into operations for the flow diagrams.

Equipment List

Equipment used in a facility are key to determining benefits and costs from potential pollution prevention and energy conservation opportunities. Prior to the assessment the Team should try to obtain information about major pieces of equipment. Information to collect about equipment will vary with the type of equipment. Chapter 5 describes industrial operations common in many types of facilities. Chapters 6-10 describe types of energy consuming equipment. Review of these chapters will provide a general understanding of common operations and equipment. This will provide some insight into what types of information are needed to evaluate a particular opportunity. Information to collect for various pieces of equipment includes the following.

- Equipment Rating
- Average Load
- Energy Source
- Hours of Operation
- How big is the tank?
- What are the operation requirements?
- At what pressure does the system generate steam or compressed air?
- How much liquid does the tank typically contain?
- What is the equipment TjRating aik Tc 00.015 Tc 0 0645F1 9.75 1tb?phmin

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If the Team is experiencing difficulty identifying pollution prevention options, the Team should try tapping into other information sources and technical assistance. Appendix A- Sources of Information provides a number of technical assistance resources, such as pollution prevention clearinghouses, Internet resources, and technical support.

To begin developing a list of options, the Team should identify the most problematic areas such as compressed air leaks, increased monitoring of boiler efficiency, large volume or highly toxic waste streams, inconsistencies with written procedures, lack of environmental ethic, or poor housekeeping efforts.

Another method to identify energy conservation or pollution prevention opportunities is to evaluate each energy source or waste stream individually. First, the Team should determine the cause and effect of the waste stream by tracking the waste stream back through the process to input materials; and then identify potential ways to reduce the waste streams. For example, if the waste stream is dry absorbent contaminated with hydraulic oil, one may be able to back track to the cause for the usage of dry absorbent to a leaking valve. By fixing the leaking valve, there is an opportunity to (1) reduce hazardous waste generated, and (2) reduce the amount of hydraulic oil purchased.

One should also consider a wide range of projects. The following provides a list of potential pollution prevention approaches that should be considered during the option generating process.

- Policy Changes
- Procedural Changes
- Equipment Modifications
- Material Substitution
- Training
- Efficiency Improvements
- Waste Stream Segregation
- Housekeeping Practices
- Inventory Control
- Reuse of Materials
- Equipment Maintenance (i.e., repair compressed air, steam, and fluid leaks

Identify and Fill Data Gaps

Once the list of energy conservation and pollution prevention opportunities has been generated, the Team should review the data that has been collected. The purpose of this review is to ensure that the Team has all the data that it needs to complete a feasibility analysis for the all the options. This would include light or temperature measurements, counting light fixtures, etc. If any information has not been collected the Team should, make every attempt to collect it before leaving.

Wrap-up Meeting

Finally, the Team should sit down with the process supervisor and other management personnel to review the data collected. The Team should also discuss overall observations and general energy conservation and pollution prevention opportunities that will be addressed in the following phases of the assessment. Obtaining input from facility personnel at this point is key to gaining support for implementation of opportunities.

2.2.3 Feasibility Analysis Phase

The third phase of the assessment methodology is the feasibility analysis. The feasibility analysis phase consists of three post-assessment activities: (1) prioritization of opportunities, (2) evaluation of technical and economic feasibility, and (3) generation of an assessment report.

2.2.3.1 Prioritization of Opportunities

Because of time and resource constraints, most facilities have to 341987-0. Tw dmos tr 0 an assesr

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- Energy conservation and pollution prevention opportunity recommendations and analysis

The report should contain all the information needed to present the recommended opportunities to facility managers for possible implementation.

2.2.4 Implementation

Management support is the single most important element in successfully implementing opportunities from an industrial assessment. Regardless of the size or nature of the organization, top management must exhibit active and continuing leadership and interest in the results of the assessment. Facility employees will apply their best efforts to the opportunity only if their supervisors display a constant awareness of energy conservation and pollution prevention. With management support, the assessment be successfully implemented.

Actions taken to implement energy conservation and pollution prevention projects vary greatly from project to project and company to company. Some facilities may decide to use in-house expertise to

Exhibit 2.6: Example Process Description

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Mars Screen Printing Process Description

This plant uses screen printing to produce, in several varieties and color schemes, fleet (transportation truck) decals, beverage dispensing machine colored panels and tooth brush backings. Raw materials include plastic sheets, rolls and spools of plastic stock, inks, adhesives, urethane and various other chemicals and solvents related to image production and printing operations.

The printing process begins with the plant receiving a mylar sheet with a positive image, paper copy or computer file from clients. Some artwork is done in-house. Images received on a computer disk, and other images developed on-site, are processed in a computerized system to yield a mylar positive. The image sheets are then transported to the screen-making department.

Screen images are produced in several steps. First, large screens are coated with a photo sensitive emulsion in an automated system. Emulsion is applied to smaller screens manually. Coated screens are then covered with mylar sheets containing positive images and are placed on a "burn table" which exposes the screen to ultraviolet light for a specified period of time which hardens the emulsion through transparent

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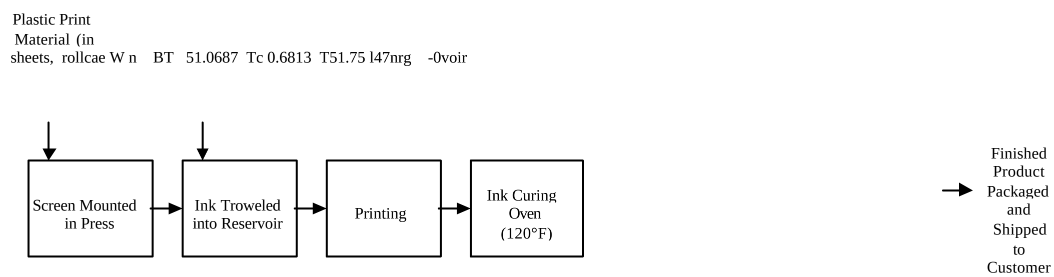
Exhibit 2.7: Exampl e Flow Diagram for the Mars Screen Printing, Screen Making Operation

Exhibit 2.8: Example Flow Diagram for the Mars Screen Printing, Printing Operation



and

Exhibit 2.9: Example Flow Diagram for the Mars Screen Printing, Cleaning Operations

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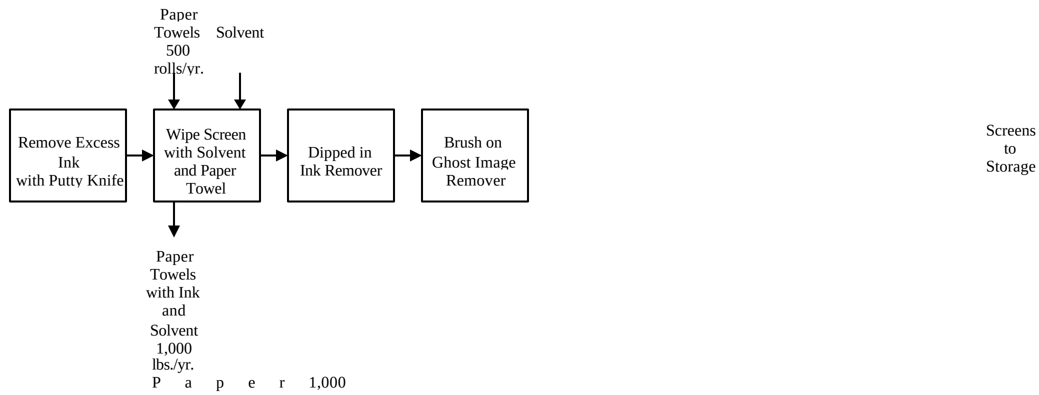


Exhibit 2.10 through Exhibit 2.12 are tables of energy consumption and cost information collected from Mars Screen Printing. Information collected for energy usage should be collected for each energy source for the same time period. The tabular format presented here provides a concise and uniform way to present information for review.

Exhibit 2.10: Example Electrical Summary

Month	Energy Usage (kWh)	Energy Charge ($)	Peak Demand (kW)	Demand Cost ($)	Other Costs ($)	Reactive Cost ($)	Total Elect. Cost ($)	Unit Elect. Cost ($/kWh)
Jan	250,000	19,185.42	584.0	7,965.82	215.13	110.15	27,476.52	0.078
Feb	254,400	19,495.87	556.4	7,595.74	214.97	116.98	27,423.56	0.077
Mar	246,800	18,979.84	552.8	7,530.38	213.21	111.22	26,834.65	0.077
Apr	247,600	16,077.64	551.6	4,245.78	194.66	113.77	20631.85	0.065
May	275,600	17,937.39	590.8	4,617.85	201.35	114.30	22,870.89	0.065
Jun	313,600	20,365.63	633.6	4,905.38	209.51	116.58	25,597.10	0.065
Jul	324,800	21,582.86	620.0	4,919.60	216.13	112.84	26,831.43	0.066
Aug	316,000	21,050.37	620.8	4,946.63	214.93	116.75	26,328.68	0.067
Sep	273,200	17,943.95	594.0	4,632.62	201.60	108.94	22,887.11	0.066
Oct	260,000	17,058.38	574.0	4,468.58	198.46	110.82	21,836.24	0.066
Nov	266,800	17,440.93	580.8	4,466.06	199.60	112.29	22,218.88	0.065
Dec	237,600	18,308.30	581.6	7,860.44	212.19	108.54	26,489.47	0.077

Notes

Exhibit 2.11: Example Natural Gas Summary

Month	Energy Usage (CCF)	Energy Usage (MMBtu)(

M M B t u)

Notes

Exhibit 2.13: Summary of Energy Usage

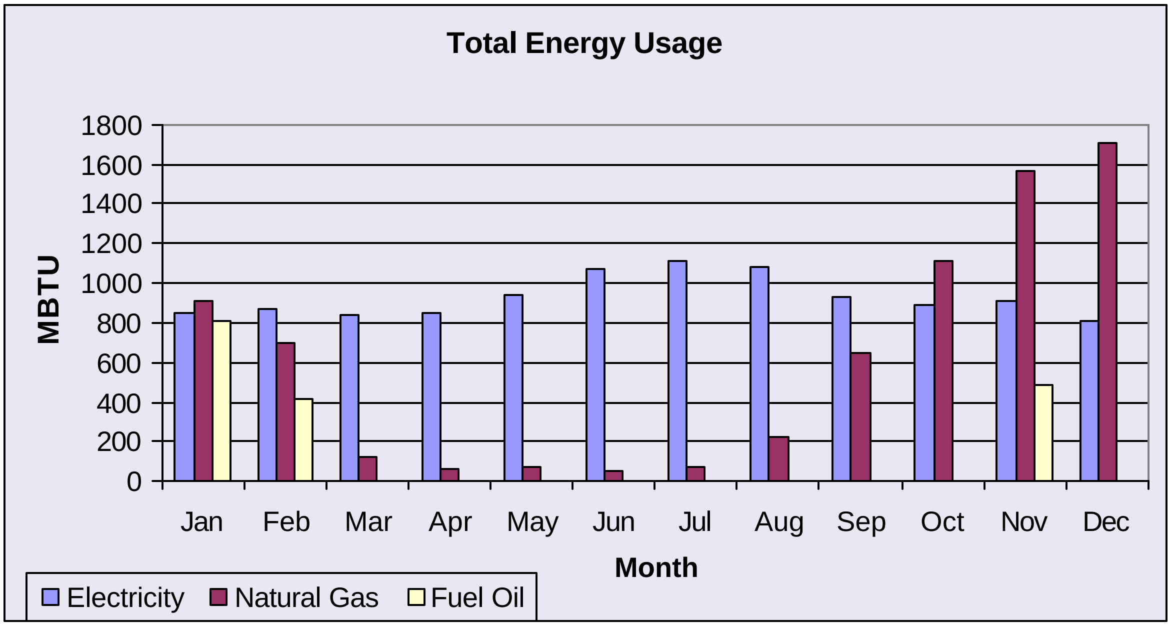
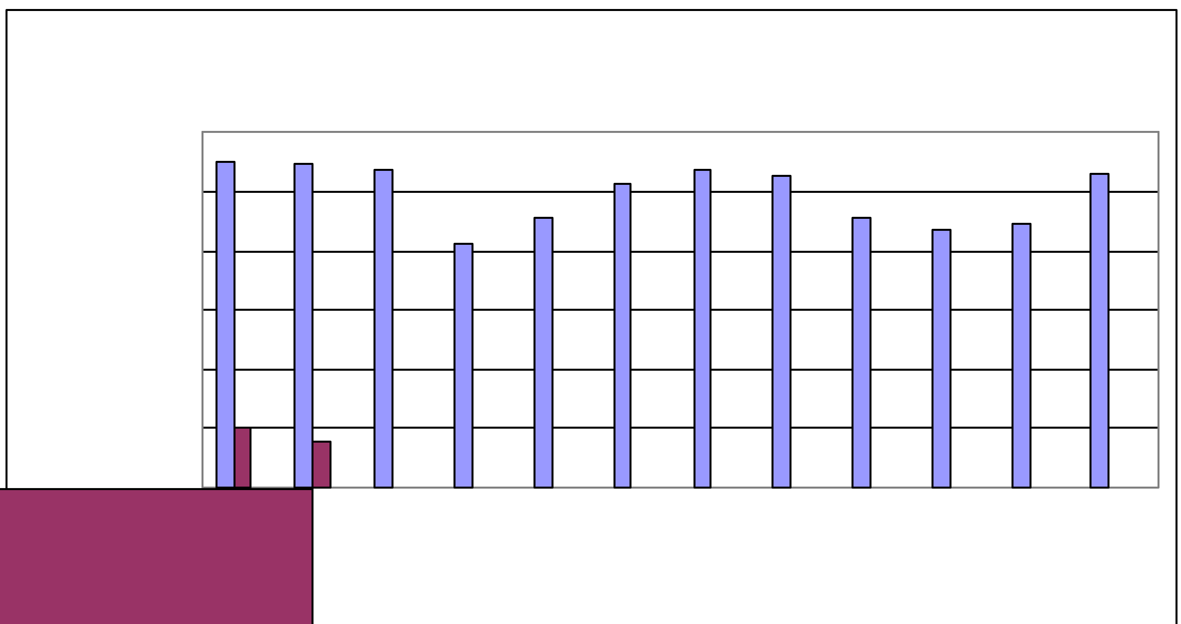


Exhibit 2.14: Summary Energy Costs



Notes

Exhibit 2.15: Electrical Costs

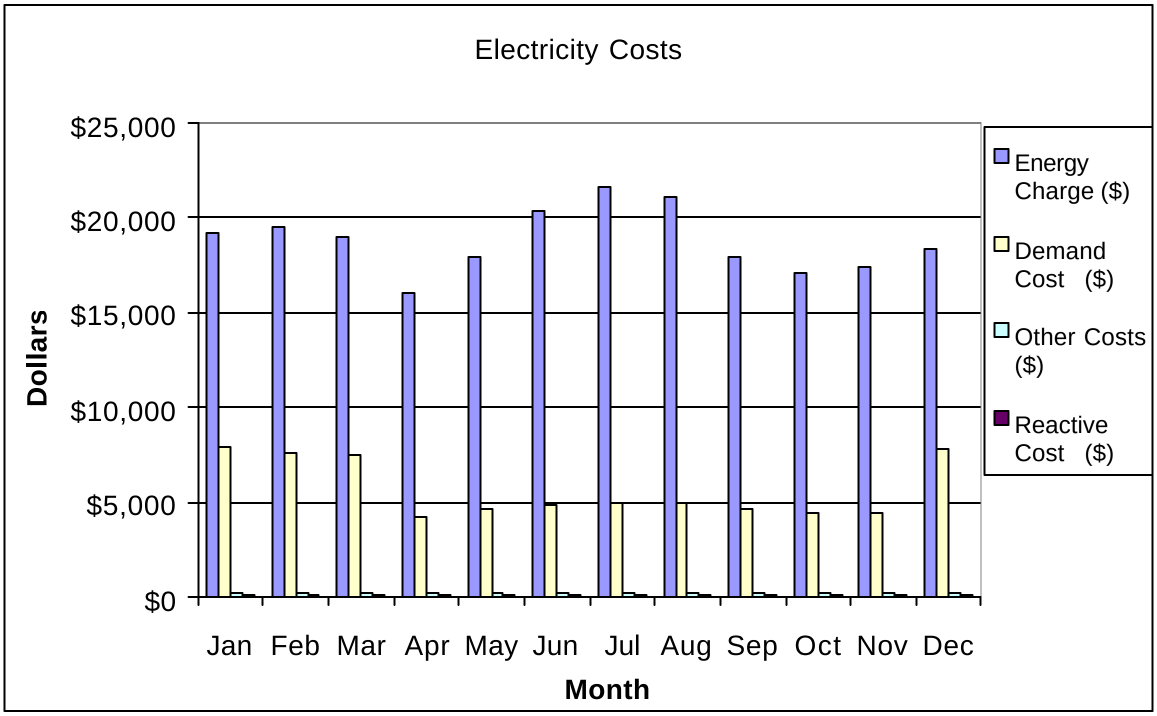
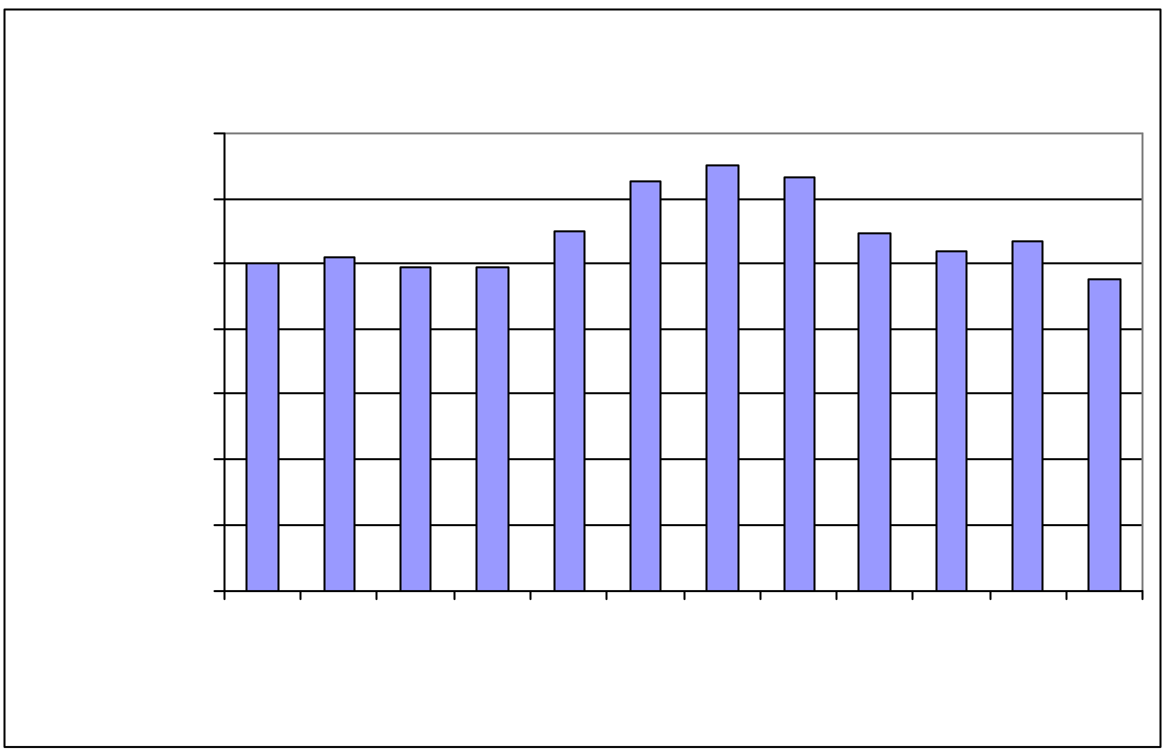


Exhibit 2.16: Mars Screen Printing Electricity Usage



Notes

Raw material and waste generation information collected during an assessment should be compiled in an easy to reference format. Exhibit 2.17 presents one format for presenting raw material information. Raw material usage information should be collected for those materials that pertain to opportunities identified during the assessment to avoid unnecessary information collection. This will save time and labor for the more important task of evaluating opportunities.

Exhibit 2.17: Example Raw Material List for Mars Screen Printing

Material	

Notes

The assessment team should also collect information about equipment that will be necessary to evaluate identified opportunities. Exhibit 2.19 provides some example information collected for Mars Screen Printing. This information will be used to calculate energy usage and waste reductions as well as cost savings.

Exhibit 2.19: Example Equipment List and Pertinent Information

Boilers

- Fuel Source – Natural Gas and Fuel Oil #2
- 150 BHP
- Steam generated at 150 PSI
- Average Load – 75%
- No Condensate Return
- 18 hrs/day in summer, 24 hrs/day in winter
- Used for process heat and space heating

Air Compressors

- One Screw Type Compressor – 100 HP
- One Reciprocating Compressor – 50 HP
- Air Pressure 70 PSI
- Used for equipment actuation
- Intake temperature - 85°F
- Average Load – 80%
- Operation 18 hrs per day

Emulsion Removal Tank

- 3 ft x 5 ft x 5 ft
- No cover
- Not heated

Ink Curing Oven

- Steam heat from boilers
- Insulated
- No covered opening

Curing Oven

- Natural Gas
- Operation Temperature 120°F
- Operation Hours 16 hrs/day

The assessment team should brain storm possible opportunities to be implemented in the facility. After the team has developed its initial list of opportunities the team should list these out and collect information necessary to evaluate each opportunity. A list of potential opportunities for our fictitious facility, Mars Screen Printing is given in Exhibit 2.20.

Exhibit 2.20: Energy Conservation and Pollution Prevention Opportunities for Mars Screen Printing

Energy Conservation Opportunities

1. Increase Monitoring of Boiler Efficiency to Maximize Fuel Use
2. Repair Compressed Air Leaks
3. Repair Steam Leaks
4. Return Condensate for Supply Water Pre-heating
5.

3.

4 .-

4 .

Notes

Pollution Prevention Opportunities

1. Cover Cleaning Tanks to Minimize Evaporative Losses
2. Recover Solvent from Exhaust for Equipment Cleaning
3. Minimize Ink Mixing to Reduce Excess
4. Improve Housekeeping
5. Substitute Non-Hazardous Inks for Current Inks

Using the opportunity list generated for our fictitious facility, an example decision matrix is provided in Exhibit 2.21. Chapter 3 discusses methods to evaluate the pollution prevention and energy conservation opportunities identified during an opportunity assessment.

Exhibit 2.21: Example Decision Matrix

Opportunity	Payback Period	Cost Savings	Technical Feasibility	Operational Impact	Compliance Issues
Energy Conservation Opportunities					
1. Increase Monitoring of Boiler Efficiency to Maximize Fuel Use to Operational C					

Notes

Exhibit 2

Notes

3.1.2 Assumptions

Inevitably the Assessment Team will need to make assumptions or estimates when information is not available or simply doesn't exist. In these cases, the assessment team will be required to make reasonable estimates based on available information, observation and best professional judgement. Any time the assessment team is required to make estimates or assumptions it is important to document this in the analysis write-up for future reference. These estimates or assumptions may include any assumptions with regard to labor costs, utility or waste disposal costs, hours of operation, or loads, etc. Assumptions do not necessarily need to all be stated in the background information but should be clearly stated when made.

3.1.3 Impacts

The impact that the current operation has should be described as part of the current practice. This would be the impact that the current practice has on the facility or operation energy consumption, waste generation, air emissions, and etc. For example, ink is mixed manually and personnel responsible for ink mixing consistently mix too much ink. The impact of this practice would be excess raw material purchases, increased waste disposal, and air emissions. For energy conservation opportunities the impacts that would be described might include increased energy consumption and air emissions, or increased demand charges.

3.1.4 Raw Material Costs

Raw materials account for a large percentage of an industrial facility's expenses. Raw materials include any material purchased for the purpose of producing a product or items or to be used in clean-up and ancillary operations. The Assessment Team can obtain raw material cost information from purchase records at the facility. In addition, when accounting for raw material costs, the Team should account for material management costs when applicable. For instance, if an opportunity will greatly reduce raw material purchases and there is an associated labor cost for managing the material (i.e., moving it around the facility, managing the containers, etc.) the team should include the reduced labor costs when evaluating the opportunity.

3.1.5 Energy Costs

Energy costs or utility costs are also major operating expenses for industrial operations. Some operations are very energy intensive requiring large amounts of energy for heating of materials to produce a product. The Assessment Team should review and account for energy costs during the assessment. Chapter 2 discussed the collection of electric, natural gas, or other energy source information to allow graphs and summary tables to be prepared. The following sections will discuss how to read the utility bills and define some of the terminology used.

3.1.5.1 Electric Bills and Rates

The structure of electric bills differs from region to region. The rates and structure of utility bills cannot be set arbitrarily since all utility companies are regulated by a Public Utility Commission or Public Utility Board of the state in which it operates. Approval is needed for any change in rates or structure and any change is subject to reviews confirming the necessity of such change. The rates reflect the requirement to maintain a sound financial condition of a utility company and also to pay a "reasonable return" to the shareholders.

The Electric Bill: Its Components and Where the Money Goes

1. Components Of Your Electric Bill
   - Customer Charge
   - Demand Charge
   - Energy Charge
   - Reactive Demand Charge
   - Sales Tax

Notes

2. What Is Included In The Customer Charge?
   - Fixed monthly amount designed to recover:
     - Service drop - wires from transformer to connection on building.
     - Meter.
     - Billing, credit and collection and related costs.
     - Customer service - costs to encourage safe, efficient and economical use of electricity.
3. What Is Included In The Demand Charge?
   - Generally based on highest 15-minute integrated kW demand during month or 80% of highest demand during winter months.
   - Designed to recover:

     Investments in generating plants.

     Investments in transmission system - 345,000, 115,000 & 34,500 volt lines and sub-stations.

     Investments in distribution system - all voltages below 34,500 volts, including distribution transformer.
4. What Is Demand (Load)?

   A. Assume: Fifty (50) - 100 watt light bulbs.

   All 50 bulbs are on at the same time.

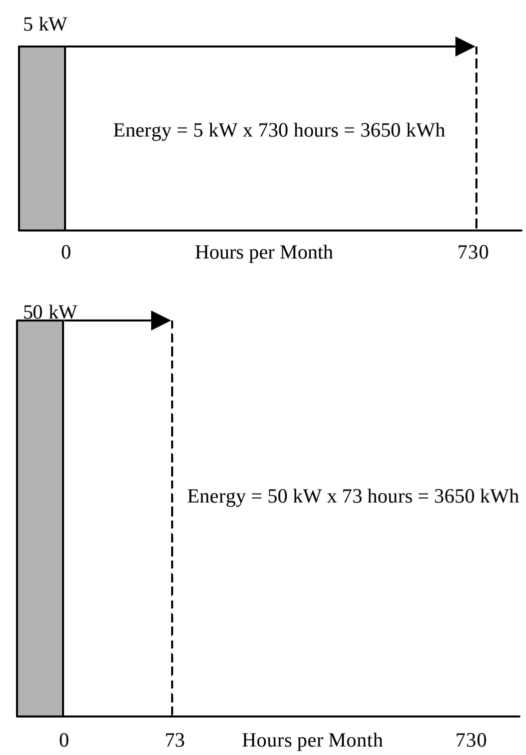
   50 bulbs x 100 watts each = 5000 watts

   B. Total Demand (Load) on System:

   5000 watts/1000 = 5 kilowatts (5 kW)

   This is illustrated in Exhibit 3.1.

Exhibit 3.1: Relation of Demand (kW) to Energy (kWh)



5. What Is Included In the Energy Bill?
   - Price per kWh designed to recover:

   Variable costs to generate electricity

   Oil costs

   Nuclear fuel costs

   Varies with voltage levels due to losses
6. What Is the Reactive Demand Charge?
   - An amount per kVAR of reactive demand in excess of 50% of monthly demand (LGS is 50% of first 1,000 kW of monthly on-peak kW demand and 25% of all additional monthly on-peak demand).
   - No kVAR billing unless power factor below 90% (higher for customers with demands in excess of 1,000 kW).
   - Designed to recover cost of capacitors used to offset effects of customers with poor power factor.

Notes

7. Sales Tax

   -

Notes

section briefly discusses the pertinent information that the assessment team will need to evaluate various opportunities.

3.1.6.1 Hazardous and Regulated Non-hazardous Waste Disposal

Hazardous and regulated non-hazardous waste disposal is a significant line item cost for facilities. When calculating hazardous waste disposal costs, the assessment team must include these items.

1. Disposal fees
2. Transportation costs
3. In-house labor for management (labor for drumming the waste, moving to hazardous waste storage, and filing paperwork)
4. Reduction in containers purchase for disposal

Not all of these costs will apply to every waste. For example if the facility is purchasing over pack drums for some of their wastes and not others. The team should use best professional judgement when applying these factors.

3.1.6.2 Solid Waste Disposal

Solid waste is what most people think of as trash. It would include waste paper, cardboard, personal items, food wastes, etc. While solid waste is not as expensive as hazardous waste to dispose of, it is still a significant expense. When calculating solid waste costs and cost savings, the team must include these items.

1. Tipping fees (fee for disposal in landfill or other similar fee)
2. Transportation costs, if any
3. Rental and pick-up fees for trash containers
4. In-house labor costs, if any

Again, the team should use best professional judgement to include or not include these and other costs.

3.1.6.3 Air Emission Management Costs and Emission Fees

Air emissions have become an increasingly important issue for industrial plants. Evaluation of opportunities that significantly reduce air emissions should include these items.

1. Air emission fees
2. Changes in air emission control costs
3. Changes in monitoring requirements for both environment and health and safety.
4. Changes in labor for management of air emissions.

3.1.6.4 Sanitary and Storm Sewer Discharge Fees

Sanitary and storm sewer discharge fees do not tend to be large line item costs for many facilities. Changes in fees as a result of implementing an opportunity should be accounted for or noted even if significant. Items that should be included in a cost evaluation are:

1. Discharge fee
2. Labor for on-site management of waste water or other solutions discharged to the sewer
3. Changes in treatment costs, if any.

There may be other items that may be added for various operations. The assessment team should include all significant items.

3.2 Describe the Recommended Opportunity

Notes

A description of the recommended action needed to accomplish the energy conservation or pollution prevention should be given in simple language with a minimum of technical details. The recommended action should include a description of the proposed change including equipment changes, process modifications, and changes in procedures. In addition, this description should point out the advantages and disadvantages in implementation of the opportunity. This description of the recommended action does not need to include calculations of energy and waste reduction, as these will be included in the next sections.

The advantages should include items like reduced waste generation, reduced energy consumption, improved efficiency of operations, etc. The disadvantages should include items like increased labor, noxious odors, extensive facility modifications

Notes

Exhibit 3.3: Common Units of Measure and Conversions to BTUs (U.S. Dept of Commerce, 1974)

Type of Energy	Common unit of Measure	BTU Equivalent
Butane, Liquefied	Gallons (Gal)	91,600 BTU/Gal
Coal, Anthracite	Pound(s) (lb or lbs)	13,900 BTU/lb
Coal, bituminous	Pound(s) (lb or lbs)	14,000 BTU/lb
Coal, lignite	Pound(s) (lb or lbs)	11,000 BTU/lb
Coal, Sub-bituminous	Pound(s) (lb or lbs)	12,600 BTU/lb
Electricity	Kilowatts-hours (KW)	3,412 BTU/KWh
Fuel Oil #2	Gallons (Gal)	140,000 BTU/Gal
Fuel Oil #6	Gallons (Gal)	152,000 BTU/Gal
Kerosene	Gallons (Gal)	134,000 BTU/Gal
Natural Gas	Cubic Feet (CF) or Hundreds of Cubic Feet (CCF) Therms	1,000 BTU/CF 100,000 BTU/therm
Propane, Liquefied	Gallons (Gal)	103,300 BTU/Gal

Exhibit 3.4: Units of Measure for Various Applications (U.S. Dept of Commerce, 1974)

Application	Units of Measure	BTU Equivalent
Air Conditioning / Refrigeration	Tons	12,000 BTU/hr
Heating	BTUs	---
Motors	Horsepower (hp)	2545 BTU/hr
Boilers		

Notes

- Changes in raw material consumption
- Changes in hazardous waste generation
- Changes in solid waste generation
- Changes in air emission generation
- Changes in energy usage

Implementation of a pollution prevention opportunity may need to include all these factors or may include only a few. When performing any type of comparisons for pollution prevention opportunities; care should be taken to use the same unit of measure for all types of materials used in the analysis. This means that to ensure consistency in your calculations all raw materials should be converted to the same unit of measure if possible. For example, if a facility lists it raw materials for a printing operation as 60,000 gal of ink and 20,000 lbs. of ink remover, the unit should be converted to either both be pounds or both be gallons.

After performing these energy conservation and pollution prevention calculations, this information will then be used to calculate the cost savings for the given opportunity.

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3.4 Technical Evaluation of Energy Conservation and Pollution Prevention Projects

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Exhibit 3.5: Typical Technical Evaluation Criteria

- Will it conserve energy or reduce waste?
-

internal costs and savings, including environmental criteria. LCC includes all *internal* costs plus *external* costs incurred throughout the entire life cycle of a product, process, or activity.

Notes

3.5.1 Common Methods of Comparing Financial Performance

Financial performance indicators are needed to allow comparisons to be made between competing project alternatives. Three methods of comparison are currently in widespread use: Payback Period, Net Present Value, and Internal Rate of Return.

3.5.1.1 Payback Period

The payback period is used most often. The purpose of the payback analysis is to determine the length of time it will take before the costs of a new project is recouped. The formula used to calculate the Payback Period is:

Equation: Payback period (in years) = I/(N-C)

where I = initial investment, start up costs (in dollars)

C = annual cost of current practice (in dollars/year)

N = annual cost of new practice (in dollars/year)

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A TD 0.1279 T3 Tw (-) Tj 3Tj 140.25 2 TD 0.0981 Tc80.3998 T270 Tjnire certainp cosw I/

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For an investment to be cost beneficial, it must return more dollars in the future (i.e., benefit) than the amount of dollars spent in the present (i.e., the cost of the investment) to account for this difference in value. In other words, the dollar benefits gained in the future must be greater than the initial investment. This method progressively reduces (discounts) the value of costs and revenues occurring in future years. The formula for NPV is:

Equation: $I + [(AS - CE)_1(PVIF)_1 + (AS - CE)_2(PVIF)_2 + ... + (AS - CE)_n(PVIF)_n] = NPV$

where I = initial investment, start-up cost (expressed as a negative number)

AS = annual savings (cash inflows)

CE = capital expenses (cash outflows)

$(AS - CE)_1$ = net cash flow year 1

$(AS - CE)_2$ = net cash flow year 2

$(AS - CE)_n$ = net cash flow year n

$PVIF = 1/(1 + r)^t$ = present value interest factor

r = discount rate of money (i.e., current rate of return)

t = incremental time period, 0 thru n, normally expressed in years

The first step to determining the net present value of a proposed project is to determine the net difference (net cash flow) for each year over the specified time period $(AS\text{-}CE)_n$.

The second step is to calculate the present value interest factor (PVIF) based on the companies discount rate. The following equation is used to calculate the PVIF for each year of the specified time period.

Equation: $PVIF = 1/(1+r)^t$

where r = discount rate of money (i.e., current value of money to the company)

t = incremental time period (i.e., 1, 2, 3, etc.), normally expressed in years

The PVIF is calculated for each incremental time period. The PVIF always equals one, when n=0; the start-up costs. As the time period (n) increase the PVIF decreases.

The third step is to multiply the net difference in cash flows for each incremental time period determined in Step 1 one by the corresponding PVIF determined in Step 2 to calculate the present value (PV) of the money in today's dollars. The following equation is used to calculate the PV for each time period.

Equation: PV = (AS – CE) X (PVIF); at a given time period (n)

The last step is to sum the PV's for each incremental time period (0 through n) and then subtract the star-up cost (I) to obtain the net present value (NPV) of implementing the project.

A project is deemed profitable if its net present value is greater than zero. When the NPV is greater than zero a project is sufficient to (1) pay off the initial star-up costs, (2) pay off interest payments to creditors who lent the company money to pay for the start-up costs, (3) provide the required return to shareholders or a company's financial requirements, and (4) increase economic value in the company.

Net present value is a very useful indicator because it is a direct measure of a projects profitability in dollars and therefore most directly relates to a company's value of money. It does however, depend significantly on the value of the discount rate. In general, net present value is one of the strongest financial performance indicators because it has few limitations and can be used in all types of analyses.

3.5.1.3 Internal Rate of Return

The Internal Rate of Return (IRR) is another technique used in decision making. The purpose of the IRR is to determine the interest rate (r) at which NPV is equal to zero. If that rate exceeds the hurdle rate

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(defined as the minimum acceptable rate of return on a project), the investment is deemed worthy of funding. The formula for IRR is:

Equation: $I + [(AS - CE)_1(PVIF)_1 + (AS - CE)_2(PVIF)_2 + ... + (AS - CE)_n(PVIF)_n] = 0$

where I = initial investment, start-up cost (expressed as a negative number)

AS = annual savings (cash inflows)

CE = capital expenses (cash outflows)

$(AS - CE)_1$ = net cash flow year 1

$(AS - CE)_2$ = net cash flow year 2

$(AS - CE)_n$ = net cash flow year n

$PVIF = 1/(1 + r)^t$ = present value interest factor

r = discount rate of money (i.e., current rate of return)

t = incremental time period, 0 thru n, normally expressed in years

In practice, IRR is usually calculated through trial and error, where different interest rates are tried until the IRR is found. Using the IRR financial performance indicator, projects are ranked according to their IRRs, and projects with IRRs in excess of the appropriate discount factor are accepted. Although, IRR and NPV methods will lead to the same accept – reject decisions for an individual project, they can give contradictory signals concerning choices between mutually exclusive projects. That is, a given project might have a higher IRR but a lower NPV than an alternative project. This problem arises because the IRR is the implied reinvestment rate (discount rate) for cash flows under the IRR method while the discount rate used in the NPV method is a company's cost of capital. If the IRR for a project is very different from the cost of capital, these differing reinvestment rates can lead to differences in project ranking. In most situations, reinvestment of cash flows at a rate close to the cost of capital is more realistic; therefore, the NPV method is generally superior.

3.5.2 Additional Economic Analysis Tools

Life Cycle Costing (LCC) tool and the Total Cost Assessment (TCA) tool are introduced below as concept overviews. Both tools can be used to establish economic criteria to justify energy conservation and pollution prevention projects. TCA is used to describe *internal* costs and savings, including environmental criteria. LCC includes all *internal* costs plus *external* costs incurred throughout the entire life cycle of a product, process, or activity.

3.5.2.1 Life-Cycle Cost Analysis

Life-cycle costing (LCC) has been used for many years by both the public and private sector. It associates economic criteria and societal (external) costs with individual energy and pollution prevention opportunities. The purpose of LCC is to quantify a series of time-varying costs for a given opportunity over an extended time horizon, and to represent these costs as a single value. These time varying cost usually include the following.

- *Capital Expenditures* - Costs for large, infrequent investments with long economic lives (e.g., new structures, major renovations and equipment replacements).
- *Non-recurring Operations and Maintenance (O&M)* - Costs reflecting items that occur on a less frequent than annual basis that are not capital expenditures (e.g., repair or replacement of parts in a

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Exhibit 3.6: TCA Cost Categories

<table>
<tr><th>Direct Costs</th><th>Indirect or Hidden Costs</th><th>Liability Costs</th></tr>
<tr><td>Capital Expenditures
Buildings
Equipment
Utility connections
Equipment Installation
Engineering
Operations and Maintenance Expenses/Revenues
Raw materials
Labor
Waste disposal
Utilities
Value of recovered materials</td><td>Compliance Costs
Permitting
Reporting
Monitoring
Manifesting
Insurance

On-Site Waste Management

Operations of On-Site Pollution Control Equipment</td><td>Penalties and Fines

Personal Injury and Property Damage</td></tr>
</table>

3.6 Energy Conservation and Pollution Prevention Project Examples

This section presents two energy conservation and pollution prevention projects from the fictitious manufacturing facility discussed in Chapter 2 to illustrate the technical and economic concepts presented in this chapter. They are presented in a simple format that could be used for a report. The assessment team

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percentage of oxygen at 6.2%. By controlling combustion the lean mixture could be brought to 10% excess air or an excess O_2 level of 2%. This could provide a possible fuel savings of 3%.

The 300 HP natural gas boiler is used both for production and heating. It is estimated that 100% of the natural gas is consumed in the boiler.

Therefore the total savings would be:

Savings in Fuel (therms/yr): = (% burned in boilers) x (annual therms per year) x (percent possible fuel savings)

= (1.0 x (56,787 therms/yr) x (0.02)

= 1,136 therms/yr

Savings in Dollars ($/yr): = (therms Saved/yr) x (cost/therm)

= 1,136 therms/yr x $0.644/therm

= $732/yr

3.6.1.4 Implementation

It is recommended that you purchase a portable flue gas analyzer and institute a program of monthly boiler inspection and adjustment of the boiler used in the plant. The cost of such an analyzer is about $500 and the inspection and burner adjustment could be done by the current maintenance personnel. The simple payback is:

$500 cost

- A 75% reduction in solvent emissions (MEK from the ink) will be achieved by using the "environmentally preferred" ink over the current ink formulation.
- A 25% reduction in the usage of ink remover will be achieved by using the "environmentally preferred" ink over the current ink formulation.
- A 20% reduction in paper towel usage will be achieved by using the "environmentally preferred" ink over the current ink formulation.
- Current material usage and waste generation

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material purchase and waste generation costs directly related to the use and disposal of the current ink formulation.

Exhibit 3.8: Annual Cost of Current Ink Formulation at Mars Screen Printing

Cost Element	Units Purchased	Unit Cost	Annual Cost
Raw Materials Purchased			
Ink	60,000 gal.	$2.60/gal.	$156,000
Ink Remover	20,000 gal.	$1.40/gal.	$28,000
Paper Towels	500 rolls	$1.10/roll	$550
Waste Disposal			

Notes

The formula for NPV is:

Equation: $NPV = I + [(AS - CE)_1(PVIF)_1 + (AS - CE)_2(PVIF)_2 + ... + (AS - CE)_n(PVIF)_n]$

where I = initial investment, start-up cost (expressed as a negative number)

AS = annual savings (cash inflows)

CE = capital expenses (cash outflows)

Notes

C_2 = net cash flow year 2

C_n = net cash flow year n

The first step is to develop a cash flow spread sheet, as in the NPV calculation, to determine the net cash flow. The second step is to pick an initial IRR percentage (an educated guess) and calculate the present value (PV) cash flow. The third step is to sum the PV cash flows for each time period to determine if it equals zero. The process of choosing an IRR value is repeated until the sum of the PV cash flows equals zero. Exhibit 3.11 demonstrates the iterative process to calculate the IRR for the Mars Screen Printing project.

Exhibit 3.11: IRR Calculation for Mars Screen Printing

Year	Net Difference (net cash flow)	PVIF (r = 5%)	PV (r = 5%)	PVIF (r = 20%)	PV (r = 20%)	PVIF (r = 17%)	PV (r =17%)
0	- $75,000	1.00	- $75,000	1.00	-$75,000	1.00	-$75,000
1	$33,785	0.95	$32,176	0.83	$28,154	0.85	$28,876
2	$7,785	0.91	$7,061	0.69	$5,406	0.73	$5,687
3	$33,785	0.86	$29,185	0.58	$19,552	0.62	$21,094
4	$7,785	0.82	$6,405	0.48	$3,754	0.53	$4,154
5	$33,785	0.78	$26,471	0.40	$13,577	0.46	$15,410
Sum of "PV Cash Flows" =			$26,298		-$4,556		$222

For the iterative process of calculating the IRR, a value of plus or minus $500 is normally considered acceptable. Therefore, the internal rate of return for implementing "environmentally friendly" ink at the Mars Screen Printing is calculated to be 17%. Mars Screen Printing should implement the "environmentally friendly" ink project because the actual IRR, 17%, is greater than the company's required 5% IRR on all projects.

Notes

REFERENCES

1. *Federal Facility Pollution Prevention: Tools for Compliance*; 1994, U.S. Environmental Protection Agency. Office of Research and Development, Cincinnati, OH 45268. EPA/600/R-94/154.
2. *Pollution Prevention Act of 1990*
3. *Facility Pollution Prevention Guide;* 1992, U.S. Environmental Protection Agency. Office of Research and Development, Cincinnati, OH 45268. EPA600R92088.
4. *Energy Conservation Program Guide for Industry and Commerce: NBS Handbook 115*; 1974, U.S. Department of Commerce. National Bureau of Standards, Washington DC 20402.
5. *Energy Conservation Program Guide for Industry and Commerce: NBS Handbook 115 Supplement 1*; 1974, U.S. Department of Commerce. National Bureau of Standards, Washington DC 20402.

4.1.1.2 Use of Electricity in the Industry

Notes

Electrical energy use, commonly found in the following systems and operations, presents significant opportunities for exploration during the industrial assessment.

- Mixing operations
- Melting and refining metallic and non-metallic materials
- Holding molten material
- Material Transportation
- Cleaning and finishing (air compressors)
- Miscellaneous assembly equipment
- Computers and other controls
- Material handling
- Packaging operations
- Environmental controls
- Lighting
- Heating, Ventilation, and Air Conditioning

4.1.2 Power Factor

Power factor quantifies the reaction of alternating current (AC) electricity to various types of electrical loads. Inductive loads, as found in motors, drives and fluorescent lamp ballasts, cause the voltage and current to shift out of phase. Electrical utilities must then supply additional power, measured in kilovolt-amps (kVA), to compensate for phase shifting. To see why, power must be examined as a combination of two individual elements.

The total power requirement constituents can be broken down into the resistive, also known as the real component, and reactive component. Useful work performance comes from the resistive component, measured in kilowatts (kW) by a wattmeter. The reactive component, measured in reactive kilovolt-amps (kVAR), represents current needed to produce the magnetic field for the operation of a motor, drive or other inductive device but performs no useful work, and does not register on measurement equipment such as the watt meter. The reactive components significantly contributes to the undesirable heating of electrical generation and transmission equipment formulating real power losses to the utility.

Power factor derives from the ratio of real, usable power (kW), to apparent power (kVAR). During the industrial assessment recommendations toward reduction of the power factor in fact indicate reduction of reactive losses. To accomplish this goal, the industrial electricity user must increase the power factor to a value as close to unity as practical for the entire facility. The supplying utility should be consulted for the determination of the requisite amount of capacitance necessary for correction to the desired power factor. For example, The number in Exhibit 4.1 is multiplied by the current demand (kW) to get the amount of capacitors (kVAR) needed to correct from the existing to the desired power factor. Mathematically, power factor is expressed as

$$PF = \frac{kW}{kVA}$$

Power factor can also be defined as the mathematical factor by which the apparent power is multiplied in order to obtain active power.

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4.1.3.2 System Analysis

The user will obtain the lowest electric cost by operating as close to a constant load as possible (load factor 100 percent). The closer a plant can approach this ideal situation, the lower the monthly demand charge will be. The key to a high-

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Exhibit 4.3: Highest Demands for Hypothetical Billing Period of May

Date	Time	kW	kW Above 5990 kW
May 10	10:00a.m.	6320	330
May 24	10:30a.m.	6220	230
May 14	11:00a.m.	6145	155
May 5	1:30p.m.	6095	105
May 20	2:30p.m.	6055	65
May 15	10:30a.m.	6025	35
May 15	10:00a.m.	6010	20
May 8	2:00p.m.	6000	10
May 9	2:00p.m.	5995	5
May 13	1:30p.m.	5995	5
May 5	2:00p.m.	5990	--

To effect this reduction requires a total sheddable load of at least 330 kW. If additional sheddable loads are available, a greater reduction in peak demand can be considered. It should be noted that the task of

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4.1.4.1 Example of a Typical Electric Bill

1. The utility rate schedule A-7 is the key to analyzing the electric bill. It is normally included as part of the contract.

2. The energy used expressed in kilowatt-hours (kWh) is determined by the difference of two monthly meter readings times the billing constant (2A). The billing constants (2A) and (3A) are also described as "Meter Multipliers". They are determined by the product of the current and potential transformer ratios installed at the particular location.

3. The reactive power used, sometimes called "wattless power", expressed reactive kilowatt ampere hours (kVARh) is determined from a separate reactive meter similar to the kWh meter (2) above.

4. The maximum demand in kilowatts for the current month is read from a separate register on the kWh meter. The value is the largest quantity of kilowatts consumed during a time interval prescribed in the contract.

Exhibit 4.4: Example Electric Bill

Billing Demand:	3840	
Billing Constants:	kWh 12000	kVARh 12000
Maximum Demand:	3840	
Reactive Demand:	2438	
Demand Customer or Service Charge:	$3,615.70	
Energy Charge:	$29,010.33	
Gross Bill:	$32,626.03	
Voltage Discount:	$706.77 Cr	
Power Factor Adjustment:	$266.38 Cr	
Net Bill:	$31,652.88	

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5. The reactive demand in kVAR is calculated from the formula kVAR - kW (kVARh/kWh).

6. The billing demand is the average of the maximum demand for the past 11 months and the current month's demand. The minimum is half of the past 11-month value.

7. Date and time span of the current billing.

8. The service charge, as specified in the rate schedule, is based on the billing demand item 6 and the service charge, is also used as the minimum billing if the energy usage falls to a low value.

9. The electrical energy charge is based on the kilowatt hours used as shown in item (2). Certain adjustments are made to the energy charge determined from the meter readings as follows:

   a) Energy cost adjustment known as "ECAC" varies with the change in fuel cost to the utility.

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The wintertime hour periods are from October 1 to April 30; the energy demand charges change between the following hours:

Partial peak hours - 8:30 am to 4:30 pm = 8 hours

Peak hours - 4:30 pm to 8:30 pm = 4 hours

Partial peak hours - 8:30 pm to 10:30 pm = 2 hours

Off peak hours - 10:30 pm to 8:30 am = 10 hours

Example 4: Rate schedule A-23 is applied to electrical load demands of 4,000 and above 5 kilowatts (kW) of demand per month. All other charges and "time of day" billing hours and periods are the same as rate schedule A-22. Additional rates are available for the purchase of supply voltage of 4,500 or 12,000 volts, this schedule provides for a high voltage discount of the total energy and demand charges.

4.1.6 The Demand Charge

This charge compensates the utility company for the capital investment required to serve peak loads, even if that peak load is only used for a few hours per week or month. The demand is measured in kilowatts (kW) or kilovolt amperes (kVA). These units are directly related to the amount of energy consumed in a given time interval of the billing period. The demand periods vary with the type of energy demand; the high fluctuating demand has a short demand period, which can be as short as five minutes, but generally demand periods are of 15 or 30 minutes. The period with the highest demand is the one used for billing demand charges.

Example: If the demand for a plant is 70 kilowatts for the first 15-minute period and for the next 15-minute period the demand increases to 140 kilowatts and then drops back to 70 kilowatts for the remainder of the bim(Of purchase and forn) Tj 124.5 maximums change

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This is particularly true during the normal working day hours. Over the past few years this condition has

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4.3 Alternative Energy Sources

Renewable energy sources account for approximately eight percent of the U.S. annual energy production. About half of this goes to generate electricity while the remaining half is used for transportation, space heating, and water heating.

Hydroelectric power generation comprises the largest percentage of the renewable energy category at more than fifty percent. Hydropower generation is used primarily for generation of electricity. Electricity generated from hydroelectric plants has increased as a result of increased water availability and improved efficiency.

Solar energy comprises about one percent of the renewable energy. Solar energy is used in three processes; heliothermal, heliochemical, and helioelectrical. Heliothermal is the absorption of the sun's radiation to produce heat for processes such as water heating. Applications of heliothermal processes are called active solar systems. Heliochemical solar energy is when the sun's radiation causes chemical reactions like photosynthesis. Helioelectrical is the conversion of the sun's radiation into electrical energy. Application of helioelectrical processes is usually termed photovoltaic systems. Solar energy can be accumulated in a number of solar collectors, which vary according to application. Solar energy has cost constrains, but recently there has been a resurgence in interest in solar energy, especially with environmental concerns.

Wind has been used for centuries as a power source to turn windmills for grinding grains and pumping water. Due to the variability of wind, generation of electricity using wind turbines is fairly expensive, the more wind the cheaper electricity generation. Energy generated from wind comprises less that half a percent of renewable energy. The use of wind turbines is limited to those areas with a more constant supply of wind.

Geothermal energy generation, approximately five percent of renewable energy generation, is limited to certain areas of the world where there are geysers, hot springs, or access to the earth’s internal thermal energy. Geothermal sources which are rich in hot water and steam from these sources is used to power low pressure turbines to generate electricity either directly or through a binary process. The "direct process" is to use the heated water and steam directly to power turbines while the "binary process" is to use a secondary fluid such as freon to power the turbine.

Biomass fuels include a wide variety of materials such as wood, peat, wood charcoal, bagasse, biogas, and liquid fuels produced by biological processes. Biomass fuels are the second largest source of renewable energy generation at about forty-one percent. Wood materials are usually burned in fireplaces and boilers to produce heat with little preprocessing. Wood charcoal is wood, which has been heated to remove most of the moisture resulting in a higher BTU value. Peat is a material in the early stages of transformation to coal and is generally low in sulfur, nitrogen, and ash. Peat, before harvesting, is greater than 90 percent water so drying is necessary before use. Bagasse is a fibrous residue material from sugarcane processing and is burned in boilers like wood. Biogas is generated from anaerobic digestion of waste materials. This gas is a useful source of energy and the remaining sludge materials are used for fertilizer. Much research has been done on waste to ethanol processes. These are biological processes that are used to generate liquid fuels. The waste to ethanol process is not yet economically competitive with current energy sources and is not commercially practiced.

Municipal solid waste incinerators have increased in popularity over the past few years. Heightened interest is a result of the closing of many landfills and the increasing capacity requirements for waste disposal. There are hundreds of municipal solid waste incinerators in the U.S.

4.4 Pollution Prevention and Waste Generation

All of the above energy sources impact the environment either through emissions of pollution causing materials, flooding of areas by hydroelectric dams, mining, or drilling. The U.S. has reduced energy related air pollution through regulations requiring better emission control and cleaner fuels. In addition, other wastes and pollution generated as the result of energy generation such as ash from the burning of solid waste and other materials is also regulated. As these regulations become more stringent, pollution prevention and waste generation from energy generating operations will be critical.

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4.4.1 Regulatory Requirements

Over the past three decades, the generation of wastes that are released to the environment through any media have become more stringently regulated. Environmental compliance and waste management costs increase in proportion to the number, volume, and complexity of a facility's waste streams. Simply stated, the less waste a facility generates the lower the treatment and disposal costs; not generating wastes is the wisest approach to waste management. This section gives an overview of major environmental requirements the Assessment Team should refer to the Code of Federal Regulations or the U.S. EPA web site for specific information on these regulations.

4.4.1.1 Air Emissions

The 1990 amendments to the CAA significantly affect facilities in several ways. Facilities located in nonattainment areas may be subject to more stringent emission levels on existing permitted sources such as painting/degreasing operations, power plants, or incinerators, and new regulations on many small sources that were not regulated previously such as print shops, dry cleaning operations, and gasoline stations. The air toxics provisions are likely to mandate new or additional control equipment for new and existing sources. The list of air toxics to be regulated has grown beyond the original list of seven, to a new list of 189 substances. The expanded list of air toxics, coupled with the new provisions to reduce emissions in nonattainment areas nation wide, means that many small sources typically found at facilities must now have permits.

Sources of air emissions in industrial facilities include but are not limited to cleaning and degreasing operations, painting or paint removal processes, heaters, furnaces, boilers, and printing. These operations are common in many types of facilities. Control technologies are available to help reduce the release of regulated emissions from many of these sources. For example, technologies available to reduce emissions from boilers include low NOx burners and flue gas recirculation. In addition, many facilities have changed the types of fuels that are used for boilers and furnaces to low sulfur fuels. For instance, conversion of boiler burners from Fuel Oil No. 4 to Fuel Oil No. 2 would significantly reduce emissions.

4.4.1.2 Water Discharges

The primary regulation for wastewater management is the National Pollutant Discharge Elimination System (NPDES), developed in accordance with the Clean Water Act. The CWA requires NPDES permits for the discharge of pollutants from any point source into waters of the United States. Permits are required for industrial facilities as well as facilities treating domestic wastewater. NPDES permits typically contain limits on the quantities of specific pollutants that can be discharged from the facility. The NPDES permit system encourages facilities to restrict their usage of regulated substances in order to comply with the discharge limits.

EPA has established 34 NPDES Primary Industry Categories. Any permit issued to a facility included in one of these categories contains specific effluent limitations and a compliance and sampling schedule to meet the limitations. Technology-based treatment limits form the basis of most effluent limitations.

The pretreatment program sets standards for the control of industrial wastewater discharged to publicly-owned treatment works (POTWs). The goal of the pretreatment program is to protect human health and the environment by reducing the potential

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largest components of municipal solid wastes by weight (37 percent) and volume (about 32 percent), totaling nearly 66.5 million metric tons in 1990. Construction and demolition debris wastes accounts for more 25 percent of all municipal solid waste in the United States. The majority of these wastes are landfilled

Many State and local regulations prohibit the disposal of specific wastes at sanitary landfills. Wisconsin, for instance, bans tires and used oil. The Assessment Team should refer to State or local regulations for the most up-to-date landfill regulations.

Apart from regulatory incentives, the greatest incentive for applying pollution prevention to municipal solid wastes is the cost savings from reduced disposal fees. In addition, recycling programs may

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4.4.2.1 Processes Generating Wastes and Types of Wastes Generated

In order to be able to deal successfully with any waste issues, the Assessment Team has to know what usually constitutes waste and where and how it is generated. Nothing can be as valuable as personal experience but even an inexperienced person performing the assessment can get a good idea from the following list of waste materials for various operations.

• Raw Materials	Containers, packing	Spoiled batches
	Off-spec and expired lots	
• Processes	Cleaning	Coating/Painting
	Reactions	Planting/Anodizing/Chromating
	Machining	Casting/Molding
	Testing	Extracting/Refining
	Printing	Packaging
• Cleaning	Alkaline baths	Acidic baths
	Solvents	Rags
	Sludges	Oil and Grease
	Grit	Rinse water
• Painting	Thinner	Paint sludge
	Overspray	Filters
	Containers	Unused paint
	Paint stripper	Masking
• Machining	Metal chips	Trimming waste
	Cutting coolants	Tapping oil
	Hydraulic oil	Tramp oil
	Filters	Rags
• Printing	Lithographic plates	Plate process solutions
	Silver	Photo process solution
	Press washes	Rags
	Paper	Inks

4.4.2.2 Industry Compendium of Processes Producing Waste

Processes that generate wastes can be categorized by the standard industrial classification (SIC) code for easy of reference as shown in Exhibit 4.5. These processes are not limited to the industrial operations classified into the given classification code but can be part of processes in other industrial facilities. The assessment team should be aware that the opportunities listed may be applied to industrial operations in other SIC codes.

Exhibit 4.5: Compendium of Processes Producing Waste

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Chemical processing (SIC: 28,29)	• Blending/mixing • Reaction to form product • Vessel cleaning	• Tank clean-out solutions • Tank clean-out solids • Reagent (liquid and powder) spills to floor • Reaction by products • Air emissions- Dust from powdered raw material	• Use Teflon lined tanks • Clean lines with "Pigs" instead of solvents or aqueous solutions • Use squeegees to recover clinging product prior to rinsing • Use Clean In Place (CIP) systems • Clean equipment immediately after use • Treat and reuse equipment cleaning solutions • Use cylindrical tanks with height to diameter ratios close to one to reduce wetted surface • Use tanks with a conical bottom outlet section to reduce waste associated with the interface of two liquids • Increase use of automation • Convert from batch operation to continuous processing • Use dry cleaning methods whenever possible • Use squeegees, mops and vacuums for floor cleaning • Use pumps and piping to decrease the frequency of spillage during material transfer • Install dedicated mixing equipment to optimize re-use of used rinse and to preclude the need for inter-run cleaning • Use in process recycling whenever possible • Install floating covers on tanks of volatile materials to reduce evaporation • Order paint pigments in paste form instead of dry powder to eliminate hazardous dust waste
Food processing (SIC: 20)	• Mixing/blending • Cooking/baking	• Equipment cleaning waste waters • Floor washing waste waters • Solid materials from mixer cleaning (e.g. dough) • Spent cooking oils	• Use dry cleaning methods whenever possible • Use high pressure washing equipment • Use squeegees and mops and for floor cleaning • Use continuous processing to eliminate the need for inter-run cleaning

Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures

Metal
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Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Printing			

Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Printing (lithography, gravure, flexography, letterpress, screen) (SIC: 27) continued	• Clean-up	• VOC emissions • Left over ink from fountains • Waste roller cleaning solution • Dirty rags • Paint skin from open ink containers • Used plates	• Use press cleanup rags as long as possible before • disregarding • Recycle waste ink and cleanup solvent • Use automatic cleaning equipment • Remove rollers from the machines and clean in a closed solvent cleaner • Prevent excessive solvent usage during cleaning (operator training) • Segregate spent solvents (by color) and reuse in sub-sequent washings • Improve cleaning efficiency by maintaining cleaning system (rollers, cleanup blade)
Surface coating (SIC: 24, 25, 34-39)	• Painting	• Off-specification or out-dated paint • Empty paint and solvent containers • Paint sludge • Spent paint filters • Booth clean-out waste (overspray) • Spent cleaning sol-vent • VOC emissions	• Use tight fitting lids on material containers to reduce • VOC emission • Convert to higher efficiency technologies • Convert to electrostatic powder coating • Convert from water curtain spray booths to a dry system • Convert to robotic painting • Use low VOC or water based paint • Purchase high volume materials in returnable bulk containers • Train operators for maximum operating efficiency • Automate paint mixing
	• Painting continued	•	• Use compressed air blowout for line cleaning prior to solvent cleaning • Shorten paint lines as much as possible to reduce line cleaning waste • Schedule production runs to minimize color changes • Recycle cleaning solvent and reuse • Use paint without metal pigments
	• Plating (electro electroless-) • Anodizing	• Spent alkaline cleaning solutions • Spent acid baths • Spent cyanide cleaning solutions • Spent plating solutions • Filter sludge • Waste rinse water • Waste water treatment sludge • Vent scrubber waste	• Use high purity anodes to increase solution life • Lower the concentration of plating baths • Reduce drag-in with better rinsing to increase solution life • Use deionized water for make-up and rinse water to increased solution life • Extend solution life with filtering or carbonate freezing • Use cyanide free solutions whenever possible • Replace cadmium-based solutions with zinc solutions • Replace hexavalent chromium solutions with trivalent solutions • Return spent solutions to the manufacturer • Use lower concentration plating baths • Reduce drag-out by racking parts for maximum drainage • Reduce drag-out by slowing withdrawal speed and increasing drain time • Rack parts for maximum drainage • Use drain boards between tanks for solution recovery

Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Surface coating (SIC: 24, 25, 34-39) (cont.)			• Reduce water use with counter current rinsing • Use fog nozzles over plating tanks and spray rinsing instead of immersion rinsing • Use reactive rinsing • Mechanically and air agitate rinse tanks for complete mixing • ·

Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Surface preparation/ cleaning (SIC: 24, 25, 34-39) continued			• Use silhouette entry covers to reduce evaporation area • Avoid inserting oversized object to reduce piston effect • Allow drainage before withdrawing object • Eliminate the need for cleaning with improved handling practices
	• Aqueous cleaning	• Spent cleaning solutions • Waste rinse waters • Oil sludge • Tank sludge	• Remove sludge from tanks on a regular basis • Minimize part contamination before washing

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Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	Common Waste Streams	Pollution Prevention Measures
Paper and pulp manufacturing (SIC: 26)	• Wood Preparation • Pulping • Screening • Washing • Thickening • Bleaching • Stock preparation • Paper machine • Finishing and • Converting	• Wood waste (saw dust, bark) • Acid and Alkaline waste waters • Toxic waste waters and sludges • Wood fiber waste • Non-hazardous waste water treatment sludge	• Use diffusion pulp wash systems to maximize efficiency • Maintain spray water temperature of 60- 70F to maximize rinse efficiency • Employ a closed cycle mill process to minimize waste water production • Reuse rich white water in other applications • Use felt showers to minimize the amount of fresh water use • Recycle white water • •

Exhibit 4.5: Compendium of Processes Producing Waste (cont.)

General Industrial Category	Unit Operation	

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- Certify that the percentage of recovered materials to be used in the performance of the contract will be at least the amount required by applicable specifications, and
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materials at the facility, as well as the requisition of chemicals from the HMCC area to individuals or shops. Inventory tracking can also be improved with the aid of a tracking system.

- *Inventory Controls* - should be establish through central storage and inventory points for chemicals and materials used in various locations at the facility. These storage points (or satellites) could coincide with flammable lockers already located throughout the facility and could be used to store the hazardous materials issued to each shop. Further, each satellite should maintain a written inventory of materials that would be updated as materials are used and stocked. These inventories would be cross checked against the computer tracking system to verify the location and usage of materials purchased. Materials used could be stored (daily or weekly) after use.
- *Purchase* - of hazardous materials routinely used in large quantities should be available for quick delivery.
- *Review and Inspection* – of procedures ensures proth theRing

- *Portable Tank Unit* - consists of a 24.5-

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- There may be many conflicts between competing goals, such as recyclability and cost reduction.
- Recycled packaging can be more expensive than new materials.

Improve Hazardous Materials and Waste Management, Secondary Containment, and Labeling Procedures

Not only should substitutes be found and used in place of the hazardous materials, but also on-hand supplies should be reduced. Ensure proper hazardous waste storage and labeling procedures are being followed and train personnel to insure compliance with local, State, and Federal regulations. Containers used to store hazardous waste (e.g., paint waste, batteries, waste flammable liquids) must be properly identified with a hazardous waste label. The specific information required to be on the label includes the generator's USEPA identification number, the words "hazardous waste", USEPA hazardous waste number, substance name, and generation date or start/ending accumulation dates.

It is generally good practice to store other wastes (i.e., waste oil, waste antifreeze, used oil absorbent pads) in well-labeled containers with secondary containment. It is also a good practice to make sure all containers are labeled, especially if they contain hazardous materials. In addition, metal drums stored outside should be covered so the integrity of the drums will not be compromised.

Benefits of Improved Hazardous Materials and Waste Management, Secondary Containment, and Labeling Procedures

- Helps to avoid future liabilities from regulatory agencies.
- Reduces the potential generation of waste through mislabeling, improper storage and handling, and exposure to weather.
- Reduces the quantity of hazardous waste generated.
- Reduces the reporting burden and cost of hazardous waste disposal.

Limitations of Improved Hazardous Materials and Waste Management, Secondary Containment, and Labeling Procedures

There are no direct limitations to improving hazardous materials and waste management, secondary containment, and labeling procedures.

Improve Spill Clean-up Procedures

All industrial operations should improve their spill prevention and cleanup practices to reduce waste generation. This involves a hierarchy of options that are listed below.

- *Use drip pans* - to collect the fluids during the draining process and to collect minor drips and leaks during servicing. This will prevent the leaks from dripping to the floor that will reduce the need to use absorbent material or rags to clean the spills. This will also reduce labor time to clean the floors.
- *Shop Vacuum for Oil Spills* - provide the most environmentally sound way of managing uncontained oil. This process ensures recoverability of the spilled oil for future recycling prospects. Several vacuums are commercially available for use in wet or dry situations.
- *Reusable pads and wringers* – can be used to clean the spills and leaks. These pads are highly absorbent and can be used several times 4 –10 before having to be disposed. Once the absorbent pads are saturated with oil, the pads can be passed through a wringer that sits on top of a 55-gallon drum which removes a large amount of the oil, allowing the pad to be reused. Facilities should discuss what materials the reusable pads and wringer can be used with to avoid any safety issues.
- *Collect and reuse dry sweep* - if it is not possible to use absorbent pads. It is recommended that the shops purchase or construct a dry sweep "sifter". This device is simply a mesh screen which filters usable dry sweep from saturated dry sweep. The saturated dry sweep forms clumps that cannot pass through the screen, whereas the unclumped, clean dry sweep can be reused. A small trap door located at the bottom of the drum is then used to distribute the reusable dry sweep. Once the dry sweep is spent, the dry sweep can be compacted. Compaction of spent sorbents can be accomplished

On-Site Recycling

Internal Supply Reuse

Material reuse can be an environmentally friendly effective solution to excess materials. Reuse

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- Periodic cleaning, repair, and maintenance and an on-going expense to utilizing returnables.
- Design of returnable containers may inhibit handling systems.
- The added tare weight of returnables may increase transportation costs and have negative ergonomic

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- *Replace Turfgrass with Native Plants* - which are hearty and require low maintenance.
- *Improve Mowing Practices* – to reduce waste. Mowers should be set so that no more than 1/3 of the lawn height (no more than 1 inch total) is removed with each mowing. Also, keep mower blades sharp and leave grass clippings in place after mowing.
- *Compost Yard Waste* – and substitute it for organic matter such as mulch and topsoil, normally purchased for grounds maintenance.
- *Develop Standard Operating Procedures (SOPs)* - and other outreach materials for contractors and/or staff that are involved in grounds maintenance activities. SOPs and other materials should describe and promote environmentally sound approaches to landscaping.

<u>Benefits of Implementing an Environmentally Preferred Grounds Maintenance Practices</u>

- Reduces the total solid waste disposal costs by decreasing the waste stream.
- Minimizes the hazardous waste stream by reducing potentially toxic fertilizer, pesticide, and herbicide use.
- Potential hazardous waste disposal costs can be decreased.
- Reduces water usage, energy usage, and labor costs.

<u>Limitations of Implementing an Environmentally Preferred Grounds Maintenance Practices</u>

- Re-landscaping can be economically prohibitive.
- Outside contractors often handle facility maintenance.

Substitute Low Mercury Fluorescent Tubes for Standard Tubes

Low mercury fluorescent tubes can be directly substituted for many standard fluorescent tubes. The mercury content of these tubes is much lower than standard tubes and the many of the tubes will meet TCLP testing for non-hazardous waste.

5.3.3.2 Recycling

There are many recycling opportunities available to facility maintenance personnel. Recycling programs can be utilized to recycle or reuse:

- Steel containers and Oil filters,
- Scrap Metal and Wood (pallets),
- Fluorescent light bulbs and Lamp ballasts,
- Shop towels,
- Antifreeze, and
- Wash water.

These recycling opportunities and their associated benefits and limitations are discussed in further detail below.

Implement a Used Oil Filter/Steel Container Recycling Program

Used oil filters and steel containers, such as empty aerosol cans and paint cans are often disposed of in the municipal solid waste stream, when they can be recycled. A comprehensive used steel container recycling program for industrial and shop operations can reduce non-hazardous solid waste and environmental liability from landfilling of containers that once contained petroleum based products. Used oil is removed from oil filters either via crushing, shredding or dismantling for use in fuel blending operations, waste to energy recovery, or oil reclaiming operations. The steel recovered from used oil filters, aerosol cans, and paint cans, are crushed into dense cubes, and used by steel mills as a raw material.

5.4.1 Process Description

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Metal working includes processes that machine, treat, coat, plate, paint and clean metal parts. There are two major segments of the industry: job shops that process materials owned by other parties on a contractual basis, and captive shops that are part of larger manufacturing facilities. Metal fabrication processes are integral parts of aerospace, electronic, defense, automotive, furniture, domestic appliance, and many other industries. Metal working operations involve various metal cutting processes that include the following.

- Turning
- Drilling
- Milling
- Reaming
- Threading
- Broaching
- Grinding
- Polishing
- Planing
- Cutting and shaping

Metal working processes use cutting tools of some sort that travel along the surface of the work piece, shearing away the metal ahead of it. Most of the power consumed in cutting is transformed into heat, the major portion of which is carried away by the metal chips, while the remainder is divided between the tool and work piece.

Turning processes and some drilling are done on lathes, which hold and rapidly spin the work piece against the edge of the cutting tool. Drilling machines are intended not only for making holes, but for reaming (enlarging or finishing) existing holes. Reaming machines using multiple cutting edge tools also carry out this process. Milling machines also use multiple edge cutters, in contrast with the single point tools of a lathe. While drilling cuts a circular hole, milling can cut unusual or irregular shapes into the work piece.

Broaching is a process whereby internal surfaces such as holes or circular, square or irregular shapes, or external surface like keyways are finished. A many-toothed cutting tool called a broach is used in this process. The broach’s teeth are graded in size in such a way that each one cuts a small chip from the work piece as the tool is pushed or pulled past the work piece surface, or through a leader hole. Broaching of round holes often gives greater accuracy and better finishing than reaming.

Metal working processes often apply a liquid (or sometimes gases) to the work piece and cutting tool

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The following provides a brief description of each type of source reduction activity identified to reduce waste metalworking fluid.

Preventive Maintenance Program

Preventive maintenance activities such as periodic seal and wiper replacement can extend the working life of the fluid by preventing contamination with tramp oils. Metalworking fluid performance starts with a preventive maintenance program that includes:

- Use of high quality, stable cutting and grinding fluids;
- Use of demineralized water for mixing purposes;
- Fluid concentration control;
- Control of fluid chemistry (pH, dissolved oxygen, etc.);
- Fluid contamination prevention;
- Periodic sump and machine cleaning;
- Period gasket, wiper and seal inspections and replacements to minimize tramp oil contamination;
- Regular cleaning of metalworking fluid through filtering or centrifugation, in order to minimize microbe growth by controlling tramp oil buildup; and
- Assignment of responsibility for fluid control to one person. Perio59c sump ion;

A periodic schedule of metalworking fluid testing can also alert plant staff to deteriorating fluid 77f75 -i,a8 T5 TD 0.

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breakdown of the fluid's qualities. Many synthetic fluids offer greater thermal stability at high temperatures, resisting oxidation better than non-synthetic fluids.

Gases can sometimes be used in place of coolants, because they can cool work pieces and tools with no work piece contamination. Air is the most frequently used gas, and is employed both in dry cutting and with other fluids. Nitrogen and carbon dioxide are occasionally used as well, but their cost is high and therefore their applications are limited.

Benefits of Source Redu

Exhibit 5.1: Available Technologies for Alternatives to Chlorinated Solvents for Cleaning and Degreasing

Technology Type	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
Aqueous Cleaners	• No ozone depletion potential • May not contain VOCs • Many cleaners reported to be biodegradable	• Excellent for removing inorganic and polar organic contaminants • Used to remove light oils and residues left by other cleaning processes • Used to remove heavy oils, greases, and waxes at		

Exhibit 5.1: Available Technologies for Alternatives to Chlorinated Solvents for Cleaning and Degreasing (cont.)

Technology Type	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
Petroleum Hydrocarbons	• Produce no wastewater • Recyclable by distillation • High grades have low odor and aromatic hydrocarbon content (low toxicity) • High grades have reduced evaporative loss	• Used in applications where water contact with parts is undesirable • Used on hard-to-clean organic contaminants, including heavy oil and grease, tar, and waxes • Low grades used in automobile repair and related service shops	• No water used, so there is less potential for corrosion of metal parts • Compatible with plastics, most metals, and some elastomers • Low, liquid surfaces (ase, tar, and waxes j -PTnTc 0.348 Tw (rnhy75 0.7h 0.8lr 0.s 2 Tc2) T( ) Tse j -Ps267	

Limitations of Aqueous Cleaners

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- Some aqueous cleaners contain organic substances that may be hazardous.
- Aqueous cleaners are generally not as fast or effective as traditional halogenated solvents.
- Material Safety Data Sheets (MSDSs) for individual products should be consulted before use.
- Metal corrosion may occur if parts cannot be dried quickly enough.
- Stress corrosion cracking can occur in some polymers as a result of contact with alkaline solutions.
- Compatibility of the product/process with water must be carefully investigated.

Semi-Aqueous Cleaners

Semi-aqueous cleaners comprise a group of cleaning solutions that are composed of natural or synthetic organic solvents, surfactants, corrosion inhibitors, and other additives. The term semi-aqueous refers to the use of water in some part of the cleaning process, such as washing, rinsing, or both. Semi-

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Benefits of Semi-Aqueous Cleaners

The primary pollution prevention benefit of semi-aqueous cleaners is that they are non-ozone depleting. However, they may be partly or completely composed of VOCs. In addition, their use commands substantially more concern about aquatic toxicity and human exposure than does the use of aqueous cleaners. Most semi-aqueous cleaners are reported to be biodegradable. One benefit of semi-aqueous cleaners is that distillation and membrane filtration technologies are being developed that will permit recycling and reuse of the products.

The following benefits have been identified with semi-aqueous cleaners.

- May be more aggressive in removing heavy organic contaminants.
- May have lower corrosion potential with water-sensitive metals.
- Penetrate small spaces more easily because they have lower surface tensions.
- Semi-aqueous cleaners are noncorrosive to most metals and generally are safe to use with most plastics.

-Aqueous Cleaners

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content and low evaporative loss rates. However, planned recovery of VOCs is an important part of pollution prevention if these solvents are to be used.

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The following benefits of petroleum hydrocarbon solvents have been identified.

- No water is used with petroleum hydrocarbon cleaners, so there is no potential for water corrosion or for water to become trapped in cavities.
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Miscellaneous Organic Solvents

This group covers a wide range of solvents that may be beneficial as a replacement technology, particularly on a small scale, such as bench-top or spot cleaning. Types of miscellaneous organic solvents that are commonly used include alcohols, liner methyl siloxanes, vegetable oils, ketones, esters, and ethers.

Alcohols are polar solvents and have good solubility for a wide range of inorganic and organic soils. The lighter alcohols are soluble in water and may be useful in drying operations.

Ketones have good solvent properties for many polymers and adhesives. Lighter ketones, such as acetone, are soluble in water and may be useful for certain rapid drying operations. Heavier ketones, such as acetophenone, are nearly insoluble in water. Ketones generally evaporate completely without leaving a residue. Some ketones such as methyl ethyl ketone (MEK) and methyl isobutyl ketone (MIBK) o4ton llan.252tt9.5 -11.25 T

80% n-butyl acetate and 20% n-butyl alcohol is used to dissolve oil, fats, waxes, metallic resinates, and many synthetic resins such as vinyl, polystyrene, and acrylates. Also, the mixture dissolves less highly polymerized alkyd resins and shellac.

- Ethyl lactate is another ester that has useful solvent properties. The use of ethyl lactate is relatively

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Limitations of Supercritical Fluids

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components without disassembly that otherwise must be disassembled because the aerosol penetrates narrow spaces.

Limitations of Carbon Dioxide Snow

- Heavier oils, alone or mixed with light oils, may require chemical precleaning and/or heating to be completely removed.
- The CO_2 must be purified because of its tendency to dissolve contaminants from the walls of tanks in which it is stored. Purification equipment adds expense to the CO_2 snow cleaning process.
- When surfaces are excessively chilled by long dwell times, airborne impurities may condense and settle on the clean surface.
- CO_2 snow has low Mohs hardness and will not scratch most metals and glasses. However, hard particulates such as sand that may be present on a surface potentially could cause scratching when carried by the gas stream.

Process Changes

Process changes can either eliminate the need for cleaning or apply techniques that eliminate or reduce the use of solvents.

Another possibility is to combine an alternative cleaning solution with a process change. Sometimes the cleaning effectiveness of a solvent substitute is not adequate, and a process change can improve the effectiveness of the substitute. In such a case, a process change is combined with solvent substitution to create a cleaner technology. In other cases, the process change may involve reducing the amount of solvent or making it amenable to recycling.

The following five common process changes for cleaning and degreasing are presented below:

- Add-on controls to existing vapor degreasers,
- Completely enclosed vapor cleaner,
- Automated aqueous cleaning,
- Aqueous power washing, and
- Ultrasonic cleaning.

Exhibit 5.2 summarizes the Pollution Prevention Benefits, Reported Application, Operational Benefits, and Limitations of each to provide a range of technologies to allow preliminary identification of those that may be applicable to specific situations.

<u>*Add-on Controls to Existing Vapor Degreasers*</u>

Add-on controls are features that can be incorporated into an existing degreaser to reduce air emissions. These process changes include the following:

- Operating controls,
- Covers,
- Increased freeboard height,
- Refrigerated freeboard coils, and
- Reduced room draft/lip exhaust velocities.

Operating Controls

The add-on controls limit air emissions through changes in operating practices or through equipment modifications. Operating controls are practices that reduce work load-related losses. These can be easily incorporated into the operating procedure, but their impact on emission reduction is significant. Air emissions can be reduced by slowing down the rate of entry of the work load into the (open-top vapor

Exhibit 5.2: Available Technologies for Cleaning and Degreasing (cont.)

Cleaning/Degreasing Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations

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Exhibit 5.3: CEVC Cleaning Cycle

Stage	Vendor Recommended Time Setting
Solvent Heat-up (once a day)	Variable to Raise Temperature to 70 °C
Solvent Spray (optional)	10 – 180 sec.
Vapor Fill	8 – 40min. (Varies according to mass of work load and type of metal.)
Degreasing	20 – 180 sec.
Condensation	120 sec.
Air Recirculation	120 sec.
Carbon Heat-up	Variable
Desorption	60 sec.
Adsorption	60 – 240 sec.

Unlike a conventional degreaser, there are no significant idling losses between loads, downtime, or during shutdown. The CEVC can be operated as a distillation unit to clean the liquid solvent in the sump. To distill, the unit is switched on without any workload in the chamber. After most of the solvent is converted to vapor, the residue in the sump is drained out and the vapors in the chamber are condensed in the chiller to recover the solvent. CEVC thus provides a good alternative for meeting pollution prevention objectives.

Energy requirements of the CEVC are higher compared with a conventional degreaser. The CEVC operates on a 480-V AC electric supply and consumes approximately 22 kW of power. The higher energy is

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- No additional facility modifications are needed to meet OSHA requirements for plant ambient solvent levels.
- The CEVC has fully automated cycles and runs unattended except for loading and unloading. The unit adjusts automatically to any type of workload and unseals the working chamber when the cycle is complete.

Limitations of Completely Enclosed Vapor Cleaning

- The CEVC has relatively high capital cost compared to a conventional OTVC.
- The CEVC has longer cleaning cycles for the same capacity.
- It has a relatively higher energy requirement because of the alternating heating and cooling stages.

Automated Aqueous Cleaning

Small machine parts are often cleaned in batches of thousands by immersion into a solvent solution or a solvent vapor. An alternative to this process is the automated aqueous parts washer. Instead of immersion, the automated aqueous washer sprays an aqueous solution across the parts to remove oil and debris. Parts travel through a series of chambers, each with different concentrations of cleaning and rinsing solutions. Excessively sprayed solution is recovered and reused. Similar automated cleaners are also available for semi-aqueous cleaning solutions.

The configuration of the system promotes good contact between cleaning solutions and the parts. One example of an automated aqueous cleaner consists of a series of five compartments though which the soiled metal parts are transported. The parts are transported form one compartment to the next by a helical screw conveyor. The parts are sprayed successively with solutions from five holding tanks (one for each compartment). The first compartment sprays hot water on the parts. The second and third compartments spray detergent solutions at two different concentrations on the parts. The fourth compartment is for a clean water rinse. The fifth and final compartment sprays a rust inhibitor solution, if required. The fifth compartment is followed by a dryer that vaporizes any water droplets remaining on the parts. The cleaned parts drop out of the dryer onto a vibrating conveyor from which they are collected.

The automated aqueous washer also makes use of a "closed loop" system, whereby the used solutions are not disposed of daily but can be recirculated for a relatively continuous operation. The cleaning solutions are recaptured after use and sent to a separator tank. One separator tank is provided for each compartment. In these tanks, the oil floats to the surface and is skimmed off by a pump. Dirt and suspended particles settle down at the bottom of the tank. The bulk of the solution is recirculated back to the holding tanks for reuse. Some makeup solution is needed periodically to replace losses from evaporation and dragout. Detergent chemicals are also replenished periodically.

Because the closed-loop system eliminates daily disposal of spent solutions, the same cleaning solution can be recirculated and used for several days without changing. At the end of the week (or whenever the contaminants reach a certain level), the holding tanks are emptied and fresh solutions are made up. Because recovery and reuse of the cleaning solution is automatic, the unit requires very little operator attention. In contrast to vapor degreasing or traditional batch aqueous cleaning processes, the continuous operation of this conveyorized unit enables production efficiency. The only operator involvement is for unloading a barrel of soiled parts into the hopper that feeds the parts to the compartments.

Several variations of the automated aqueous cleaners are available. Different types of filters, oil-water separators, and sludge thickeners are some of the features offered. Some new units claim zero wastewater discharge, with fresh water added only to make up for evaporation in the drier.

Benefits of Automated Aqueous Cleaning

Automated aqueous cleaners use aqueous cleaning solution instead of solvents to achieve high-quality cleaning. This available technology replaces the hazardous solvent waste stream with a much less hazardous wastewater stream. These automated machines also have features to significantly reduce the amount of wastewater generated. These machines remove some of the contamination from the parts being

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Benefits of Aqueous Power Washing

The aqueous power washer is similar to the automated aqueous washer in that it combines innovative process technology with the use of an aqueous (or semi-aqueous) cleaning solution. Both technologies eliminate the use of solvents for cleaning. When combined with a "closed-loop" technology, in which the cleaning solution is recirculated, aqueous power washing also reduces water and cleaning solution disposal requirements. The benefits of the aqueous power washer are the following.

- Aqueous cleaners can be used in applications where solvent cleaning was used previously.
- Aqueous cleaners provide more efficient cleaning compared to manual aqueous tank cleaning.
- Cleaning times are reduced.
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Testing must be performed to obtain th

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- A lower concentration of cleaning solution can be used and possible lower toxic agents such as neutral or biodegradable detergents can be employed.
- Although capital costs may be higher with ultrasonic cleaning, reduced solvent expense can often pay for a system in a short period of time.

Limitations of Ultrasonic Cleaning

- Wastewater generated has to be treated and discharged.
- Ultrasonic cleaning requires that the part can be immersed in the cleaning solution.
- Dryers may need to be employed to obtain a dry part.
- Testing must be performed to obtain the optimum combination of cleaning solution concentration

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Distillation

Distillation is the process of separating two miscible liquids based on the difference in their vapor

Advantages of this arrangement include less involvement of the generator and receiving facility in deciding on equitable terms and conditions (these may already be dictated by the material exchange) and the ability to participate in an exchange without the facilities having to identify themselves with one another. A disadvantage of a material exchange is that the generator will pay more for this service; many information

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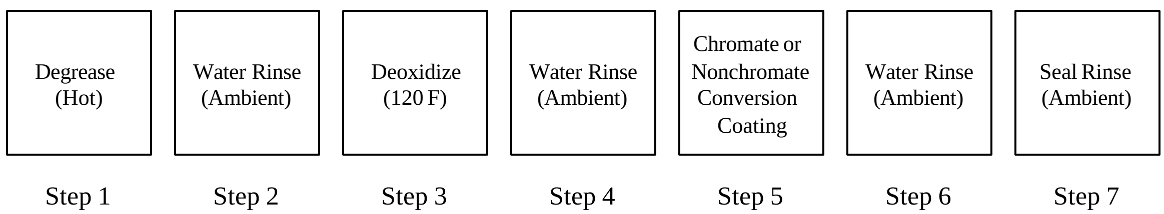
include Alodine® 1200 and Accelagold®. The active ingredient in these solutions is hexavalent chromium in chromate (CrO_4^{-2}) and dichromate ($Cr_2O_7^{-2}$) chemical forms.

Conversion coatings are widely used in the manufacture and maintenance of aluminum prior to painting or as a final finish. In most cases, the conversion coating imparts corrosion protection and provides an excellent base for paint adhesion. In a smaller number of cases the conductive properties of the coating allow it to be used for electrical bonding applications. Recent developments in conversion coating formulations have lead to the development of nonchromate conversion coatings for limited applications.

A typical process for applying a conversion coating to aluminum with either a chromate or nonchromate formulation, consists of a seven-step process that includes two rinse steps. (See Exhibit 5.5.)

Exhibit 5.5: Typical Conversion Coating Process for Aluminum



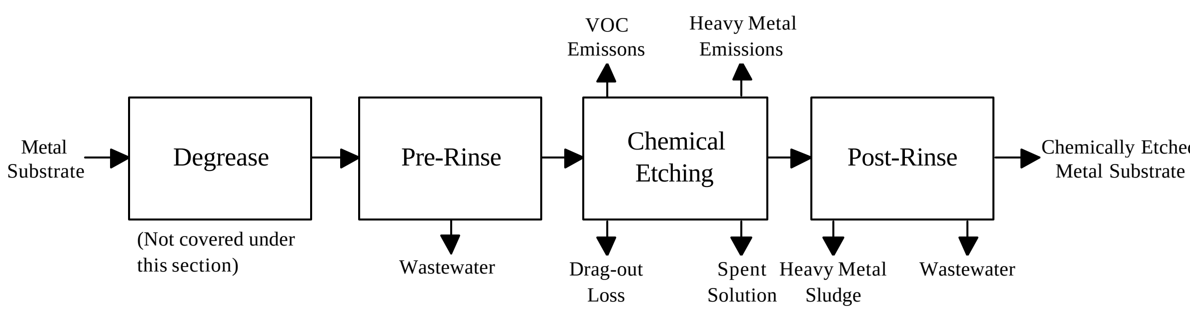
5.6.2 Waste Description

Chemical etching, either phosphating or chromate conversion coating regardless of complexity requires four basic steps; Degrease, Pre- Rinse, Chemical Etch, and Post- Rinse. Each phase of the chemical etching process generates air emissions and solid waste. This section of the document deals with the waste streams generated from the pre-rinse, chemical etching, and post-rinse process steps. Detailed information on Degreasing is contained in Section 5.5, Cleaning & Degreasing.

Pre-rinsing, after degreasing and before chemical etching, is essential to prevent contamination and to maintain the pH of the phosphate bath, but rinsing can generate high volumes of wastewater. A more efficient process, cost savings and wastewater minimization can be attained through process modifications.

Exhibit 5.6 describes the basic waste streams generated from a typical chemical etching operation.

Exhibit 5.6: Simplified Material Balance of a Chemical Etching Process Step



For certain types of operations, a post-rinse stage is included to remove drag-out of unreacted acids, sludge deposits, corrosive salts, and other contaminants that remain on the work piece following chemical etching. Because more rinse cycles are required with post-rinsing than pre-rinsing, the post-rinse can also generate high volumes of wastewater. However, efficient process modifications can reduce overall costs and wastewater.

5.6.3 Pollution Prevention Opportunities

Pollution prevention opportunities for the chemical etching industry exist in both the source reduction and recycling categories. These opportunities are discussed in further detail below.

5.6.3.1 Source Reduction

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The chemical etching industry has many opportunities for pollution prevention through source reductio

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etching operations to extend bath life and improve finished product quality; rinsing by immersion, spray rinse system, and counter-flow rinsing.

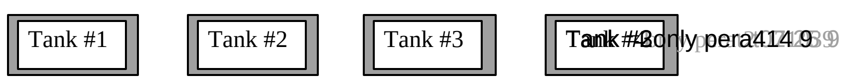
Rinsing by immersion is ideal for situations in which the production flow through the process is relatively slow (i.e., less than 2 ft/min on a continuous basis) and production is intermittent. A facility operator considering the installation of an immersion system should consult with a specialized contractor about design and layout.

Exhibit 5.7 illustrates two typical immersion system layouts. Exhibit 5.7(a) shows the more common layout for a typical batch operation; Exhibit 5.7(b) shows a less-common layout that would rely on a conveyor to carry work pieces in and out of the tanks in a continuous process.

A spray rinse system is often recommended for a paint and coatings operation that has a conveyor line with a speed greater than 2 ft/min. Facility operators considering the installation of a spray washer line would be well advised to consult with a specialized contracting company. In general, when planning for a spray washer, the facility operator needs to consider how the layout will affect process flow. The spray washer system must be designed so that work pieces easily pass through the pretreatment process, allowing adequate time for the solutions to drain between each tank.

A spray washer system cannot be properly designed unless the conveyor line speed and the part sizes are known. The dimensions of the spray tunnel must be based on the silhouette of the maximum part size. The spray nozzles inside the tunnel must be located on risers so that they are only a few inches away from the largest part.

Exhibit 5.7: Immersion Rinse System Schematic



When possible, a system should be designed so that spray rinses precede every process tank. Although the rinses are at low pressures, they enhance pretreatment by preventing the contamination of tanks with chemicals from a preceding tank. Operation of such spray washers is relatively inexpensive because low volumes of water are used.

Given the vast number of work pieces and parts of varying size that can pass through a spray system each day for certain operations, nozzles can often be misdirected. Thus, a maintenance engineer should routinely check to see that spray nozzles are pointing in the correct direction.

A design feature often overlooked regards conveyors that pass work pieces through the tunnel, dry-off oven, and spray booths, as shown in Exhibit 5.8. The advantage of such design is that line workers are only needed for hanging and offloading work pieces.

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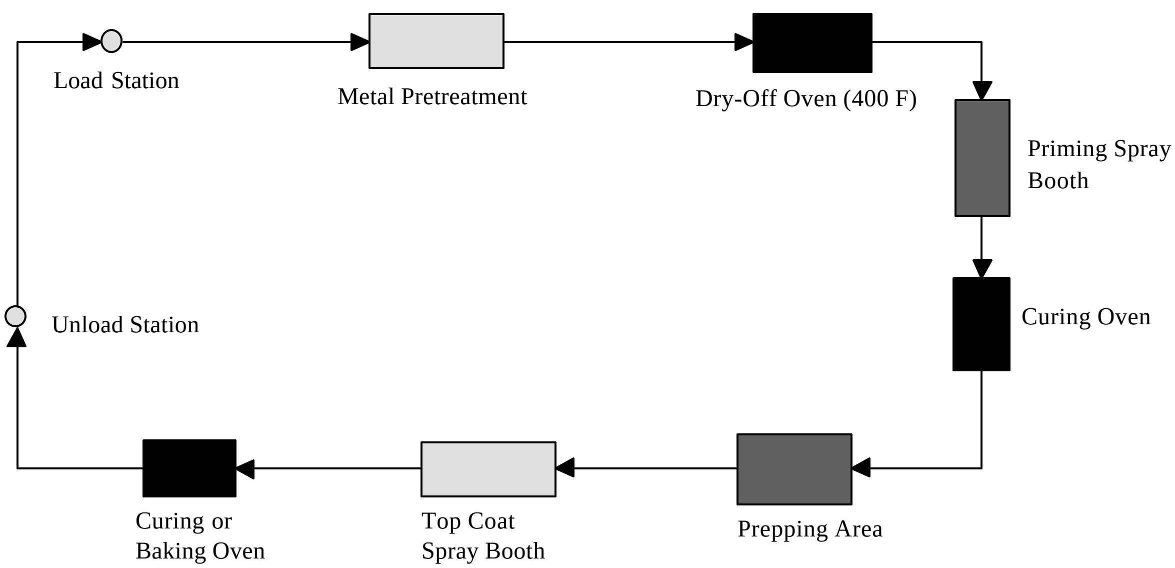
Exhibit 5.8: Schematic of a Conveyorized Paints and Coatings Operation



Counter-flow rinsing is an effective method for thoroughly washing contaminants from the work pieces after degreasing or phosphating, in addition, it is an effective method for minimizing water usage. Fundamentally, a counter-flow rinsing system is a sequence of baths in which replenished rinse water moves in opposite direction of the process flow. Thus, the work piece progresses from dirtier to cleaner rinse water. The system maximizes water use by replenishing the rinse water in the processing bath. Rinse water effluent is ultimately released to the wastewater treatment system as overflow from the first (dirtiest) bath in the sequence.

Benefits of Rinsing after Degreasing

- Removes surfactants and other contaminants that can undermine the integrity of the metal deposition and the quality of the finished piece.
- Minimizes the amount of drag-in from high alkaline degreasing baths to the near-neutral chemical etching bath.
- Reduces the need for raw chemicals therefore decreasing the cost.
- Increases the useful life of the chemical etchant.
- Longer bath life reduces wastewater.
- Thorough cleaning promotes proper adhesion.

Limitations of Rinsing after Degreasing

- Often requires large amounts of floor space.
- Capital and maintenance costs may be high.

Check for Cleanliness Prior to Etching

The cleanliness of the substrate as the work piece enters the phosphating step or as it leaves the final rinse tank should pass the water break-free or the towel-wipe test. In the water break-free test, a squirt bottle is used to pour deionized water over a cleaned substrate. The water should run off in a sheet rather than bead up. While the test may demonstrate that oils and greases have been removed from the work piece, it will not confirm that the surfactants from the degreaser have also been removed. To do this, one needs to rinse the

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part with a small quantity of deionized water and then determine the pH of the water. This can easily be done using pH papers.

To determine that metal fines, smut, and other contaminants have been removed, a clean paper towel should be wiped across the wet surface of the work piece. Whereas the test may not always result in a perfectly clean towel, relative changes in cleanliness can be assessed.

Benefits of Checking for Cleanliness

- Demonstrates that oils and greases have been removed.
- Minimizes contamination of the chemical etching bath.
- Minimizes the amount of drag-in from high alkaline degreasing baths to the near-neutral chemical etching bath.
- Insures longer bath life that reduces wastewater and raw chemical usage.
- Indicates the effectiveness of the utilized rinses

Limitations of Checking for Cleanliness

- Does not confirm that surfactants from the degreaser have been removed.
- A combination of both the water break-free and the towel-wipe test must be used to ensure cleanliness.

Choosing a Phosphate Formulation and Qualifying the Phosphate Coating

Paints and coatings facility operators typically confer with chemical vendors in the selection of a phosphate formulation. Indeed, one vendor may be able to offer a better formulation than another vendor, especially if the performance requirements are unique.

The choice of formulation can be significant in terms of achieving optimum coating properties. It is especially prudent for the operator to discuss special requirements with a chemical vendor, particularly if the finished work piece will be subjected to aggressive environments. In some situations, laboratory tests may need to be conducted to verify that the selected coating will be able to provide the required finish. In general, choosing a formulation on the basis of price is inadvisable.

Benefits of Choosing the Proper Phosphate Formulation

- The proper etchant formulation will achieve optimum coating properties.
- Proper formulas will reduce waste stream of ruined pieces.

Limitations of Choosing the Proper Phosphate Formulation

- Lab tests may be required to determine the optimum formula.
- The cost of the optimum formula may be prohibitive.
- The optimum formulation may be more environmentally hazardous than a substitute.

Alternative Sealing Processes

Some operations subject work pieces to a final rinse bath after chemical etching to harden the deposited coating, providing an enhanced long-term corrosion resistance. This process step is included in operations for aAlternative Sealing ProcgTD /F5 j 67.5 Tc -0.1875 Tw ( ) Tj -335.25 -17.25gtfhhich Twta12 ingigh v

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both form pollutants of concern, hexavalent chromium is particularly toxic and is a suspected carcinogen; thus, residuals must be disposed of as hazardous waste, which can add significant costs to the process.

- *Nonchromate Sealers* - also form a protective film over exposed areas of the substrate, although not through a chemical reaction with the base metal. Several nonchromate sealant formulations have been developed, but their effectiveness for enhancing the durability of a work piece as compared with chromate-based sealers has yet to be fully established. Nonetheless, when the finished work piece will be used in applications requiring less-demanding corrosion resistance, nonchromate sealers can present an attractive alternative. The great advantage that nonchromate sealers hold over chromate based formulations is that they are non-toxic. Thus, an operator can realize significant benefits by red/3503 Tw (behcinglimi Theurabilinelatlly of as rk ps waste, ws must be.25 0 314D 0 Tc -0.1875 Tw ( ) Tj -7

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Exhibit 5.9 Major Metal Plating Wastes and Constituents

Air Emissions	Key Constituents
Solvent releases from degreasing operations	Solvents
Chromium	-1,1,1-Trichlorethane

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Product Replacements

Product replacements may be utilized for decorative coatings, but for technical purposes metal coatings are essential. Hard coated metals are expected to resist acidic attack, combat high temperatures, and reduce friction. While paint and plastics have limited replacement values as decorative coatings, they cannot withstand the abuse that hard coated metals stand up to. Paint and plastics have been used as product replacements for hard coated metals successfully in very selective decorative coating applications. The act of eliminating the plating operation from a product design is best achieved during product design.

Exhibit 5.10 Waste Minimization/Pollution Prevention Methods and Technologies

Exhibit 5.11 Waste Minimization Opportunities Available to the Metal Plating Industry

Category	Examples	Applications	Limitations
General Waste Reduction Practices	• Improved operating procedures • Drag-out reduction • Rinse-water use reduction • Air emissions reductions	• Applicable to all conventional plating operations • Should be considered standard operating procedures and/or good design • Cost benefits typically outweigh any necessary expenditures	• Existing facilities may be able to accommodate changes due to process configuration, space constraints, etc.
Alternative Processes	• Thermal Spray Coatings • Vapor Deposition • Chemical Vapor Deposition	• Primarily repair operations although they are now being incorporated into original manufacturing • Primarily high-technology applications than can bear additional costs • Expected to improve product quality and life	• Technologies in varying states of development; commercial availability may be limited in certain areas • Expense often limits application to expensive parts (e.g., aerospace, electronics, military) • May require improved process controls, employee training, and automation
Process Solution Maintenance	• Convention Maintenance Methods • Advanced Maintenance Methods • Process Monitoring and Control	• Conventional methods applicable to all plating operations	• Advanced methods may require significant changes in process design, operation, and chemistry • Application limited for some plating process/technology combinations (e.g., microfiltration not applicable to copper or [illegible]rations

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Chemical Vapor Deposition

In Chemical Vapor Deposition (CVD) processes, a reactant gas mixture impinges on the substrate upon which a deposit is made. The different variations of CVD are distinguished by the manner in which the precursor gases are converted into the reactive gas mixture. Typically in CVD, gas precursors are heated to form a reactive gas mixture. A precursor material, otherwise known as a reactive vapor delivers the coating species. It is usually in the form of a metal halide, metal carbonyl, a hybrid, or an organmetallic compound. The precursor may be in either gas, liquid or solid form. Gases are delivered to the chamber under normal temperatures and pressures, while solids and liquids require high temperatures and/or low pressure in conjunction with a carrier gas. Once in the chamber, energy is applied to the substrate to facilitate the reaction of the precursor material upon impact. The ligand species is liberated from the metal species to be deposited upon the substrate to form the coating. Since most CVD reactions are endothermic, regulating the amount of energy input may control the reaction. The most useful CVD coatings are nick

<u>*Notes*</u>

accelerated from an ion gun or other source. Titanium, aluminum, copper, gold, and palladium are typically coated with the ion plating method. A benefit of both ion plating methods is that the substrate does not have to be extremely clean before plating. Capitol costs for this technology are typically high; therefore it is used in applications where high value-added equipment is being coated.

- *Ion Implantation* – does not produce a discrete coating; the process alters the elemental chemical composition of the surface substrate by forming an alloy with energetic ions. All surface contaminants must be removed prior to plating using ion implantation.

All three PVD methods allow coatings to be deposited as thin as 0.00005mm and as thick as 0.025mm. Most commonly chromium, titanium, gold, silver, and tantalum are coated.

All reactive PVD hard coating processes combine:

1. A method for depositing the metal;
2. Combining with an active gas, such as nitrogen, oxygen, or methane; and
3. Plasma bombardment of the substrate to ensure a dense, hard coating.

Benefits of Physical Vapor Deposition

- Even deposition rates.
- The PVD coating process does not involve a bath operation, therefore eliminating the environmentally hazardous waste released due to drag-out.
- High resistance to friction.
- PVD typically requires less substrate cleaning than conventional plating therefore reducing the amount of cleaning solvents entering the waste stream.
- PVD does not add any new toxic waste streams.
- Good adhesion to the substrate.

Limitations of Physical Vapor Deposition

- High start up costs.
- The coating may be contaminated with other molecules if the work area is not properly prepared.

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Process Efficiency

Through process efficiency the waste streams involved with conventional plating systems can be reduced. Small changes in processes can often net large results in preventing pollution and cost reduction. The following procedures can be used to maximize process efficiency.

- Drag-out reduction.
- Rinse water reduction.
- Conventional maintenance methods.
- Advanced Maintenance technologies.

Drag-Out Reduction

Drag-out of process fluid into rinse water is a major source of pollution in any plating shop. The volume of drag-out discharged from a process is determined by some factors that cannot be altered easily, such as part shapes and process fluid concentrations. The effects of many other contributing factors, however, are readily reduced by common techniques. Reduction of drag-out not only reduces the mass of pollutants reaching the wastewater stream but also reduces the amount of chemical loss suffered by the process. Because most drag-out reduction methods require only operator training or small process changes, the cost savings and other benefits realized quickly offset any implementation expenses incurred. Drag-out reduction techniques include the following.

- *Plating Solution Control* – minimizes drag-out by reducing bath viscosity with the lowest concentration or highest temperature possible, reducing surface tension with wetting agents, preventing the build-up of contaminants in process tanks by monitoring carbonate accumulation, and using high purity electrodes to reduce impurities from falling out and contaminating the solution.
- *Withdrawal Rates and Drainage* – are critical to minimizing drag-out. Maximizing the drip time, using drip shields or boards to capture and return drag-out as a rack or barrel is transported away from the process, using tanks to collect drag-out, and utilizing air knives to enhance drainage will return the maximum drag-out volume.
- *Positioning of Parts on the Rack* – is important both for quality as well as drag-out reduction considerations. The best position is typically determined by experimentation. Parts should not be racked over one another, but they should be positioned to consolidate runoff streams, and oriented so that the lowest profile emerges from the fluid as the rack is removed.

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Plating bath contaminants can also be removed through the following techniques to extend the bath life.

- *"Dummy Platting"* – or electrolysis is a method of reducing the mass of contaminant metals in a plating bath by plating them onto a dummy panel. During dummy plating, a current density much lower that that used for normal plating is applied.
- *Carbonate Freezing* – is applicable to sodium-based cyanide plating baths. When cooled to a temperature of approximately 3^oC, sodium carbonate crystals form and can be removed easily.
- *Carbon Treatment* – is a common method of reducing organic contamination in plating baths. Carbon treatment may only consist of occasionally substituting carbon for normal cartridges in the existing filtration equipment.

Advanced Maintenance Technologies

Advanced maintenance technologies are relatively new, but they are employed to treat specifically difficult to maintain bath solutions. The following four treatments typically utilized are:

- *Microfiltration* – is a membrane-based technology applied primarily to aqueous and semi-aqueous cleaning solutions. This technology separates emulsified oils and other colloids from the cleaner chemistry, thereby extending the life of the process bath.
- *Ion Exchange* – is applied to chromic acid solutions to remove cations, such as copper, zinc, or iron that are introduced into plating baths from racks and parts. For chromic acid purification, ion exchange competes with ion transfer and membrane electrolysis.
- *Acid Sorption* – is applied to acid solutions, such as pickling or sulfuric acid anodizing baths, to remove dissolved metals.
- *Ion Transfer* – is a common technology with applications generally restricted to chromic acid plating baths, etched, and anodizing baths. The goal of this technology is to selectively remove cations from chromic acid process fluids.

Benefits of Process Bath Maintenance

- Extends bath solution life.
- Reduces chemical use.
- Reduces waste disposal.

Limitations of Process Bath Maintenance

- Start-up costs can be expensive.
- Expensive start-up and maintenance costs for certain processes.
- Can cause time delays in the plating process.

5.7.3.2 Recycling

Chemical recovery technologies either recover drag-out and return it to the process or recover a constituent of the drag-out chemistry, usually a dissolved metal, and recycle it in another process. Recovering drag-out reduces raw material costs by returning otherwise lost components to the process and reduces the mass of regulated ions reaching the waste treatment system, which lowers costs and aids in complying with discharge limits. Recycling takes places both on-site and off-site.

On-Site Recycling

On-site recycling technologies typically recover plating solution lost from drag-out in the rinse tanks; usually a dissolved metal. The following briefly summarizes the types of technology commonly used.

- *Evaporation* - with atmospheric and vacuum systems are the most common chemical technology used in the plating industry. Atmospheric evaporators are most common, and relatively inexpensive to purchase, and easy to operate. Vacuum evaporators are mechanically more sophisticated and

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Limitations of Off-site Recycling

- Slightly more expensive than land disposal.
- Limited to spent solvents, precious metal wastes, and high purity common metal wastes.

5.8 Paint Application

The following section provides a process des

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Eliminate the Need to Paint

Eliminating the need to paint a part due to better process engineering and design would be the highest form of source reduction. Although one should be cautious that the environmental impacts associated with the alternative design are not worse over-all.

The need for painting can sometimes be avoided by selecting materials that combine both function and aesthetics. Use of injection-molded plastic shells in place of painted metal cabinets is widely practiced in the electronics industry. Building construction employing the use of vinyl siding, PVC and FRP plastics, precolored concrete, and metal trim materials such as stainless steel, copper, bronze, and aluminum are known.

The area of surface-coating-free materials is not as widely explored nor marketed as non-, low-VOC coatings as a means to reduce the environmental impacts from painting operations. In addition, to implement

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- Applying the Coating – can be done through three primary methods including electrostatic attraction by corona charge, elecrostatic attraction using turbo-charging guns, and fluidized beds. None of the coating methods involve solvents or generate hazardous wastes. Also clean-up efforts are minimal, benefiting both pollution prevention and time and materials resources.
- Curing the Coated Part – entails heating the powder-coated part in a convection or infrared oven at temperatures between 325 °F and 400 °F for approximately 8 to 20 minutes. When the powder coating is cured, some vapors, approximately 0.5 to 5 percent by weight of powder coating, are emitted into the atmosphere. These are comprised mainly of water and some organics. The organics are not solvents, but rather plasticizers or resins emitted at the high baking temperature. It is questionable whether the air emissions are truly VOCs. In fact, most air pollution regulatory agencies assume that the emissions from powder coating operations are essentially zero; therefore, operators are usually not required to measure or record their emissions. Facility personnel should consult the regulations for their area for applicable regulations

Benefits of Powder Coatings

- The act of applying powder coatings does not contribute to air, water, or hazardous waste pollution.
- VOC emissions are essential zero.
- Clean-up efforts are minimal, benefiting both pollution prevention and time and materials resources.

Limitations of Powder Coatings

- The substrate has to be completely clean before powder coating, therefore introducing the wastes associated with degreasing, cleaning, and etching.
- The stripping of powder coating from hooks and rejected parts produces pollution.
- The curing process emits vapors, at 0.5 to 5.0 percent by weight, of the powder coating.

Water-Borne Coatings

The term "water-borne" describes coatings in which the predominant solvent is water. Organic solvents (VOCs) are also used but, for the most part, their concentration is small. In many formulations the ratio between the amount of water and organic solvent is 80:20.

The organic solvents, often referred to as co-solvents, enhance the formulation of the coating film, especially during the drying process when the water is evaporating from the deposited coating. As resin manufacturers develop new resin technologies, they are reducing the amount of co-solvent required to form the film. Currently, new formulations exist that contain no co-solvents, and consequently have zero VOCs. Manufacturers do not yet have a long-term performance history; therefore, most end-users generally consider the more conventional water-borne coatings.

When dealing with water-borne coatings, the end-users must thoroughly understand the terminology most regulations use. For instance, 1.0 gallon of a water-borne coating contains many ingredients: the resin (or binder), pigments, extender pigments, coalescing agents, a small quantity of co-solvents, and usually a fairly substantial amount of water. The volatile portion of the coating comprises the co-solvents and water. In a gallon can, the co-solvents, which are considered to be the VOCs, may account for less than 1.0 pound. In other words, the VOC content of the coating may only be 1.0 pound/gallon. The VOC regulations, however, require that the VOC content of the coating be calculated as if no water were in the coating. Depending on the coating formulation, the VOC content, less water, may be considerably higher, such as c 1.31dTw (most2D (

and leveling properties similar to their solvent-borne counterparts. The acrylic latexes include other polymers such as vinyl acrylic and styrene acrylic. The resins are high molecular weight polymers dispersed as discrete particles in water. Acrylic latexes are known for their good exterior durability and excellent resistance to ultraviolet (UV) degradation. In outdoor exposure, they retain their

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- Some water-borne epoxy water-reducible air/force dried coatings contain chromates, and therefore require disposal as hazardous waste.

Solvent-Borne Coatings

Although air pollution agencies actively promote water-borne coatings, all solvent-borne coating cannot yet be replaced. Some companies will require solvent-borne coatings into the 21st century. Fortunately, VOC contents are gradually decreasing, viscosities are becoming manageable, and paint chemists continue work on developing new solvents that are not VOCs, hazardous air pollutants (HAPs), or ozone depleting compounds (ODCs). These new solvents may offer a wide range of new opportunities.

The classification of solvent-borne coatings is further sub-divided into the following categories.

- *Solvent-Borne Alkyds and Modified Alkyds That Air or Force Dry* – are basically oil-modified polyesters that form from a reaction between an alcohol and an organic acid. Each combination has its own distinctive chemical and physical properties. In addition, properties of alkyds such as hardness, gloss retention, color retention, sunlight resistance, etc.; can be improved by modifying alkyds with other resins. Typical modifications add styrene, vinyl toluene, acrylics, silicone, or other polymers. Any of these modified products are more commonly known as modified alkyds.

- *Alkyd Derivative Combinations That Cure By Baking* – include high sold alkyds, acrylics, polyesters oil-free, melamine- and urea-formaldehyde, and phenolics. Unlike the air/force dry alkyds, this group of coatings provides excellent physical and chemical properties. The primary difference is that cross-linking of the resins takes place when the coating reaches a certain minimum temperature. For most such coatings, curing takes place at temperatures above 250 °F, but the curing time may be too long (over 30 minutes) for most production painting facilities. These coatings have properties similar to water-borne alkyd-type baked coatings. As with the water-borne coatings, these solvent-borne counterparts are commonly applied to steel shelving, steel racks used in stored and warehouses, metal office furniture and equipment, and large appliances (e.g., dishwashers, refrigerators, etc.).

- *Catalyzed Epoxy Coatings* – constitute the counterparts to the water-borne epoxy coating that can achieve heavier film builds for many applications. Most commonly, these coatings are air- or force-dried, two-component materials compromising two separate packages. Component A being the epoxy resin and component B being a polyamine, or some other resin. Catalyzed epoxies are beneficial when requiring resistance to many chemicals, solvents, and alkalies, such as soaps and detergents. In addition, these coatings have excellent resistance to fresh water, salt water, and hot water. For these reasons they are a popular choice for protecting structures such as offshore drilling platforms, ships, and bridges, where resistance to marine environments is critical. Facilities also use them to coat industrial and potable water tanks and pipelines. Compliant epoxies are available that meet military specifications such as MIL-P-23377 (primer), MIL-P-53022 (primer), MIL-C-22750 (topcoat), and MIL-P-24441 (primer and topcoat systems).

- *Catalyzed Two-Component Polyurethanes* – are formed by the reactions of a polyisocyanate with a polymer that contains hydroxyl functionality. Two-component polyurethanes are supplied in two separate containers, of which the first is component A and the second is component B. Component

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borne coatings. Hazardous waste disposal and the discharge of contaminated water, however, are considerably less.

- *Radiation Cured Coatings* – cure when they are exposed to specific wavelengths of ultraviolet (UV) or electron beam (EB) radiation. VOC emissions are very low, even approaching zero for some formulations because curing takes place without the need for solvents to evaporate. While EB coatings receive energy from an electric heated filament or cathode, low-pressure mercury arc lamps generate the energy to cure the UV curable coatings. In order to ensure a consistent film cure, the mercury arc lamps must be positioned within a few inched of the coated substrate. This is why the substrate must have a very simple geometry, such as a flat or uniformly round shape. Adding colored pigments to the formulation retards curing and extends curing times; therefore, most of the coatings being used are clear.
- *Unicarb System* – is designed to use liquid carbon dioxide (CO_2) as a solvent for coatings. Because of the excellent solubility characteristics of CO_2 (non VOC), additional solvents can be added to the conventional or high solids coating resins. The Unicarb System is a two component delivery system, where the coating resin and CO_2 are feed to and mixed at the spray gun. The coating viscosity drops to a manageable level and excellent atomization takes place.

Benefits of Specialized Coatings

- Radiation cured coatings and autodeposited coatings can have VOC contents that approach zero.
- Autodeposition and electrodeposition generate minimal water pollution.
- Autodeposition and electrodeposition pose little or no fire hazard.
- Autodeposition coatings are non-toxic.
- Autodeposition and electrodeposition have high transfer efficiencies, therefore minimizing waste.
- Electrodeposition can be applied to steel, galvanized steel, and aluminum, to provide a hard, flexible, corrosion resistant coating.
- Vapors for radiation-cured coatings are easily exhausted with no measurable air quality damage.
- Extremely short curing times are possible with radiation curing.
- The Unicarb System can reportedly reduce VOC emissions by as much as 50 to 80 percent, and increase transfer efficiency by up to 30 percent.

Limitations of Specialized Coatings

- Specialized coatings are not applicable in most situations.
- Autodeposition and electrodeposition are only cost-effective for large production shops with high throughput.
- Autodeposition is only applicable for steel substrates.
- Radiation cured coatings are limited to substrates with simple geometries, such as flat or uniformly round shapes.
- Health concerns have been raised in the radiation curing industry over operator exposure to hazardous vapors.
- The capital expense associated with switching from a conventional system to Unicarb is relatith\267

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the equipment used to apply the paint directly reduces the amount of waste and air emission generated from the application through source reduction.

The most important equipment to affect transfer efficiency, and thus pollution prevention, in a paint and coating facility is the spray gun. The conventional air atomizing spray gun described in the process description section is considered to have a low transfer efficiency, therefore, creating excessive air emissions

<u>*Notes*</u>

medium- and large-size targets, and in some cases to coat small parts, providing surprisingly appealing finishes.

EPA transfer efficiency table values which appear in various EPA documents, such as Control Technique Guidelines, New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants, are approximately 40 percent for the air-assisted airless spray gun.

Benefits of Air-Assisted Airless Spray Guns

- Reduces air emissions and waste generation from overspray.
- Effective in coating large surface areas quickly.
- Can be adjusted to coat small and medium sized parts with a quality finish.
- Transfer efficiencies of 40 percent and greater can be obtained.

Limitations of Air-Assisted Airless Spray Guns

- Poorly atomizes the top and bottom of the fan.

<u>*Electrostatic Spray Guns*</u>

This category of spray guns embraces a wide range of technologies; electrostatic guns can use conventional air, airless, air-assisted airless, and HVLP atomizing technologies. The paint operator has a wide range of spray gun designs from which to choose.

All of the electrostatic technologies have one thing in common: the gun imparts an electrostatic charge to the coating particles as they emerge from the spray gun nozzle. The operator must be sure to ground the target well so that the charged coating particles will be attracted to the grounded part and deposit

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Limitations of Electrostatic Spray Guns

- An electric hazard is introduced into the paint application process.
- Poor grounding can result in lower transfer efficiency rates.
- Application specifications and operating procedures are more stringent than other spray gun application technology.
- Extensive operator training is required.

Improved Spray Application Techniques

In addition to purchasing new spray application equipment, improving your facilities current spray techniques will also reduce waste volumes with little to no capital expense. The following list provides some suggested improved application techniques.

- Move Closer to the Part – A typical gun to target distance should be 8 to 12 inches. In general, as the distance increases, transfer efficiency diminishes.
- Reduce The Fluid Flow Rate – If the fluid pressure and corresponding fluid flow rate are high, the stream of paint emerging from the spray gun travels a relatively long distance before bending and falling to the ground. Such a flow rate has a very short residence time within the spray gun and requires a large amount of energy for proper atomization.
- Optimize The Fan Width – Properly adjust the fan width of the spray gun to match the size of the part; especially, when changing part size and geometry frequently to reduce overspray.
- Optimize The Painting Pattern (Gun-Stroke) – Reduce the size of the leading and trailing edges of the spray stroke while eliminating overlap in painting strokes.

Benefits of Improved Spray Application Techniques

- Reduced air emissions.
- Reduced wastes from clean-up operations.
- Lower raw material costs.
- Increased air filter life span.

Limitations of Improved Spray Application Techniques

There are no limitations associated with improving spray application techniques.

5.8.3.2 Recycling

There are no recycling options available for the paint application process due to the nature of the process.

5.9 Paint Removal

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separate from the substrate. This approach, however, generates organic vapors, which raise concerns about threats to worker health and about damage to the ozone layer of the atmosphere, as well as considerable sludge and wastewater laden with solvent.

Common methods for applying chemical paint strippers include immersion in dip tanks and spray, brush, or roller application. Other conventional paint stripping methods consist of propelling a dry media (sand, aluminum oxide) at the surface to remove the coating though impaction or abrasion. Although dry media, such as sand, is considered environmentally better than traditional chemical solvents, such as methylene chloride, a large solid waste stream is generated because the recyclability rate of the media is generally low, or none at all. In addition, airborne particulates are created from the blasting process that may or may not contain heavy metals (dependent on the media and type of coating being removed) which also raises worker health concerns.

5.9.2 Waste Description

The types of wastes generated from paint stripping depend on the method of removal being employed. Chemical paint strippers typically generate air emissions (VOCs or HAPs), spent stripping baths, sludge (containing both solvent and removed paint), and contaminated rinsewaters. While, dry media paint strippers typically only generate spent abrasives commingled with the removed coating and air emissions in the form of dust particulates). With dry media stripping techniques, the major concern is dust emissions and

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process requirements (material compatibility) and an appropriate financial review (i.e., payback period, etc.) should be conducted.

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Benefits of Solvent Based Paint Removers

- Minimizes hazardous waste disposal.
- Reduces HAP emissions from immersion tank paint stripping operations.
- Eliminates exposure to solvents.
- Meets environmental regulations regarding the use of ozone depleting substances (ODSs).

Limitations of Solvent Based Paint Removers

- Slower paint removal rates than methylene chloride.
- Increased cost for nonhalogenated solvents per gallon.
- Reduced lifespan of solvent.

Aqueous Based

Parts can be stripped of paint using aqueous based chemicals at elevated temperatures. These chemicals are biodegradable and can be discharged into the sewer system, virtually eliminating hazardous waste disposal costs. However, certain hazardous constituents in the paint may contaminate the solution. Local discharge regulations will need to be evaluated prior to discharging or disposing the contaminated solutions.

Unlike the traditional practices of using a cold tank in conjunction with chlorinated solvents, no chlorinated solvent waste streams are generated with a heated tank using aqueous/biodegradable cleaners. Effluent streams associated with the use of heated immersion tank aqueous strippers would be the aqueous solution and sludge products composed of paint, grease, oil, and dirt. The parts requiring stripping are immersed into the solution and then agitated to speed up the stripping process. In conjunction with optional equipment such as filtration systems and skimmers, the chemical solution may be recycled and used again.

Most of the aqueous strippers are alkaline in nature. These are different from acid strippers in that acid strippers may attack the metal parts, causing structural weakening (hydrogen embrittlement). In addition, acid stripent wpsT -11.2   -36 -fj   -36 -11.25krts requiring8oiTmly elquirinareeeduatilizion syocess. aft sysipping p Tj   22041 0 TD 0 Tc

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Plastic Media Blasting (PMB)

Plastic Media Blasting (PMB) is a dry abrasive blasting process designed to replace chemical paint stripping operations and conventional sand blasting. This process uses soft, angular plastic particles as the blasting medium.

PMB is performed in a ventilated enclosure such as a small cabinet (glove box), a walk-in booth, a large room, or airplane hanger. The PMB process blasts the plastic media at a much lower pressure (less than 40 psi) than conventional sand blasting. PMB is well suited for stripping paints, since the low pressure and relatively soft plastic medium have minimal effect on the surfaces beneath the paint.

Plastic media are manufactured in 6 types and a variety of sizes and hardness. The plastic blasting media types are:

- Type I Polyester (Thermoset),
- Type II Urea formaldehyde (Thermoset),
- Type III Melamine formaldehyde (Thermoset),
- Type IV Phenol formaldehyde (Thermoset),
- Type V Acrylic (Thermoplastic), and
- Type VI Polyallyl diglycol carbonate) (Thermoset).

PMB facilities typically use a single type of plastic media for all PMB work. For example, the majority of Department of Defense (Air Force, Army, Navy) PMB facilities use either Type II or Type V media. Type V media is not as hard as Type II media and is more gentle on substrates. Type V media is more commonly used on aircraft. Type II is better for steel surfaces.

After blasting, the media is passed through a reclamation system that consists of a cyclone centrifuge, a dual adjustable air wash, multiple vibrating classifier screen decks, and a magnetic separator. In addition, some manufacturers provide dense particle separators as a reclamation system. The denser particles, such as paint chips, are separated from the reusable blast media, and the reusable media is returned to the blast pot. Typically, media can be recycled ten to twelve times before it becomes too small to remove paint effectively. Waste material consists of blasting media and paint chips. The waste material may be classified as a RCRA hazardous waste because of the presence of heavy metals. An alternative solution to handling this hazardous waste is to locate a vendor that will "lease" blast media to an installation and then recycle the media to recapture the metals. This option eliminates media waste from the PMB facility waste stream.

Benefits of Plastic Media Blasting

- Media can be recycled for use approximately 10-12 times.
- Wastewater disposal costs (typical in chemical paint stripping operations) are virtually eliminated with PMB.
- Eliminates the production of waste solvents when compared to chemical paint stripping.

Limitations of Plastic Media Blasting

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Wheat Starch Blasting

Wheat starch blasting is a user-friendly blasting process wherein wheat starch can be used in systems designed for plastic media blasting (PMB), as well as systems specifically designed for wheat starch blasting. The wheat starch abrasive media is a crystallized form that is non-toxic, biodegradable, and made from renewable resources. The media is similar in appearance to plastic media, except that it is softer.

The wheat starch blasting process propels the media at less than a 35-psi nozzle pressure for most applications. The low pressure and relatively soft media have minimal effect on the surfaces beneath the paint. For this reason, wheat starch

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Sponge Jet Blasting

Sponge jet blasting is a form of abrasive blasting which uses grit-impregnated foam and foam without grit as the blasting media. The sponge blasting system incorporates these various grades of the water-based urethane-foam for use as a cleaning media to prepare the surfaces, and the abrasive media grades

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a charcoal filter, microfilters and, finally, a deionization system to ensure that the water is Grade A deionized water. The recovered deionized water is recycled back into the process.

Benefits of High Pressure Water Jet Blasting

- Reduces hazardous waste by 90%.
- Selectively removes individual coating-layers.
- Pre-washing and masking is not needed in most applications.
- No size limitations for parts being stripped.
- Wastewater stream is compatible with conventional industrial wastewater plants.
- Reduces the process material costs significantly.
- Reduces labor hours for the stripping process by 50%.
- No dust or airborne contaminants generated.
- Requires no cleanup after stripping.

Limitations of High Pressure Water Jet Blasting

- High capital costs.
- Removes one layer at a time.
- May not remove corrosion.
- The substrates to be removed will impact personal protection and waste collection/disposal considerations.
- Coating debris sludge is a potential hazardous waste.

Sodium Bicarbonate Blasting

Sodium bicarbonate stripping processes are used as alternatives to traditional chemical paint stripping. Bicarbonate of soda (or sodium bicarbonate) is a soft blast media with a heavier specific gravity and less hardness than most plastic abrasives. The bicarbonate of soda stripping process can be used with or without water. It is most frequently used with water, which acts as a dust suppressant. In this form, compressed air delivers the sodium bicarbonate medium from a pressure pot to a nozzle, where the medium mixes with a stream of water. The soda/water mixture impacts the coated surface and removes old coatings from the substrate. The water used dissipates the heat generated by the abrasive process, reduces the amount of dust in the air, and assists in the paint removal by hydraulic action. Workers do not need to prewash or mask the surface of the material being stripped. Settling or filtration can separate the solid residue from the wastewater generated from this process.

The effectiveness of bicarbonate of soda stripping depends on optimizing a number of operating parameters, including nozzle pressure, standoff distance, angle of impingement, flow rate, water pressure, and traverse speed. In general, bicarbonate of soda stripping systems remove paint slower than most methods (other than chemical paint stripping) currently used. The type of equipment used in this stripping process may also have significantly different results.

Use of sodium bicarbonate in its dry form (or when not fully mixed with water) can create a cloud of dust that will require monitoring and may require containment to meet air standards and worker exposure g 5h35 0 TD 0.14187p

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bicarbonate, thus reducing the risk. Be sure to have a local Industrial Health Specialist check the air for any resident metals.

The waste generated from bicarbonate of soda stripping systems in the wet form is wet slurry consisting of sodium bicarbonate medium, water, paint chips, and miscellaneous residues such as dirt and grease. Some installations are employing centrifuges to separate the water from the contaminated waste stream, thus reducing the amount of hazardous waste being disposed. Filtered wastewater containing dissolved sodium bicarbonate may be treated at an industrial wastewater treatment plant. In its dry form, waste generated includes nuisance dust, paint chips, and miscellaneous residues such as dust and grease. The solid waste may be suitable for disposal in a sanitary landfill. Analysis of wastewater and waste solids is required prior to disposal. Wastewater and bicarbonate residue disposal requirements will depend on the toxicity of the coatings and pigments to be removed. The sodium bicarbonate medium can not be recycled. The paint chip,

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Limitations of Laser Stripping

- Characteristics of both the contaminant and substrate must be known so that the optimal absorption frequency can be used.
- The system is time and equipment intensive.

Cryogenic Stripping

Cryogenic paint stripping can be classified into the following two categories:

- Carbon dioxide pellet blasting, and
- Liquid nitrogen blasting.

A brief description of each type of technology is provided below with associated benefits and limitations.

Carbon Dioxide Pellet B

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- Leaves no residue on the component surface.
- Effective in precision cleaning.
- Introduces no new contaminants.

Limitations of Carbon Dioxide Pellet Blasting

- CO_2 blasting is not always a one-pass operation; an effective blasting operation usually requires multiple passes to achieve the desired effect.
- Can have high capital costs.
- Fixed position blasting operation can damage the component's surface.
- Generates solid waste containing coating chips that are potentially hazardous; medium does not add to the volume of solid waste.
- Rebounding pellets may carry coating debris and contaminate workers and work area.
- Some coating debris may redeposit on substrate.
- Nonautomated system fatigues workers quickly because of cold temperature, weight, and thrust of the blast nozzle.

Liquid Nitrogen Blasting

Liquid nitrogen cryogenic blasting is a variation of the PMB method that involves chilling the work piece to embrittle the coating before subjecting it to impaction with a plastic media. The piece is sprayed with liquid4itrogen in3to pratus which ium doroplas 0 in Tj 11774mine by0689ow wheel5 Tw (213 -135 -18 TD /F3 9.75 Tf 0

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- *Screen Printing* - employs a porous screen of fine silk, nylon, or stainless steel mounted on a frame. Printing is done on the paper by applying ink to the screen, then spreading and forcing ink through the fine openings with a rubber squeegee. Versatility is the major advantage of screen printing since any surface (e.g., wood, glass, metal, plastic, fabric. etc.) can be printed.

The principle raw materials used by the commercial printing industry are inks and substrates. A substrate is any material upon which ink is impressed, such as paper, plastic, wood, or metal.

Other raw materials used by the industry include gravure cylinders, photographic films, photoprocessing chemicals developers, fixers, wash baths, reducers, intensifiers, printing plates, plate processing chemicals, fountain solutions, cleaning solvents, and rags. Exhibit 5.12 illustrates a typical commercial offset lithographic printing operation. Printing begins with the preparation of artwork or copy, which is photographed to produce an image. A proof is made which will be used to compare with the printed product and make adjustments to the press. The photographic image is transferred to a plate. In the platemaking step, the image areas of the plate are made receptive to the ink. In the printing step, ink is applied to the plate, then transferred to rubber blanket and then to the substrate.

The substrate accepts the ink, reproducing the image. The substrate is then cut, folded, and bound to produce the final product. Printing can be divided into six separate steps: (1) image processing, (2) proofing, (3) platemaking, (4) makeready, (5) printing, (6) finishing. The operations involved in these steps are summarized below.

5.10.1.1 Image Processing

Most printing operations begin with art and copy (or text) preparation. Once the material is properly arranged, it is photographed to produce transparencies. If an image is to be printed as a full color reproduction, then color separations are made to provide a single-color image or record which can then be used to produce this single –color printing plate for lithography or the cylinder for gravure. Once the film has been developed, checked, and re-photographed (if necessary), it is sent on to the plate- or cylinder-making operation.

The printing industry employs graphic arts photography in the reproduction of both artwork and copy, using materials similar to those in other fields of photography. The materials include a paper, plastic film, or glass base cover with a light-sensitive coating called a photographic emulsion. This emulsion is usually composed of silver halide salts in gelatin. Silver halides include silver chloride, silver bromide and silver iodide.

Some processes such as letterpress or lithography use a photographic negative to transfer an image to the plate. Gravure, screen printing, and other lithographic processes require positives. These are produced by printing negatives onto paper or film. The resulting images have tone values similar to the object or copy that was photographed.

5.10.1.2 Proof

A proof is produced after the image processing step as part of internal job control, and it may also serve as a communication tool between printer and client. It is used for both single-color and multi-color printing.

5.10.1.3 Plate Processing

The type of printing process depends on the intermediate image carrier, a plate or cylinder that accepts ink off a roller and transfers the image to a rubber blanket. The blanket, in turn, transfers it to the paper. The type of ink and press used, number of impressions that can be printed, the speed with which they are printed, and the characteristics of the image are all determined by the type of image carrier.

The four different types of image carriers generally used are manual, mechanical, electrostatic, and photomechanical.

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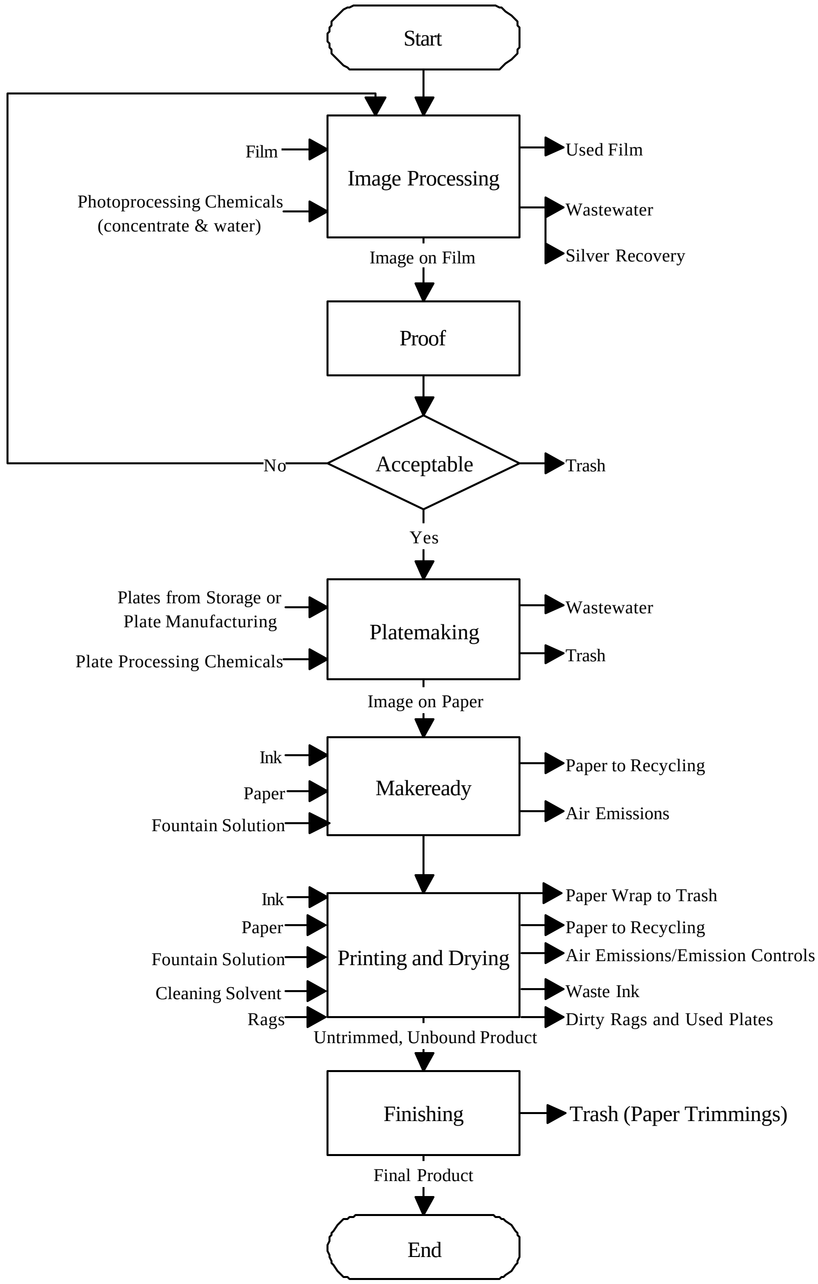
Exhibit 5.12: Process Flow Diagram for a Typical Commercial Printing Operation



- *Manual Image Carriers* – consist of hand-set composition, wood cuts, linoleum blocks, copperplate or steel-die engravings. Manually made images are seldom used now except for commercial use in screen printing.
- *Mechanical Image Carriers* – are produced mainly for relief printing. There are two categories: (1) hot metal machine composition and (2) duplicate printing plates. Intaglio printing also uses mechanically made plates. These include pantograph engravings, used for steel-die engraving, and engraving made with geometric lathes, which produce scrolls for stock and bond certificates and paper currency. Mechanically made gravure cylinders are also used for printing textiles, wrapping papers, wallpapers, and plastics.

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amount of replenisher chemical required. However, squeegees must be used only after the film image has hardened, because they can damage the image if it has not fully hardened.

During photographic processing, films are commonly washed with water, using parallel tanks systems to remove hypo from the emulsion. In a parallel system, fresh water enters each wash tank and effluent leaves each wash tank. Employing a countercurrent washing system can increase the removal efficiency of hypo.

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- Countercurrent rinse tanks can decrease the amount of wastewater generated, and increase efficiency.
- Presensitized lithographic plates, plastic plates, or hot metal plates can replace hazardous waste generating metal etching or plating processes.

Limitations of Plate Processing Changes

- Countercurrent rinse systems require a large amount of floor space and a high initial equipment cost.
- Modifying the type of plates used can be expensive.

Makeready

Paper is the largest raw material item and is the most expensive component of the printing operation.

<u>*Notes*</u>

Although UV inks reduce the amount of waste generated, they cost 75 to 100 percent more than conventional heat-set inks and some of the chemicals in these inks are toxic. In addition, conventional commercial paper recycling procedures cannot de-ink papers printed by UV inks.

- *Automatic blanket cleaners* - can also be used to increase efficiency, thereby reducing the amount of

Notes

Silver and Other Photoprocessing Chemicals

Basically, photoprocessing chemicals consist of developer, fixer, and rinse water. Keeping the individual process baths as uncontaminated as possible is a prerequisite to the successful recycling of these chemicals. Silver is a component in most photographic films and paper and is present in the wastewater produced. Various economical methods of recovering silver are available (e.g. metallic replacement, chemical precipitation, electrolytic recovery), and a number of companies market equipment that will suit the needs of even the smallest printing shop.

A common method of silver recovery is electrolytic deposition. In an electrolytic recovery unit, a low voltage direct current is created between a carbon anode and a stainless steel cathode. Metallic silver plates onto the cathode. Once the silver is removed, the fixing bath may be able to be reused in the photographic development process by mixing the de-silvered solution with fresh solution. Recovered silver is worth about 80% of its commodity price.

Another method of silver recovery is metallic replacement. The spent fixing bath is pumped into a cartridge containing steel wool. An oxidation-reduction reaction occurs and the iron in the wool replaces the silver in the solution. The silver settles to the bottom of the cartridge as sludge.

To recycle used film, it may be worthwhile to sort the film into “largely black” versus “lar segments, since the rate of payment for mostly black film may be twice that for mostly clear.

Technologies for reuse of developer and fixer are available and include ozone oxidation, electrolysis, and ion exchange.

Benefits of Silver Recycling

- Equipment that will suit the needs of even the smallest printing shop is available.
- Reduces the mass of waste entering the wastesteam.
- Allows the fixing bath to be reused.
- The recovered silver is worth approximately 80% of the commodity price.

Limitations of Silver Recycling

- For economic reasons, film should be separated into “mostly black” versus “mostly clear.”

5.11 Waste Water Treatment

Water is an indispensable part of almost all industrial activities and in most cases becomes contaminated during the process. Many industrial plants have pre-treatment processes for wastewater to reduce the quantities or toxicity of pollutants in the wastewater. In most cases this is required when the publicly-owned treatment works (POTW) is not equipped to hand the contaminants in a particular facilities wastewater.

The POTW must process wastewater from a variety of sources including communities, industrial processes, commercial usage (office buildings and small businesses) and storm and ground water. Wastewater is 99.94 percent water with the remainder being contaminates in the form of dissolved or suspended solids. The suspended matter is often referred to as “suspended solids” to differentiate it from pollutants in solution. “Sewage” usually connotes human waste, but the term also includes everything else that makes its way from homes to sewers, coming from drains, bathtubs, sinks, and washing machines. There are basically three types of sewage systems that convey wastewater:

- Sanitary Sewer System - A system that carries liquid and water carried wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground, storm, and surface wastes that are not admitted intentionally.
- Storm Sewer System - A system that carries stormwater and surface water, street wash and other

- Combined Sewer System - A system intended to receive both sanitary wastewater and storm or surface water.

This section briefly discusses wastewater pretreatment.

Notes

5.11.1 Process Description

Wastewater is generated in many of the operations discussed earlier in this chapter. Many of these facilities will be required to pretreat their wastewater prior to discharge to the sanitary sewer. Pretreatment of wastewater usually involves flocculation, pH adjustment, settling to remove solids. Sometimes

Notes

prevent mixing by the wind. Shallow ponds are usually aerobic; meaning that oxygen is present, throughout; only a layer of sludge on the bottom being anaerobic. Algae grow by taking energy from the sunlight and consuming the carbon dioxide and inorganic compounds released by the action of the bacteria in the pond. The algae, in turn, release oxygen needed by the bacteria to supplement the oxygen introduced into the lagoon by the wind action. The most critical factor is to insure that enough oxygen will be present to maintain aerobic conditions. Otherwise odor problems can be bothersome. The sludge from the bottom has to be periodically removed by dredging. Advantages of oxidation ponds are easy construction, simple operation and maintenance. Among disadvantages are large space requirements and frequent removal of algae from the effluent.

Exhibit 5

Notes

5.11.2 Waste Description

There are two wastes produced from wastewater treatment operations: water and sludge. The water is discharged to the sanitary sewer if it meets discharge permit limits. The sludge is disposed of as either hazardous or non-hazardous waste depending on the plant operations and constituents in the sludge.

5.11.3 Pollution Prevention Opportunities

Pollution prevention opportunities for wastewater treatment processes are classified according to the waste management hierarchy in order of relevance; first, source reduction techniques, then secondly, (in-process) recycling options.

5.11.3.1 Source Reduction

There are many source reduction opportunities for wastewater as discussed in earlier sections of this chapter.

5.11.3.2 Recycling

Recycling and reuse opportunities exist both on and off-site for facilities. Recycling and reuse have innumerable benefits both financially and environmentally.

In some cases it is possible to recycle water before it reaches the wastewater treatment process the assessment team should review sources of wastewater carefully to evaluate possible opportunities for reuse of water in process. Other times it may be possible to reuse a portion of treated wastewater in less critical plant operations or to reclaim contaminants from the wastewater. For example, it may be possible to process waters containing high concentrations of metal through an electrolytic recovery unit (or other equipment of similar function) to reclaim the metals in the water for later reuse or recycling.

Notes

REFERENCES

1. *Guide to Cleaner Technologies, Cleaning and Degreasing Process Changes*: 1994; U.S. Environmental Protection Agency. Office of Research and Development, Washington DC 20460. EPA/625/R-93/017
2. *Guide to Cleaner Technologies, Alternatives to Chlorinated Solvents for Cleaning and Degreasing:* 1994; U.S. Environmental Protection Agency. Office of Research and Development, Washington DC 20460. EPA/625/R-93/016.
3. Callahan and Green; *Hazardous Solvent Source Reduction*: 1995; McGraw-Hill, New York, 10020; ISBN 0-07-009749-6.
4. *Manual: Pollution Prevention in the Paints and Coatings Industry*: 1996; U.S. Environmental Protection Agency. Office of Research and Development, Washington, DC 20460. EPA/625/R-96/003.
5. *International Waste Minimization Approaches and Policies to Metal Plating*: 1996; U.S. Environmental Protection Agency. Office of Solid Waste, Waste Minimization Branch, Washington, DC 20406. EPA/530/R-96/008
6. *Guide to Cleaner Technologies, Alternative Finishes*: 1994; U.S. Environmental Protection Agency. Office of Research and Development, Washington, DC 20406. EPA/625/R-94/007.
7. Freeman, Harry M., *Industrial Pollution Prevention Handbook*, 1995; McGraw-Hill, New York, NY 10020; ISBN 0-07-022148-0.
8. Joint Services Pollution Prevention Handbook, “Paint Stripper, Hot Tank,” Revision: 8/96; Internet address: Http://enviro.nfesc.namy.mil/p2library/8-27_896.html
9. Joint Services Pollution Prevention Handbook, “Paint Stripping Using Wheat Starch Blasting,” Revision: 8/96; Internet address: Http://enviro.nfesc.namy.mil/p2library/5-07_896.html
10. Joint Services Pollution Prevention Handbook, “Degreasing and Paint Stripping Using Sponge Blasting,” Revision: 7/96; Internet address: Http://enviro.nfesc.namy.mil/p2library/5-06_796.html
11. Joint Services Pollution Prevention Handbook, “High and Medium Pressure Water Paint Stripping 8/96; Internet address: Http://enviro.nfesc.namy.mil/p2library/5-02_896.html
12. Joint Services Pollution Prevention Handbook, “Paint Stripping Using Sodium Bicarbonate Medium,” Revision: 8/96; Internet address: Http://enviro.nfesc.namy.mil/p2library/5-02_896.html
13. 12th Annual Aerospace Industry, Hazardous Materials Management Conference, “FLASHJET Paint Stripping Effects on Material Properties”, Conference Proceedings from August 1997, Technology Group 2.
14. Joint Depot Maintenance Analysis Group Technology Assessment Division, *9*.

Notes

Replacement of underloaded motors with smaller motors will allow a fully loaded smaller motor to operate at a higher efficiency. This arrangement is generally most economical for larger motors, and only when they are operating at less than one-third to one-half capacity, depending on their size.

The identification of oversized motors will require taking electric measurements for particular pieces of equipment. The recording wattmeter is the most useful instrument for this purpose to analyze the load over a representative period of time.

Another approach that provides an instantaneous reading is to measure the actual speed and compare it with the nameplate speed. The fractional load, as a percent of full nameplate load, can be determined by dividing the operating slip by the full-load slip. The relationship between load and slip is nearly linear. Other s

For example, the annual savings for replacing a 50-horsepower motor operating at 25 percent of rated load with a 15-horsepower motor that will operate near full load is:

$$L_{FL} = 0.746\,(hp)\left(\frac{1}{Eff_{FL} - 1}\right)$$

Notes

$$L_{PL} = 0.746\,(hp)\,(PL)\left(\frac{1}{Eff_{PL} - 1}\right)$$

where

L = losses - kW

Eff = motor efficiency

subscripts

FL = at full load

PL = at partial load

$$L_{FL} = 0.746(15)\left(\frac{1}{0.90} - 1\right) = 1.24kW$$

$$L_{PL} = 0.746(50)(0.25)\left(\frac{1}{0.837} - 1\right) = 1.82kW$$

Reduction in Losses = 0.58 kW

Annual Savings = 0.58 kW x 6,000 hrs/yr x $0.05/kWh = $174

<u>*Notes*</u>

Each of these factors has its own variables, including changes in production schedules, variations in motor load, and demand charges. Some of these figures may be difficult to pinpoint.

Even when savings calculations are attempted, they can be subject to error because the actual efficiency of the particular motor is generally not known. All manufacturers do not use the same test technique to measure efficiency; as a result, ratings stamped on nameplates may not be comparable. Most manufacturers in the United States use a "nominal" efficiency that refers to a range of efficiencies into which a particular motor's efficiency must fall. Statistical techniques are used to determine t efficiency of a motor with any given nominal efficiency. For example, a nominal efficiency of 90.2 percent has a minimum efficiency of 88.5 percent.

Many users report adopting high-efficiency motors as standard practice without attempting to justify the premium except in the case of larger-sized motors. In general, paybacks of approximately one year have been experienced.

Published ratings vary for specific motors. For instance, a 100-hp, 1,800-rpm, totally enclosed, fan-cooled motor from one manufacturer has a guaranteed minimum efficiency of 90.2 percent at full load in the standard line and 94.3 percent in the high-efficiency line. The equivalent size motor of another manufacturer has the same 90.2 efficiency rating for the standard model, but the high-efficiency model has a guaranteed minimum efficiency of 91.0 percent. Verification of actual efficiency of a particular motor requires the use of sophisticated testing equipment.

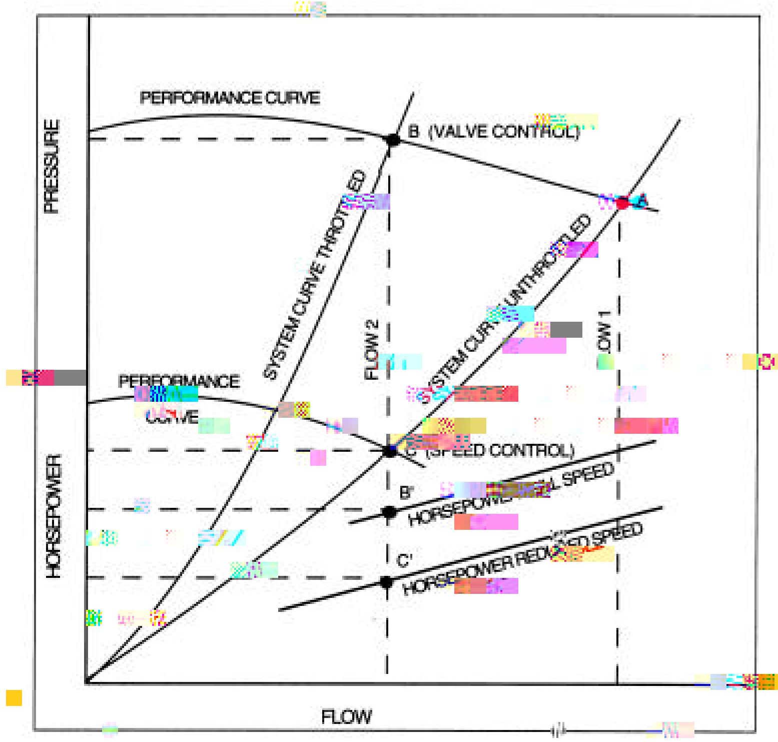
Because of this variation, the use of the guaranteed minimum efficiency is more conservative in evaluating savings because all motors should be equal to or higher than the value specified. Exhibit 6.2 and Exhibit 6.3 compare standard T-frame TEFC motors with high-efficiency motors.

Exhibit 6.2: Typical Efficiency Comparison for 1 800 rpm Motors: General Electric

	Standard T-Frame TEFC				**High Efficiency TEFC**			
	Nominal Average Expected Efficiency			Guaranteed Minimum	Nominal Average Expected Efficiency			Guaranteed Minimum
Horse power	Full Load	75% Load	50% Load	Full-Load Eff	Full Load	75% Load	50% Load	Full-Load Eff
10	83.0	82.0	81.0	Not Available	90.2	91.0	91.0	88.9
15	84.0	84.0	83.0		91.7	92.4	92.4	90.6
20	86.0	87.0	87.0		93.0	93.6	93.6	92.0
25	86.0	87.0	87.0		93.0	93.6	93.0	92.0
30	88.0	88.0	88.0		93.0	93.6	93.6	92.0
40	88.0	88.0	87.0		93.6	94.1	93.6	92.7
50	89.0	89.0	89.0		94.1	94.1	94.1	93.3
75	91.5	91.5	91.0		95.0	95.0	94.5	94.3
100	92.0	92.0	91.0		95.0	95.0	95.0	94.3 91.5
125	91.5	91.5	90.0		95.0	95.0	94.1	94.3

<u>*Notes*</u>

Exhibit 6.4: Fan Drive: Variable Speed vs. Valve Control



Notes

Consequently, significant savings are possible when speeds can be reduced. The new fan horsepower with variable speed is show in Exhibit 6.6.

Exhibit 6.6: Fan Horsepower with Variable Speed Motor

CDM%	Fan hp	Duty Cycle	Weighted hp
100	35	10	3.5
80	18	40	7.5
60	7.56	40	3.024
40	2.24	10	0.224
		Total	13.948

The variable speed drive requires less than half the energy of the outlet damper for this particular duty cycle.

The annual savings (AS) is:

AS = (32.6 hp - 13.948 hp) x 6,000 hrs x $0.041/hp-hr = $4,590/yr

The installed cost of variable drive for a 35-hp motor is approximately $10,000. Equipment costs per hp decrease significantly with size, starting at about $250/hp for a 75-hp motor.

In actual practice, the efficiency of the motor should be factored in for a more accurate saving calculation based on kW input. The efficiency of the motor begins to drop significantly below 50 percent of rated capacity.

The above calculations assume a free discharge. If a static head is present, as in the case of a pump, the static head changes the system curve so that the affinity laws Tjr5 re f.103 0 3.948

The above 09lculation sassume a 5 -12 d75 -11n0.2taiimatanalys th3 0 3.94id f.103com35.ei

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the belt contacts the sheaves. The chief advantages of mechanical drives are simplicity, ease of maintenance, and low cost. Their chief disadvantage is a moderate degree of maintenance and less accurate speed control (normally 5 percent).

Notes

Exhibit 6.7: Dupont Recommended Light Levels for Service Building Interiors (Cont.)

Area	Footcandles* in Service	Area	Footcandles* in Service
Tool cribs	30	Auxiliaries, boiler feed pumps, tanks, compressors, power switchgear, battery rooms, screen house, intake well, transformer rooms, etc.	20
Gate houses		Catwalks	3
Pedestrian entrance	20	Water-treating area	20
Car entrance	5	Refrigeration compressors, air compressors, etc.	20
Solvent storage and dispensing		Pump houses	20
Storage in drums	5	Warehouses--general traffic area	5
Dispensing	10	Warehouses (in storage area)	[illegible]

5

D

Notes

Exhibit 6.9: Dupont Recommended Illumination Levels for Outdoor Areas*

Area	Footcandles* in Service	Area	Footcandles* in Service
Bulletin and poster boards	10-V	Railroad yards	0.2
Flood lighting-building exteriors	15-V(max)	Roadways	
Entrances		Curves and intersections	0.5
Active (pedestrian or conveyance or both)	5	Platforms, catwalks, stairs, ladders, etc.	
Inactive (normally locked, infrequently used)	0.5	Platform operating decks	5
Loading and unloading platforms	3	Catwalks, stairs, and ladders	3
Protective lighting		Plant parking lots	
Boundaries and fence	0.2	General parking areas	0.3
Vital locations or structures	5	Entrances, exits, and walkways	2
Building surroundings	1	Gasoline dispensing pumps	3
General inactive area	0.1	Outdoor work areas	3

* As a matter of reference in comparing outdoor lighting values, the intensity of full moonlight a the earth's surface is approximately 0.025 footcandles.

6.2.2 Light Meter Audit

After standards have been adopted, a light meter audit to determine the existing lighting levels should be conducted for the entire facility. The condition of the lamps and fixtures should be taken into account when the audit is made. The cleanliness of the fixtures has an important effect on the light output. Also, some depreciation of light intensity occurs over the life of most lamps. If group relamping has been used, the lighting level will depend on the age of the lamps. Light loss of 10 to 15 percent is normal for standard 40 W fluorescent lamps that are approaching end of life.

6.2.3 Methods to Reduce Costs

Notes

are more tolerant of starts and the increased cost of energy compared with the tube cost. The break-even point for fluorescent lighting is usually 5 to 15 minutes, depending on the electric rate, lamp cost, and lamp replacement labor rate. With incandescent lights, however, energy will be saved each time they are turned off. For high-intensity discharge (HID) lamps, it is usually not practical to turn lights off for brief periods (less than 30 minutes) because of the long lamp restart time.

6.2.3.2 Automatic Controllers

A technique for ensuring that lights are turned off when the room is unoccupied is to use presence detectors (infrared, capacitance, or ultrasonic)

6.2.3.5 Lower-Wattage Fluorescent Lamps and Ballasts

Notes

A reduction in fluorescent light level by removing lamps from service can result in a spotty effect that is unattrac

Notes

Initial problems of reliability with the electronic ballasts appear to have been overcome. Electronic ballasts, however, have many small components and a relatively short product history compared with the simple construction and long-established high reliability of the magnetic ballasts.

With electronic ballasts, approximately 10 less watts per two 34-

Notes

- Units are individually controlled, permitting them to be shut off when not needed.
- Lighting effectiveness is improved by permitting the most advantageous positioning. Reflection and shadows can be avoided.

6.2.3.8 Lighting System Replacement

Existing incandescent or mercury lighting systems are usually candidates for replacement. Incandescent lighting is suitable for certain applications, but its low efficiency makes it uneconomical for general illumination. A rapid payback can almost always be shown for replacing mercury with more efficient light sources, especially with high-pressure sodium.

If a lighting system must be designed to fit a new or modified installation, the alternative systems, listed with their relative outputs in Exhibit 6.10 should be considered.

High-pressure sodium (HPS) lamps provide the most light per energy input and are the most economical when their color characteristics are suitable (the decided yellow color of low-pressure sodium lamps is usually unsatisfactory for most industrial areas). This lamp is offered in a wide choice of wattages, ranging from a nominal 70 watts to 1,000 watts. Luminaire manufacturers also offer a broad variety of luminaires suitable for various applications in outdoor lighting, manufacturing, and office lighting.

Exhibit 6.10: Alternative Lighting Systems Approximate Initial Lumens per Watt Including Ballast

Type of Light	Smaller Sizes	Middle Sizes	Larger Sizes
Low Pressure Sodium	90	120	150
High Pressure Sodium	84	105	126
Metal Halide	67	75	93
Fluorescent	66	74	70
Mercury	44	51	57
Incandescent	17	22	24

Notes

6.2.4.1 Incandescent

The following features can describe incandescent lighting (light produced by heating an element until it glows).

- Main reason for use is color rendition and dimming, although recently dimming has been made available for other types of light.
- Reduced wattage / reduced output replacements are now available although no more efficient.
- One type of PAR lamp is now being offered which has an infrared reflective film that makes the filament hotter and brighter.

6.2.4.2 Fluorescent

Fluorescent lighting can be summed as follows:

- Light is produced by emitting an electronic field, causing the phosphorous to glow (fluoresce).
- More energy efficient.
- Varying levels of color rendering are available depending on the quality of the rare earth phosphors, and the cost. Color rendering is arbitrary way to compare the color of the light using sunlight as 100 percent.
- New T8 (one inch diameter) lamps produce light more efficiently than previous lamps, but must be used with electronic ballasts.
- Compact fluorescent - twin tube, exit signs.

6.2.4.3 High Energy Discharge

The following types of lamps fall under the high energy discharge category:

- Mercury Vapor,
- Metal Halide,
- High Pressure Sodium, and
- Low Pressure Sodium.

Notes

Notes

7.1.1.1 Boiler Efficiency Tips

Notes

8. The frequency and amount of blowdown depend upon the amount and condition of the feed-water. Check the operation of the blowdown system and make sure that excessive blowdown does not occur. Normally, blowdown should be no more than 1% to 3% of steam output.

Notes

Although blowdowns are an absolute necessity for the operation of a boiler, it is important that one realizes that, depending on the pressure, each blowdown decreases the efficiency of the boiler. Exhibit 7.5 illustrates the decrease in efficiency where the percent blowdown is calculated as follows:

$$\frac{\dot{M}_{\text{Blowdown}}}{\dot{M}_{\text{Steam Produced}}} \times 100$$

Note how sharply the efficiency loss increases with higher pressures.

Exhibit

Notes

Incomplete Combustion:

Carbon	+	Oxygen	=	Soot + Aldehydes
				Water
				CO_2
Hydrogen		Nitrogen		CO
				Nitrogen

Perfect combustion (referred to as stoichiometric combustion) is the process of burning the fuel without an excess of combustion air. This process should develop the "ULTIMATE CO_2" (see Exhibit 7.6).

Exhibit 7.6: Ultimate CO_2 Values

Fuel	CO_2 %
Natural Gas (can vary)	11.7-12.1%
Propane	13.7%
No.2 Oil	15.2%
No.4 Oil	16.0%

While these values can be sometimes achieved, Exhibit 7.7: Boiler Combustion Mixtures shows more realistic desired values.

Exhibit 7.7: Boiler Combustion Mixtures

Fuel	CO_2	O_2	Excess Air
Natural Gas	10.5%	3.5-4.0%	20%
Propane	11.5-12.0%	3.5-4.0%	20%
No.2 Oil	11.5-12.0%	3.5-4.0%	20%
No.4 Oil	12.5-13.0%	3.5-4.0%	20%

Carbon, in burning to carbon monoxide, gives off only about one third of the available heat. A one eighth inch coating of soot on the heat exchanger increases fuel consumption by over 8% as a rule of thumb. Incomplete combustion that results in the formation of CO is dangerous because it is odorless, colorless, tasteless, and contrary to popular belief, it is non-irritating. The gas is also lighter than air and consequently, if it is escaping from a plugged or leaking boiler fireside, can rise to occupied areas. CO can only be detected with special test or monitoring equipment.

Causes of Incomplete Combustion

1. Insufficient or too much oxygen
   - Air problems (rule of thumb - 1 cubic foot of air for every 100 Btus of gross heating value).
   - Minimum air intake openings for a given input.

     Oil - unconfined = 28 square inches per gallon

     Confined = 140 square inches per gallon

     Gas - draft hood = 1 square inch per 5,000 Btu

     Barometric = 1 square inch per 14,000 Btu

     Direct = 1 square inch per 17,500 Btu
2. Insufficient or too much fuel

Notes

- Fuel is not vaporized - possible reasons

  Worn nozzle

  Clogged nozzle

  Pump pressure is incorrect

  Pump, lines, filter or tank lines are clogged

  Cold fuel

- Water in fuel - possible causes

  Supplier doesn't supply quality fuel

  Tank is located outside

  Cover the fill opening and vent to protect from rain

3. Insufficient or inconsistent heat

   - The ignition system is used to provide the proper temperature (called kindling point) for the light off of the vaporized fuel under design conditions. When design conditions are not met, light off will not occur.
   - An established flame is usually sufficient to maintain the kindling point. However, anytime the combustion temperature falls below the kindling point, the combustion triangle is broken and combustion stops. A safety device will shut the fuel off within 3 seconds of flame failure.

<u>Calculating Combustion Efficiency</u>

The calculation of combustion efficiency is based upon three factors.

1. Chemistry of the fuel
2. Net temperature of the stack gases
3. The percentage of oxygen or carbon dioxide by volume in the stack gases

Eyeballing the flame for color, shape and stability is not enough for maximizing efficiency. Commercial analyzers are available to accurately gauge combustion efficiency. The simplest units measure only O_2 or CO_2. Exhibit 7.8 lists efficiencies for common heat generation devices.

Exhibit 7.8: Combustion Efficiencies

Process Type	Efficiency [%]
Fireplace	10-30
Space Heater	50-82
Commercial Atmospheric Gas Boiler	70-82
Oil Power Burner	73-85
Gas Power Burner	75-83
Condensing Furnace (Gas or Oil)	85-93

There are no standard performance efficiency levels that commercial boiler manufacturers must adhere to. Efficiency is reported in different terms:

- Thermal Efficiency – A measure of effectiveness of the heat exchanger that does not account for radiation and convection losses.

Notes

- Fuel to Steam Efficiency -

Notes

7.1.2.2 Elimination of Steam Leaks

Significant savings can be realized by locating and repairing leaks in live steam lines and in condensate return lines. Leaks in the steam lines allow steam to be wasted, resulting in higher steam production requirements from the boiler to meet the system needs. Condensate return lines that are leaky return less condensate to the boiler, increasing the quantity of required make-up water. Because make-up water is cooler than condensate return water, more energy would be required to heat the boiler feed water. Water treatment would also increase as the make-up water quantity increased. Leaks most often occur at the fittings in the steam and condensate pipe systems. Savings for this measure depend on the boiler efficiency, the annual hours during which the leaks occur, the boiler operating pressure, and the enthalpies of the steam and boiler feed water where enthalpy is a measure of the energy content the steam and feed water.

Exhibit 7.10 lists average cost savings and energy conservation from implementation of this opportunity.

Exhibit 7.10: Steam Leak Repair: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr) co492

Notes

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database. All values are averages based on the database data. The implementation rate for this measure was 33%.
2. One example from the IAC database to further clarify the costs is as follows: Installing variable speed drives and corresponding controls on two 250 hp combustion air fans at a food processing plant resulted in energy and cost savings of 488,445 MMBtu/yr and $28,000/yr. The implementation cost was $80,000.
3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

7.1.2.4 Maintenance of Steam Traps

A steam trap holds steam in the steam coil until the steam gives up its latent heat and condenses. In a flash tank system without a steam trap (or a malfunctioning trap), the steam in the process heating coil would have a shorter residence time and not completely condense. The uncondensed high-quality steam would be then lost out of the steam discharge pipe on the flash tank. Steam trap operation can be easily checked by comparing the temperature on each side of the trap. If the trap is working properly, there will be a large temperature difference between the two sides of the trap. A clear sign that a trap is not working is the presence of steam downstream of the trap. Non-working steam traps allow steam to be wasted, resulting in higher steam production requirement from the boiler to meet the system needs. It is not uncommon that,

Notes

use of variable orifice discharge modules (VODMs). VODMs are similar to steam traps in that they return condensate but also can remove non-condensable gases. In a system that does not contain VODMS, these gases can remain in the steam coil of the equipment being heated and can form pockets of gas that have the effect of insulating the heat transfer surfaces, thus reducing heat transfer and decreasing boiler efficiency. Exhibit 7.13 lists average cost s

Notes

Exhibit 7.14: Fuel Savings Realized by Preheating Combustion Air

Furnace Outlet	**Combustion air preheat temperature, °F**									
Temp. °F	400	500	600	700	800	900	1000	1100	1200	1300
2600	22	26	30	34	37	40	43	46	48	50
2500	20	24	28	32	35	38	41	43	45	48
2400	18	22	26	30	33	36	38	41	43	45
2300	17	21	24	28	31	34	36	39	41	43
2200	21	20	23	26	29	32	34	37	39	41
2100	16	18	22	25	28	30	33	35	37	39
2000	15	17	20	23	26	29	31	33	36	38
1900	14	16	19	22	25	27	30	32	34	36
1800	13	16	19	21	24	26	29	31	33	35
1700	13	15	18	20	23	25	27	30	32	33
1600	12	14	17	19	22	24	26	28	30	32
1500	11	14	16	19	21	23	25	27	29	31
1400	10	13	16	18	20	22	25	27	28	30

Note: 1. Numbers represent fuel savings in percent.

2. Natural gas with 10% excess air. Other charts are available for different fuels and various amount of excess air

7.2.2 Types of Heat Recovery Equipment

Choosing the type of heat recovery device for a particular application depends on a number of factors. For example air-to-air equipment is the most practical choice if the point of recovery and use are closely coupled. Air-to-liquid equipment is the logical choice if longer distances between the heat source and heat requirements are involved. Included in this section are five types of heat recovery systems:

- Economizers
- Heat pipes
- Shell and tube heat exchangers
- Regenerative units
- Recuperators

7.2.2.1 Economizers

Economizers are air-to-liquid heat exchangers. Their primary application is to preheat boiler feed water. They may also be used to heat process or domestic water, or to provide hot liquids for space heating or make-up air heating equipment. The basic operation is as follows: Sensible heat is transferred from the flue gases to the de-aerated feed water as the liquid flows through a series of tubes in the economizer located in the exhaust stack.

Most economizers have finned tube heat exchangers constructed of stainless steel while the inlet and outlet ducts are carbon steel lined with suitable insulation. The maximum recommended waste gas temperature for standard units is around 1,800°F. According to economizer manufacturers, fuel consumption is reduced approximately 1% for each 40°F reduction in flue gas temperature. The higher the flue gas temperature is, the greater potential for energy savings.

Notes

7.2.2.2 Heat Pipes

The heat pipe thermal recovery unit is a counterflow air-to-air heat exchanger. Hot air is passed through one side of the heat exchanger and cold air is passed through the other side in the opposite direction. Heat pipes are usually applied to process equipment in which discharge temperatures are between 150 and 850 °F. There are three general classes of application for heat pipes:

1. Recycling heat from a process back into a process (process-to-process)
2. Recycling heat from a process for comfort and make-up air heating (process-to-comfort)2.

<u>*Notes*</u>

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comfort of the workers and also reduces the energy use of the facility. This process can be accomplished by two different means. The first and most common device used is the ceiling fan. The fan draws the air from above the fan and forces it downward by the power of the specific motor and blade combination. The resulting motion is an air plume, with the warm air moving downward and outward and essentially creating a mixture like the one shown in Exhibit 7.15(b). The total air volume and coverage is dependent on the motor size, height of the fan and the specifications of the fan blade (design, size, rpm). Ceiling fans are also applicable in cooling conditions. It creates motion in the air and this can assist with evaporative cooling of the skin surface.

The total number of fans needed in a facility can be determined by the following equation.

$$\frac{\text{Total Plant Area}}{\text{Fan Coverage Area}} = \text{Number Fans Needed}$$

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savings these alternative sources can produce should be evaluated in relation to the cost to install them. For example, consider the replacement of a 500,000-Btu-per hour electric heater with a 500,00-Btu-per-hour natural gas heater.

Annual Cost of Electric Heater

= 500,000 Btu/hr x $14.65/10^6 Btu x 80% Eff. - 6,000 hrs/yr = $35,200

Annual Cost of Natural Gas Heater

= 500,000 Btu/hr x $3.00/10^6 Btu x 50% Eff. x 6,000 hrs/yr = $4,500

The energy cost saving is = $35,200 - $4,500 = $30,700/yr

7.3.2.1 Radiant Heaters

Radiant heaters are used for heating spaces by converting electric or gas energy to heat. It is important to think thoroughly about the whole picture before recommending radiant heaters because

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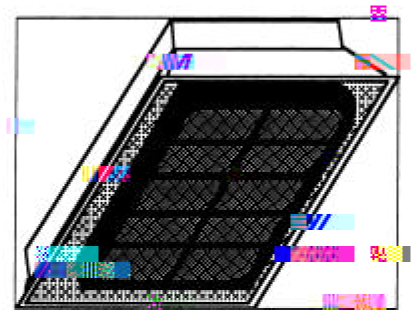
absorptivity, and transmissivity are the fractions of incidental radiation reflected, absorbed, and transmitted, respectively.

Exhibit 7.16: Infrared Radiant Heater



Radiant systems can also replace conventional heating methods in process heating. Since radiation does not need to travel through a medium, more heating work can be accomplished in less space. The response time when compared with convection heaters can prove to be an advantage in these industrial applications. The shutdown time for an infrared burner varies from one to 30 seconds. Gas or electric radiant heaters may be used for different heating applications. Applications include cooking, broiling, melting and curing metals, curing and drying rubber and plastics, and preshrinking and finishing of textiles.

7.4 FURNACES AND BURNERS

Furnaces and burnernd 3Gasf ectric

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These systems feature fixed orifices in both gas and air streams, and these orifices are sized to pass proportional amounts of gas and air at equal pressure drops, pressure drop signals are fed to a ratio controller which compares them. One of the outstanding features of this system is that the air/fuel ratio can be adjusted by turning a dial. Since a burner can be thrown off correct gas ratios by changes in ambient air temperature and humidity, this ratio adjustment feature permits the operator to set the burner back to peak operating efficiency with very little effort.

On multiple burner furnaces, the combustion products of all burners mix together before they reach the flue gas sampling point. Furnaces should have manifolded flue gas outlets to obtain a common sampling point for flue gas analysis. If, for example, some of the burners are unintentionally set lean, and others rich, the excess air from the lean burners could consume the excess fuel from the rich burners, producing flue gas with optimum CO_2 and practically no free oxygen or combustibles. Samples of these gases could be misleading and show correct air/gas ratio, when in fact they are not. Also, if a burner is set rich and the excess combustibles in the flue gases find air in the stack and burn there, flue gas analysis will again suggest that the burner is properly adjusted.

To overcome the problem of misleading flue gas analysis in multi-burner furnaces, metering orifices should be installed on the gas lines to each burner. If pressure drops across all orifices are identical, gas flow to each burner will be the same.

7.4.4 Furnace Pressure Controls

Furnace Pressure Controls afford additional energy savings, particularly on topflued furnaces. If a furnace operates under negative pressure, cold air is drawn into it through badly fitted doors and cracks. This cold air has to be heated, adding to the burden on the combustion system and wasting fuel. If the furnace operates at high positive pressure, flames will sting out through doors, site ports and other openings, damaging refractories and buckling shells. Ideally a neutral furnace pressure overcomes both these problems. Automatic furnace pressure controls maintain a predetermined pressure at hearth level by opening or closing dampers in response to furnace pressure fluctuations.

In summation, good air/fuel ratio control equipment and automatic furnace pressure controls are two useful weapons for combating energy waste in heating operations. Properly applied, they also offer the side benefits of improved product quality and shortest possible heating cycles.

7.4.5 Furnace Efficiency

Conventional refractory linings in heating furnaces can have poor insulating abilities and high heat storage characteristics. Basic methods available for reducing the heat storage effect and radiation losses in melt and heat treat furnaces are:

1. Replace standard refractory linings with vacuum-formed refractory fiber insulation material.
2. Install fiber liner between standard refractory lining and shell wall.
3. Install ceramic fiber linings over present refractory liner.

Refractory fiber materials offer exceptional low thermal conductivity and heat storage. These two factors combine to offer very substantial energy savings in crucible, reverberatory and heat-treat furnaces. With bulk densities of 12-22 lbs/cu ft, refractory fiber linings weigh 8% as much as equivalent volumes of

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system.

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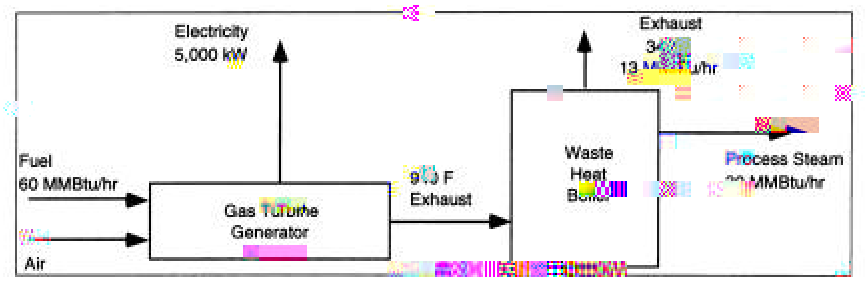
Exhibit 7.19: Gas-Turbine Cycle



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- Water treatment method - high-pressure steam turbines require more sophisticated boiler feed water treatment
- Dual burners - burners capable of burning more than one fuel add flexibility to use lowest cost fuel
- Degree of automation - fully automatic systems increase price significantly
- Duct burner in exhaust stream - increases output and permits generation of higher pressure steam
- Steam condenser - permits additional electrical generation from steam turbine at some loss in efficiency
- Generator type - power factor is improved with higher cost synchronous generator
- Parallel or independent operation will affect switchgear selection.

After the operating conditions and cogeneration facilities have been fully defined, the savings and investment estimates should be revised to complete the initial evaluation of the cogeneration facility.

7.6 Thermoenergy Storage Systems

The application of thermal storage is based on savings from using lower cost electrical rates with night-time operation to provide daytime thermal needs. Two conditions must be present to make thermal storage attractive.

First, there must be a significant difference between night and daytime electrical costs. The difference can be increased by higher summertime rates and inclusion of a ratchet provision for the next 11 months. Utilities generally encourage thermal storage because it permits them to transfer a portion of their daytime load from expensive peaking facilities to nighttime base-loaded, higher efficiency coal and nuclear plants.

Accordingly, the electric rate structure will encourage customers to shift their electrical load from daytime peak hours to nights and weekends by any or all of the following provisions in the rate structure.

- Time-of-day energy charge
- Demand charges (per kW peak power consumed during peak hours each month)
- Winter/summer rates for energy and/or demand charges
- A ratchet clause (monthly demand is the same or same percentage of the highest demand in previous 11 months).

Second, the daytime refrigeration load must result in high daytime cost, generally from peak demands, which have the potential to be reduced with thermal storage. Plants with one-shift operation or high solar load can be good candidates. Thermal storage has found application, for example, in office air conditioning. On the other hand, industrial plants with three-shift operation are normally not good candidates because of their higher content load.

Before considering thermal storage as a means of reducing electrical cost, alternate methods should be evaluated, as in most energy conservation approaches. Some possible alternate methods are absorption refrigeration, demand control, load scheduling, and using an emergency generator for peak shaving.

7.6.1 High Spot Evaluation

Where thermal storage appears to be a viable option, a high spot evaluation should be made to determine if further investigation is justified (see Exhibit 7.21). The incremental electrical cost must be broken down into its separate components for this evaluation. In this example, it is assumed there is no off-peak demand charge and the off-peak electrical energy rate is less than the on-peak rate. er inve thisa3 inve thirnatednsy [redacted] thermal storage will have on [redacted] of average loads will not be [redacted]

[redacted] than for a conventional [redacted] requires more energy per ton. [redacted] increased by 17 [redacted]

[redacted] in an attractive payback. [redacted] saving over the full year of [redacted] all energy flows and costs is [redacted] be answered as part of the [redacted]

- Should the thermal storage be for heating storage, cooling storage, or both?
- Should the system handle 100 percent of the cooling load or only the portion needed for load leveling?
- Should the storage system be water or ice?
- Should the storage system be for a daily or weekly cycle?

  Generally, systems have been for daily cycles and load levelers only.

Exhibit 7.21: Thermal Storage High Spot Evaluation

[redacted]

<u>*Notes*</u>

REFERENCES

1. "Testing & Measurement" Bulletin 4011 Bacharch Inc.
2. "Boiler Efficiency" Bulletin CB 7767 Cleaver Brooks Co.
3. "Heat-Timer Model HWR" File No. 30-E-1 Heat Timer Co.
4. "Digi-Span" File No. 980M Heat Timer Co.
6. "Auto. Vent Damper" Form No. 60-2523 Honeywell Inc.
7. "Chronotherm 3" Form No. 68-0056-1 Honeywell Inc.
8. "Perfect Climate" Products Form 70-2317/8-92 Honeywell
9. "Flame Safeguard Manual" No. 708107 Honeywell
10. "Principles of Steam Heating" Dan Holohan
11. Maine Oil & Solid Fuel Board Rules
12. NFPA Code #31 Installation of Oil Burning Equipment
13. "Boiler Efficiency Improvement" Dyer/Maples
14. "Application Data for Burners" Form No. 30-60004A Iron Fireman Div. Dunham Bush Co.
15. Grainger, Inc., Air Circulators, Dayton Fans, p. 2318.
16. McMaster-Carr Supply Company, *Net Prices Catalog*.
17. Rutgers University, Industrial Assessment Report No. RU-00146, ECO No. 03, pp. 28-30.
18. Chase Industries, Bulletin No. 8102, 1981.
19. Colorado State University, *Allied Signal Energy Conservation Training Program*, 1994.
20. Buckley, Norman A., "Application of Radiant Heating Saves Energy," *ASHRAE Journal*, V. 31, No. 9, September 1991, p. 18.
21. Incropera, Frank P. and DeWitt, David P., *Fundamentals of Heat and Mass Transfer, 3rd Ed*., John Wiley & Sons, 1990.
22. University of Tennessee, Industrial Assessment Report No. TN-0535, ECO No. 01, pp. 32-33.
23. Georgia Institute of Technology, Industrial Assessment Report No. GT-0541. ECO No. 02, pp. 8-11.
24. Marks' Standard Handbook for Mechanical Engineers, McGraw

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CHAPTER 8. PRIME MOVERS OF ENERGY

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This chapter discusses equipment used to move liquids and gases from place-to-place in a facility or used to pressurize liquids or gases in industrial facilities. A description of each piece of equipment, its general uses, operation, and common opportunities for energy conservation are presented. There will be case studies referenced throughout the chapter that can be found in Appendix E.

8.1 Pumps

Pumps are widely used for transfer of liquids from one place to another. Pumps are usually driven by electric motors; thus some of the considerations about pumps and electric motors might overlap. For some specific applications, pumps can be driven by compressed air or hydraulically.

There are many types of pumps used in industry depending on the including: centrifugal pumps (used predominantly for transfer of large volumes), metering pumps (used for precise delivery of liquids to a point of application and ensuring the constant discharge regardless of backpressure in the lines), and progressive cavity pumps or peristaltic pumps (used for delivery of very viscous materials and others).

Pump manufacturer generally provide pump curves at the time of the sale. They are essential for establishing the operation range and if any changes for pumping systems are considered the curves have to be considered.

8.1.1 Operation

Opportunities for savings in pump operation are often overlooked because pump inefficiency is not readily apparent. Pumps can run inefficiently for several reasons:

1. Present operating conditions differ from the design conditions. This change often occurs after a plant has undertaken a water conservation program.
2. Oversized pumps were specified and installed to allow for future increases in capacity.
3. Conservative design factors were used to ensure the pump would meet the required conditions.
4. Other design factors were chosen at the expense of pump efficiency when energy costs were lower.

8.1.1.1 Pump Survey

A survey of pumps should concentrate on the following conditions associated with inefficient pump operation. These are discussed in order of decreasing potential for energy savings in existing installations. For the survey to produce worthwhile savings, only pumps above a certain size, such as 25 horsepower, need to be checked:

1. Excessive pump maintenance. This problem is often associated with:
   a. Oversized pumps that are heavily throttled.

   b. Pumps in cavitation.

   c. Badly worn pumps.

   d. Pumps that are misapplied for the present operation.
2. Any pump system with large flow or pressure variations. When normal flows or pressures are less than 75 percent of their maximum, energy is probably being wasted from excessive throttling, large bypassed flows, or operation of unneeded pumps.
3. Bypassed flow. Bypassed flow, either from a control system or deadhead protection orifices, is wasted energy.
4. Throttled control valves. The pressure drop across a control valve represents wasted energy, which is proportional to the pressure drop and flow.
5. Fixed throttle operation. Pumps throttled at a constant head and flow indicates excess capacity.

Notes

6. Noisy pumps or valves. A noisy pump generally indicates cavitation from heavy throttling or excess flow. Noisy control valves or bypass valves usually mean a high pressure drop with a corresponding high energy loss.
7. A multiple pump system. Energy is commonly lost from bypassing excess capacity, running unneeded pumps, maintaining excess pressure, or having a large flow increment between pumps.
8. Changes from design conditions. Changes in plant operating conditions (expansions, shutdowns, etc.) can cause pumps that were previously well applied to operate at reduced efficiency.
9. A low-flow, high-

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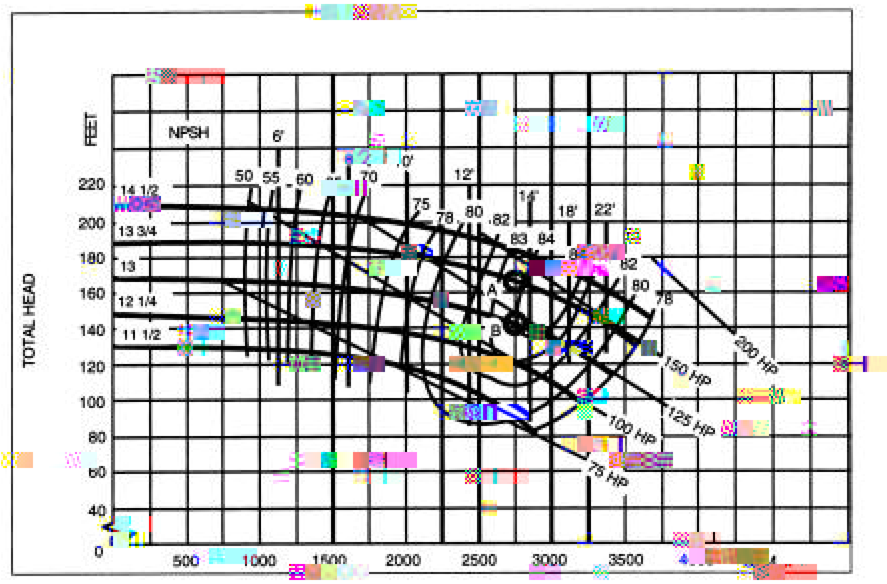
Exhibit 8.1: Typical Centrifugal Pump Characteristics



2. Point A: Oversized pump (13.75-inch impeller) throttle back to 2,750 gpm.

3. Point B: Trimmed impeller (13 inches) throttled back to 2,750 gpm.

   bhp = (140 x 2,750) / (3,960 x 0.84) = 115.7

4. Annual Savings = 135.6 - 115.7 = 19.9 bhp

   $/yr = 19.9 x (1/0.90) motor eff. ´ 6,000 hrs/yr ´ $0.041/hp-hr = $5,440

As with other equipment, energy conservation for pumps should begin when the pump is designed. Nevertheless, the savings from modification of an existing system often justify the cost.

The following example illustrates the application of affinity laws for variable frequency drive pump savings. With fans the affinity laws can be applied directly because the system resistance is purely flow-related. With pumps or fans having a static head offset, the system resistance curve also changes with pump speed.

A typical centrifugal pump curve in Exhibit 8.2 shows that by throttling the 1,750 rpm motor the pump delivers 2,500 gpm at 236 ft. head. Given a system analysis showing that 150 ft. of head is required to deliver 2,500 gpm with no throttling, the savings for operating the pump at reduced speed without throttling can be determined by the following trial-and-error method.

The affinity laws are:

$$S_1 / S_2 = Q_1 / Q_2 = (H_1 / H_2)^{1/3} = (BHP / BHP\ )$$

Notes

7. From the pump curve determine BHP_1 for Q_1 at 3,114 gpm.

   $BHP_1 = 258$

8. Calculate BHP_2 using affinity law

   $BHP_2 = BHP_1 \ (S_2 / S_1)^3$

   $= 258 \ (1{,}405/1{,}750)^3 = 258 \times 0.5175$

   $= 133.5$ BHP

9. From the pump curve determine the actual BHP (BHP_A) for the original operating point at 2,500 gpm.

   $BHP_A = 230$ BHP

10. Determine reduction in horsepower:

    BHP savings = 230 - 133.5 = 98.5 BHP

    Note the savings are not found from BHP_1-BHP_2, BHP_A-BHP_2

These calculations can be performed for other types of pumps using the curves presented in Exhibits 8.3 – 8.5. Manual calculation of savings for variable speed drives will be tedious if they must be determined for a number of conditions. Computer programs can simplify the task.

Exhibit 8.3: Typical Pump and System Curves, Driven by Adjustable Speed Drive

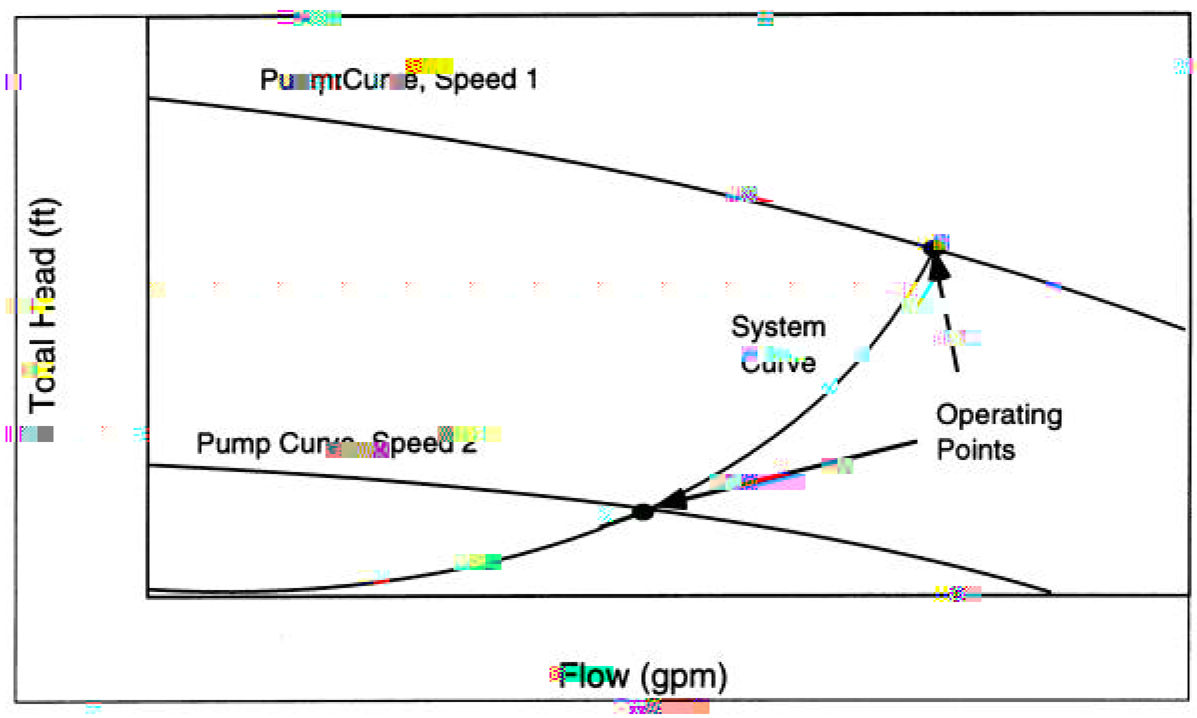


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Exhibit 8.4: Typical Pump and System Curves for Pump with Throttling Valve

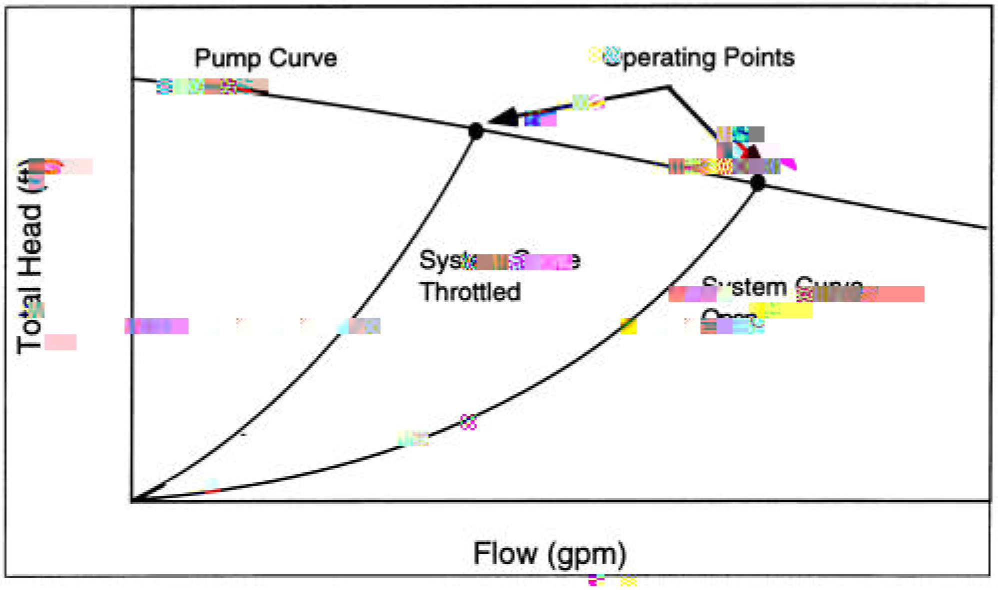
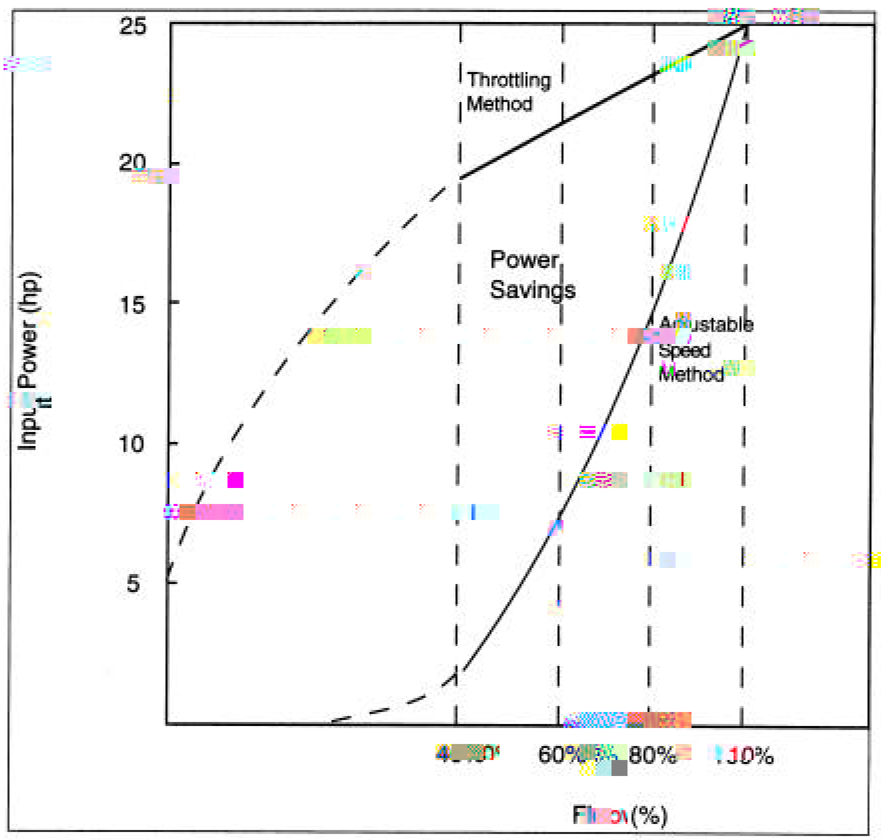


Exhibit 8.5: Pump Power Requirements for Throttling and Adjustable Speed Motors



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8.1.2 Considerations for Installation Design

The position of the pump with respect to the reservoir from which the liquid is to be taken is of utmost importance. If the pump is higher than the tank from which the fluid is being pumped the boiling of the fluid at local temperature can occur. The formation of the bubbles is called cavitation. The bubble collapse can happen at the higher pressure region (tips of the impeller), thus causing “cavitation erosion.” This results in a very low pump and damage of the impeller will follow soon. In order to avoid cavitation in the pump, the installation has to satisfy a condition of net positive suction head (NPSH). The manufacturer of the pump supplies the net positive suction head required and that is the minimum pressure head at the inlet for the type and model of the pump that has to be maintained in order to avoid cavitation inside the pump. The net positive suction head required accounts for pressure drop inside the pump. The pressure head at the inlet has to be calculated for each installation. Conventional tools for pressure losses in pipes are commonly used and adequate. Since the occurrence of bubbles forming inside the housing of the pump is absolutely forbidden, the backpressure of the system is of the same importance as NPSH. Adequate backpressure will prevent the formation of bubbles and can be achieved, if not currently available, by installation of backpressure valve.

Exhibit 8.6: Comparative Energy Usage with Various Methods of Control

Operating Situation	Hours of

Notes

Exhibit 8.7: Nominal Efficiency of Fans at Normal Operating Conditions

Type of Fan	Efficiency %
Axial Fan	85-90
Centrifugal Fans	
Airfoil Impellers	75-80
Backward-Curved Impeller	70-75
Radial Impeller	60-65
Forward-Curved Impeller	55-60

Reductions in exhaust airflow are usually obtained by adjustment of dampers in the duct. Damper control is a simple and low-cost means of controlling airflow, but it adds resistance, which causes an increase

<u>Notes</u>

Before alternate methods of volume control are considered, the condition of the existing fan and duct system should be checked. Some factors that can reduce fan efficiency are:

1. Excessive static-pressure losses through poor duct configuration or plugging.
2. Duct leakage from poor joints or flange connections, access doors left open, damage or corrosion, etc.
3. An improperly installed inlet cone, which inadequately seals the fan inlet area and allows excessive air recirculation.
4. Excessive fan horsepower caused by poor fan maintenance, such as bad bearings, shaft misalignment, worn impeller blades, or corroded fan housing.
5. Dirt and dust accumulations on fan blades or housing.
6. Buildup of negative pressure.

Once the existing system operates as efficiently as possible, alternate methods to control flow can be evaluated.

8.2.1 Inlet Vane Control

Inlet vane control is the most commonly used device for automatic control of centrifugal or in-line fan output after damper control. Prespinning as well as throttling the air prior to its entry into the wheel reduces output and saves power. Fans must be of sufficient size to permit retrofitting; the wheel diameter should be larger than 20 inches.

8.2.2 Reduced Speed

When fan output can be reduced permanently, an economical method is to change belt sheaves. A slower-speed motor can also be used if the first approach is not suitable. A two-speed motor is another alternative if the fan operates at low volume for a significant portion of the time but full capacity is still required part-time.

As an example of the savings to be realized from a reduction in fan speed, assume the exhaust airflow requirements have been reduced 50 percent on a 20-horsepower centrifugal fan. Reducing fan rpm 50 percent

Notes

Screw compressors have fewer moving parts than reciprocating compressors have and are less prone to maintenance problems. However, especially for older types of screw compressors, screw compressors tend to use more energy than reciprocating compressors do, particularly if they are oversized for the load. This is because many screw compressors continue to rotate, whereas reciprocating compressors require no power during the unloaded state.

This section includes energy conservation measures for increasing outside air usage, reducing air leakage around valves and fittings in compressor air lines, recovering air compressor cooling water, recovering air compressor waste heat, pressure reduction, adding screw compressor, controls, compressor replacement, and adding low-pressure blowers.

8.3.1 Waste Heat Recovery

For both screw and reciprocating compressors, approximately 60% to 90% of the energy of compression is available as heat, and only the remaining 10% to 40% is contained in the compressed air. This waste heat may be used to offset space heating requirements in the facility or to supply heat to a process. The heat energy recovered from the compressor can be used for space heating during the heating season. The amount of heat energy that can be recovered is dependent on the size of the compressor and the use factor. The use factor is the fraction of the yearly hours that the compressor is used. For this measure to be economically viable, the compressor should be located near the heat that is to be used.

Exhibit 8.9: Compressor Waste Heat Recovery: Costs and Benefits is used. For this 7l 0 .13151 13151 13151 TD

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Exhibit 8.10: Pressure Reduction: Costs and Benefits

Options[1]	**Installed Costs ($)**[2]	**Energy Savings (MMBtu/yr)**	**Cost Savings ($/yr)**[3]	**Simple Payback (yr)**
Pressure Reduction	864	187	2,730	1.0

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database. All values are averages based on the database data. The implementation rate for this measure was 48%.
2. One example from the IAC database to further clarify the costs is as follows: Reducing the air pressure control setting on a 75 hp air compressor from 115 psig to 100 psig resulted in energy savings of 22,500 kWh and cost savings of $1,180/yr. The implementation cost was $270, resulting in a simple payback of three months.
3. The energy cost savings is based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

8.3.3 Elimination of Air Leaks

Air leaks around valves and fittings in compressor air lines may represent a significant energy cost in manufacturing facilities. Sometimes up to 20% of the work done by the compressor is to make up for air leaks. The energy loss as a function of the hole diameter at an operating pressure of 100 psi is shown in Exhibit 8.11. When determining the energy savings from elimination of air leaks, the g r75 670.5 0 Tjc$froh (The)t77 -11.25

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resulted in energy savings of 35,750 kWh and cost savings of $2,760/yr. The implementation cost was $500.

3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

Equations for Air Flow, Power Loss, and Energy Savings

The volumetric flow rate of free air exiting the hole is dependent upon whether the flow is choked. When the ratio of atmospheric pressure to line pressure is less than 0.5283, the flow is said to be choked (i.e., traveling at the speed of sound). The ratio of 14.7 psia atmospheric pressure to 129.7 psia line pressure is 0.11. Thus, the flow is choked. The volumetric flow rate of free air, V_f, exiting the leak under choked flow conditions is calculated as follows:

$$V_f = \frac{NL \times (T_i + 460) \times C_4 \times C_5 \times C_d \times \frac{\pi D^2}{4}}{D_6 \sqrt{T_l + 460}}$$

where

V_f = volumetric flow rate of free air, cubic feet per minute

NL = number of air leaks, no units

T_i = temperature of the air at the compressor inlet, °F

P_1 = line pressure at leak in question, psia

P_i = inlet (atmospheric) pressure, 14.7 psia

C_4 = isentropic sonic volumetric flow constant, 28.37 ft/sec-°R0.5

C_5= conversion constant, 60 sec/min

C_d = coefficient of discharge for square edged orifice , 0.8 no units

π = Pythagorean constant, 3.1416

D = leak diameter, inches (estimated from observations)

C_6 = conversion constant, 144 in^2/ft^2

T_1 = average line temperature, °F

The power loss from leaks is estimated as the power required to compress the volume of air lost from atmospheric pressure, P_i, to the compressor discharge pressure, P_o, as follows :

$$L = \frac{P_i \times C_6 \times V_f \times \frac{k}{k-1} \times N \times C_7 \times \left[\left(\frac{P_o}{P_i} \right)^{\frac{k-1}{k \times N}} - 1 \right]}{E_a \times E_m}$$

where

L = power loss due to air leak, hp

k = specific heat ratio of air, 1.4, no units

N = number of stages, no units

C_7 = conversion constant, 3.03 x 10-5 hp-min/ft-lb

P_o = compressor operating pressure, psia

E_a = air compressor isentropic (adiabatic) efficiency, no units

Notes

E_a = 0.88 for single stage reciprocating compressors

E_a = 0.75 for multi-stage reciprocating compressors

E_a = 0.82 for rotary screw compressors E_a = 0.75 for rslidng cvanecompressors

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2. One example from the IAC database to further clarify the costs is as follows: Installing controls on a 100 hp compressor resulted in energy savings of 128,600 kWh and a cost savings of $6,750/yr, at an implementation cost of $1,500.

3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

8.3.6 Outside Air Usage

The amount of work done by an air compressor is proportional to the temperature of the intake air. Less energy is needed to compress cool air than to compress warm air. On average, outside air is cooler than in inside a compressor room. This is often the case even on very hot days. Piping can often be installed so that cooler outside air can be supplied to the intake on the compressor. This is particularly simple and cost-effective if the compressor is located adjacent to an exterior wall.

The energy and cost savings are dependent on the size of the compressor, the load factor, and the number of hours during which the compressor is used. The load factor is the average fraction of the rated load at which the compressor operates. The payback period is nearly always less than two years. The load factor is fairly constant for compressors that operate only when they are actually compressing air. Most reciprocating compressors are operated in this manner. When on, they operate with fairly constant power consumption, usually nearly equal to their rated power consumption; when they are cycled off, the power consumption is zero. Screw compressors are often operated in a different manner. When loaded (i.e., actually compressing air), they operate near their rated power, but when compressed air requirements are met, they are not cycled off but continue to rotate and are "unloaded." Older screw compressors may consume as much as 85% of their rated power during this unloaded state. Therefore, if a screw compressor is to be operated continuously, it should be matched closely to the compressed air load that it supplies. Often, plant personnel purchase compressors having several times the required power rating. This may be done for a variety of reasons, but often in anticipation of expansion of the facility and a commensurate increase in the compressed air requirements.

Exhibit 8.15: Outside Air Usage: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)
Outside Air Usage	593	82	1,246	0.5 0.5

Notes

reduce oil flow to the compressor. Other strategies have also been developed but are not usually found on older (pre-1975) screw-type compressors. The unloaded horsepower for screw compressors operating with these types of systems typically ranges from 80% to 90% of the full load horsepower for older compressors and from 40% to 60% for newer compressors, depending on the particular design and conditions. In any event, if the compressed air requirements are reduced during particular periods (such as a third shift), but are not eliminated entirely, then installing a smaller compressor to provide the air requirements during these periods can be cost-effective.

Exhibit 8.16: Optimum Sized Equipment: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)
Compressor Replacement	11,826	975	9,828	1.2

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database. All values are averages based on the database data. The implementation rate for this measure was 39%.
2. One example from the IAC database to further clarify the costs is as follows: A manufacturer of computer peripheral equipment replaced a 200 hp air compressor with a 75 hp air compressor. The energy savings were $61,850 kWh and the cost savings were $2,725. The implementation costs were $4,000.
3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

8.3.8 Low-Pressure Blowers

Compressed air is sometimes used to provide agitation of liquids, to control vibration units for material handling (as air lances), and for other low-pressure pneumatic mechanisms. For such purposes, it is more efficient to use a blower to provide the required low-pressure air stream. Use of low-pressure air from the blower would reduce energy consumption by eliminating the practice of compressing air and then expanding it back to low pressure for use.

Exhibit 810 0 0 rg 1lt $41 Tc60lowers

Notes

3. About 90% of energy consumption becomes heat (10%).
4. RULE OF THUMB: Roughly 20 hp per 100 cfm @ 100 psi.
5. Synchronous belts generally are not appropriate (cooling fins, pulley si no

CHAPTER 9. THERMAL APPLICATIONS

Notes

This chapter discusses thermal applications and equipment such as cooling towers, adsorption refrigeration, mechanical refrigeration, and insulation. A description of each application and equipment, its general uses, operation, and common opportunities for energy conservation are presented.

9.1 Cooling Systems

For process cooling it is always best from the standpoint of energy conservation to use the lowest form of energy first. That is, for a piece of equipment or a process that is air cooled, first use outside air (an economizer) if the outside air temperature is low enough. The next step, in appropriate climates, would be to use direct evaporative cooling. This is a process in which air passing through water droplets (a swamp cooler) is cooled, as energy from the air is released through evaporation of the water. Evaporative cooling is somewhat more energy intensive than the economizer but still provides some relatively inexpensive cooling. The increase in energy use is due to the need to pump water. Indirect evaporative cooling is the next step up in energy use. Air in a heat exchanger is cooled by a second stream of air or water that has been evaporatively cooled, such as by a cooling tower and coil. Indirect evaporative cooling may be effective if the wet-bulb temperature is fairly low. The wet-bulb temperature is the temperature indicated by a thermometer for which the bulb is covered by a film of water. As the film of water evaporates, the bulb is cooled. High wet-bulb temperatures correspond to higher air saturation conditions. For example, dry air has the ability to absorb more moisture than humid air, resulting in a lower, wet-bulb temperature.

Indirect evaporative cooling involves both a cooling tower and swamp cooler, so more energy will be used than for the economizer and evaporative cooling systems because of the pumps and fans associated with the cooling tower. However, indirect cooling systems are still less energy intensive than systems that use a chiller. The final step would be to bring a chiller on line.

Many plants have chillers that provide cooling for various plant processes. Chillers consist of a compressor, an evaporator, an expansion valve, and a condenser. Chillers are classified as reciprocating chillers, screw chillers, or centrifugal chillers, depending on the type of compressor used. Reciprocating chillers are usually used in smaller systems (up to 25 tons [88 kW]) but can be used in systems as large as 800 tons (2800 kW). Screw chillers are available for the 80 tons to 800 tons rolinytystems (up to 25 t0d1s3ef[88 kW]m8vec0yfhmpres58

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Three types of towers are widely used today. Mechanical forced-draft towers (see Exhibit 9.2), induced draft towers (see Exhibit 9.3) and hyperbolic. Mechanical forced-draft is designed to provide an air supply at ground level and at amounts that are easily controlled by fans. Unfortunately, there are some problems with this design as well. Firstly, it is a non-uniform distribution of air over the area.

Exhibit 9.1: Comparison of F.D. Blower Tower vs. Propeller Tower for 400 Tons

Cooling Tower Type	Operating Fan Motor (hp)	Fan Motor kW

4 8 Compa Motor 8 5 2 3 . 2 5 4 . 5 2 4 9 6 f 8 4 / 4 8 1 5 3 8 0 . 8 5 2 3 . 2 5 4 . 5 T 2 5 8 . 7 4 8 1 5 3 1 r g 5

Notes

250 feet, the tower orientation should be with the broad side to the winds that are prevailing in the region. Shorter towers should have long axis parallel to the prevailing winds.

Exhibit 9.3: Induced Draft Cooling Tower

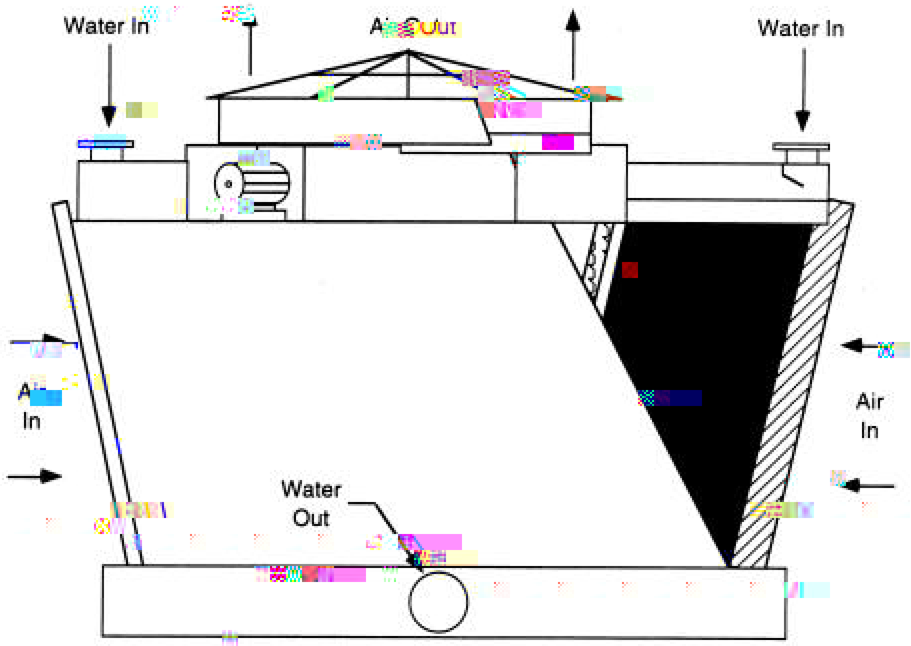

Exhibit 9.4: Free Cooling/Air Preheat

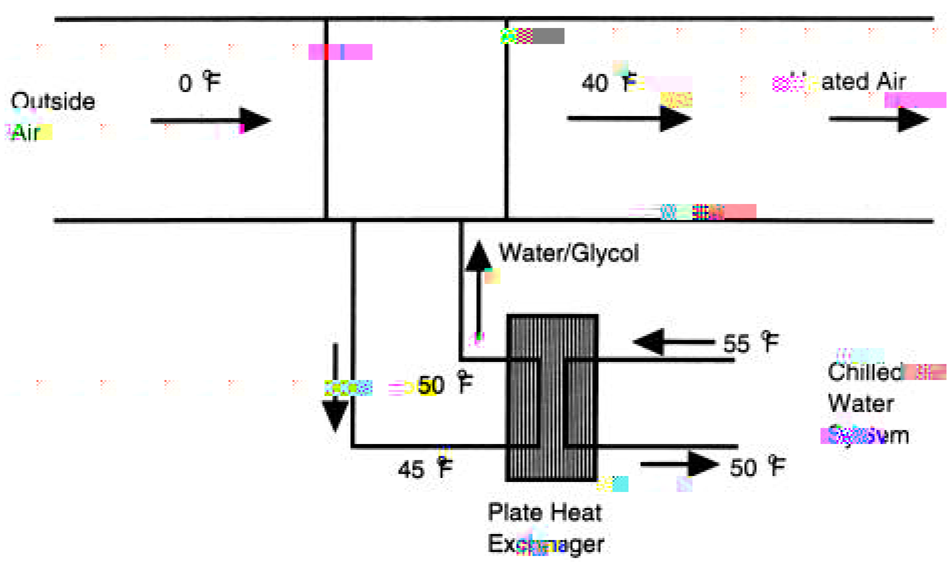

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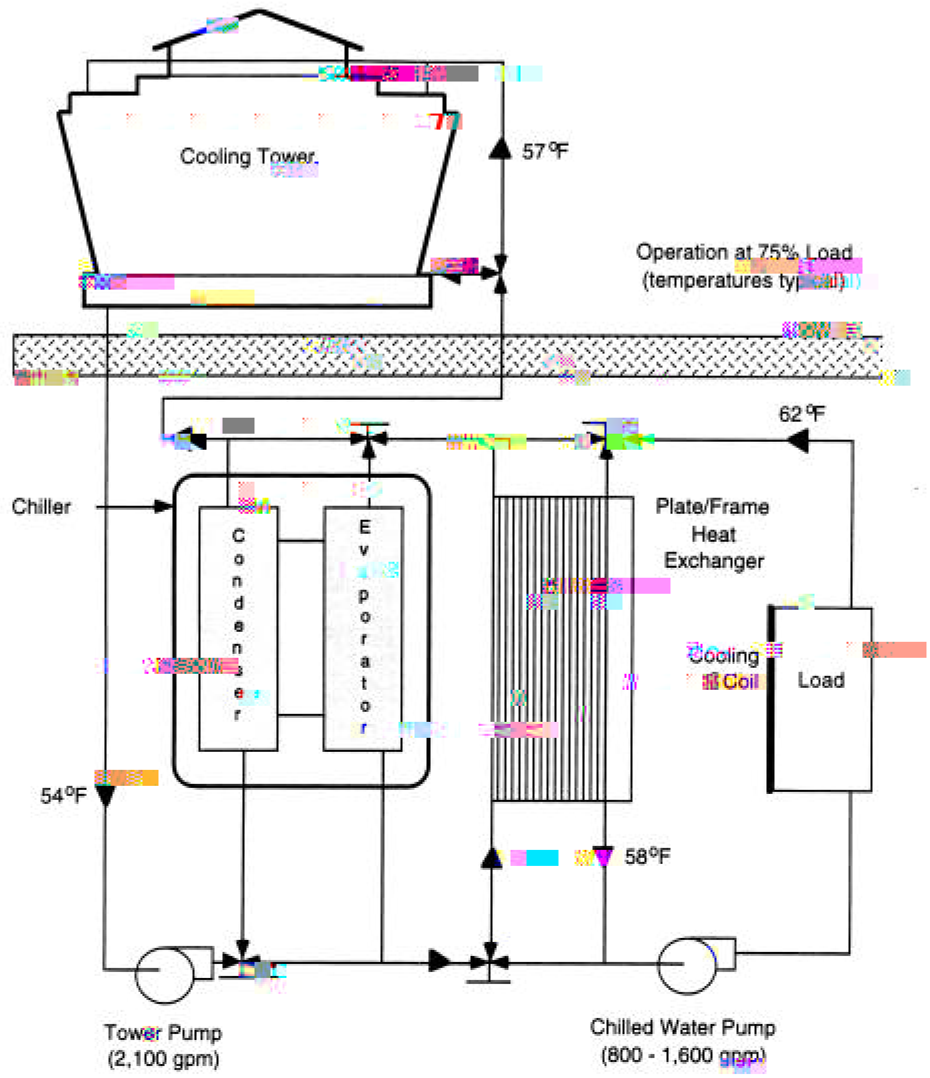
Exhibit 9.5: Indirect Free Cooling Loop



9.1.2 Typical Performance Improvements

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Notes

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database. All values are averages based on the database data. The implementation rate for this measure was 57%.
2. One example from the IAC data base to further clarify the costs is as follows: Resetting the chilled water temperature in a manufacturing plant resulted in energy savings of 39 MMBtu/yr., a cost savings of $537/yr, and no implementation cost, thus giving an immediate payback.
3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

9.1.2.3 Variable Speed (or Two-Speed) Motors for Cooling Tower Fans

Cooling tower performance is affected by the outdoor wet-bulb temperature. Higher wet-bulb temperatures correspond to higher air saturation temperatures. As air loses the ability to extract heat from water droplets flowing through a cooling tower (increasing wet-bulb temperature), a higher air flow rate is required to remove the desired amount and reduce the condenser water to the design temperature. The cooling water fan motor is often sized to perform under design conditions (i.e., full water flow rate at maximum air flow rate and design wet-bulb temperature). During periods of lower outdoor wet-bulb temperature, the design amount of cooling can be obtained with lower air flow rates. As the air flow rate decreases, the fan speed and the motor power requirements also decrease. It may then be beneficial to install a two-speed motor for the cooling tower fan to reduce the fan motor power consumption. Two-speed motors may be part of new or retrofit construction. Savings for the addition of a two-speed fan motor are estimated based on the number of hours per year that the wet-bulb occur at various temperature ranges between design wet-bulb and minimum wet-bulb temperatures and the power requirements for various air flow rates. It should also be noted that variable speed drives for fan motors achieve cooling tower energy savings in the same manner as two-speed motors.

Exhibit 9.9: Two-Speed Motors on Cooling Tower Fans: Costs and Benefits[1]

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)
Two Speed Motors on Cooling Tower Fans	4,179	164	2,400	1.7

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database in 1994. Today the database does not have a separate category for this item. The implementation rate for this measure was 20%.
2. One example from the IAC data base to further clarify the costs is as follows: Installing two-speed motors on the cooling towers at a plastic film extrusion plant resulted in energy and cost savings of 58,335 kWh/yr and $2,680/yr. The implementation cost was $8,900.
3. The energy cost savings are based on actual dollar savings as reported to IAC from the facility when compared to one-speed motors.

9.1.2.4 Hot Gas Defrost

Frost builds up on air cooler unit (freezer) evaporator coils when the unit operates at less than 32°F. Frost is the result of moisture in the air freezing to the coil as the air passes over the coil. The performance of the coil is adversely affected by frost. Frost acts as an insulator and reduces the heat transfer capability of the coil, and it restricts airflow through the coil. Frost buildup is unavoidable and must be removed periodically from the coil.

One method of frost removal is to use the hot refrigerant discharge gas leaving the compressor. During the defrost cycle, hot gas is circulated through the coil to melt the frost. Hot-gas defrost systems

Notes

may be used for all cooling unit capacities and may be included in new or retrofit construction. For retrofit applications, hot-gas defrost systems most often replace electric resistance defrost systems. Using waste heat off the hot-gas side for defrost may result in savings on the order of 10% to 20% of the total system usage.

Exhibit 9.10: Temperature vs. Time of Blower Operation

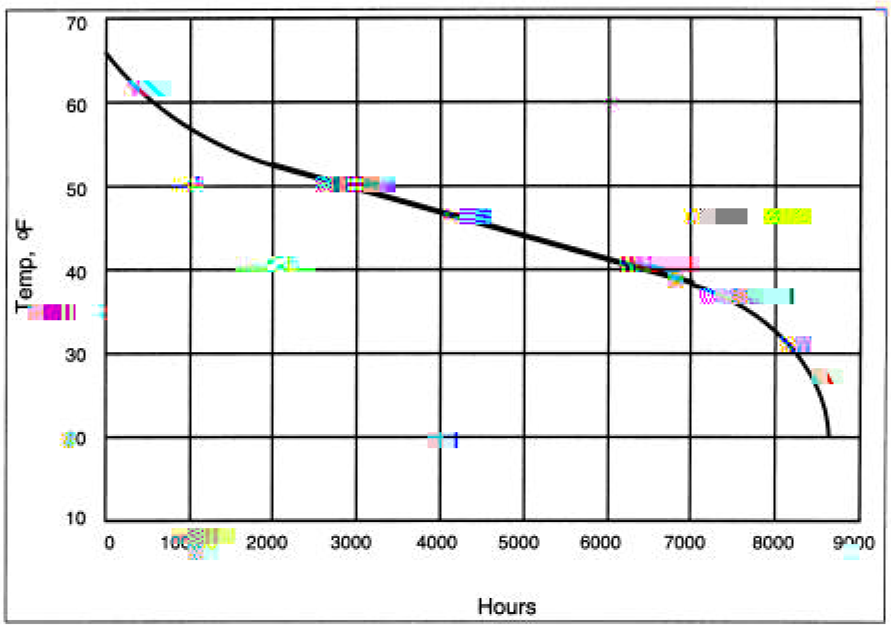

Exhibit 9.11: Evaporator Coils Defrost: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)
Hot Gas Defrost	9,750	489	6,656	1.4

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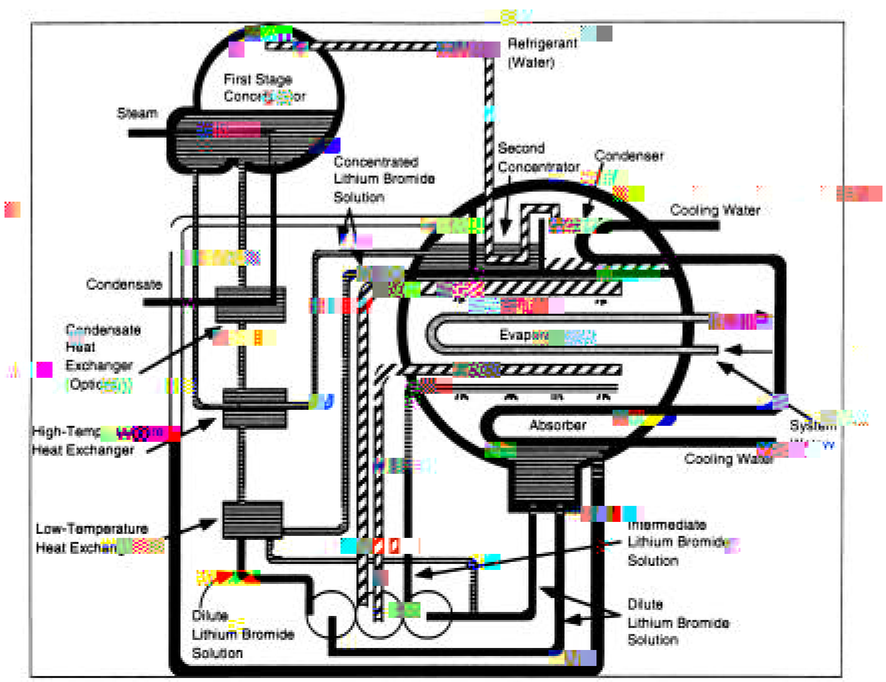
9.2.1 Operation

In the absorption cycle, two distinct chemicals are used and the cycle is driven by heat. The most common absorption system fluids are water as the volatile fluid and lithium bromide brine as the absorber fluid. Exhibit 9.12 illustrates the operation of a two-stage absorption chiller. Refrigerant enters the top of the lower shell from the condenser section and mixes with refrigerant being supplied from the refrigerant pump. Here the liquid sprays over the evaporator bundle. Due to the low vacuum (6 mm Hg) some of the refrigerant liquid vaporizes, cooling the refrigerant water to a temperature that corresponds closely to the shell pressure.

Exhibit 9.12: Two-Stage Absorption Chiller



As the refrigerant vapor/liquid migrates to the bottom half of the shell, a concentrated solution of liquid bromide is sprayed into the flow of descending refrigerant. The hygroscopic action between lithium bromide (a salt with an especially strong attraction for water) and water--and the related changes in concentration and temperature--result in the extreme vacuum in the evaporator directly above.

Dissolving lithium bromide in water also gives off heat that is removed by the cooling water. The resultant dilute lithium bromide solution collects in the bottom of the absorber where it flows down to the solution pump.

The dilute mixture of lithium bromide and refrigerant vapor is pumped through the heat exchangers, where it is preheated by a hot, concentrated solution from the concentrators (generators). The solution then flows to the first-stage concentrator where it is heated by an external heat source of steam or hot water. The condenser water used in the absorber and the condenser is normally returned to a cooling tower.

The vapor is condensed in the second concentrator where the liquid refrigerant flows to the lower shell and is once again sprayed over the evaporator. The concentrated solution of lithium bromide from the concentrators is returned to the solution pump where it is recycled to the absorber.

The degree of affinity of the absorbent for refrigerant vapor is a function of the concentration and temperature of the absorbent solution. Accordingly, the capacity of the machine is a function of the temperature of the heat source and cooling water (see Exhibit 9.13).

Two-stage absorption requires higher water temperature or steam pressure, but because no additional heat is required in the second concentrator, two-stage absorption machines are 30 percent to 40 percent more

9.2.1.2 Operating Problems

Air in leakage can be a serious operating problem. Every effort must be made to keep the system airtight, as even very small leaks can cause problems and are difficult to detect. Air entering the machine causes

- The lithium bromide solution to become highly corrosive to metals.
- The lithium bromide solution to crystallize.
- The chilled water temperature to increase.
- Refrigeration capacity to decrease.

Crystallization occurs when the lithium bromide solution does not go through the normal dilution cycle. When this happens, the solution becomes so concentrated that it crystallizes and plugs the solution lines. The unit must then be shut down and decrystallized. Crystallization can be caused by a power failure, controller malfunction, extreme variations in the condenser water temperature, or operator error in inadvertently allowing air to enter the machine. It is indicated by a rise in the outlet chilled-water temperature, a loss of solution pump (or a noisy solution pump), a loss of solution level in the absorber, and generator flooding.

Notes

Although absorption refrigeration machines are generally more difficult to operate and require more maintenance than reciprocating and centrifugal machines, they allow waste stream to be utilized more efficiently and in the proper application can result in substantial energy savings.

9.2.1.3 Direct-Fired Two-Stage Absorption Refrigeration

A recent development is the use of direct gas firing or waste heat as the energy source in lieu of steam. The gas stream must be 550°F for use in this application. Possible sources are drying ovens, heat-treating facilities, paint-baking ovens, process ovens, or any process which gives off a clean, high-temperature exhaust gas. A special advantage of this unit is that it can be directly integrated into a packaged cogeneration system.

Exhibit 9.14: Cost Comparison of Mechanical and Absorption Refrigeration

Mechanical Refrigeration	
Typical hp required Cost/ton-hr	=1hp/ton =$0.041
Absorption Refrigeration	
Typical Steam Required for single-stage Cost/ton-hr	=18 lbs @ 14 psig/ton =18 lbs/hr x $4.01/M lbs steam = $0.072
Typical steam required for two-stage Cost/ton-hr	=12 lbs/hr @ 14 psig/ton = 12 lbs/hr x $4.01/M lbs. Steam =$0.048
Typical gas required for direct-fired, two-stage Cost/ton-hr	=13,000 Btu/ton =13,000 Btu/hr x $3.00/MMBtu = $0.039

Exhibit 9.14 shows a cost comparison of mechanical vs. absorption refrigeration. The attractiveness of absorption refrigeration depends on the relative cost of electricity and fuel if prime energy is used, or the availability of waste heat, which requires no prime energy. With the unit costs selected for the manual, the two-stage absorption is slightly more costly to operate than mechanical refrigeration. Where waste heat can be utilized, absorption refrigeration is, of course, the obvious choice.

In considering the use of waste heat for absorption refrigeration, it is worth a reminder that the first step should be to determine whether reducing or eliminating the waste heat is possible. A common application is the use of absorption refrigeration to utilize steam vented to atmosphere. However, in most cases a thorough study of the steam system will identify means of balancing the system to eliminate the loss of steam.

9.3 Mechanical Refrigeration

Refrigeration machines provide chilled water or other fluid for both process and air conditioning needs. Of the three basic types of refrigeration systems (mechanical compression, absorption, and steam jet), mechanical compression is the type generally used. The other two have application only in special situations.

Absorption refrigeration is discussed in the previous section. The energy requirements of the steam jet refrigeration unit are high when compared with those for mechanical compression; therefore, the use of steam jet refrigeration is limited to applications having very low cost steam at 125 psig, a low condenser water cost, and a high electrical cost. With today's energy costs, this type of system is rarely economical.

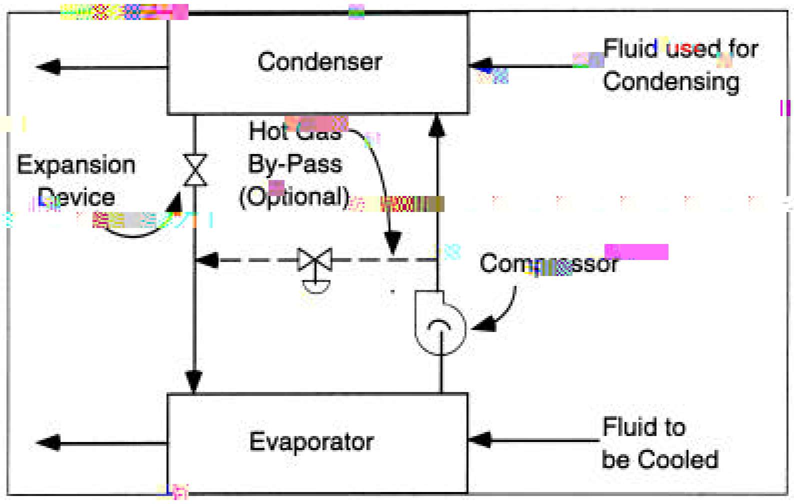
9.3.1 Mechanical Compression

The mechanical compression refrigeration system consists of four basic parts; compressor, condenser, expansion device, and evaporator. The basic system is shown in Exhibit 9.15. A refrigerant, with suitable characteristics, is circulated within the system. Low-pressure liquid refrigerant is evaporated in the

Notes

evaporator (cooler), thereby removing heat from the warmer fluid being cooled. The low-pressure refrigerant vapor is compressed to a higher pressure and a correspondingly higher saturation temperature. This higher pressure and temperature vapor is condensed in the condenser by a cooling medium such as cooling tower water, river water, city water, or outdoor air. The higher pressure and temperature refrigerant liquid is then reduced in pressure by an expansion device for delivery to the evaporator.

Exhibit 9.15: Mechanical Compression Refrigeration System



Reciprocating chiller compressors are generally used below 200 tons. Screw compressors are generally economical in the 300-

Although it is economical to operate at a lower-entering-condenser-water-temperature than the design temperature, too low a condensing temperature reduces the pressure differential across the refrigerant control (condensing pressure to vaporizing temperature), which reduces the capacity of the control and results

Notes

in starving the evaporator and unbalancing the system. As a rule, the condenser temperature (refrigerant side) should not be less than 75°F to 80°F, or less than 35°F above the refrigerant temperature in the evaporator.

The partial-load power requirements of a typical centrifugal refrigeration compressor at different entering condenser water temperatures are shown in Exhibit 9.15.

The following example calculates the annual savings from reducing the condenser water temperature. A 1,000-ton refrigeration compressor rated at 750 kilowatts at full load is operating at a 700-ton load. The condenser water temperature is reduced from 85°F to 65°F during the five winter months.

Percent design Load = (700 ton actual load) / (1,000 ton design load) x 100 = 70%

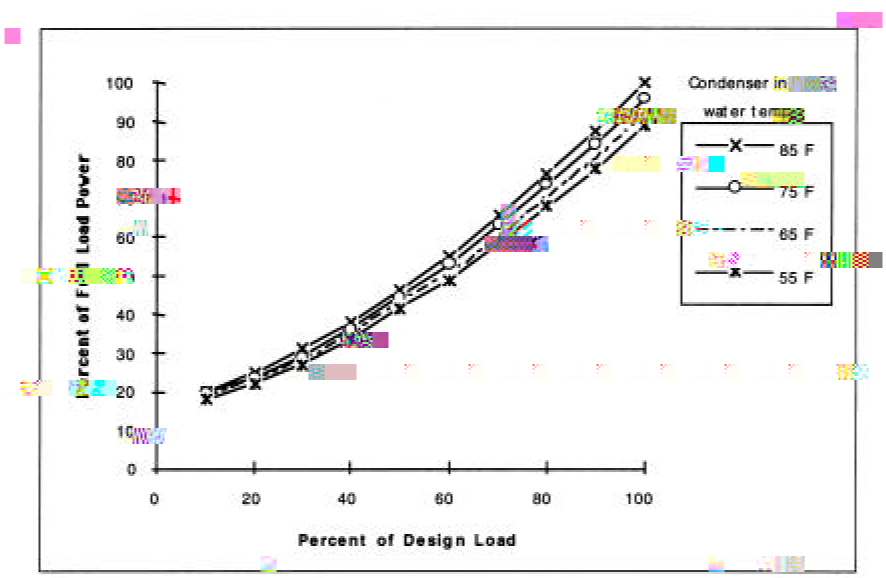
From Exhibit 9.17, the percent of full load power at 70 percent design load is:

At 85°F condenser water, 65.5 percent

At 65°F condenser water, 60.0 percent

Input kW at 85°F condenser water	= 750 x 65.6%
	= 491
Input kW at 65°F condenser water	= 750 x 60.0%
	= 450
Savings	= 41 kW
Annual Savings	= 41 kW x 6,000 hrs/yr x 5 mos/12 x 0.05 $/kWh
	= $5,130

Exhibit 9.17: Partial Load Requirement for Centrifugal Refrigeration Compressors



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From Exhibit 9.17 you can see the percent of full-load power at 75°F entering condenser water is:

At 90 percent design load, 84.0 percent

At 45 percent design load, 40.5 percent

Input kW at 900 tons = 750 kW x 84%

= 630 kW

Input kW (two units at 450 tons each)

= 750 kW x 40.5% x 2 compressors

= 608 kW

Savings = 22 kW

Annual Savings = 22 kW x 6,000 hrs/yr. x 5 mos/12 x $0.05/kWh

= $2,750

9.3.2.5 Recover Heat

Heat rejected at refrigeration machine condensers can be considered for recovery. The amount of heat rejected in the condenser is 12,000 Btu per hour plus the heat of compression is about 2,500 Btu/hr per ton, giving a total heat rejection of about 14,500 Btu/hr per ton produced. The use of a split condenser permits partial recovery of rejected heat. A split condenser uses two cooling water streams: a process stream that is preheated in the first condenser and cooling tower water for the second condenser. The preheating of a process stream reduces the heating load on the cooling tower. This heat recovery scheme is applicable only if the plant can use a low temperature heat source.

In the following example, a mechanical compressor rated at 1,000 tons is operating five months a year at an average 600-ton load. The savings from recovering 50 percent of the rejected heat to preheat water now heated by a steam hot water heater are:

Heat Rejected = 600 tons x 14,500 Btu/ton-hr

= 8,700,000 Btu/hr

Annual Savings = 8,700,000 Btu/hr x 50% x 6,000 hrs/yr. x 5 mos/12 x $4.24 / 10^6 Btu

= $46,100

9.3.2.6 Reduce Operation of Hot-Gas Bypass

On mechanical refrigeration machines, the primary elements for load controls are the suction damper or vanes, and the hot-gas bypass that prevents compressor surge at low loads. The suction vanes are used to throttle refrigerant gas flow to the compressor within the area of stable compressor operation. As load or flow drops, where it approaches the compressor surge point, the hot-gas bypass is opened to maintain constant gas flow through the compressor. Below this load point for the hot-gas bypass, compressor flow, suction, and discharge conditions remain fairly constant, so that power consumption is nearly constant. Obviously, opening the hot-gas bypass too soon, or having a leaking hot-gas bypass valve, will increase operating cost (kilowatts per ton).

It is not uncommon to find the bypass controls taken out of service, with the bypass set to maintain a fixed opening and constantly recycle high-pressure refrigerant vapors to the suction side of the compressor. A second frequent deficiency occurs when the hot-gas bypass is faulty or grossly oversized and is leaking. A third source of energy loss is faulty load control, which can cause improper operation of the hot-gas bypass

- w Reduce Operation of Hot

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instrumentation. This instrumentation includes flow meters for both the chilled water and the condenser water, pressure gauges at the inlet and outlet of both the condenser and evaporator, and temperature wells in both the inlet and outlet of the condenser and the evaporator. These temperature wells should be located in such a manner that a liquid can be placed in the well. The temperature measuring device used to test the equipment should read accurately to one-tenth of a degree.

9.4 Insulation

Although not generally viewed as a part of the mechanical design system, insulation is an important part of every piece of equipment or building where any transfer of fluids or gases takes place and the their temperature is required to be different then that of ambient air. Properly insulated pipes,2ly inw (e 0.8le) TjTj 1:2-0 T1

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9.4.1.1 Steam and Hot Water

Steam lines and hot water pipes should be insulated to prevent heat loss from the hot fluids. Recommended thickness for pipe insulation may be determined from the Exhibit 9.18. The energy and cost savings will depend on the size of the pipe (diameter and length of run), the temperatures of the fluids and the surroundings, the annual hours during which the pipes are heated, the efficiency of the heat supply, the heat transfer coefficient, and the fraction of the year during which heat loss from the pipes does not contribute to space heating. Exhibit 9.19 gives average cost savings from insulation of steam or hot water pipes.

Exhibit 9.19: Steam Lines and Hot Water Pipes: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)

Notes

9.4.2.1 Hot Media

Often, tanks containing hot fluids in manufacturing operations lack adequate insulation. The tanks may be insulated with blanket type flexible insulation (1 in. thick, 1.5 lb. density) or rigid insulation, depending on the type of tank. The savings would increase as the boiler efficiency decreases. The savings would also increase as the temperature in the tank increases.

Exhibit 9.21: Hot Tanks: Costs and Benefits [1]

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)
Hot Tanks	1,700	1,183	5,198	0.4

1. Tabulated data were taken from the Industrial Assessment Center (IAC) database. All values are averages based on the database data. The implementation rate for this measure was 44%.
2. The cost of insulation is typically around $0.50/ft^2. One example from the IAC database to further clarify the costs is as follows: Insulating the manufacturing tanks in a food plant resulted in energy savings of 135 MMBtu/yr. and cost savings of $470/yr. The implementation cost was $1,090. The tanks had a top area of 50 ft^2 and side areas of 175 ft^2 and contained fluids at temperatures between 150°F and 230°F. The tanks were located in a room at 70°F.
3. The energy cost savings are based on proposed dollar savings as reported to IAC from the center, which are usually almost identical to actual savings reported from the facility.

9.4.2.2 Cold Media

Uninsulated tanks containing cold fluids are occasionally found in applications, such as chilled water tanks that are located in areas where there can be considerable heat gain through the tank surfaces. If the air surrounding the tank is at a higher temperature than that of the tank, heat will be transferred to the contents of the tank. By insulating these tanks, Tj 0092a transfet will berreucredaund insulating these tanke canrreucr, Tj

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9.4.3.1 Dock Doors

Uninsulated dock doors can be a source of significant heat loss in manufacturing facilities. The doors can often be insulated by installing styrofoam or fiberglass in the door panels. The savings depend on the size of the doors, the efficiency of the heating system, the R-values of the insulated and uninsulated doors, and the number of degree heating hours per year. Degree Heating Hours is a measure relating ambient temperature to heating energy required. If the outside temperature is 1 degree below the base temperature in the plant for 1 hour then that represents 1 degree heating hour.

Exhibit 9.23: Dock Doors: Costs and Benefits[1]

Options[1]	Installed Costs

1MMBtu/yr).5 0 49. 4.5 TD /F2 6.75 Tf 0.375 Tc (1) Tj 3.75 0 TD 0 Tc -024315.75( ) T3-0.3954 T318equire95 Tf3-0.3954 T32951 0.85157j ET 0.851 0.8533-0.39.815 re f 171.75 594 5 06T Q BT 51945 7C

Notes

Glass Fiber

Glass fiber insulation has the disadvantage of moisture absorption and low resistance to abuse. The continuing maintenance can offset any advantage of the initial cost.

Calcium Silicate

Calcium silicate and inhibited calcium silicate provide the lowest cost system in the temperature

1.

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REFERENCES

1. Handisyde, C.C., and Melluish, D.J., *Thermal Insulation of Buildings*, HMSO, 1971
2. Malloy, J.F., *Thermal Insulation*, Van Nostrand Reinhold, 1969
3. The Association of Energy Engineers, *Corporate Energy Management Manual*, The Fairmont Press, 1979
4. Thumann A., and Mehta D.P., *Handbook of Energy Engineering*, The Fairmont Press, 1992
5. Kennedy, W. Jr., W.C. Turner, Energy Management, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1984, pp. 204-221.
6. 1989 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 1989.
7. Motor Master, Washington State Energy Office, Olympia, WA, 1992.

CHAPTER 10. HVAC

Notes

This chapter discusses heating, ventilation, and air conditioning (HVAC) equipment. A description of each type of equipment, its general uses, operation, and common opportunities for energy conservation are presented

10.1 Air Conditioning

Air conditioning is the process of treating air to control its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space. If the primary function of the system is to satisfy the comfort requirements of the occupants of the conditioned space, the process is referred to as comfort air conditioning. If the primary function is other than comfort, it is identified as industrial air conditioning. The term ventilation is applied to processes that supply air to or remove air from a space by natural or mechanical means. Such air may or may not be conditioned.

10.1.1 Equipment

Air conditioning systems utilize various types of equipment, arranged in a specific order, so that space conditions can be maintained. Basic components consist of:

- A fan to move air.
- Coils to heat and/or cool the air.
- Filters to clean the air.
- Humidifiers to add moisture to the air.
- Controls to maintain space conditions automatically.
- A distribution system to channel the air to desired locations, including dampers to control the volume of air circulated, as shown in Exhibit 10.1.

Within each basic component there are different types and styles, each with their own operating characteristics and efficiency, method and materials of construction, and cost, all of which greatly affect the initial design and resulting operating economics of the system. While this manual is directed principally to conservation with existing installations, ideally energy conservation should start during the initial design and equipment selection stages of the system.

10.1.1.1 Fans

The centrifugal fan with a backward-curved impeller is the predominant fan used in "built-up" type air conditioning units, while the forward-curved impeller centrifugal fan is used in "package" type air handling units.

10.1.1.2 Coils

Coils are used in air conditioning systems either to heat or cool the air. The typical coil consists of various rows deep of finned tubing. The number of fins per inch varies from 3 to 14. The greater the number of fins per inch and row's depth that a coil contains, the greater its heat transfer rate will be. An increase in heat transfer surface results in an increase in heat transfer efficiency and also in increased airflow resistance that will, in turn, require increased fan horsepower.

Heating coils will use either steam or hot water as a heating medium. The primary purpose of the coil depends upon its location in the air handling system. A preheater is the name given to a coil located in the makeup outdoor air duct. The preheater's purpose is to raise the temperature of makeup air to above freezing. The heating coil doing the final heating of the air before it enters the conditioned space is referred to as a reheater. Its purpose is to maintain satisfactory space temperature by adding heat to the supply air when it is required.

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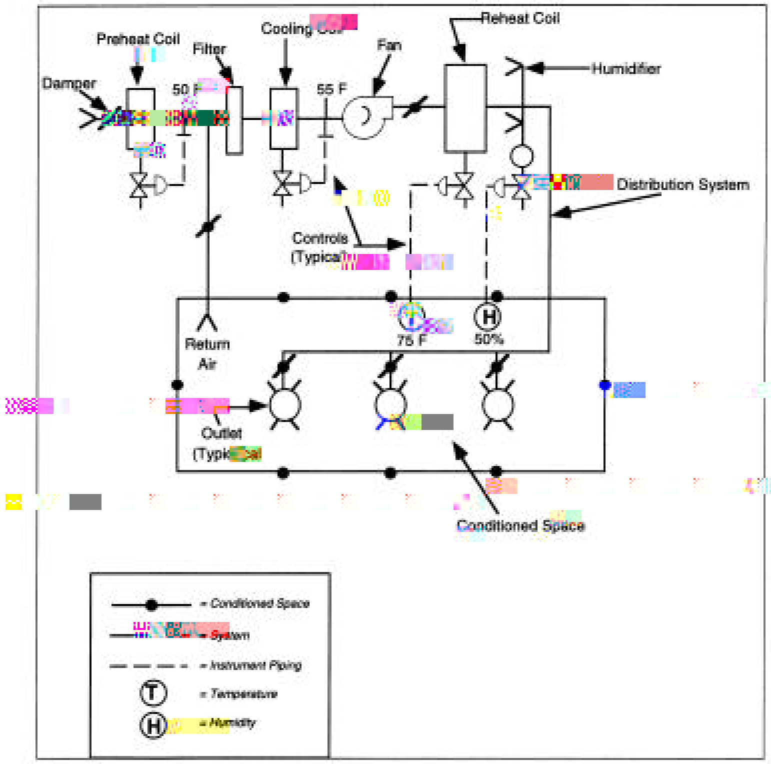
Exhibit 10.1: Air Conditioning Equipment



Cooling coils similar to that of the heating coils described above except that the coils cool the air instead of heating. The cooling medium used is chilled-water, brine, or refrigerant in a direct expansion-type coil. Direct expansion-type coils are used on small systems when a chilled water system is not economical. Chilled water is used on all other systems when the air temperature required is above 50°F. When the air

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Three operating characteristics distinguish the various types of air cleaners: efficiency, airflow resistance, and life or dust-holding capacity. Efficiency measures the ability of the air cleaner to remove particulate matter from an air stream. The interpolation of air cleaner ratings for efficiency and holding capacity is complicated by the fact that there are three types of tests, along with certain variations, employed for testing filters. The operating conditions that exist are so varied that there is no individual test that will adequately describe all filters. Air cleaners

Notes

conditioning deals with changing the properties of air to provide desired results in the conditioned space. The psychrometric chart, a graphical representation of the thermodynamic properties of moist air, is an invaluable aid in illustrating and solving air conditioning problems.

Since the properties of moist air are affected by barometric pressure, corrections must be made when equipment installation is done at other than sea level (29.92 inches Hg). Psychrometric charts are available for elevations at sea level, 2,500 feet, 5,000 feet, 7,500 feet, and 10,000 feet. Also, charts are available for different temperature ranges. The properties of moist air shown on a psychrometric chart are dry bulb (DB) temperature, wet bulb (WB) temperature, dew point temperature (DP), relative humidity (RH) in percent, specific humidity (W) in grains per pound, specific enthalpy (h) in Btu per pound, and specific volume (V) in cubic feet per pound. A description of these terms is listed in Appendix D. These properties can be found by using a typical psychrometric chart.

10.1.3 Computation

The following formulae and factors are used in the air conditioning field:

Btu = (lbs) (sp. heat) (Δt)   Btcfm (lb15cT. heat)   D

Notes

1. Design of systems
2. Method of operation
3. Operating standards
4. Maintenance of control systems
5. Monitoring of system
6. Competence of operators

Examples of various energy-saving methods used in the following sections are based on a facility having the following characteristics:

1.	Supply fan capacity:	10,000 cfm @ 3,0 in S.P., 6.8 bhp
2.	Outdoor air:	30% = 3,000 cfm
3.	Return air:	70% = 7,000 cfm
4.	Room temperature:	75°F DB, 62.5°F WB, 55.0°F DP, 50% RH
5.	Room loads:	summer = 108,000 Btu/hr/(sensible heat)
		winter = 216,000 Btu/hr/(sensible heat)
6.	Space, volume:	55,000 cu. ft.
7.	Space, area:	5,500 sq. ft.
8.	Space, cfm/sq.ft.:	1.8
9.	Space, supply air temp.:	summer design = 65°F, winter design = 95°F
10.	Design preheater load :	162,000 Btu/hr = 169 lbs/hr (based on 50°F disc. temp.)
11.	Design on cooling coil load:	364,500 Btu/hr = 30 tons
12.	Design outdoor temp.:	summer = 95°F DB, 78°F WB; winter 0°F
13.	Design outdoor degree days :	5,220 (65°F), 3,100 (55°F), 2,100 (50°F)
14.	Design outdoor avg. winter temp.:	41.4°F (Oct. to Apr. inclusive)
		< 67.0°F, 3,052 hrs/yr
		38.0°F = Avg. < 50°F, 3,543 hrs/yr
		33.0°F = Avg. < 40°F, 2,162 hrs/yr
15.	Equiv. hrs/season refrig. at full load:	750 hrs

10.1.4.1 Operate Systems Only When Needed

Air conditioning systems, including refrigeration machines, pumps, and cooling tower systems, should be operated only when areas are occupied (for comfort air conditioning systems) and when processes are operating (for non-comfort air conditioning system). It is not uncommon for systems to operate continuously. Reducing operating hours will reduce electrical, cooling, and heating requirements. Continuous operation during normal working hours of 8 a.m. to 5 p.m., five days per week, such as that for an office building is a good example of excessive operation of equipment.

The savings resulting from reducing operating hours from 168 hours per week to 50 hours per week is calculated as follows.

Savings from Reduced Fan Operation

= (Supply fan bhp) (Cost, $/hp-yr) [(hrs/wk shut off) / (hrs/wk current operation)]

= (6.8) ($360) [(168 - 50) / (168)] = $1,720/yr

<u>Notes</u>

Total Annual Savings

Cooling	=	$3,070 (from previous example)
Reheating	=	<u>3,040</u>
Total	=	$6,110

<u>Heating Example</u>

The savings resulting from changing the room thermostat setting from 75°F to 68°F during the heating season is calculated as follows.

Given:

1. Room heating load at 75°F = 216,000 Btu/hr
2. Room heating load at 68°F = (216,000)(68/75) = 195,800 Btu/hr

Annual Cost$_{75°F}$

= {[(24)(deg day)(design htg. load, Btu/hr)] / [room T - outside T]}(stm. cost, $/MM-Btu)

= {[(24)(5,220)(216,000)] / [(75 – 0)]}{$4.24 / 10^6} = $1,530

Annual Cost$_{68°F}$

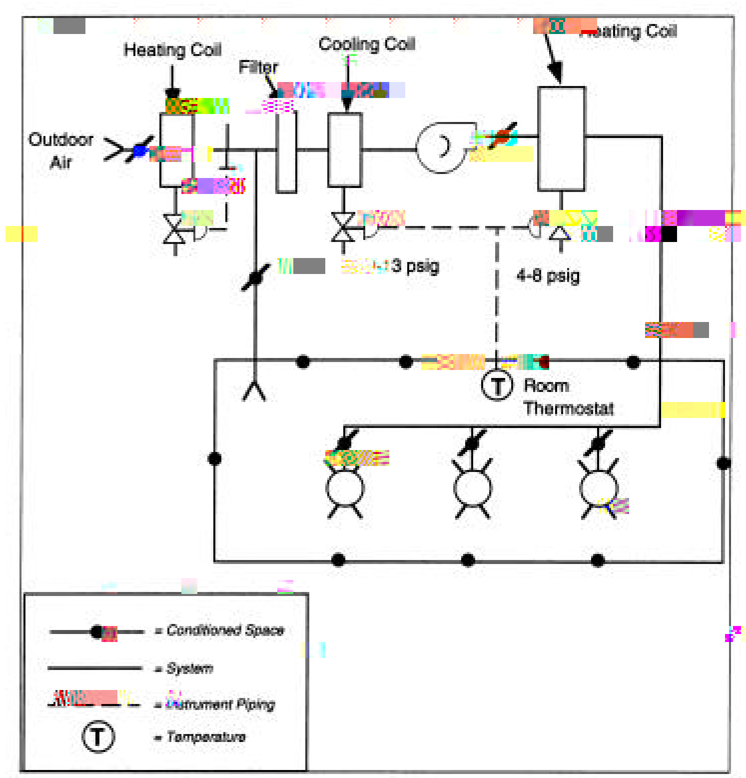
= (Annual cost at 75°F) [(68°F - winter average temp.) / (75°F - winter average temp.)]

= ($1,530)[(68 - 41.4) / (75 - 41.4)] = $1,211

Annual Savings = $1,530 - $1,211 = $319

Note: Difference in cost is proportional to temperature difference maintained with ambient temperature

Exhibit 10.2: Modified Air Conditioning System Controls



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10.1.4.3 Eliminate Reheat

When humidity control is required, the conventional method is to cool the air to the required dew point temperature to remove the excess moisture and then reheat the air to deliver it at the desired humidity and temperature as illustrated in Exhibit 10.2. The cost of reheating for humidity control is not considered justified in today's energy situation for comfort air conditioning systems.

The inclusion of a humidity standard is not recommended for normal air conditioning comfort standards and should be discontinued. Likewise, no system should operate in a manner that requires it to heat and cool at the same time. At any given instant the system should be either heating or cooling--never both. The process of cooling and then reheating is inefficient, whether for humidity control or because of system design.

10.1.4.4 Economizer Cycle

Many air conditioning systems operate with a fixed minimum amount of outdoor air. The mechanical refrigeration load on these systems can be reduced by modifying the system to utilize outdoor air at up to 100 percent of its supply airflow when outdoor air is cooler than return air. This is referred to as an economizer cycle. Many systems do not have an economizer cycle and fail to take advantage of its potential savings.

An economizer cycle will eliminate or reduce mechanical cooling when the outdoor air is cooler than return air. When outdoor air is warmer than return air, only the minimum amount of outdoor air required for fresh air supply is used.

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Exhibit 10.3: Economizer Cycle (Outdoor Temp. Switchover, Mixing Temp. Control)

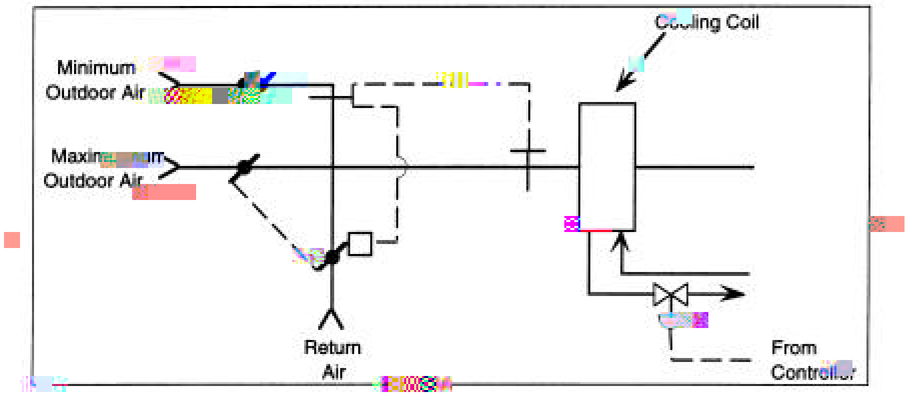

Exhibit 10.4

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Outdoor Temperature Method

The saving resulting from an economizer cycle with outdoor temperature switchover at 56.5°F on a year-round air conditioning system (continuously operating) is calculated as follows. The preheater discharge temperature is controlled at 40°F. Savings are determined in two steps.

1. Economizer savings when the outdoor temperature is < 40°F. The temperature of the air entering the cooling coil when the outdoor air is less than 40°F is 64.5°F.*

   = {[(cfm)(1.08)(temp. diff.)] / [Btu/ton]}(hp/ton)(refrig., hp/ton)(cost, $/hp-yr) x {(hrs temp < 40°F) / (8,760)}

   = {[(10,000)(1.08)(64.5 - 56.5)] / [12,000]}(1.25) ($360)(2,162/8,760) = $800/yr

2. Economizer savings when the outdoor temperature is between 40°F and 56.5°F. (Above 56.5°F only minimum 30% outdoor air is used.) The average temperature of air entering the cooling coil is approximately 67°F*, which represents the midpoint between the maximum and the minimum temperature that would occur.

   = {[(10,000)(1.08)(67* - 56.5)] / [12,000]}{(1.25) ($360)[(3,052) / (8,760)] = $1,481/yr

		Max	Min
Outdoor temp.	=	56.5ºF	40.0ºF
30% outdoor air	=	17.0	12.0
70% return air @ 75'F	=	52.5	52.5
Avg. temp.	=	69.5	64.5

Average = (69.5°F + 64.5°F) / 2 = 67°F

Annual Savings for Condition A

Outdoor temp. < 40°F = $ 800

Outdoor temp. between 40°F and 56.6°F = 1,400

Total $2,280

*Temperature of air entering coil.

Enthalpy Switchover Method

Given the same conditions as the previous example, the savings from an economizer cycle using the enthalpy method. To determine either enthalpy, the wet bulb (WB) temperature or dry bulb temperature (DB) and relative humidity are needed. Tnth(DB) DB)

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has been used is such a system; it requires heat, and the air change is 5.6 minutes (1.8 cfm per square foot, 10-foot ceiling height).

The method used in reducing the system's airflow has a great influence on the amount of horsepower saved. Three methods normally used are:

1. Fan discharge damper
2. Fan vortex damper (fan inlet)
3. Fan speed change

The savings resulting from reduced reheat and fan horsepower on a year-round air conditioning system when the airflow is reduced from 1.8 cfm per square foot (5.6 minute air change) to 1.1 cfm per square foot (9.1 minute air change) can be calculated as follows.

1. Find the new airflow

   cfm 2 = (cfm)[(air change 2) / (air change 1)] = 10,000 (1.1/1.8) = 6,110

2. Find the new supply temperature:

   Supplied air inlet temp. = room temp. - [(given room sensible load, Btu/hr]) / [(1.08)(cfm)]

   = 75 - [(108,000) / (1.08 x 6,110)] = 58.6°F

3. Find the savings from reheat reduction:

   $Cost_{1.8}$ = (cfm) (1.08) (T_2

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Exhibit 10.7: Effect of Volume Control on Fan Horsepower

$ Savings			
Method	Fan hp	Reheat	Total
Outlet Damper	349/yr	2,900/yr	3,249/yr
Inlet Vane Damper	1,100/yr	2,900/yr	4,000/yr
Fan Speed	1,560/yr	2,900/yr	4,460/yr

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10.2.1 Equipment Sizing Practices

Usually all existing energy consuming systems are oversized. The reasons for oversizing of HVAC equipment include:

1. All HVAC design procedures are conservative.
2. A "Safety Factor" is then applied.
3. Design is for a near-extreme weather condition that is very seldom obtained (2-3% of annual hours).
4. Standard equipment size increments usually result in further oversizing.

Any attempt to conserve energy amplifies the effect of statements above. Operating efficiencies of equipment decrease with decreasing load - usually exponentially.

10.2.1.1 Reducing Capacity by Fan/Pump Slowdown

The capacity of HVAC systems can be reduced by using a slowdown technique to reduce the hp output. It should be noted that reducing the hp output of fan and pump motors will also reduce their efficiency. Exhibits 10.9 and 10.10 illustrate the affects of this technique.

$$\frac{HP_1}{HP_2} = \left[\frac{CFM_1}{CFM_2}\right]^3$$

OR

$$\frac{HP_1}{HP_2} = \left(\frac{GPM_1}{GPM_3}\right)^3$$

Thus:

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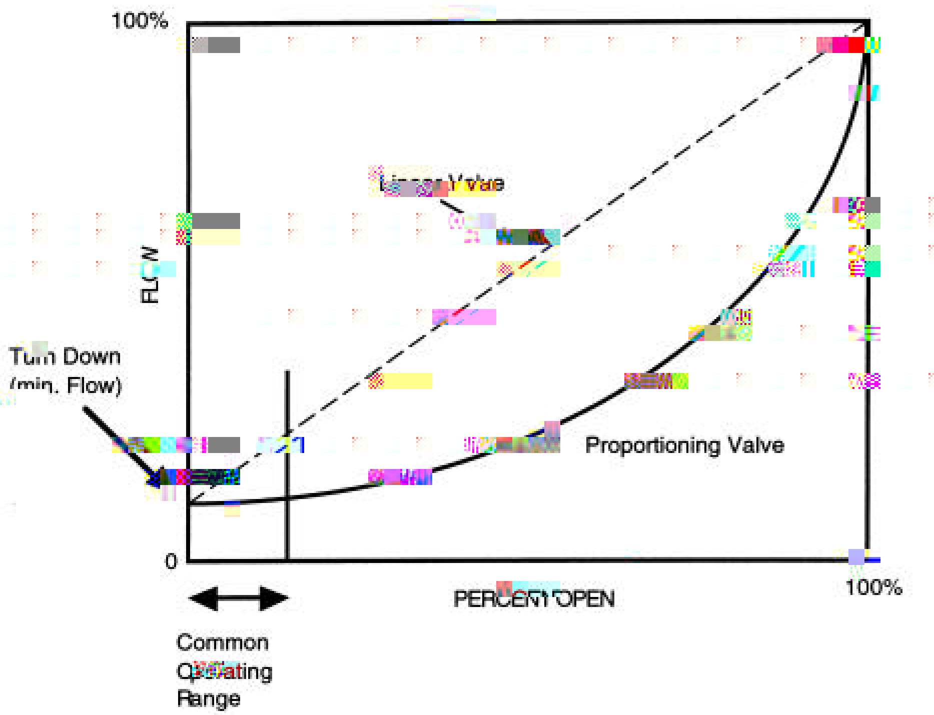

10.2.1.2 Maximize HVAC Savings

Energy conservation in HVAC systems can be maximized by using these techniques:

1. Reduce fan & pump horsepower - replace motors if necessary.
2. Reduce operating time - turn it off when not needed.
3. Retrofit existing HVAC systems to some form of VAV (Variable Air Volume) systems.
5. Eliminate or minimize reheat.
6. Maintain, calibrate & upgrade control systems.

These techniques were discussed in detail earlier in the chapter for independent systems but can be applied to HVAC system components. When evaluating HVAC requirements and energy conservation measures, facilities should take into consideration all heating and cooling loads as illustrated in Exhibit 10.11. This will provide the correct criteria for evaluations and cost savings estimates.

10.2.2 Design for Human Comfort

Providing comfortable conditions for people engaged in the working process is not a superfluous lux69s2.8 Hum6T Tc -0.095rorocesyTc t0 T3e workiecessary.

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The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) publish standards for many aspects of HVAC design. One example is ASHRAE Standard 62-

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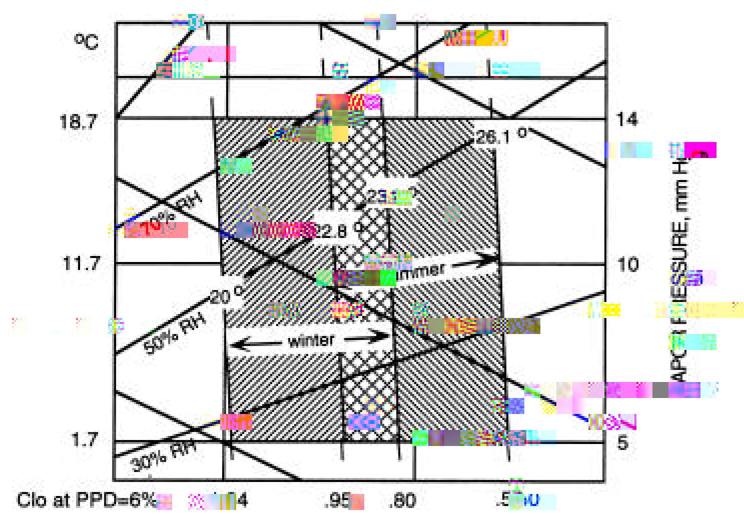
2. Winter
   - $T_{room} \geq 72°F$
   - $\phi_{room} \leq 30\%$
   - ≥ 0.3 ACH (residential)

Exhibit 10.12 defines the comfort zone for personnel using criteria such as temperature and vapor pressure. From this chart the comfort zone for consideration in the HVAC design is:

1. Summer
   - $73°F \leq T_{db} \leq 81°F$
   - $20\% \leq \phi \leq 60\%$
2. Winter
   - $68°F \leq T_{db} \leq 75°F$
   - $30\% \leq \phi \leq 70\%$

Most of the work on comfort since about 1970 has been to redefine the x-axis on the comfort chart to be more general (i.e., include effects of heat radiation, clothing, metabolism, air motion, etc.). There are different approached to quantifying comfort. To minutely quantify comfort is the EUROPEAN approach (reason: they don't heat their buildings as much). The UNITED STATES approach is to adjust the thermostat (becoming less acceptable to do so).

Exhibit 10.12: Comfort Zone Detail



10.2.2.1 Factors Affecting Comfort

There are three major factors affecting personnel comfort. These are biological, dothing, and environmental indices.

Biological factors that affect personnel comfort include respiration, metabolism, and the types of activities personnel are performing. Exhibit 10.13 illustrates the biological factors that affect a persons comfort. For example, a persons average core temperature is:

$$T_{CORE} = 37°C \pm 1°C \ (98.6°F)$$

but their actual skin temperature may be:

$$T_{SKIN} = 92.7°F \text{ (buffer, adjusts to ambient)}$$

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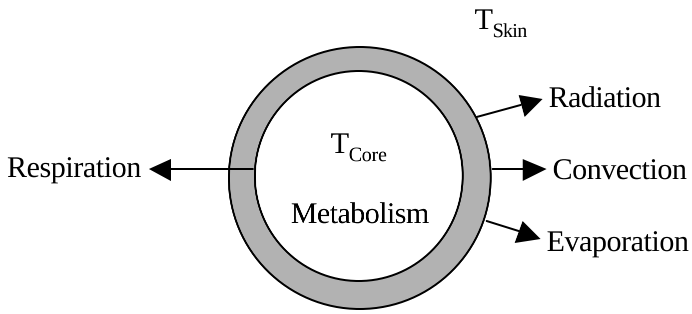
Exhibit 10.13: Biological Factors Affecting Comfort



A person's activity has a great affect on their metabolic heat generation. For example an adult male's heat generation rate during three different activities would be:

- 100 W; seated at rest
- 850 W; heavy exercise
- 1,500 W; Olympic Athlete

Exhibit 10.14 lists the heat flux generated for various activities further illustrating how much activity affects comfort.

Exhibit 10.14: Heat Flux Generated by Various Activities

Various Activites[a]	Btu/h-ft^2	met[b]
Resting		

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Exhibit 10.17: Garment Insulation Values

Garment[a] Description	I/clo	Garment[a] Description	I/clo
Underwear		*Dresses and Skirts[b]*	
Man's briefs	0.04	Skirt (thin)	0.14
Panties	0.03	Skirt (thick)	0.23
Bra	0.01	Long-sleeve shirt dress (thin)	0.33
T-shirt	0.08	Long-sleeve shirt dress (thick)	0.47
Full slip	0.16	Short-sleeve shirt dress (thin)	0.29
Half slip	0.14	Sleeveless, scoop neck (thin)	0.23
Long underwear top	0.20	Sleeveless, scoop neck (thick)	0.27
Long underwear bottom	0.15	Sweaters	
Footwear		Sleeveless vest (thin)	0.13
Ankle-length athletic socks	0.02	Sleeveless vest (thick)	0.22
Calf-length socks	0.03	Long-sleeve (thin)	0.25
Knee socks (thick)	0.06	Long –sleeve (thick)	0.36
Panty hose stockings	0.02	*Suit Jackets and Vests (lined)*	
Sandals/thongs	0.02	Single-breasted (thin)	0.36
Slippers (quilted, pile-lined)	0.03	Single-breasted (thick)	0.44
Boots	0.10	Double breasted (thin)	0.42
Shirts and Blouses		Double breasted (thick)	0.48
Sleeveless, scoop-neck blouse	0.12	Sleeveless vest (thin)	0.10
Short-sleeve, dress shirt	0.19	Sleeveless vest (thick)	0.17
Long-sleeve, dress shirt	0.25	*Sleepwear and Robes*	
Long-sleeve, flannel shirt	0.34	Sleeveless, short gown (thin)	0.18
Short-sleeve, knit sport shirt	0.17	Sleeveless, long gown (thin)	0.20
Long-sleeve, sweat shirt	0.34	Short-sleeve hospital gown	0.31
Trousers and Coveralls		Long-sleeve, long gown (thick)	0.46
Short shorts	0.06	Long-sleeve pajamas (thick)	0.57
Walking shorts	0.08	Short-sleeve pajamas (thin)	0.42
Straight trousers (thin)	0.15	Long-sleeve, long wrap robe (thick)	0.69
Straight trousers (thick)	0.24		
Sweat pants	0.28	Long-sleeve, short wrap robe (thick)	0.48
Overalls	0.30		
Coveralls	0.49	Short sleeve, short robe (thin)	0.34

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Environmental indices that affect personnel comfort include factors such as temperature, humidity, and air flow. Operating temperatures that take into account humidity can be determined using the following equations.

$$T_o = \frac{h_r T_r + h_c T_a}{h_r + h_c}$$

$$T_o = \alpha T_r + (1 - \alpha) T_a$$

where T_r = mean radiant temperature

T_a = dry bulb temperature

$$\frac{1}{3} \leq \alpha \leq \frac{2}{3}$$

$$T_r = \frac{1}{N} \sum_{i=1}^{N} T_i$$

Exhibit 10.18 lists equations for convection heat transfer coefficients for various activities.

Exhibit 10.18: Convection Heat Transfer Coefficients

Equation	Limits	Condition	Remarks/Sources
$Hc=0.061V^{0.6}$	40<V<800	Seated w/moving air	Mitchell (1974)
Hc=0.55	0<V<40		
$Hc=0.475 + 0.44V^{0.67}$	30<V<300	Reclining w/moving air	Colin & Houdas (1967)
Hc=0.90	0<V<30		
Hc=0.92V0.53	100<V<400	Walking in still air	V is walking speed Nishi & Gagge (1970)
$Hc=(M-0.85)^{0.39}$	1.1<M<3.0	Active in still air	Gagge (1976)
$Hc=0.146V^{0.39}$	100<V<400	Walking on treadmill in still air	V is treadmill speed Nishi & Gagge (1970)
$Hc=0.068V^{0.69}$	30<V<300	Standing in moving air	Seppeman (1972)
Hc=0.70	0<V<30		

Where h_c is in Btu/h ft^2

V is in fpm

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Exhibit 10.21: Humidity Control Through Cooling Override

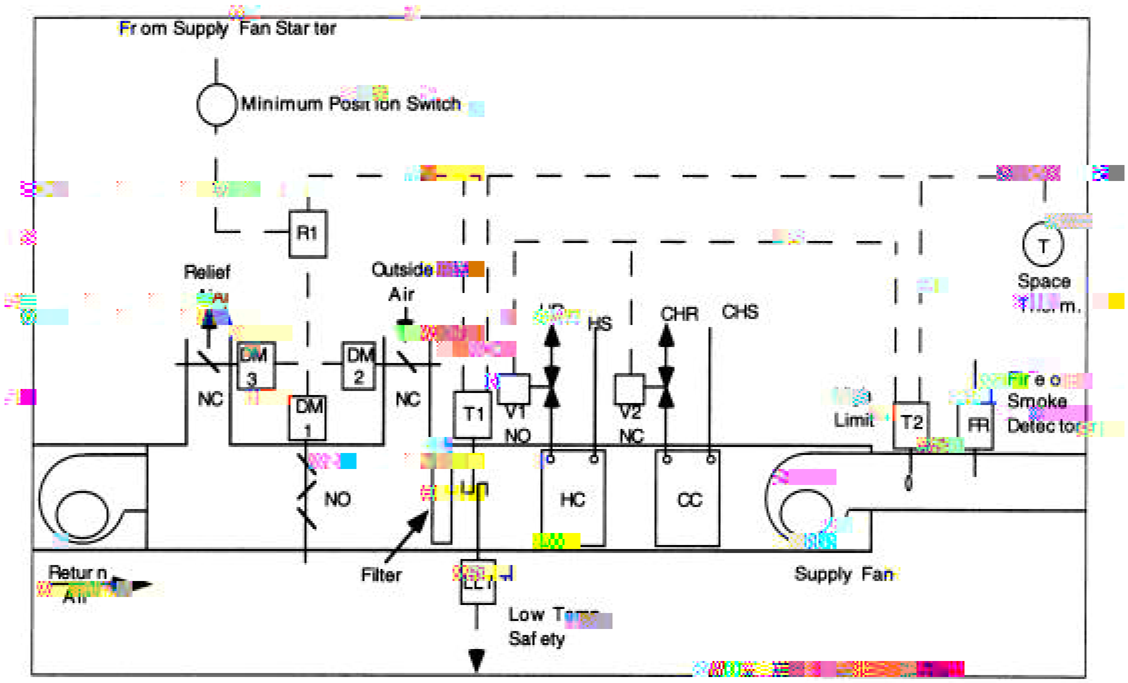

Exhibit 10.22: Single Zone - All Direct Control from Space Thermostat

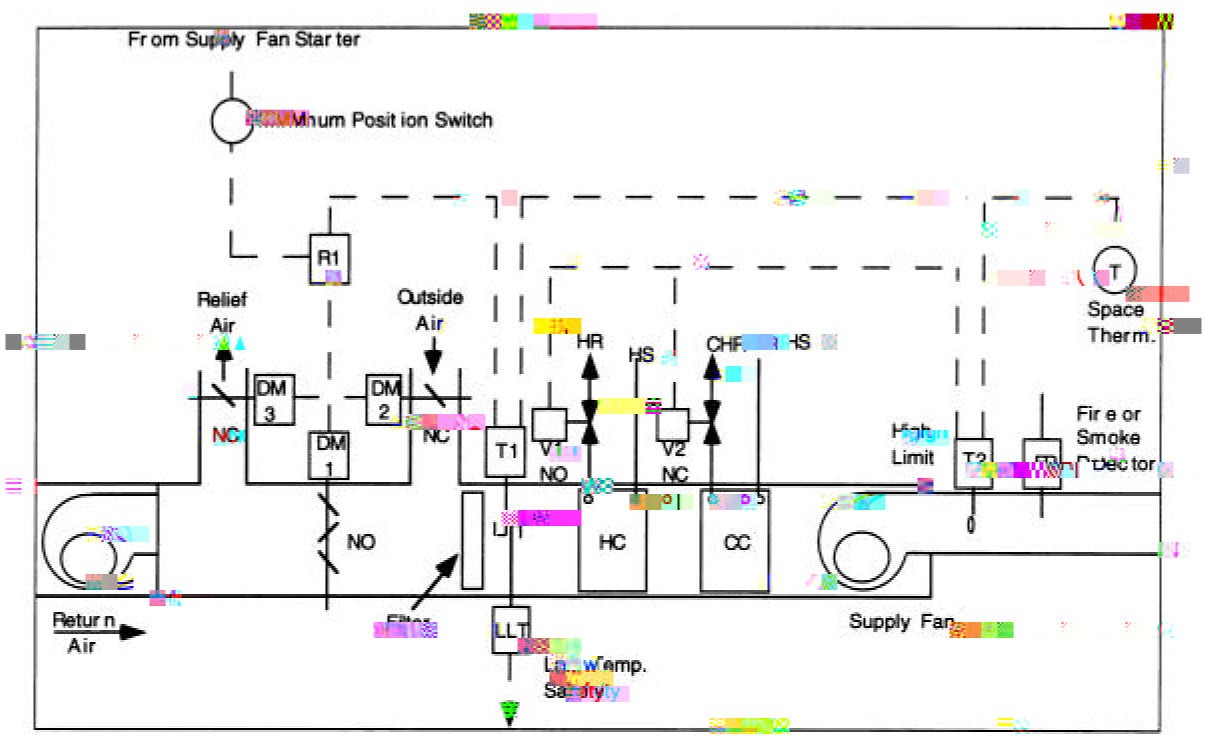

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Exhibit 10.23: Dual Duct Air Handling System

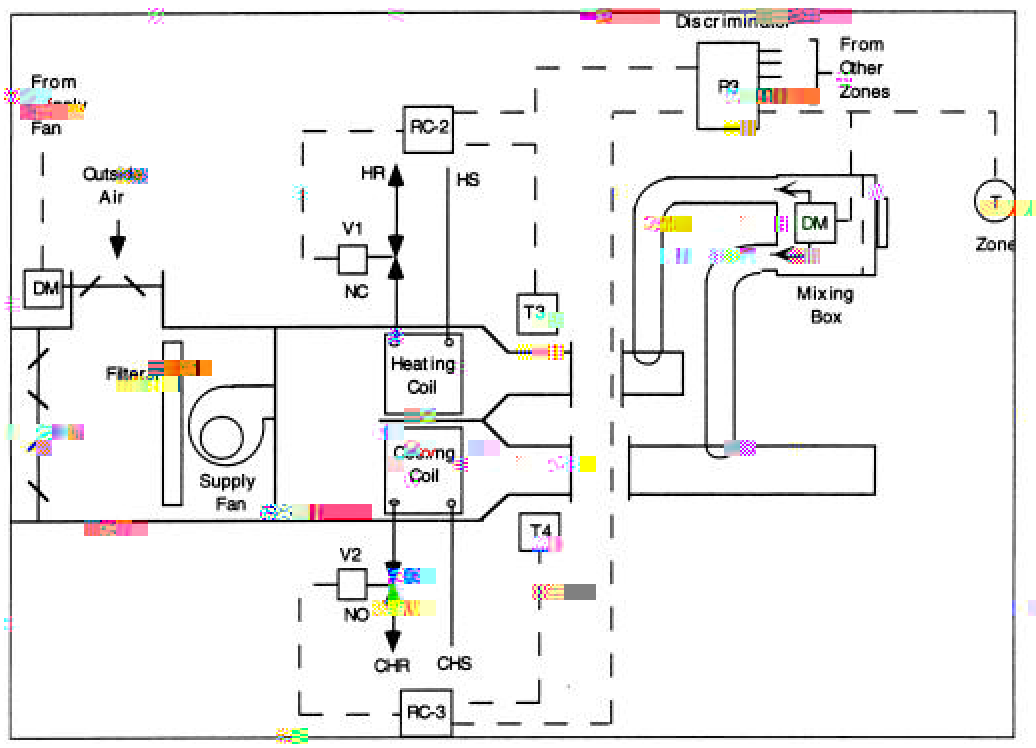


Exhibit 10.24: Multi-zone Air Handling Unit

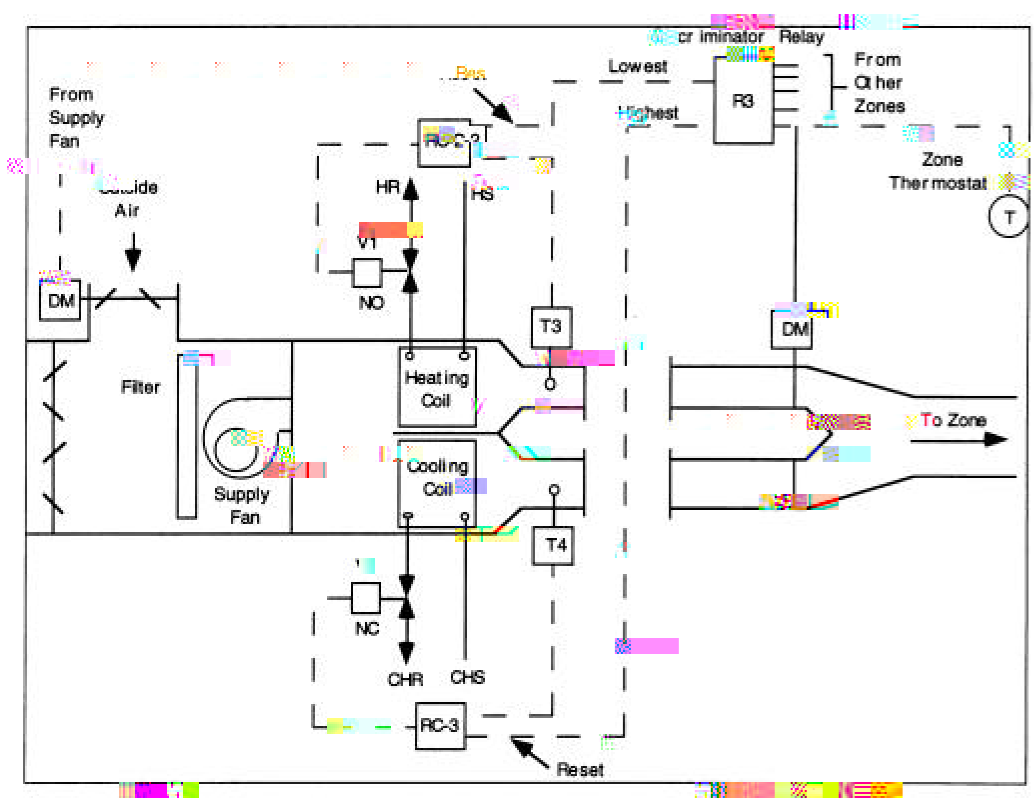
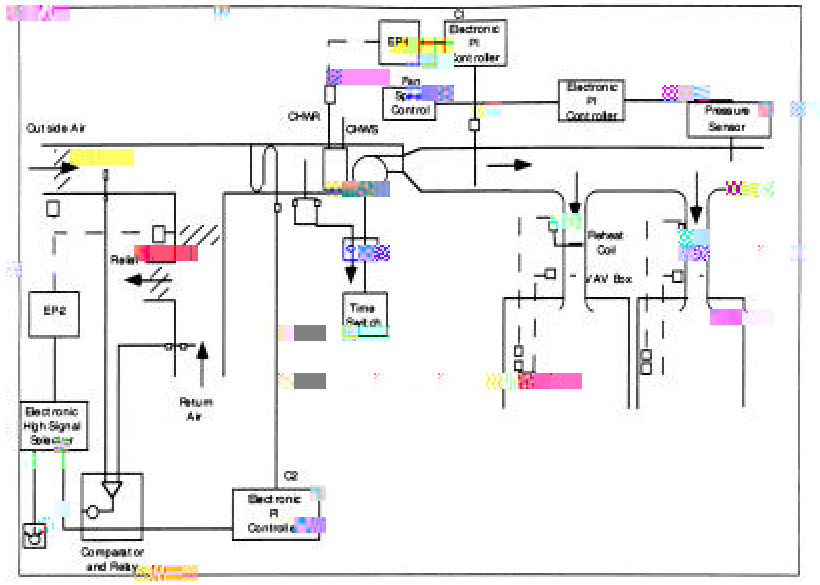


Exhibit 10.25: Hybrid VAV Control System



10.3 VENTILATION

Many operations require ventilation to control the level of dust, gases, fumes, or vapors. Excess ventilation for this purpose can add significantly to the heating load. All air that is exhausted from the building must be replaced by outside air.

During the heating season the air must be heated to room temperature by makeup air units or by infiltration and mixing with room air. When process heating is also involved, excess ventilation results in a loss of energy at all times.

A common problem during the winter heating season is negative building pressure resulting from attempting to exhaust more air than can be supplied. The most obvious problem encountered with air starvation is difficulty in opening doors. Negative pressure will lead to a number of other problems.

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process heating is involved, the resulting higher summer exhaust rate is not a problem. However, when process heating is involved, such as with ovens, the higher exhaust rate will increase the heat loss.

10.3.1 Losses

Losses of air from buildings are inevitable. The air which was heated will slowly seep through gaps around windows, doors and ducts. It is a phenomenon one has to deal with. On the other hand, not only that

* 1.08 = 60 min/hr x 0.075 lbs/cgg0ftx 0.024 speciici heat of air Tj 322 0 TD 0 Tc -0.1875 Tw ( ) Tj -4261 -675 TD /F0 6

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ENERGY CONSERVATION RESOURCES

1. Silver, Daniel M. "The Sustainable Energy Guide: International Resources for Energy-Efficiency and Renewable Energy." International Institute for Energy Conservation Publications, Washington DC, 1994.
2. Energy Conservation Program Guide for Industry and Commerce, NBS Handbook 115 and Supplement, U.S. Department of Commerce and Federal Administration, U.S. Government Printing Office, 1975.
3. Industrial Market and Energy Management Guide, American Consulting Engineers Council, Research and Management Foundation, 1987.
4. Levers, W.D., The Electrical Engineer's Challenge in Energy Conservation., *IEEE Trans. Of Industrial Applications*, 1A-11,4,1975
5. Windett, A.S., *Reducing the Cost of Electricity Supply*, Gower Press, 1973
6. Zackrison, H.B., Energy Conservation Techniques for Engineers, Van Nostrand Reinhold Company, 1984.
7. California Environmental Protection Agency, *Waste Audit Study of the Electric Utility Industry*, Cal-EPA, Department of Toxic substance Control, December 1991.
8. Flavin, Christopher and Alan B. Durning. *Building on Success: The Age of Energy Efficiency*. Worldwatch Institute, Washington, D.C., 1988.
9. Culp, Archie W. *Principles of Energy Conversion*. McGraw-Hill, New York, 1991.
10. Freeman, S. David. *Energy: The New Era*. Walker, New York, 1974.
11. Shinskey, F. Greg. *Energy Conservation Through Control*. Academic Press, New York, 1978.
12. Dumas, Lloyd J. *The Conservation Response: Strategies for the Design and Operation of Energy-Using Systems*. Lexington Books, Lexington, Mass, 1976.
13. Hafemeister, David W. *Energy Sources: Conservation and Renewables*. AIP Conference Proceedings, American Institute of Physics, New York, 1985.
14. Stasiowski, Frank A. *Nine Hundred and Forty Three Ways to Save Energy*. Practice Management Associates, Ltd., Newton, Massachusetts, 1991.
15. Kreith, Frank and George Burmeister. *Energy Management and Conservation*. National Conference of State Legislatures, Denver, CO, 1993.
16. Geller, Howard S. and John M. DeCicco. *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*. American Council for an Energy Efficient Economy, Washington, D.C., 1992.
17. Watson, Donald. *Energy Conservation Through Building Design*. McGraw-Hill, New York, 1979.
18. Institute of Electrical and Electronics Engineers. *IEEE Recommended Practice Energy Conservation and Cost-Effective Planning in Industrial Facilities*. IEEE , New York, 1984.
19. Kreith, Frank and Ronald West. *CRC Handbook of Energy Efficiency*. CRC Press, Boca Raton, 1997.

Notes

POLLUTION PREVENTION PUBLICATIONS

Title	EPA Document Number
The Automotive Refinishing Industry.	EPA 625/791/016
The Automotive Repair Industry.	EPA 625/791/013
The Commercial Printing Industry.	EPA 625/790/008
The Fabricated Metal Products Industry.	EPA 625/790/006
The Fiberglass-Reinforced And Composite Plastics Industry.	EPA 625/791/014
The Marine Maintenance And Repair Industry.	EPA 625/791/015
The Mechanical Equipment Repair Industry.	EPA 625/R92/008
Metal Casting And Heat Treating Industry.	EPA 625/R-92-009
The Metal Finishing Industry.	EPA 625/R92/011
Municipal Pretreatment Programs.	EPA 625/R93/006
Non-Agricultural Pesticide Users.	EPA 625/R93/009
The Paint Manufacturing Industry.	EPA 625/790/005
The Pesticide Formulating Industry.	EPA 625/790/004
The Pharmaceutical Industry.	EPA 625/791/017
The Photoprocessing Industry.	EPA 625/791/012
The Printed Circuit Board Manufacturing Industry.	EPA 625/790/007
Research And Educational Institutions.	EPA 625/790/010
Selected Hospital Waste Streams.	EPA 625/790/009
Wood Preserving Industry.	EPA 625/R93/014
<u>OTHER MANUALS:</u>	
Facility Pollution Prevention Guide	EPA 625/R92/088
Opportunities For Pollution Prevention Research To Support the 33/50 Program	EPA/600/R92/175
Life Cycle Design Guidance Manual.	EPA/600/R92/226

Notes

Title	EPA Document Number
Achievements In Source Reduction And Recycling For Ten Industries In The United States	EPA/600/291/051
Background Document On Clean Products Research And Implementation	EPA/600/290/048
Opportunities For Pollution Prevention Research To Support The33/50 Program	EPA/600/R92/175
Waste Minimization Practices At Two CCA Wood Treatment Plants	EPA/600/R93/168
WMOA Report And Summary – Fort Riley, Kansas	EPA/600/S2-90/031
WMOA Report And Summary – Philadelphia Naval Shipyard/ Governors Island	EPA/600/S2-90/062
Management Of Household And Small-Quality-Generator Hazardous Waste In The United States	EPA/600/S2-89/064
WMOA Report And Summary – Naval Undersea Warfare Engineering Station, Keport, WA	EPA/600/S2-91/030
WMOA Report And Summary – Optical Fabrication Laboratory, Fitzsimmins Army Medical Center, Denver, Colorado	EPA/600/S2-91/031
WMOA Report And Summary – A Truck Assembly Plant	EPA/600/S2-91/038
WMOA Report And Summary – A Photofinishing Facility	EPA/600/S2-91/039
WMOA Report And Summary – Scott Air Force Base	EPA/600/S2-91/054
Guidance Document For The Write Pilot Program With State And Local Governments	EPA/600/S8-89/070
Machine Coolant Waste Reduction By Optimizing Coolant Life	EPA/600/S2-90/033
Recovery Of Metals Using Aluminum Displacement	EPA/600/S2-90/032
Metal Recovery/Removal Using Non-Electrolytic Metal Recovery	EPA/600/S2-90/033
Evaluation Of Five Waste Minimization Technologies At The General Dynamics Pomona Division Plant	EPA/600/S2-91/067
An Automated Aqueous Rotary Washer For The Metal Fabrication Industry	EPA/600/Sr-92/188
Automotive And Heavy Duty Engine Coolant Recycling By Filtration	EPA/600/S2-91/066
Automotive And Heavy Duty Engine Coolant Recycling By Distillation	EPA/600/Sr-92/024
Onsite Waste Ink Recycling	EPA/600/Sr-92/251
Diaper Industry Workshop Report	EPA/600/S2-91/251

Notes

Title	EPA Document Number
Industrial Pollution Prevention Opportunities For The 1990's	EPA/600/Sr-91/052
Hospital Pollution Prevention Case Study	EPA/600/S2-91/024
Waste Minimization Audit Report: Case Studies Of Minimization Of Cyanide Waste From Electroplating Operations	EPA/600/S2-87/055
Waste Minimization Audits At Generators Of Corrosive And Heavy Metal Wastes	EPA/600/S2-87/056
Waste Minimization Audit Report: Case Studies Of Minimization Of Solvent Wastes From Parts Cleaning And From Electronic Capacitor Manufacturing Operations	EPA/600/S2-87/057
Waste Minimization In The Printed Circuit Board Industry – Case Studies	EPA/600/S2-88/008
Waste Minimization Audit Report: Case Studies Of Minimization Of Solvent Wastes And Electroplating Wastes At A DOD Installation	EPA/600/S2-88/010
Waste Minimization Audit Report: Case Studies Of Minimization Of Mercury-Bearing Wastes At A Mercury Cell Chloralkali Plant	EPA/600/S2-88/011
Pollution Prevention Opportunity Assessment: USDA Beltsville Agricultural Research Center, Beltsville, Maryland	EPA/600/Sr-93/008
Pollution Prevention Opportunity Assessment For Two Laboratories At Sandia National Laboratories	EPA/600/Sr-93/015
Ink And Cleaner Waste Reduction Evaluation For Flexographic Printers	EPA/600/Sr-93/086
Mobile Onsite Recycling Of Metalworking Fluids	EPA/600/Sr-93/114
Evaluation Of Ultrafiltration To Recover Aqueous Iron Phosphating/ Degreasing Bath	EPA/600/Sr-93/144
Recycling Nickel Electroplating Rinse Waters By Low Temperature Evaporation And Reverse Osmosis	EPA/600/Sr-93/160
<u>WASTE MINIMIZATION ASSESSMENT FOR:</u>	
Aerial Lifts.	EPA 600/S-94-011
Aluminum And Steel Parts.	EPA 600/S-94-010
Aluminum Cans.	EPA 600/M91/025
Aluminum Extrusions.	EPA 600/S-92-010
Automotive Air Conditioning Condensers And Evaporators.	EPA 600/S-92-007
Baseball Bats And Golf Clubs.	EPA 600/S-93-007
Caulk.	EPA 600/S-94-017

Notes

Title	EPA Document Number
Can-Manufacturing Equipment.	EPA 600/S-92-014
Chemicals.	EPA 600/S-92-004
Commercial Ice Machines And Ice Storage Bins.	EPA 600/S-92-012
Components For Automobile Air Conditioners.	EPA 600/S-92-009
Compressed Air Equipment Components.	EPA 600/M91/024
Custom Molded Plastic Products.	EPA 600/S-92-034
Cutting And Welding Equipment.	EPA 600/S-92-029
Electrical Rotating Devices.	EPA 600/S-94-018
Felt Tip Markers, Stamp Pads, And Rubber Cement.	EPA 600/S-94-013
Fine Chemicals Using Batch Processes.	EPA 600/S-92-055
Finished Metal And Plastic Parts.	EPA 600/S-94-005
Finished Metal Components.	EPA 600/S-92-030
Gravure-Coated Metalized Paper And Metalized Film	EPA 600/S-94-008
Heating, Ventilating, And Air Conditioning Equipment.	EPA 600/M91/019
Industrial Coatings.	EPA 600/S-92-028
Injection-Molded Car And Truck Mirrors.	EPA 600/S-92-032
Iron Castings And Fabricated Sheet Metal Parts.	EPA 600/S-95-008
Labels And Flexible Packaging.	EPA 600/S-95-004
Machined Parts.	EPA 600/S-92-031
Metal Bands, Clamps, Retainers, And Tooling.	EPA 600/S-92-015
Metal-Plated Display Racks.	EPA 600/S-92-019
Microelectronic Components.	EPA 600/S-94-015
Military Furniture.	EPA 600/S-92-017
Motor Vehicle Exterior Mirrors.	EPA 600/S-92-020
New And Reworked Rotogravure Printing Cylinders.	EPA 600/S-95-005
Orthopedic Implants.	EPA 600/S-92-064
Outdoor Illuminated Signs.	EPA 600/M91/016
Paper Rolls, Ink Rolls, Ink Ribbons, And Magnetic And Thermal Transfer Ribbons.	EPA 600/S-95-003

Title	EPA Document Number
Parts For Truck Engines	EPA 600/S-94-019
Penny Blanks And Zinc Products.	EPA 600/S-92-037
Permanent-Magnet DC Electric Motors.	EPA 600/S-92-016
Pliers And Wrenches.	EPA 600/S-94-004
Prewashed Jeans.	EPA 600/S-94-006
Printed Circuit Boards.	EPA 600/M91/022
Printed Circuit Boards.	EPA 600/S-92-033
Printed Labels.	EPA 600/M91/047
Printed Plastic Bags.	EPA 600/M/90/017
Product Carriers And Printed Labels.	EPA 600/S-93-008
Prototype Printed Circuit Boards.	EPA 600/M91/045
Rebuilt Railway Cars And Components.	EPA 600/M91/017
Refurbished Railcar Bearing Assemblies.	EPA 600/M91/044
Rotogravure Printing Cylinders.	EPA 600/S-93-009
Screwdrivers.	EPA 600/S-94-003
Sheet Metal Cabinets And Precision Metal Parts.	EPA 600/S-92-021
Sheet Metal Components.	EPA 600/S-92-035
Silicon-	

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TECHNOLOGY TRANSFER INFORMATION SOURCES

GOVERNMENT- NATIONAL

Provider: Asbestos Abatement/Management Ombudsman
Telephone: (703) 305-5938 or (800) 368-5888
Hours: 8:00 a.m. - 4:30 p.m. (EST) M-F
Abstract: The assigned mission of the Asbestos Ombudsman is to provide to the public information on handling, abatement, and management of asbestos in schools, the work place, and the home. Interpretation of the asbestos in schools requirements is provided. Publications to explain recent legislation are also available. Services are provided to private citizens, community services, state agencies, local agencies, local public and private school systems, abatement contractors, and consultants.

Provider: Association of Small Business Development Centers
Membership: State small business development centers
Name: Jim King
Position: Chairman, Government Relations
Telephone: (518) 443-5398
Fax: (518) 465-4992
E-mail: kingj@sysadm.suny.edu
Name: Kathleen Dawson
Position: Executive Director
Telephone: (703) 448-6124
Fax: (703) 448-6125

Provider: U.S. EPA Small Business Ombudsman Clearinghouse/Hotline
Telephone: (703) 305-5938, (800) 368-5888
Hours: Message recorder is on 24 hours a day.
Abstract: The mission of the U.S. EPA Small Business Ombudsman Clearinghouse/Hotline is to provide information to private citizens, small communities, small business enterprises, and trade associations representing the small business sector regarding regulatory activities. Technical questions are answered following appropriate contacts with program office staff members. Questions addressed cover all media program aspects within U.S. EPA.

Provider: Green Lights and Energy Star Programs
Telephone: (202) 775-6650, (888) STAR-YES [782-7937]
Abstract: The success of the Green Lights program depends on the actions taken by Partners and Allies to implement energy-efficient lighting upgrade projects, ultimately resulting in sustained pollution prevention. U.S. EPA's participant support programs provide planning and implementation guidance for successful lighting upgrade projects. U.S. EPA offers four types of support programs: Information, Planning, Analysis Tools, and Communications.

Provider: Indoor Air Quality Information Clearinghouse (IAQINFO)
Telephone: (800) 438-4318
Fax: (202) 484-1510
E-mail: iaqinfo@aol.com
Hours: 9:00 a.m. to 5:00 p.m. (EST), M-F; after-hours voice mail
Abstract: The purpose of the IAQINFO is to help you locate information to answer your questions about indoor air pollution. IAQINFO can provide information on (1) the sources, health effects, testing and measuring, and controlling indoor air pollutants; (2) constructing and maintaining homes and buildings to minimize indoor air quality problems; (3) existing standards and guidelines related to indoor air quality; and (4) general information on Federal and State legislation.

Notes

Provider: Information Resources Center (formerly the library)
Telephone: (202) 260-5922
Hours: 8:00 a.m. - 5:00 p.m., M-F (walk-in)
E-mail: libraryhq@epamail.epa.gov
Abstract: The Information Resources Center is open to U.S. EPA personnel and the public. It

Notes

GOVERNMENT – REGIONAL

Provider: National Response Center - regional programs
Telephone:

Region I	(617) 223-7265
Region II	(732) 548-8730
Region III	(215) 566-3255
Region IV	(404) 562-8700
Region V	(312) 353-2318
Region VI	(214) 665-2222
Region VII	(913) 281-0991
Region VIII	(303) 293-1788
Region IX	(415) 744-2000
Region X	(206) 553-1263

Provider: Region I Air Quality Information Line
Telephone: (617) 565-9145
Abstract: The Air Quality Information Line is a voice mail system that routes the caller to the appropriate Region I air quality point of contact for the purpose of lodging complaints, asking questions, requesting information, and providing tips.

Provider: Region I General Information

Notes

Telephone: (800) 241-1754

Notes

	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	www.state.ak.us/akdec
Affiliations:	Alaska Department of Environmental Conservation
Name:	David Wigglesworth
Position:	Acting Director
Telephone:	(907) 269-7571
Fax:	(907) 269-7600
E-mail:	CompAsst@envircon.state.ak.us
Name:	Scott Lytle
Position:	Manager
Name:	Toll Free Hotline (State)
Telephone:	(800) 510-2332

Provider:	Alaska Small Business Development Center
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Affiliations:	Association of Small Business Development Centers
	U.S. Small Business Administration
Name:	Jan Fredericks
Position:	State Director
Telephone:	(907) 274-7232
Fax:	(907) 274-9524
E-mail:	anjaf@uaa.alaska.edu

Provider:	Arizona Small Business Assistance Program
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	www.adeq.state.az.us/admin/do/comp.htm
Affiliations:	Arizona Department of Environmental Quality, Customer Service
Name:	Gregory Workman
Position:	Program Manager
Telephone:	(602) 204-4337
Fax:	(602) 207-4872
E-mail:	workman.gregory@ev.state.az.us
Name:	Toll Free Hotline (State)
Telephone:	(800) 234-5677

Provider:	Arizona Small Business Development Center
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	www.dist.maricopa.edu/sbdc
Affiliations:	Association of Small Business Development Centers
	Maricopa Community College
	U.S. Small Business Administration
Name:	Michael York
Position:	State Director
Telephone:	(602) 731-8722
Fax:	(602) 731-8729
E-mail:	york@maricopa.edu

Provider:	Arkansas Small Business Assistance Program

Notes

Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Arkansas Department of Pollution Control and Ecology
Name: Robert Graham
Position: Small Business Ombudsman
Telephone: (501) 682-0708
Fax: (501) 682-0707
E-mail: help-sba@adeq.state.ar.us

Provider: Arkansas Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.ualr.edu/~sbdcdept
Affiliations: Association of Small Business Development Centers
U.S. Small Business Administration
University of Arkansas at Little Rock
Name: Janet Nye
Position: State Director
Telephone: (501) 324-9043
Fax: (501) 324-9049
E-mail: jmnye@ualr.edu

Provider: California Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.arb.ca.gov/cd/cd.htm
Affiliations: California Environmental Protection Agency, Air Resources Bureau
Name: Peter Venturini
Position: Director
Telephone: (916) 445-0650
Fax: (916) 327-7212
E-mail: helpline@arb.ca.gov
Name: Toll Free Hotline (State)
Telephone: (800) 272-4572

Provider: California Small Business Development Center Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.commerce.ca.gov/small
Affiliations: Association of Small Business Development Centers
Name: Kim Neri
Position: State Director
Telephone: (916) 324-5068
Fax: (916) 324-5084
E-mail: kimn@smtp.doc.ca.gov

Provider: California South Coast Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.aqmd.gov/business

Notes

Affiliations: California South Coast Air Quality Management District
Name: Natalia Porche
Position: Director
Telephone: (909) 396

Notes

Position:

Notes

Provider: Florida Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.dep.state.fl.us/air/programs/sbap/index.htm
Affiliations: Florida Department of Environmental Protection, Bureau of Air Regulations
Name: Bob Daugherty
Position: SBAP Principal
Telephone: (904) 488-1344
Fax: (904) 922-6979
E-mail: clark_l@dep.state.fl.us
Name: Toll Free Hotline (State)
Telephone: (800) 722-7457

Provider: Florida Small Business Development Center Network
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.fsbdc.uwf.edu
Affiliations: Association of Small Business Development Centers
U.S. Small Business Administration
University of West Florida
Name: Jerry Cartwright
Position: State Director
Telephone: (904) 444-2060
Fax: (904) 444-2070
E-mail: fsbdc@uwf.edu

Provider: Georgia Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.DNR.State.Ga.US/dnr/environ
Affiliations: Georgia Department of Natural Resources, Air Protection Bureau
Name: Anita Dorsey-Worm5Worm**Telephone:**Anita D(904)4444 Tj4 0(Ab5-0.2467-0.2467f T625 TwD-)Fl2 9376 Tf5 -0.0375224c (207

Affiliations: Telephonetme5**Name:** 026vider:Hen**Position:** **Telephone:** **Membership:** -major sources

Notes

	Businesses with 100 or fewer employees
	Independently owned businesses
Affiliations:	Hawaii Department of Health, Clean Air Branch
Name:	Robert Tam
Position:	Program Manager
Telephone:	(808) 586-4200
Fax:	(808) 586-4370

Provider:	Hawaii Small Business Development Center Network
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	www.maui.com/~sbdc/hilo.html
Affiliations:	Association of Small Business Development Centers
	U.S. Small Business Administration
	University of Hawaii at Hilo
Name:	Darryl Mleynek
Position:	State Director
Telephone:	(808) 974-7515
Fax:	(808) 974-7683
E-mail:	darrylm@interpac.net

Provider:	Idaho Small Business Assistance Program
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Affiliations:	Idaho Department of Environmental Quality
Name:	Doug McRoberts
Position:	Small Business Ombudsman
Telephone:	(208) 373-0298
Fax:	(208) 373-0417
E-mail:	dmcrober@deq.state.id.us

Provider:	Idaho Small Business Development Center
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	www.idbsu.edu/isbdc
Affiliations:	Association of Small Business Development Centers
	Boise State University
	U.S. Small Business Administration
Name:	Jame Hogge
Position:	State Director
Telephone:	(208) 385-1640
Fax:	(208) 385-3877
E-mail:	jhogge@bsu.idbsu.edu

Notes

Provider: Illinois Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.commerce.state.il.us
Affiliations: Association of Small Business Development Centers
U.S. Small Business Administration
Name: Jeff Mitchell
Position: State Director
Telephone: (217) 524-5856
Fax: (217) 524-0171
E-mail: jeff.mitchell@accessil.com
Name: Toll Free Hotline (State)
Telephone: (800) 252-3998

Provider: Illinois Small Business Environmental Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.commerce.state.il.us/dcca/files/fs/ba/ba35.htm
Affiliations: Illinois Department of Commerce and Community Affairs
Name: Mark Enstrom
Position: Program Manager
Telephone: (217) 524-0169
Fax: (217) 785-6328

Provider: Indiana Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.state.in.us
Affiliations: Indiana Department of Environmental Mgmt, Office of Pollution Prevention
Name: Maggie McShane
Position: Office of Business Relations
Telephone: (317) 232-5964
Fax: (317) 233-5627

Provider: Indiana Small Business Development Center Network
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Association of Small Business Development Centers
U.S. Small Business Administration
Name: Stephen Thrash
Position: Executive Director
Telephone: (317) 264-6871
Fax: (317) 264-3102
E-mail: sthrash@in.net
Name: Toll Free Fax on Demand Hotline
Fax: (800) 726-8000

Provider: Iowa Air Emissions Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses

Notes

Internet URL: www.iwrc.org
Affiliations: Iowa Waste Reduction Center
University of Northern Iowa
Name: John Konefes
Position: Director
Telephone: (319) 273-2079
Fax: (319) 273-2926
Name:

Notes

Businesses with 100 or fewer employees
Independently owned businesses

Internet URL: www.state.me.us/dep
Affiliations: Maine Department of Environmental Protection, Office of Pollution Prevention
Name:

Notes

Position: Program Director
Telephone: (617) 727-3260
Fax: (617) 727-3827

Provider: Massachusetts Small Business Development Center Network
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.umassp.edu/msbdc
Affiliations: Association of Small Business Development Centers
University of Massachusetts - Amherst
Name: John Ciccarelli
Position: State Director
Telephone: (413) 545-6301

Fax: (413) 545-1273
E-mail: j.ciccarelli@dpc.umass.edu

Provider: Michigan Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.deq.state.mi.us/ead/iasect/eac.html
Affiliations: Michigan Department of Natural Resources
Name: Dave Fiedler
Position: Manager, Clean Air Asst. Prog.
Telephone: (517) 373-0607
Fax: (517) 335-4729
E-mail: eac@deq.state.mi.us
Name: Toll Free Hotline (National)
Telephone: (800) 662-9278

Provider: Michigan Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: BizServe.c URL:

Notes

Fax:	(612) 297-7709
E-mail:	barbara.conti@pca.state.mn.us
Name:	Phyllis Strong
Position:	Compliance Asst. Specialist
E-mail:	phyllis.strong@pca.state.mn.us
Name:	Toll Free Hotline (State)
Telephone:	(800) 657-3938

Provider:	Minnesota Small Business Development Center
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.d.umn.edu/~jjacobs1/sbdc.html
Affiliations:	Association of Small Business Development Centers U.S. Small Business Administration
Name:	Mary Kruger
Position:	State Director
Telephone:	(612) 297-5770
Fax:	(612) 296-1290
E-mail:	mary.kruger@state.mn.us

Provider:	Mississippi Small Business Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Chemical marketers Independently owned businesses
Affiliations:	Mississippi Department of Environmental Quality
Name:	Jesse Thompson
Position:	BAP Principal
Telephone:	(601) 961-5171
Fax:	(601) 961-5742
E-mail:	jesse_thompson@deq.state.ms.us
Name:	Toll Free Hotline (National)
Telephone:	(800) 725-6112

Provider:	Mississippi Small Business Development Center
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.olemiss.edu/depts/mssbdc
Affiliations:	Association of Small Business Development Centers U.S. Small Business Administration
Name:	Raleigh Byars
Position:	State Director
Telephone:	(601) 232-5001
Fax:	(601) 232-5650
E-mail:	rbyars@olemiss.edu

Provider:	Missouri Small Business Development Center
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees

RL:

Notes

	University of Missouri
Name:	Max Summers
Position:	State Director
Telephone:	(573) 882-0344
Fax:	(573) 884-4297
E-mail:	sbdc-mso@ext.missouri.edu

Provider:	Missouri Small Business Technical Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.state.mo.us/dnr/deq/tap/hometap.htm
Affiliations:	Missouri Department of Natural Resources
Name:	Byron Shaw, Jr.
Position:	Chief, Business Assistance Unit
Telephone:	(573) 526-5352
Fax:	(573) 526-5808
Name:	Toll Free Hotline (National)
Telephone:	(800) 361-4827

Provider:	Montana Small Business Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.deq.mt.gov/pcd/index.htm
Affiliations:	Montana Department of Environmental Quality, Air Quality Division
Name:	Mark Lambrecht
Position:	Project Manager
Telephone:	(406) 444-1424
Fax:	(406) 406-4441
Name:	Toll Free Hotline (National)
Telephone:	(800) 433-8773

Provider:	Montana Small Business Development Center
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Affiliations:	Association of Small Business Development Centers U.S. Small Business Administration
Name:	Ralph Closure
E-mail	Acting Director
Telephone:	(406) 444-4780
Fax:	(406) 444-1872
E-mail	rclosure@mt.gov

Provider:	Nebraska Small Business Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Affiliations:	Nebraska Department of Environmental Quality
Name:	Dan Eddinger

Notes

Provider: Nebraska Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.nbdc.unomaha.edu
Affiliations: Association of Small Business Development Centers
U.S. Small Business Administration
University of Nebraska at Omaha
Name: Robert Bernier
Position: State Director
Telephone: (402) 554-2521
Fax: (402) 554-3473
E-mail: rbernier@cbafaculty.unomaha.edu

Provider: Nevada Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Nevada Department of Environmental Protection
Name: David Cnes,c1875 Tw (444 0.75 re f BT 99 548.25 TD /F2 9.75 Tf ( ) Tj 0 -11.25 TD 6-0.12l Tf ( ) Tj

Notes

Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Association of Small Business Development Centers
Santa Fe Community College
Name: J. Roy Miller
Position: State Director
Telephone: (505) 438-1362
Fax: (505) 471-9469
E-mail: rmiller@santa-fe.cc.nm.us

Provider: New York Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: New York State Environmental Facilities Corporation
Name: Marian Mudar
Position: Environmental Program Manager
Telephone: (518) 457-9135
Fax: (518) 485-8494
E-mail: mudar@nyefc.org
Name: Toll Free Hotline (State)
Telephone: (800) 780-7227

Provider: New York Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Association of Small Business Development Centers
Name: James King
Position: State Director
Telephone: (518) 443-5398
Fax: (518) 465-4992
E-mail: kingjl@sysadm.suny.edu

Provider: North Carolina Small Business and Technical Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.sbtdc.org
Affiliations: Association of Small Business Development Centers
Name: Scott Daugherty
Position: Executive Director
Telephone: (919) 715-7272
Fax: 919) 715-7777
E-mail: srdaughe.sbdc@mhs.unc.edu

Provider: North Carolina Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: North Carolina Department of Health and Natural Resources
Name: Fin Johnson
Position: Program Manager
Telephone: (919) 733-0824

Notes

E-mail: hschick@odod.ohio.gov
Name: Toll Free Hotline (National)
Telephone: (800) 848-1300
Name: Toll Free Hotline (State)
Telephone: (800) 248-4040

Provider: Oklahoma Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.deq.oklaosf.state.ok.us.SBAPintr.htm
Affiliations: Oklahoma Department of Environmental Quality
Name: Adrian Simmons
Position: Wood Furniture, Emissions
Name: Alwin Ning
Position: Electroplating & Printing
Telephone: (405) 271-1400
Fax (405) 271-1317
Name: Judy Duncan
Position: Director, Customer Services Div.
Name: Kyle Arthur
Position: Degreasing, Dry Cleaning, Title V
Name: Toll Free Hotline (State)
Telephone: (800) 869-1400

Provider: Oklahoma Small Business Development Center
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Affiliations: Association of Small Business Development Centers
Southeastern Oklahoma State
U.S. Small Business Administration
Name: Grade Pennington
Position: State Director
Telephone: (800) 522-6154
Fax (405) 920-7471
E-mail: gpennington@sosu.edu

Provider: Oregon Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.deq.state.or.us
Affiliations: Oregon Department of Environmental Quality, Air Quality Division
Name: Terry Obteshka
Position: Director
Telephone: (503) 229-6147
Fax (503) 229-5675
E-mail: obteshka.terry@deq.state.or.us
Name: Toll Free Hotline (State)
Telephone: (800) 452-4011

Provider: Oregon Small Business Development Center Network
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees

Notes

	Independently owned businesses
Affiliations:	Association of Small Business Development Centers
	Lane Community College
	U.S. Small Business Administration
Name:	Edward (Sandy) Cutler
Position:	State Director
Telephone:	(541) 726-2250
Fax	(541) 345-6006
E-mail:	cutlers@lanecc.edu

Provider:	Pennsylvania Air Help Small Business Assistance Program
Membership:	Businesses classified as non-major sources
	Businesses with 100 or fewer employees
	Independently owned businesses
Internet URL:	Busi TD -0r5 0 T6w 12.75 0 TD (San06rf 0.1143 To6rf 0.1143 To6rf 0.19Tj 14.25 0 TD 0.2701 Tc -0.45

Independently owned businesses **Internet URL:**

Notes

Affiliations: Association of Small Business Development Centers
Bryant College
U.S. Small Business Admini-22twtD (P (Affil5( ) Tj 57.10 0 TD 0 Tc -0.1875 Tw 3 ( ) Tj -282 -1 4.5 TD /F

4 0 1) 2 3 7 5 T c 3 5 (e) T j 5 9 . . 5 0 T D - 0 . 2 8 9 5 T 4

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	Independently owned businesses
Internet URL:	www.dba.state.virginia.us
Affiliations:	Association of Small Business Development Centers U.S. Small Business Administration
Name:	Robert Wilburn
Position:	State Director
Telephone:	(804) 371-8253
Fax	(804) 225-3384
E-mail:	rwilburn@dba.state.va.us

Provider:	Virginia Small Business Policy and Technical Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.deq.state.va.us/osba/smallbiz.html
Affiliations:	Virginia Department of Environmental Quality
Name:	Richard Rasmussen
Position:	Manager
Telephone:	(804) 698-4394
Fax	(804) 698-4510
E-mail:	rgrasmusse@deq.state.va.us
Name:	Toll Free Hotline (State)
Telephone:	(800) 592-5482

Provider:	Washington Small Business Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Affiliations:	Washington Department of Ecology
Name:	Leighton Pratt
Position:	Small Business Ombudsman
Telephone:	(360) 407-7018
Fax	(360) 407-6802

Provider:	Washington Small Business Development Center
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Internet URL:	www.sbdc.wsu.edu
Affiliations:	Association of Small Business Development Centers U.S. Small Business Administration Washington State University
Name:	Carol Riesenberg
Position:	State Director
Telephone:	(509) 335-1576
Fax	(509) 335-0949
E-mail:	riesenbe|@wsu.edu

Provider:	West Virginia Small Business Assistance Program
Membership:	Businesses classified as non-major sources Businesses with 100 or fewer employees Independently owned businesses
Affiliations:	West Virginia Office of Air Quality
Name:	Fred Durham
Position:	Director

Telephone: (304) 558-1217
Fax (304) 558-1222
E-mail: durhaf@mail.wvnet.edu

Notes

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Provider: Wyoming Small Business Assistance Program
Membership: Businesses classified as non-major sources
Businesses with 100 or fewer employees
Independently owned businesses
Internet URL: www.deq.state.wy.us/ms/outweb.htm

Notes

PRIVATE COMPANY - INTERNATIONAL

Provider: Alliance for Responsible Atmospheric Policy
Membership:

Notes

Position: Executive Secretary
Telephone: (609) 737-1902
Fax (609) 737-2743
E-mail: ecs@electrochem.org

Provider: Technical Association of the Pulp and Paper Industry
Membership: Pulp and paper industry professionals
Pulp and paper manufacturers
Pulp and paper processors
Pulp-derived chemical products manufacturers
Internet URL: www.tappi.org
Affiliations: American Forest and Paper AssociationP r
P

Notes

Provider: American Fiber Manufacturers Association
Membership: Fibers, filaments, and yarns manufacturers

Notes

Telephone:	(703) 525-0511
Fax	(703) 525-0515
E-mail:	cfa@cfa-hq.org

Provider:	Cosmetic, Toiletry, and Fragrance Association
Membership:	Personal care product distributors
	Personal care product manufacturers
	Raw materials suppliers
Internet URL:	www.ctfa.org
Affiliations:	Cosmetic Ingredient Review
Name:	Joyce Graff
Position:	Manager, Environmental Affairs
Telephone:	(202) 331-1770
Fax	(202) 331-1969

Provider:	Fertilizer Institute
Membership:	Consultants
	Fertilizer distributors
	Fertilizer manufacturers
	Raw materials suppliers
Name:	Jim Skillen
Position:	Dir., Envir. & Energy Programs
Telephone:	(202) 675-8250
Fax	(202) 544-8123

Provider:	Fire Retardant Chemical Association
Membership:	Fire retardant materials producers
	Fire retardant materials users
Name:	Russel C. Kidder
Position:	Executive Vice President
Telephone:	(717) 291-5616
Fax	(717) 295-9637

Provider:	Foodservice and Packaging Institute, Inc.
Membership:	Disposable foodservice product distributors
	Disposable foodservice products manufacturers.
	Equipment manufacturers
	Raw materials suppliers

Notes

E-mail:	communications@ifi.org
Name:	Toll Free Hotline (National)
Telephone:	(800) 638-2627

Provider:	International Slurry Surfacing Association
Membership:	Asphalt slurry seal companies Professionals involved in asphalt slurry seal
Internet URL:	www.history.rochester.edu/issa
Affiliations:	Foundation for Pavement Rehabilitation and Maintenance Research
Name:	John Fiegel
Position:	Executive Officer
Telephone:	(202) 857-1160
Fax	(202) 857-1111
E-mail:	issa@spa.com

Provider:	Metal Finishing Suppliers Association
Membership:	Metal finishing materials suppliers
Internet URL:	www.metal-finishing.com/mfsa.htm
Name:	Dr. Rebecca Spearot
Position:	Environmental Affairs Chair
Name:	Ken Hankinso
Position:	Environmental Affairs Vice Chair
Name:	Richard W. Crain
Position:	Executive Director
Telephone:	(630) 887-0797
Fax	(630) 887-0799

Provider:	National Association of Chemical Distributors
Membership:	Chemical distributors
Internet URL:	www.nacd.com
Affiliations:	National Association of Chemical Distributors Education Foundation
Name:	Geoffrey O'Hara
Position:	Director, Government Affairs
Name:	William Allmond
Position:	Director, Regulatory Affairs
Telephone:	(703) 527-6223
Fax	(703) 527-7747

Provider:	National Association of Chemical Distributors Education Foundation
Membership:	Chemical distributors Chemical manufacturers Chemical marketers Chemical recyclers Chemical users
Internet URL:	www.nacd.com/NACDEF
Affiliations:	National Association of Chemical Distributors
Name:	Lisa Capone
Position:	Program Manager
Telephone:	(703) 527-6223
Fax	(703) 527-7747

Provider:	National Association of Chemical Recyclers
Membership:	Chemical recyclers
Internet URL:	www.bismarck.com/nacr/nacr.html
Affiliations:	Cement Kiln Recycling Coalition

Notes

Name: H. Peter Nerger
Position: President
Telephone: (202) 296-1725
Fax (202) 296-2530
E-mail: 103612,514@compuserve.com

Provider: National Association of Printing Ink Manufacturers, Inc.
Membership: Printing ink manufacturers
Internet URL: www.napim.org/napim
Affiliations: National Printing Ink Research Institute
Name: George Fuchs
Position: Environmental Manager
Telephone: (201) 288-9454
Fax (201) 288-9453
E-mail: napim@napim.org

Provider: National Paint and Coatings Association
Membership: Chemical coatings manufacturers
Chemical coatings users
Paint distributors
Paint manufacturers
Paint users
Raw materials suppliers
Internet URL: www.paint.org
Name: J. Andrew Doyle
Position: Executive Director
Telephone: (202) 462-6272
Fax (202) 462-8549
E-mail: npca@paint.org
Name: Sonya McDavid
Position: Asst. Dir. Environmental Affairs
Name: Stephen R. Sides
Position: Director, Health, Safety, & Env.

Provider: National Pest Control Association
Membership: Pesticides applicators
Internet URL: www.pestworld.com
Name: Bob Rosenberg
Position: Director of Government Affairs
E-mail: Bob_Rosenberg@msn.com
Name: Gene Harrington
Position: Manager of Government Affairs
E-mail: Harrington@pestworld.org
Name: Rob Lederee
Position: CEO & Executive Vice President
Telephone: (703) 573-8330
Fax (703) 573-4116
E-mail: Lederer@pestworld.org

Provider: Pharmaceutical Research and Manufacturers of America
Membership: Research-based pharmaceutical operations
Internet URL: www.phma.org
Affiliations: Pharmaceutical Research and Manufacturers of America Foundation
Name: Thomas White
Position: Associate Vice President

Notes

Telephone:	(202) 835-3546
Fax	(202) 835-3597

Provider:	Polyisocyanurate Insulation Manufacturers Association
Membership:	Polyiso insulation manufacturers Raw materials suppliers
Name:	Rebecca Loyd
Position:	Secretary
Telephone:	(202) 624-2709
Fax	(202) 628-3856
E-mail:	pima@buildernet.com

Provider:	Powder Coatings Institute
Membership:	Powder coating equipment suppliers Powder coating facilities Powder coating materials manufacturers Powder

Notes

Internet URL: www.socma.com
Name: Cheryl O. Morton
Position: Director, Technical Affairs
Name: Graydon Powers
Position: President
Name: Mary J. Legatski
Position: Director, Government Relations
Name: Robert Grasso
Position: ion) 2960 Tw 575 Tf ( ) TjTj 7.5 [illegible]

Name:
Position: Robert Grasso

Notes

	Chemical users
Affiliations:	Chemical Manufacturers Association Federation of State Chemical Associations
Name:	Michael DeVito
Position:	Executive Director
Telephone:	(617) 451-6282
Fax	(617) 695-9568

Provider:	Michigan Chemical Council
Membership:	Chemical distributors Chemical manufacturers Chemical marketers
Affiliations:	Chemical Manufacturers Association Federation of State Chemical Associations
Name:	Andrew Such
Position:	Executive Director
Telephone:	(517) 372-8898
Fax	(517) 372-9020

Provider:	Ohio Chemical Council
Membership:	Chemical distributors Chemical manufacturers Chemical marketers Chemical recyclers
Internet URL:	www.ohiochem.org
Affiliations:	Chemical Manufacturers Association
Name:	Peggy Smith
Position:	Secretary/Executive Director
Telephone:	(614) 224-1730
Fax	(614) 224-5168
E-mail:	ohchem@infinet.com

Provider:	Pennsylvania Chemical Industry Council
Membership:	Chemical engineers Chemical manufacturers Chemical marketers Chemical recyclers
Internet URL:	www.pcic.org/home.html

Notes

	Chemical recyclers
Internet URL:	www.txchemcouncil.org
Affiliations:	Chemical Manufacturers Association Federation of State Chemical Associations
Name:	Jim Woodrick
Position:	President
Telephone:	(512) 477-4465
Fax	(512) 477-5387
E-mail:	kncard@mail.eden.com

UNIVERSITY - NATIONAL

Provider:	Center for Clean Products and Clean Technologies at the University of Tennessee
Membership:	Academic researchers
Internet URL:	www.ra.utk.edu/eerc/clean2.html
Affiliations:	University of Tennesee - Knoxville University of Tennessee Energy, Environment, and Resources Center
Name:	Gary A. Davis
Position:	Director
Telephone:	(423) 974-4251
Fax	(423) 974-1838
E-mail:	davisg@eerc.gw.utk.edu

Provider:	Center for Clean Technology at UCLA
Membership:	Academic researchers
Internet URL:	www.cct.seas.ucla.edu
Affiliations:	University of California- Los Angeles
Name:	Dr. Selim Senkan
Position:	Director
Telephone:	(310) 206-3071
E-mail:	cct@seas.ucla.edu

Provider:	Hazardous Substance Research Center South & Southwest
Membership:	Academic researchers
Internet URL:	www.eng.lsu.edu/center/hsrc.html
Affiliations:	Georgia Institute of Technology Louisiana State University Rice University U.S. Environmental Protection Agency
Name:	Danny D. Reible
Position:	Director
Telephone:	(504) 388-6770
Fax	(504) 388-5043
E-mail:	cmreib@lsuvm.sncc.lsu.edu

Provider:	Indiana Pollution Prevention and Safe Materials Institute
Membership:	Academic researchers
Internet URL:	www.ecn.purdue.edu/IPPI/
Affiliations:	Purdue University
Name:	Lynn A. Corson Ph.D.
Position:	Director
Telephone:	(317) 494-6450
Fax	(317) 494-6422
E-mail:	corsonl@ecn.purdue.edu

Notes

EPA Region 3 Home Page
http://www.epa.gov/region3/
- This website provides access to information regarding EPA Region 3 offices, programs, staff, and announcements.

EPA Atmospheric Pollution Prevention Division
http://www.epa.gov/appd.html
- This site provides information on the activities of EPA's Atmospheric P2 Division. Information on the Energy Star Program, Green Lights Program, Methane Outreach Program, publications, and software tools are also located at this website.

Global Environmental Network for Info Exchange (GENIE)
http://www-genie.mrrl.lut.ac.uk
- Started in 1992 by the Economic and Social Research Council, the Global Environmental Change Data Network Facility seeks to make information exchange among researchers more convenient.

Great Lakes Regional Environmental Information System
http://epawww.ciesin.org/
- The Great Lakes Website is a regional directory and data access system developed by CIESIN with support from the EPA's great Lakes Program, and the Great Lakes National Program Office. It provides directory information, on-line resources, documentation of EPA's activities in the Great Lakes Region, and a P2 forum for P2 technical assistance providers and P2 vendor information.

Great Lakes Regional Pollution Prevention Roundtable
http://www.hazard.uiuc.edu/wmrc/greatl/
- This site provides a forum for the exchange of information on pollution prevention programs, technologies and regulations impacting the Great Lakes region.

Great Lakes Regional Pollution Prevention Roundtable Tech Info Database
http://es.epa.gov/p2pubs/techpubs/descript.html
- This site provides access to past discussion topics on the Great Lakes Regional Pollution Prevention Roundtable.

International Cleaner Production Info Clearinghouse (ICPIC)
Telnet service through: fedworld.gov
- The ICPIC site provides international resources on cleaner production techniques.

Kentucky Pollution Prevention Center
http://www.kppc.org/about.html
- The Kentucky Pollution Prevention Center (formerly Kentucky Partners) is Kentucky' TDr/de Tj Tw (TgwkvTj -3 -11.25

Notes

Pacific Northwest Pollution Prevention Center (PPRC)
http://pprc.pnl.gov/pprc
- The PPRC is a nonprofit organization that works to protect the public health, safety and the environment by supporting projects that result in pollution prevention and toxics use elimination and reduction. The database includes over 300 P2 projects. The site offers search engines, up-to-date newsletters, P2 conference schedules and abstracts on P2 research projects. Request for Proposals (RFP) Clearinghouse provides information about P2 projects.

P2 GEMS
http://turi.uml.edu/P2GEMS
- P2GEMS is an Internet search tool for facility planners, engineers, and managers that provides technical, process, and materials management information on the web. It provides access to over 500 P2 resources on the Internet.

P2 Pillar Needs Assessment Report for FY96
http://www.wl.wpafb.af.mil/pprevent
- This site provides access to summaries of the U.S. Air Force Environmental, Safety and Occupational Health Technology Needs Survey. Pollution prevention needs and research on available technology to address these needs are included in a two volume publication.

Pollution Prevention Yellowpages
http://www.p2.org/nppr_yps.html
- The *P2 Yellowpages* is linked to the Enviroene website and provides information on state, local, and federal pollution prevention technical assistance programs.

<u>Material Substitution</u>

EPA RTI's Solvent Alternative Guide (SAGE)
http://clean.rti.org/
- This Database includes a guide to help web browsers find less toxic solvent alternatives. The Solvent Substitution Database in the Enviroene site is another useful website to explore. Hazardous Solvent Substitution Data Systems, Solvent Handbook Database Systems, Department of Defense Technical Library, and the National Center for Manufacturing Science Alternatives Database links are available from Enviroene.

Environmental Stewardship - Pollution Prevention - Los Alamos National Laboratory (P3O)
Material Substitution Resource List
http://perseus.lanl.gov/NON-RESTRICTED/MATSUB_List.html
- This website provides information on material substitution alternatives and links to over 26 material substitution related sites on the Internet.

Illinois Waste Management and Research Pollution Prevention Program
http://www.inhs.uiuc.edu/hwric/p2.html
- This site offers a publications list provided by the HWRIC, a division of the Illinois Department of Energy and Natural Resources.

<u>Recycling Information</u>

Environmental Stewardship - Recycling Programs - Los Alamos National Laboratory
http://perseus.lanl.gov:80/PROJECTS/RECYCLE
- This internet site documents the recycling programs at the Los Alamos National Laboratory. Recycled materials are listed along with links to other recycling information sites in the country.

Global Recycling Network
http://grn.com/grn/
- This site provides recycling related information to buyers and sellers of recyclable commodities.

Notes

Recycler's World
http://www.recycle.net
- This site was established as a world-wide trading site for information related to secondary or recyclable commodities, by products, used surplus items or materials.

Technical Associations, Technology Transfer, and Industry

Air & Waste Management Association
http://www.awma.org/
- This site provides industry publications, membership information, a buyer's guide, meeting dates, employment and educational resources, and links to other relevant sites.

Air & Water Management Association
Delaware: http://www.awma.org/section/delaware/delawaremain.htm
South Atlantic: http://www.stackhawk.com/sasmtgs.htm
Baltimore and Washington: http://www.awma.org/baltwash/baltwas.htm
Virginia: http://www.awma.org/dominion/dominion.htm
- These websites contain information regarding the A&WMA activities for members in EPA Region 3.

The American Plastics Council
http://www.plasticsresource.com/
- The website is organized and formatted to meet the needs of specific user groups. The APC provide general and environmental information on the server.

Envirobiz - International Environmental Information Network
http://www.envirobiz.com/
- The site is sponsored by the International Environmental Information Network, and it provides information about various businesses, policies, environmental technologies, events, products, and environmental services. The site also has searchable databases.

Environmental Law Institute
http://www.eli.org/
- Incorporates ELI publications, programs, law and policy documents related to environmental law.

The National Institute of Standard and Technology (NIST)
http:/www.nist.gov/
- NIST provides a wide variety of services and programs to help U.S. industry, trade other government agencies, academia and the general public improve the quality of their products. The website provides access to international uniform practices.

National Technology Transfer Center's Environmental Technology Gateway
http://www.nttc.edu/environmental.html
- This site is an excellent source of links to other environmental information. It provides information on technology transfer, manufacturing industries, business assistance, conferences, programs, phone numbers, Pollution Prevention Yellow Pages, other general information and links to over 150 websites. Information includes links to various agencies (EPA, DOE, DOD, NASA, and others), federal laboratories, and White House information.

NIST's Manufacturing Extension Partnership
http://www.mep.nist.gov/
- Provides hands-on technical assistance to America's smaller manufacturers.

Notes

Project XL
http://199.223.29.233/ProjectXL/xl_home.nsf/all/homepage
- Project XL is a national pilot program that tests innovative ways of achieving better and more cost-effective public health and environmental protection. Under Project XL, sponsors (private facilities, industry sectors, Federal facilities, and communities) can implement innovative strategies that produce superior environmental performance, replace specific regulatory requirements, and promote greater accountability to stakeholders. The website provides information on the specific XL projects, legal and policy documents, EPA contacts and access to an XL Communities Home Page.

The Tellus Institute
http://www.tellus.com
- The Tellus Institute is a nonprofit organization that offers P2 information regarding resource management and environmental issues.

UCLA Center for Clean Technology (CCT)
http://cct.seas.ucla.edu/cct.pp.html
- The site provides information on P2 research conducted at the CCT. Research and novel educational efforts focus on developing innovative technologies and improving the understanding of the flow of materials.

United Nationals Environment Program
http://www.unep.or.jp/
- This site provides a survey of databases on environmentally sound technologies

The Water Environment Federation
http://wef.org/
- The WEF provides information on information searches, links, catalogs, events, missions and other activities as they relate to water issues.

Waterwiser
http://www.waterwiser.org/
- Waterwiser provides a source of information on water efficiency and conservation.

<u>Design for the Environment</u>

Carnegie Mellon University Green Design Initiative Home Page
http://www.ce.cmu.edu/GreenDesign/
- This site provides access to research, publication lists, and education programs in green design.

Pacific Northwest Laboratory's Design for Environment Page
http://pprc.pnl.gov/pprc
- The PPRC is a nonprofit organization that works to protect public health, safety and the environment by supporting projects that result in pollution prevention and the elimination or reduction in toxics use. The database includes over 300 P2 projects. The request for Proposals (RFP) Clearinghouse provides information about P2 projects. The site offers search engines, up-to-date newsletters, P2 conference schedules and
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State Internet Programs

Alabama DEM

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Kentucky Pollution Prevention Center
http://www.kppc.org/
- Pollution prevention staff, newsletters, training calendar and information on the materials exchange, ISO 14000/EMS Alliance, Wood Waste Alliance, environmental justice and other useful sites are available.

Kentucky Business Environmental Assistance Program
http://gatton.gws.uky.edu/KentuckyBusiness/kbeap/kbeap.htm
- Regulatory updates, publications, permit applications and other related sites are accessible through this site.

Louisiana DEQ Home Page
http://www.deq.state.la.us/
- This site provides access to DEQ Offices and a calendar of events. The search engine searches for specific topics by using key words and phrases.

Maine DEP's P2 Resource List
http://www.state.me.us/dep/p2list.htm
- In addition to providing general P2 information on their website, the Maine Department of Environmental Quality lists pollution prevention resources available on the Internet. Technology transfers, P2 equipment information, on-line networking, library information, document search, chemical data, regulatory, recycling, and environmental software links are listed in the server.

Michigan DEQ
http://www.deq.state.mi.us/ead/
- This website contains pollution prevention information provided by the Michigan EPA. Regional information regarding the Environmental Assistance Division is provided. Program descriptions, contact names, bulletins, calendars, publications, fact sheets and other Internet linkages to Environmental sites are listed.

New Jersey Technical Assistance Program for Industrial Pollution Prevention
http://www.njit.edu/njtap
- This site contains information on NJTAP's functions: provides environmental opportunity assessments; functions as an information clearinghouse for literature and videotapes related to pollution prevention; delivers education and training; and adopts and develops novel pollution prevention technologies.

New York Dept. of Environmental Conservation, P2 Unit
http://www.dec.state.ny.us/website/pollution/prevent.html
- The P2 Unit provides technical and compliance assistance to help public and private interests. The P2 Unit implements regulatory programs and encourage public and private interests to avoid generating pollutants and to reduce, reuse and recycle waste materials to attain a 50-percent reduction in waste.

North Carolina Waste Reduction Resource Center of the Southeast
http://owr.ehnr.state.nc.us/wrrc/
- The WRRC, located in Raleigh, NC, was established in 1988 to provide multimedia waste reduction support for U.S. EPA Regions III and IV.

Ohio EPA Office of Pollution Prevention
http://www.epa.ohio.gov/opp/oppmain.html
- This website lists the service provided by the Ohio EPA and provides an extensive list of resources available in researching pollution prevention opportunities.

Pennsylvania DEP - P2 and Compliance Assistance
http://www.dep.state.pa.us/dep/deputate/pollprev/pollution_prevention.html
- Access to publications, conference information and current events, as well as green technologies and technical assistance.

Notes

Plating/Finishing

American Electroplating and Surface Finishing Industry Home Page
BB # 201-838-0113 or http://www.aesf.org
-The website features Industry specific information regarding P2 technologies and environmental issues in the Electroplating and surface Finishing Industry.

Finishing Industry Homepage
http://www.finishing.com
- This site provides information on new technologies, resources, conferences, and problems encountered by businesses involved in metal finishing, specifically anodizing, plating, power coating, and surface finishing.

National Metal Finishing Resource Center
http://www.nmfrc.org
- Provides vendor information, compliance assistance and access to Common Sense Initiative research and development and access to a technical database.

ISO 14000

EPA Standards Network (ISO 14000)
http://es.epa.gov/partners/iso/iso.html
- The website provides information on ISO Environmental Management Standards and their potential impact in the United States.

Exploring ISO 14000
http://www.mgmt14k.com
- A primer to the ISO 14000, this site includes features like frequently asked questions, full text articles. The site covers ISO 14000 in depth and touches on ISO 9000 as well.

International Organization on Standardization (ISO)
http://www.iso.ch/meme/TC207.html
- The official organization for information on ISO 14000 and other international standard documentation. The URL points to the actual provisions of the ISO 14000 as directed by the Technical Committee 207, its administering body.

ISO 14000 Info Center
http://www.ISO14000.com/
- This website provides information on ISO 14000 articles, education and training, opportunities, a list of certified companies, publications, organizations, and other resources.

ISO Online
http://www.iso.ch/infoe/guide.html
- ISO Online is an electronic information service providing information on international standards, ISO technical committees, meetings, and calendar.

NIST's Global Standards Program (GSP)
http://ts.nist.gov/ts/htdocs/210/216/216.htm
- NIST promotes the economic growth of U.S. industry by helping develop and apply technology. General ISO 14000 information is provided.

Printing

Laser Printer Toner Cartridge Remanufacturing Information
http://www.toners.com/
- Describes a list of products and available locations.

Notes

Notes

EcoDS (Environmentally Conscious Decision Support System)
http://shogun.vuse.vanderbilt.edu/usjapan/ecods.htm
- Site for a decision support tool for a cost-risk evaluation of environmentally conscious alternatives using streamlined LCA.

[redacted]

Notes

Properties of Air

Exhibit B.2: Com[redacted]

Component	[redacted]
N_2	
O_2	
Ar	
CO_2	
Ne	
He	
CH_4	
H_2	
SO_2	
Kr	
Xe	

[redacted]

Notes

$$\frac{P}{R\ T} \quad \frac{P}{R\ T}$$

$$\frac{P \quad P}{R\ T} \quad \frac{P}{R\ T}$$

$$\frac{P}{R\ T} \quad \frac{P_w}{R_a T}\left(\quad \frac{R_a}{R_w}\right)$$

$$\frac{P}{R_a T} \quad . \quad \frac{P_w}{R_a T}$$

<u>*Notes*</u>

$$h = h_a + W h_w$$

using

$$h_a = 0.24T$$
$$h_w = h_{fg}(at\ 32.2°F) + C_{p,s}(T - 32)$$

where

.0444 Btu/lb - F

Notes

Exhibit B.6: Conservation of Mass

Notes

Conservation of mass

$$\dot{m}_{a,1} = \dot{m}_{a,2}$$

$$\dot{m}_{a,1} w_1 = \dot{m}_{a,2} w_2 \longrightarrow w_2 = w_1$$

Conservation of energy

$$q_{1 \rightarrow 2} = \dot{m}_{a,1}(h_2 - h_1)$$

Example

0 TDotb7408 TD /F1 9. 0.7l Tj -h7R Tw ( ) Tj -15.75 0 TD 0.1963 Tc 0 Tw (Th0 TD (w) Tj - -3 -0.1875

Find : The heater size required.

/F6T6 -0.1StT13.00

<u>*Notes*</u>

Calculate the mass flow rate of air:

$$m_a \quad \frac{ft}{\quad} \quad \frac{\quad}{hr} \quad {}_{a,1}$$

$$_{a,1} \quad \frac{)}{(53.35)(495)[1 \quad (1.608)(0.004259)]} \quad 0.07961 \frac{lb}{ft^3}$$

$$m_a \quad (20{,}000 \frac{ft^3}{\min})(60 \frac{\min}{hr})(0.07961 \frac{lb}{ft^3}) \quad 95{,}534 \frac{lb}{hr}$$

$$q_{1 \quad 2} \quad (95{,}534 \frac{lb}{hr})(28.708 \quad 12.985 \frac{Btu}{lb}) \quad 1.502\, million \frac{Btu}{hr}$$

$$q_{boiler} \quad \frac{1.502 \quad 10^6}{n_{boiler}} \quad \frac{1.502 \quad 10^6}{0.8} \quad 1.878 \quad 10^6 \frac{Btu}{hr}$$

Notes

Exhibit B.8: Mass Conservation

Exhibit B.9: Boiling Curve

h_1 is all latent heat removal

h h_2 is all sensible heat removal

h_1 h_2 is total heat removal

Notes

Exhibit B.10: Boiling Curve

From the chart

$$h_1 \approx 34.5 \qquad v_1 \approx 14.01$$
$$h_2 \approx 20.2 \qquad W_1 \approx 0.013$$
$$W_2 \approx 0.0076$$

From tables $h_{w,2}$ = *18.11* Btu/lb$_a$

or

h_w C_p F F

q m_a h h W W h_w

15 T 168.75 15 m (valc -0.1875 Tw tons

or 608,278 Btu/h.

1 ton of A/C (1 ton of ice/day) (day/24 hr) (144 Btu/lb) (2000lb/ton)

where the later heat of fusion for ice is 144 Btu/lb.

1 ton fo A/C 12,000 Btu/h

$$q \quad \frac{608{,}278 \text{ Btu/hr}}{12{,}000 \text{ Btu/hr ton}} \quad 50.7\,tons$$

Notes

Heat Gain Calculations

$$Q = Q_{TRANS} + Q_{FEN} + Q_{INT}$$

where

Q_{FEN} = fenestration heat gain

Q_{INT} = internal heat gain

$$(Q_{TRANS} / A) = \alpha i_t + h(T_o - T_s) - \epsilon \delta R$$

where

= absorptance of surface for solar radiation, no unit

= solar radiation incident on surface, Btu/hr ft^2

h = heat transfer coefficient, BTU/hr ft^2

T = outdoor air temperature, $°F$

T = surface air temperature, $°F$

= emittance of surface, no units

R = difference between radiation incidence on the surface and black body radiation at T_o, Btu/hr ft^2

Notes

APPENDIX C

ENERGY AND WASTE INSTRUMENTATION FOR ASSESSMENTS

It is important to be able to gather all the information necessary for competent evaluation of energy usage and waste generation. Hardware designed to help data collection is available and should be used. Since manufacturers of measuring equipment constantly strive for better products it is a good practice to keep up with the latest development in the field. Then one is able to make use of state-of-the-art technology to achieve better results in his or her own work.

Equipment List

___1. Thermo Anemometer

___2. Velometer - (Analog)

___3. Amprobe Ampere Meter (Digital)

___4. Amprobe Ampere Meter (Analog)

___5. PWF Meter

___6. Rubber Gloves

___*7.* Infra Red-Temp Sensor - *Kane May 500*

___se 0 TD 0 Tc 4 A124 4

Notes

Product and Supplier List

Combustion Analyzer

Energy Efficiency Systems
Enerac 2000 - $3,000
Pocket 100 - $1,500
1300 Shames Drive
Westbury, NY 11590
(800) 695-3637

Universal Enterprises
KM9003 - $2,000
5500 South West Arctic Drive
Beaverton, OR 97005
(503) 644-9728

Goodway Tools Corporation
ORSAT and EFF-1
404 W. Avenue
Stanford, CT 06902 v55 Tc–0.2S13 Tj 27 G .3(503) 644

Notes

Trane Company
Clarksville, TN 37040

The Marley Cooling Tower Company
(Cooling Towers)
5800 Foxridge Dr.
Mission, KS 66202 (913) 362-1818

Roberts - Gordon Appliance Corporation
(Radiant Heaters)
PO Box 44
1250 William St.
Buffalo, NY 14240
(716) 852-4400

Air Compressors:

Ingersoll Rand Company
5510 77 Center Dr.
PO Box 241154
Charlotte, NC 28224

Gardner-Denver Company

Motors:

GE Company
Motor Business Group
1 River Rd.
Schenectady, NY 12345

Variable Speed Drives:

York International
Applied Systems
PO Box 1592-361P
York, PA 17405-1592
(717) 771-7890

ABB Industrial Systems, Inc.
Standard Drives Division
88 Marsh Hill Rd.
Orange, CT 06477

Allen Bradley
Drives Division
Ceadarburg, WI 53012-0005

Enercon Data Corporation
7464 W. 78th St.
Minneapolis, MN 55435
(612) 829-1900

Belts:

The Gates Rubber Company
990 S. Broadway
PO box 5887
Denver, CO 80217
(303) 744-1911

Additional Resources

1. Thumann, Albert, Handbook of Energy Audits, Association of Energy Engineers, Atlanta, GA (several editions).

2. Industrial Market and Energy Management Guide, American Consulting Engineering Council, Research and Management Foundation, 1987.

3. Energy Conservation Program Guide for Industry and Commerce, NBS Handbook 115 and Supplement, U.S. Department of Commerce and Federal Administration, U.S. Government Printing Office, 1975.

4. Mark's Handbook of Mechanical Engineering, Baumeister (Ed.), McGraw-Hill, Eight Edition, 1978.

5. ASHRAE Handbooks, Fundamentals, Systems, Equipment, Application, HVAC and Refrigeration Volumes, American Society of Heating, Refrigeration and Air Conditioning Engineers.

<u>*Notes*</u>

APPENDIX D

DEFINITIONS

Abrasive Blasting:	Refers to any paint stripping technique that utilizes grit and other abrasives.
Air/Fuel Ratio:	The Ratio of combustion air to fuel supplied to the burner.
Aleophilic:	A term that refers to mediums that attract oil.
Assessment:	Industrial assessments are an in-depth review of existing operations to increase efficiency of the operation through pollution prevention and energy conservation.
Barrels:	The portion of an injection molding machine through which the molten plastic is forced by the piston.
Baseline Year:	The year that pollution prevention gains are measured from.
Block:	A division of billing based on usage. The total block amount of use is divided into blocks of different price per unit of use.
BOD:	Biochemical Oxygen Demand.
Boiler:	A device where energy extracted from some type of fuel is converted into heat ful workTj 74.2.5 TD 0.5 Tc --0.2089 Tc 0.0214 T2.52:

Notes

Condensing Water:	Water that has been cooled in a cooling tower that is used to condense vaporized refrigerant in the condenser.
Constant:	Multiplier used in computing electric meter reading.
Conveyorized:	Describes equipment that is continuous.
Cooling tower:	A device to dissipate heat by evaporation of water which is trickling from different levels of the tower.
Current (Ampere):	The ampere, the rate of flow of a unvarying electric current.
CVD:	Chemical Vapor Deposition
Degree Day:	Mean daily temperature subtracted from 65 used to realistically measure heating requirements from one month to another
Degree Heating:	A measure relating ambient temperature to heating energy required. If the outside temperature is 1 degree below the base temperature in the plant for 1 hour then that represents 1 degree heating hour.
DEHP:	Diethylhexylphthalate
Delignification:	An extended pulping process that can lower contamination in the pulp.
Demand:	Highest amount of electricity used in 15-30 minute periods during any one-month. Power companies must have the generating capacity to meet the demands of their customers during these peak period, otherwise the result would be blackouts.
Demand-side Management Strategy:	Strategic energy conservation.
Dewatering:	Refers to any process designed to remove water from the waste sludge.
Digestion Liquor:	The liquid that the pulp is processed in.
Dioxins:	Are environmentally detrimental chemical compounds composed of identical carbon-oxygen framework.
Drag-out:	The fluid unintentionally removed from a bath while removing a part.
Duty Cycle:	Cj -oa repdp/F10.167ion Lf i paieceof eluidpenta oferatuon Lhat ts pwithn 1is 1 Tj 0 -11.25

-Eonsomize: DAi

Notes

Firing Rate:	As the load on a boiler varies, the amount of fuel supplied to the boiler varies in order to match the load.
Flash Rusting:	Occurs on some materials if water is allowed to sit on them, and can contaminate coatings.
Flashing:	Pressurized condensate will change phase into steam if the pressure is suddenly reduced.
Fossil Fuel:	Fuel (natural gas, coal, oil etc.) coming from the earth that was formed as a result of decomposition of vegetation or animal matter.
Fuel to Steam Efficiency:	A measure of the overall efficiency of a boiler. It accounts for radiation and convection losses.
Gloss Retention:	A measure of the amount of shine a paint maintains after time.
HAP:	Hazardous Air Pollutant
HCFC:	Hydrochlorofluorocarbons
Heat Exchanger:	A device used to recover heat from one source and transfer this heat to another source without mixing the two sources.
Heat Pipe:	A counterflow air-to-air heat exchanger.
Heat transfer coefficient:	

Notes

Load Shedding:	A scheduled shutdown of equipment to conserve energy and reduce demand.
LP Gas:	Liquid petroleum gas. This fuel is distributed in pressurized cylinders in liquid state and by releasing it is converted into gas in which form it is burnt.
Load Scheduling:	An internal clock programmed by the user to start and stop electric loads on selected days at particular times.
Lumen:	A unit for quantitative measure of light.
Makeready:	The stage in printing operations when the plates are prepared and all adjustments are made.
Make-up Air:	Air forced into the area equal to the air lost through exhaust vents.
Mar Resistance:	A measure of the ability of a paint to withstand abrasions.
Masking:	The covering of areas that are not to be subject to painting or paint removal.
Material Balance:	Shows all the materials that enter and leave a process.
MEK:	Methyl Ethyl Ketone
MIBK:	spared and all 2Tw .1542 -229.5 -18 TD 5.3322 Tc 0 TSDS(MEK:) Tj 88.5 0 TD 0 Tc -0.1875 Tw ( )

Notes

Rancidity: Is the odor produced by contaminated metal working fluids due to bacterial growth.

Ratchet: The peak demand ratchet during a billing period is kept as the peak billing

Notes

Terpenes:	A categorization of semi-aqueous cleaners.
Therm:	A measurement of heat, equivalent to 100,000 Btu.
Thermal Efficiency:	A measure of effectiveness of the heat exchanger. It does not account for radiation and convection losses.
Tramp Oils:	Include all oils that contaminate an area or another fluid.
Treatment:	The processing of materials to concentrate pollutants, reduce toxicity, or reduce the volume of waste materials. The most common example of this is wastewater treatment.
VOC:	Volatile Organic Compounds
Volt - Ampere:	The product of the rated load amperes and the rated range of regulation in kilovolts (kVA).
Water Curtains:	Are utilized to minimize overspray and fumes in a thermal spray technology

APPENDIX E

ENERGY CONSERVATION OPPORTUNITY CASE STUDIES

Notes

Information in this appendix discusses specific energy conservation opportunities in detail. This is done to illustrate how to calculate energy savings and cost savings for various opportunities. The assessment team should evaluate carefully, the specifics of the facility or operation being assessed to determine if the measures presented here can be implemented. The team should also evaluate the opportunity using facility specific information. The following case studies present only a few of the available energy conservation opportunities.

1. Implement Periodic Inspection and Adjustment of Combustion in a Natural Gas Fired Boiler
2.

oe1 -g fFan706.5 1920.0329plu.43(2) T 25 PaArG0.25 -5en210 Tj   10.25 0 TD 0 Tc -0.1875 Tw 4

<u>Notes</u>

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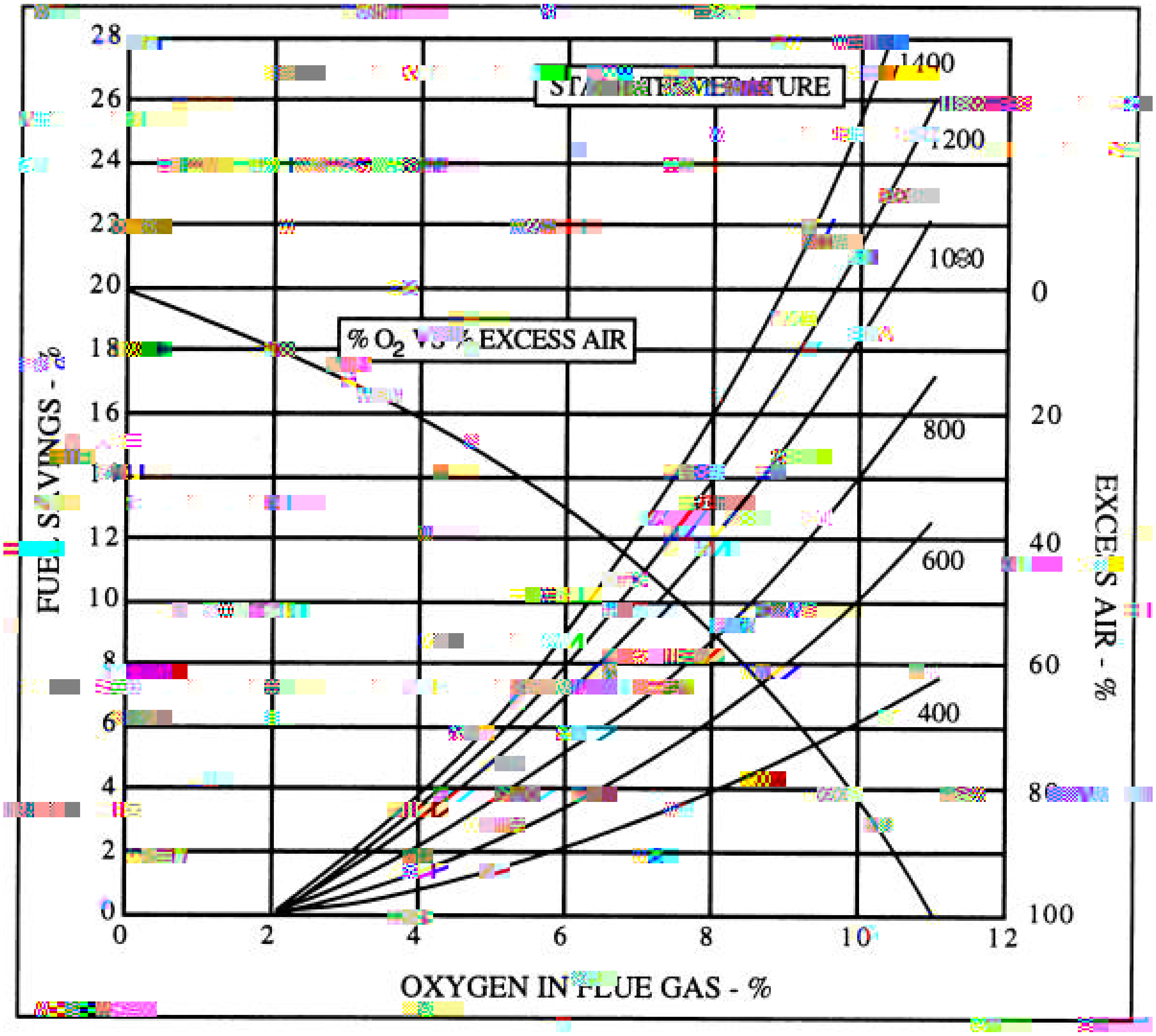
Notes

Exhibit E.1: Natural Gas Fuel Savings[1]



Notes

CASE STUDY #2: IMPLEMENT PERIODIC INSPECTION AND ADJUSTMENT OF COMBUSTION IN AN OIL FIRED BOILER

Current Practice and Observations

During an audit, flue gas samples were taken from the boiler. The boiler was operating with too much excess air resulting in unnecessary fuel consumption.

Recommended Action

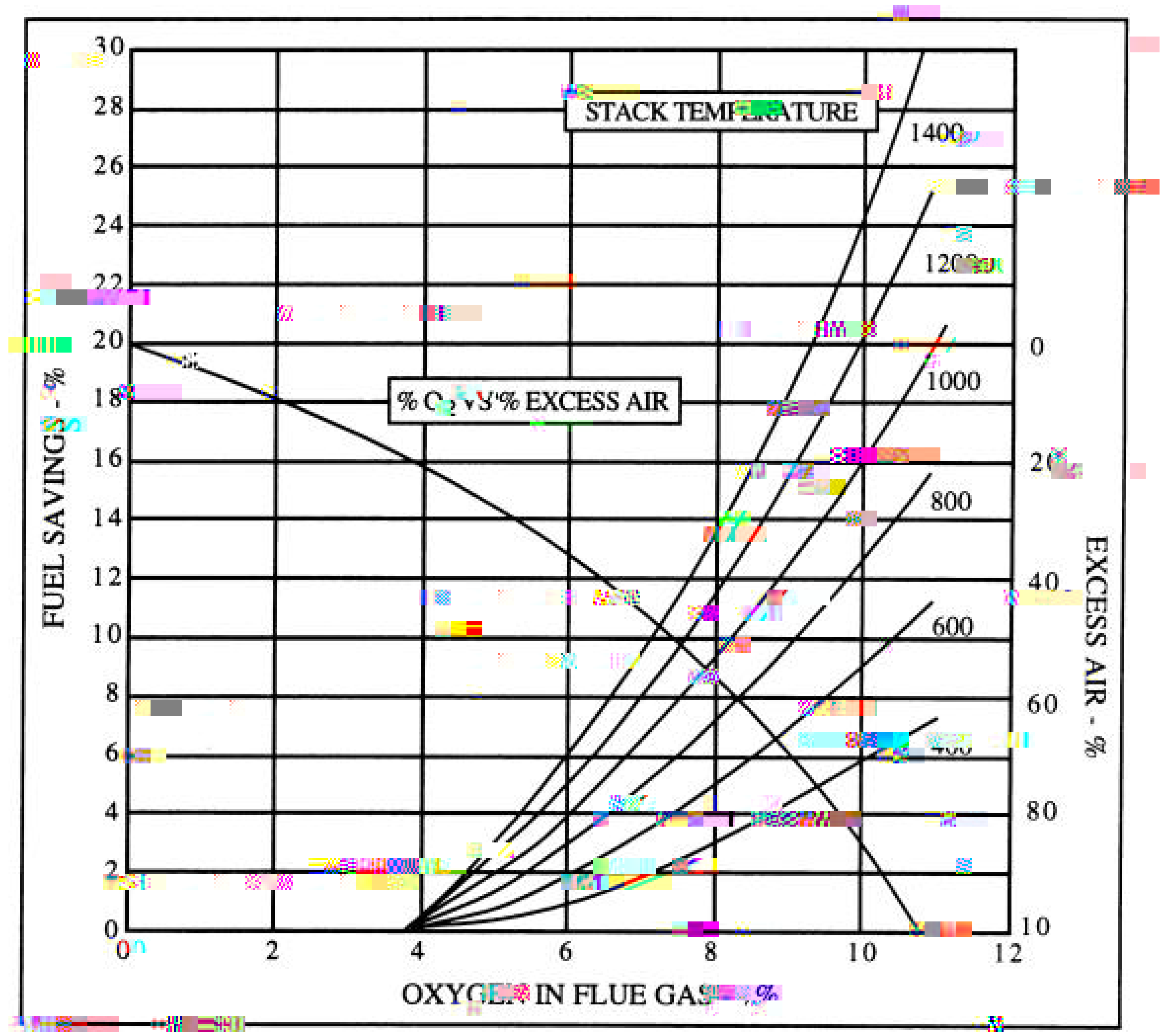
Many factors including environmental considerations, cleanliness, quality of fuel, etc. contribute to the efficient combustion of fuels in boilers. It is therefore necessary to carefully monitor the performance of boilers and tune the air/fuel ratio quite often. Best performance is obtained by the installation of an automatic oxygen trim system that will automatically adjust the combustion to changing conditions. With the relatively modest amounts spent last year on fuel for these boilers, the expense of a trim system on each boiler could not be justified. However, it is recommended that the portable flue gas analyzer be used in a rigorous program of weekly boiler inspection and adjustment for the two boilers used in this plant.

Anticipated Savings

The optimum amount of O_2 in the flue gas of an fuel oil-fired boiler is 3.7%, which corresponds to 20% excess air. The boiler measured had an O_2

Notes

Exhibit E.2: Liquid Petroleum Fuel Savings[1]



Note: Fuel savings determined by these curves reflect the following approximation. The improvement in efficiency of radiant and combination radiant and convective heaters or boilers without air pre-heaters that can be realized by reducing excess air is 1.5 times the apparent efficiency improvement from air reduction. This is due to the decrease in flue gas temperature that must follow increased air input.

As an example, for a stack temperature of 800°F and O_2 in flue gas of 6%, the fuel savings would be 3%. If desired, excess air may be determined as being 36%.

Notes

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Notes

$$E_C = BS \text{ x } B \text{ x } OH \text{ x } [H_V + C_P \text{ x } (T_f - T_i)]$$

where

BS = average batch size

B = # of batches per hour

OH = operating hours per year

H_v = heat of vaporization of water (assuming batch is 100% water)

C_P = specific heat of water

T_f = final temperature of cone

T_i = initial temperature of batter

Once the total amount of energy consumed by the ovens (E_O) is obtained, the overall oven efficiency can be determined by

$$EFF_c = \frac{E_C}{E_0}$$

The heat transfer rates for the new and the old system were then found and compared. The convective heat transfer rate in the blue flame mode was approximated to be around 1.0 Btu/hr-ft 2 -deg. F based on the characteristics of the current ovens. The radiant heat transfer rate (UR) was found by using the following equation.

$$U_R = F \times a \times s \times \frac{T_1^4 - T_2^4}{T_g - T_m} = 1.3 \frac{BBtu}{hr\ ft_2 \,°F}$$

where

F = radiation shape factor

a = absorptivity of the mold

σ = Boltzmann's constant

T_1 = radiant heater surface temperature

T_2 = mold surface temperature

T_g = gas temperature in the oven

T_m = mold temperature

Comparing these rates, U_R was found to be 30% larvr ±arvGlaz22fD06eTat=0.1875 y606 r(14.25 04e22 Tc 0 Tw (R

Notes

The results of this study showed that there was a total energy savings of 5,440 MMBtu/yr and a total cost savings of $31,280/yr. For estimation purposes, it was assumed that 65% of the total gas use was consumed in order to obtain these approximations. The cost of implementation for each oven was $10,500. For all nine ovens the total implementation cost was $94,500. This data yields a payback period of 3.0 years.

Notes

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Notes

CASE STUDY #5: REPAIR COMPRESSED AIR LEAKS

Background

The cost of compressed air leaks is the energy cost to compress the volume of lost air from atmospheric pressure to the compressor operating pressure. The amount of lost air depends on the line pressure, the compressed air temperature at the point of the leak, the air temperature at the compressor inlet, and the estimated area of the leak. The leak area is based mainly upon sound and feeling the airflow from the leak. The detailed equations are given in Chapter 8. An alternative method to determine total losses due to air leaks is to measure the time between compressor cycles when all air operated equipment is shut off.

The plant utilizes one 75 hp compressor that operates 8,520 hrs/yr. Measurements taken during the site visit showed the compressor to continuously draw 77.7 hp. Approximately 24% of this load is lost to air leaks in the plant. The majority of the air leaks are due to open, unused lines. There are several plant locations where pneumatic machinery could be connected to the primary air line, but at the time of the site visit, no machines were connected. These open lines were typically found on or near I-beams. The terms “I-beam #1, #2, and #3” are used in the Exhibits of this opportunity to label the leaks. In order to allow for correct location of these open lines, a list of the terms and their approximate locations are given below:

Terms	Description
I-Beam #1	Leak located on I-beam near rotary automatic #2.
I-Beam #2	Leak located on I-beam near catalogue machine.
I-Beam #3	Leak located on hose attached to I-beam near Machine 6700.

Recommended Action

Leaks in compressed air lines should be repaired on a regular basis.

Anticipated Savings

Values for all factors affecting the cost of compressed air leaks were determined during the site visit, and are listed in Exhibits E.3. Because of long piping runs to the equipment, the compressed air temperature is estimated to be the same as room temperature.

Exhibit E.3: Condition of Pneumatic System at Time of Site Visit

Variable	
Air temperature at compressor inlet, F	92
Atmospheric pressure, psia	14.7
Compressor operating pressure, psig	115
Air temperature at the leak, F	72
Line pressure at the leak, psig	115
Compressor motor size, hp	75
Compressor motor efficiency	91.5%
Compressor type	Screw
Number of stages	1
Compressor operating hours, per year	8,520
Electric cost, per MMBtu	$14.05

Notes

Using these values, the volumetric flow rate, power lost due to leaks, energy lost and cost for leaks of various sizes were calculated specifically for the conditions at this plant. The results are shown in Exhibit E.4.

As Exhibit E.4 shows, the cost of compressed air leaks increases exponentially as the size of the leak increases. As part of a continuing program to find and repair compressed air leaks, the Exhibit can be referenced to estimate the cost of any leaks that might be found.

Exhibit E.4: Cost of Compressed Air Leaks At This Plant

Hole Diameter	Flow Rate *cfm*	Power Loss *hp*	Energy Lost *MMBty/yr*	Energy Cost *per year*
1/64	0.5	0.1	0.2	$31
1/32	1.8	0.4	8.7	$122
1/16	7.2	1.7	36.9	$518
1/8	29.0	6.9	149.7	$2,103
3/16	65.2	15.4	334.1	$4,694
1/4	115.8	27.4	594.4	$8,351
3/8	260.6	61.7	1,334.8	$18,805

The estimated energy savings and corresponding cost savings for the air leaks found during the site visit are listed in Exhibit E.5 below:

Exhibit E.5: Summary of Savings

Machine	Leak Diameter *in*	Power Loss *hp*	Energy Savings *MMBtu/yr*	Cost Savings *per year*
Cardboard Boxes Area	1/16	1.7	36.9	$518
Cardboard Boxes Area	1/16	1.7	36.9	$518
Hand Dye	1/16	1.7	36.9	$518
Straight Knife	1/8	6.9	149.7	$2,103
Web	1/16	1.7	36.9	$518
I-beam#1	1/16	1.7	36.9	$518
I-beam#2	1/16	1.7	36.9	$518
I-beam#3	1/16	1.7	36.9	$518
TOTALS		18.8	408.0	$5,729

From Exhibit E.5 above, the total estimated energy savings from repairing the air leaks are 408.0 MMBtu./yr. and the total cost savings are $5,730/yr.

Notes

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CASE STUDY #6: INST

Notes

Notes

Anticipated Savings

Energy savings due to use of air at reduced pressure, *ES*, are estimated as follows[1]:

$$ES = (PC - PB) \times H \times C_1$$

where

PC = power consumed by compressor to agitate tank, hp

PB = power consumed by blower to agitate tank, hp

H = operating hours, 5,746 h/yr

C_1= conversion factor, 0.756 kW/hp

The volume of free air used for agitation V f at this plant as obtained from the plant personnel is 130 cfm. The power PC that is required to compress the volume of free air V_f needed for agitation from atmospheric pressure to the compressor discharge pressure can be calculated as follows[2]:

$$PC = \frac{P_i \times C_2 \times V_f \times \frac{k}{k-1} \times N \times C_3 \times \left[\left(\frac{P_o}{P_i} \right)^{\frac{k-1}{k \times N}} - 1 \right]}{E_{ac} \times E_{mc}}$$

where

P = inlet (atmospheric pressure), 14.7 psia

C_2= conversion constant, 144 in 2 /ft^2

V_f= volumetric flow rate of free air, 130 cfm

k = specific heat ration of air, 1.4 (no units)

N = number of stages, 1 stage

C_3 = conversion constant, 3.03 x 10-5 hp-min/ft-lb

P_o = pressure at the compressor outlet, 131.7 psia (117 psig)

E_{ac} = air compressor isentropic (adiabatic) efficiency, 82%

E_{ac} = 0.88 for single stage reciprocating compressors

E_{ac} = 0.75 for multi-stage reciprocating compressors

E_{ac} = 0.82 for rotary screw compressors

E_{ac} = 0.72 for sliding vane compressors

E_{ac} = 0.80 for single stage centrifugal compressors

E_{ac} = 0.70 for multi-stage centrifugal compressors

E_{mc} = compressor motor efficiency, 92% for a 100 hp motor

Thus, the power that is currently consumed by the compressor to provide air for tank agitation is calculated as follows:

Notes

modifications to tanks described below, giving a total implementation cost of $8,500. Thus, the cost savings of $5,720/yr. would have a simple payback of about 18 months.

In order for a 3 psig blower to deliver 63.5 cfm of air, the size of the air outlets in the tanks may have to be modified. Assuming that there are 12 total outlets (4 outlets per tank), the required outlet diameter is calculated from the equation for unchoked flow (less than the speed of sound) as follows:

$$D \quad \sqrt{\frac{4 \quad Q \quad \sqrt{T_l + 460}}{NL \quad C_5 \quad C_6 \quad C_7 \quad C_{db} \quad (T_l + 460) \times \sqrt{\left(\frac{P_l}{P_i}\right)^{\frac{2\times(k-1)}{k}} - \left(\frac{P_l}{P_i}\right)^{\frac{k-1}{k}}}}}$$

Notes

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CASE STUDY #1: CONSTRUCTION AND DEMOLITION WASTE RECYCLING

Notes

Current Practice and Observations

An operator in California owns a one-story fenced off wood frame building with floor dimensions of approximately 60' x 135' that is slated for demolition. It was constructed in 1942 as a "temporary" structure.

Notes

The majority of the wood sold for around $1.00 per board foot. The entire deconstruction took four weeks, and left a cleaned vacant lot.

This case study was adapted from: "Presidio of San Francisco, Building 901." Construction and Demolition Recycling Program. http://www.ciwmb.ca.gov/mrt/cnstdemo/casestud/presido/case2.htm.

CASE STUDY #2: PACKAGING REUSE

Notes

Current Practice and Observations

Before early 1990, most of a Michigan based retailers 17 facilities used polystyrene “peanuts” as packaging material to ship merchandise to its customers. Although the “peanuts” effectively protected many fragile items during shipping, some customers viewed the polystyrene packaging material as environmental unsound.

Recommended Action

Purchase a large durable paper shedder for each of the 17 facilities. Shred office paper waste at each facility for packaging.

Notes

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Notes

Implementation

The oil analysis equipment saved the facility thousands of dollars, and paid for itself in under two and a half years. The equipment significantly decreased the volume of oil and number of filters purchased, oil waste, oil filter waste, and their related costs.

This case study was adapted from: "Pollution Prevention Plan." U.S. Coast Guard Training Center, Cape May, New Jersey, 1997.

CASE STUDY #4: MAINTENANCE FLUID RECYCLING

Notes

Current Practice and Observation

A maintenance garage at a facility scheduled and performed all regular maintenance on facility machines and vehicles. The garage produced large quantities of lacquer thinners, degreasers, carburetor cleaners, gasoline, and waste oil. The majority of the wastes entered the waste stream and was disposed of in landfills or as hazardous waste.

Recommended Action

Contact an outside contractor to pick-up and recycle waste solvents. The waste solvents should be recycled using distillation, filtration, and blending to produce reusable products

Anticipated Savings

Exhibit F.4 presents an economic comparison of the current operation to the recommended action.

Exhibit F.4: Annual Operating Cost Comparison for Waste Solvent Disposal and Waste Solvent Recycling

	Disposal	**Recycling**
Disposal Charge	$4,200/year	-----
Program Fee	-----	$2,450/year
Chemical Re-sale	-----	-$1,050/year
TOTAL	**$4,200/year**	**$1,400/year**
Total Estimated Annual Savings ($4,200 - $1,400): **$2,800 per year**		

Implementation

With the implementation of a waste solvent recycling program the maintenance garage realized a reduction in cost and environmental impact. The program recycled 88,000 gallons of solvent/sludge material and 265,000 gallons of waste oil in the first year. In addition, the garage met all federal and state regulations with the program. This program would not have been possible with out a local waste solvent recycler already in place.

This case stu

<u>*Notes*</u>

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Notes

CASE STUDY #5: METAL WORKING FLUID SUBSTITUTION

Current Practice and Observations

A Swedish fixture manufacture utilized a mineral oil-based cutting oil for metalworking, a trichloroethylene solvent for degreasing, and a solvent-based paint for finishing parts. The metalworker produced 400,000 pieces per year, and was concerned about complying with air pollution standards in the future. The manufacturer was also looking for ways to reduce costs.

Recommended Action

Substitute a vegetable oil based metalworking fluid for the mineral-based oil.

Anticipated Savings

A reduction in metalworking fluid costs of $5,000 per year was estimated. Since no extra equipment is necessary for the substitution, there should not be any capital costs and the payback should begin immediate.

Implementation

The manufacturer found that the substitution of the vegetable oil-based cutting lubricant decreased mineral solvent vapor by 30 tons. The substitution also allowed changes to be made in the degreasing and finishing of the product. The environmentally detrimental degreaser was replaced with an alkaline detergent solution, and a powder-coating system was implemented for finishing. These additional changes significantly decreased emissions and saved $415,800 per year with a capital investment of $383,00.

This case study was adapted from: "Substitution of metalworking Fluid Promotes Less Need for Organic Solvent." Enviro$ense. http://es.epa.gov/studies/cs457.html.

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CASE STUDY #6: INSTALL AN AUTOMATED AQUEOUS CLEANER

Current Practices and Observations

A medium-sized metal finishing company in Connecticut used vapor degreasing, alkaline tumbling, and hand-aqueous washing methods to prepare its products for the plating process. The plant wanted to expand capacity without increasing solvent consumption.

Recommended Action

Install an automated aqueous cleaner to accommodate the growth in production, but leave the vapor degreasing, alkaline tumbling, and hand-aqueous washing equipment in place. Treat the small increase in wastewater generated by the automated cleaner with the existing wastewater treatment plant.

Anticipated Savings

Exhibit F.5 shows the anticipated reduction in waste generation for the metal finishing company.

Exhibit F.5: Waste Volume Reduction by Using the Automated Aqueous Washer

Conventional Cleaning Waste Stream	Volume Generated (gal/yr.)	Automated Washing Waste Stream	Volume Generated (gal/yr.)
Vapor Degreasing[a]		**Automated Washing[a]**	
Wastewater in separator	200	Wastewater	143,000
Still bottom in sludge	1,400	Oily Liquid	962
Alkaline Tumbling[b]		**Automated Washing[b]**	
Wastewater	1,010,880	Wastewater	85,800
		Oily Liquid	577
Hand-Aqueous Washing[c]		**Automated Washing[c]**	
Wastewater	296,400	Wastewater	57,200
		Oily Liquid	385

[a]*Based on 5,200 barrels/yr. run on automated washer instead of vapor degreaser.*

[b]*Based on 3,120 barrels/yr. run on automated washer instead of alkaline tumbler.*

[c]*Based on 2,080 barrels/yr. run on automated washer instead of had-aqueous washer.*

Implementation

The automated cleaner is utilized for most of the new work, and has been found to use 90 percent less water compared with alkaline tumbling, and 80 percent less when compared to hand aqueous washing. Because the cleaning solutions are recovered and reused in the automated washer, consumption of cleaning chemicals (and the solutions arssesutirough con Tj 48) w re 4t less whenow rutiatomatedtumblingsoak -39proc comr lu12 TD 0. 0

<u>*Notes*</u>

This case study was adapted from: "Guide to Cleaner Technologies: Cleaning and Degreasing ental Protection Agency, Office of Research and Development, 1994. EPA/625/R-93/017.

CASE STUDY #7: RECYCLING OF CLEANER THROUGH FILTRATION

Notes

Current Practice and Observations

In 1984, a chassis designer and manufacturer was producing 470,000 automotive frames, 90,000 axle housings and 250,000 van extensions. The die-cut and stamped metal chassis were produced for the automotive industry. Prior to stamping, the parts were coated with an oil-based forming compound. Once the stamping was completed, the parts were washed in hot (70^{o}C) alkaline cleaner (pH 12) to remove the oil and grease. With prolonged use, oil contamination deteriorated the efficiency of the alkaline cleaner. Every two weeks the manufacturer was dumping 28 cubic meters of wash, but wanted to reduce disposal costs, raw material costs, and environmental damage.

Recommended Action

Install an ultrafiltration system to recycle the cleaner and recover waste oil.

Anticipated Savings

Exhibit F.6 presents the economic comparison of the current operation to the recommended action. ev5 0 Tw4481-0.2277 606(v

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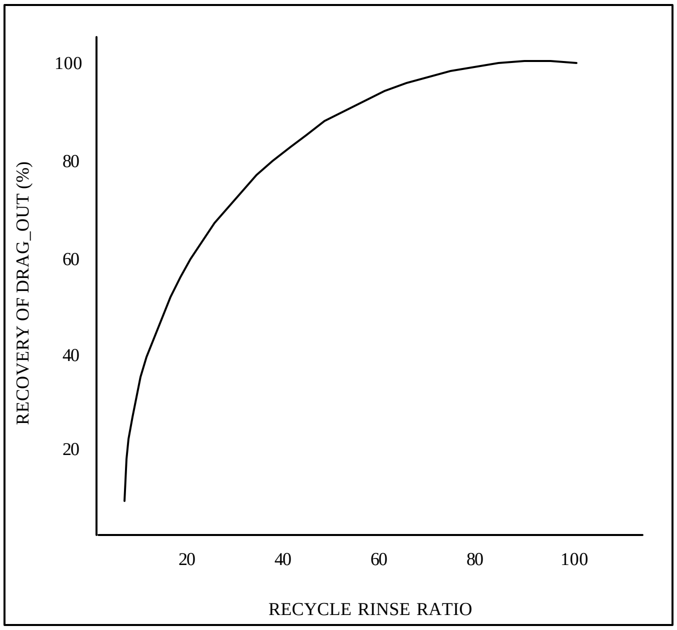
Exhibit F.7: Drag-Out Recovery as a Function of Recycle Rinse Ratio



Notes:
Recyle rinse ratio = recycle rinse flow / drag-out flow rate.
Recycle rinse flow rate = surface evaporation from bath

This case study was adapted from: "The Navy Best Management Practices." Http://www.bmpcoe.org, 1997.; and Environmental Regulation and Technology: The Electroplating Industry. U.S. Environmental Protection Agency, 1985. EPA/625/10-85/001.

Notes

CASE STUDY #9: WASTE REDUCTION IN THE CHROMATE CONVERSION PROCESS

Current Practice and Observations

A manufacturer utilized captive plating, ammonium chloride zinc barrel plating, and chromate conversion coatings in the production of door and window hardware. The operation produced 160 drums of hazardous metal hydroxide sludge a year. The manufacturer wanted to reduce the volume of hazardous waste needing disposal.

Recommended Action

Install a sludge dryer to dewater the waste material, thus reducing the volume of hazardous waste needing disposal.

Anticipated Savings

Exhibit F.8 presents an economic comparison of the current operation to the recommended action.

Exhibit F.8: Economic Comparison of Wet Sludge Disposal versus Dried Sludge Disposal

	Wet Sludge Disposal	Dried Sludge Disposal

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CASE STUDY #10: PLATING PROCESS BATH MAINTENANCE

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Current Practice and Observations

A Canadian based plater used a continuous "bleeding" process to discard contaminants of the pickling liquor. The acidic "bleed" was than neutralized with lime.

Recommended Action

Install a cartridge filter, ion exchanger, a feed pump, a sand filter, and a 400-gallon water supply tank. Pump the pickle acid from the reservoir tank through a media filter to remove dirt and oil particles, then a second smaller filter to remove very fine particles. Pass the pickled acid on to the water displacement phase, which allows the pickled acid into the resin bed of the ion exchange unit. Reuse the water from the ion exchanger by sending it back to the water supply tank. Drain the iron from the ion exchanger, and use a counterflow of water to return the trapped sulfate ions to the sulfuric acid tank.

Anticipated Savings

Exhibit F.9 presents an economic analysis of the proposed operation.

Exhibit F.9: Operating Cost Analysis for Recommended Bath Maintenance Practices

	Anticipated Start-Up Costs
Capital Costs	
Design and Supply of Equipment	$84,000
Equipment Installation	$10,000
Start-up, Supplies, Etc.	$2,500
TOTAL	**$96,500**
	Anticipated Annual Savings
Feedstock	
Sulfuric Acid	$25,942
Lime	$17,995
TOTAL Anticipated Annual Savings	**$43,937**
Payback Period:	**2.33 years**

Implementation

The plater realized almost immediate benefits with the installation of the maintenance equipment. Chemical (feedstock) use dropped almost immediately. Sulfuric acid use dropped by 561,531 pounds in the first year and lime use decreased by 224 tons in the same time period for a total chemical reduction of 89 percent. In addition to the predicted amount of economic savings, another $8,000 was saved annually on sludge hauling. Using the new maintenance process resulted in the reduction of iron content of the acid solution from an initial 7.7 percent to a steady 2-3 percent. Since pickling uniformity is a product quality improvement, product quality was at least as good as before the equipment was installed.

This case study was adapted from: "Use of Acid Purification Unit on Pickling Liquor Reduces Iron Concentration." Enviro$ense, Case Study: CS464. http://es.epa.gov/studies/cs464.html.

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CASE STUDY #11: CLOSED-LOOP PLATING BATH RECYCLING PROCESS

Notes

Current Practices and Observations

A plating operation based in Wisconsin uses an anhydrous chromic acid in its plating bath and an insoluble sulfide treatment system for cleaning. The company's typical disposal consists of 25 percent solids by weight at a cost of $0.19 per gallon of sludge. The operator wants to reduce chemical consumption and waste disposal costs.

Recommended Action

Install 75-gallon per hour closed-loop recycling system that concentrates the chromium plating bath drag-out in the rinse stream and removes it so that the plating solution bath can be returned to the main processing tank.

Anticipated Savings

The total cost to install the recovery system was estimated at approximately $60,000. If the savings in plating chemicals alone are considered, the investment would have a net cost of approximately $9,000 per year. However, if the analysis also includes the savings in treatment chemicals and in solid waste disposal charges, totaling $28,400 per year, there would be a net savings before taxes of nearly $20,000 per year and the system would pay for itself in just under four years.

Implementation

The plating company installed the 75-AExhibhe F.1ateTw (The8 under four years.) Tj 220.5 0 T40 Tj 7ned to the 4al

CASE STUDY #12: WATER-BORNE PAINT AS A SUBSTITUTE FOR SOLVENT-BASED COATINGS

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Current Practices and Observations

<u>*Notes*</u>

Exhibit F.11

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CASE STUDY #15: WHITE WATER AND FIBER REUSE IN PULP AND PAPER MANUFACTURING

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CASE STUDY #16: CHEMICAL SUBSTITUION IN PULP AND PAPER MANUFACTURING

Current Practice and Observations

A pulp and paper manufacturer produced products for book publishers and other intermediate product manufactures. The paper was coated with a solvent/heavy metal coating to increase the durability and v6as coatBT 512.2s

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This case study was adapted from: "Accelerating Industrial Pollution Prevention through Innovative Project Financial Analysis; With Application to the Paper and Pulp Industry." U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation, 1993. EPA/742/R-93/004.

Notes

Exhibit F.16: Economic Comparison of On-Site versus Off-Site Ink Recycling

	Case A	Case B
Material Balance, (Pounds per Month)		
Waste ink	200	200
Fresh ink for blending	400	100
Reformulated ink	600	300
Additional fresh ink	0	300
Total available ink	600	600
Operating Cost, (dollars per month)		
Waste ink	$0	$0
Fresh ink for blending (@ $1.55/lb)	$620	$0
Buy back reformulated ink (@ $3.00/lb	$0	$900
Buy additional fresh ink (@ $1.55/lb)	$0	$465
Total Operating Costs to Recycle Ink	$620	$1,365
Anticipated Annual Savings per Month	$745	
Payback Period	7.92 months	

Implementation

With a cost savings in operating costs of $745 per month the $5,900 initial capital investment for the on-site ink recycler can be recovered in just less than 8 months. The time and labor costs of preparing waste ink for off-site recycling are comparable to that required to prepare and operate the on-site ink recycler.

This case study was adapted from: Guides to Pollution Prevention, The Commercial Printing Industry. *U.S. Environmental Protection Agency, Office of Research and Development, 1990. EPA/625/7-90/008.*

CASE STUDY #18: SOLVENT REDUCTION IN COMMERCIAL PRINTING INDUSTRY

Notes

Current Practice and Observations

A commercial screen printing firm produces a wide variety of products including decals, banners, point-of-purchase displays, and original equipment manufacture. Over the 40 years of its operation, this company has experienced toughening environmental and health regulations on local, state, and federal levels. Many regulations have required expensive changes or threats of high fines for noncompliance. About 60 percent of the company's printing is done with traditional solvent-based inks and 40 percent with ultraviolet (UV) curable inks. Open tanks of solvent-based cleaning product allowed large amounts of VOCs to evaporate directly into the shop.

Recommended Action

Install an in-process 5-gallon recycling still to recover solvents for reuse within a closed system.

Anticipated Savings

The following economic comparison is based on a conservative set of assumptions. These

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