POTENTIAL ENVIRONMENTAL EFFECTS OF
ENERGY CONSERVATION MEASURES IN
NORTHWEST INDUSTRIES

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SUMMARY

The Bonneville Power Administration (Bonneville) commissioned the Pacific Northwest Laboratory (PNL)^(a) to prepare this report to aid the agency in the preparation of environmental documents to support conservation programs.

Bonneville has identified 101 plants in the Pacific Northwest that account for 80% of the region's industrial electricity consumption. These plants offer a precise target for a conservation program. PNL determined that most of these 101 plants were represented by 11 major industries. We then reviewed 36 major conservation technologies used in these 11 industrial settings to determine their potential environmental impacts.

Energy efficiency technologies designed for industrial use may result in direct or indirect environmental impacts. Effects may result from the production of the conservation measure technology, changes in the working environment due to different energy and material requirements, or changes to waste streams. Industry type, work-place conditions, worker training, and environmental conditions inside and outside the plant are all key variables that may affect environmental outcomes. To address these issues this report has three objectives:

- Describe potential conservation measures that Bonneville may employ in industrial programs and discuss potential primary impacts.
- Characterize industrial systems and processes where the measure may be employed and describe general environmental issues associated with each industry type.
- Review environmental permitting, licensing, and other regulatory actions required for industries and summarize the type of information available from these sources for further analysis.

The negative impacts from manufacturing a conservation measure can be offset by gains made in its operation. For example, an energy-efficient motor requires a greater quantity of copper and silicon steel than a standard variety. However, these requirements are offset by potentially increased

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motor life, which may reduce motor rewinding, thus reducing solvent and combustion pollutants. This and other new conservation technologies can also directly alter process waste streams. For example, some filtering techniques, such as electrolytic separation, are capable of recovering metals for resale. In instances where entirely new technologies replace existing approaches, the relative environmental effects are dependent on the specific technologies being compared.

Where electrical equipment replaces equipment that burns natural gas or other fuels in an industrial setting, the issue of fuel-switching must be addressed. The industry's reduction in environmental impacts resulting from fuel-switching must be weighed against the impacts that will result from increased electricity generation.

Potential impacts from electronic equipment may include worker exposure to electromagnetic fields. Researchers suspect that such exposure may result in health effects. However, there is a great deal of uncertainty surrounding this issue, and regulatory agencies have provided little guidance for occupational settings.

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1.0 INTRODUCTION

The Bonneville Power Administration (Bonneville) commissioned the Pacific Northwest Laboratory (PNL) to prepare this report to aid the agency in the preparation of environmental documents to support conservation programs. Bonneville has taken a leading role among federal agencies in assessing the environmental impacts of its conservation acquisition programs. These efforts have included research programs into residential ventilation and indoor air quality, an assessment of the potential effects of commercial conservation activities, and the preparation of environmental documents under the National Environmental Policy Act (NEPA).

Bonneville has determined that most of the energy conservation potential in the Pacific Northwest resides in the region's 101 largest industrial electricity users. Bonneville estimates that these plants consume about 80% of the electricity used for industrial purposes in the Pacific Northwest. These plants represent 11 industry types as defined by two-digit Standard Industrial Classification (SIC) codes. PNL determined the four-digit SIC codes for the plants to better determine potential environmental effects. Where very similar processes were employed, PNL combined some industry types. The list of 101 industrial plants and an explanation of SIC codes comprises Appendix A. The 11 original industry groups were condensed to 9 for purposes of our analysis.

An assessment of the environmental impacts of energy conservation measures could include impacts resulting from measure production, operation, or disposal. This report focuses on impacts in the operation stage. Industry type, work-place conditions, worker training, and environmental conditions inside and outside the plant are all key variables that may affect environmental outcomes. The type and amount of environmental effect a measure will have is largely dependent on the processes to which it is applied.

Chapter 2 contains a description of potential conservation measures that Bonneville may employ in an industrial program, and summarizes potential environmental effects. A quantitative assessment of potential impacts is beyond the scope of this document.

Chapter 3 describes the processes and environmental issues associated with the major industry types. These industries include the following: metal mining, food processing, wood products, pulp and paper, chemicals, petroleum refining, cement, primary metals, metals fabrication, and electronics and transportation equipment. Appendix B contains additional information about permit requirements and the types of information available from environmental permits.

In Chapter 4 we provide specific information about health effects that may result from environmental impacts. Health information is also discussed in Appendix C, which gives an overview of occupational injury and disease statistics.

The agencies regulating industrial pollution and occupational safety and health form a complex and extensive regulatory framework. As previously mentioned, Appendix B discusses the informational contents of permits. Chapter 5 describes the regulatory framework, and identifies agency responsibilities and their topical jurisdictions.

Tables summarizing the industrial processes and conservation measures reviewed in this report can be found in Chapter 6.

As a resource for follow-up research or for those doing environmental assessments, Appendix D contains a list of the agency contacts used to compile much of the information in this report. The references in Chapter 7 may also be useful.

2.0 ENERGY CONSERVATION MEASURES

This chapter describes the energy conservation measures that the Bonneville Power Administration has chosen as potential candidates for future programs. For each measure, a brief discussion of the technology is given, including current and potential industrial applications, followed by potential environmental impacts that may result from installing the measures. The focus is on the effects of each measure as it is applied in industrial processes, rather than the manufacture or disposal of the measure. Wherever possible, mitigation techniques are also discussed. We do not assess the potential effects of changing electricity loads or the potential benefits from downsizing the capacity of electrical distribution systems.

2.1 MEASURE SELECTION

The energy conservation measures targeted by Bonneville include innovative process technologies, automation, and the use of controls and management systems, as well as energy-efficient upgrades to existing equipment and installations. Table 2.1 lists the energy conservation measures discussed in the following sections in the order that they appear.

2.2 CONTROLS

Control technology adds precision and analysis to functions that often must be completed regardless of the control technology employed. Motors, compressors, and pumps must all be turned on and off, but advanced controls can allow for proper sequencing, warm up, and control of electrical surges. This section discusses control technologies for motors, arc furnaces, manufacturing processes, and energy systems. Information regarding the manufacture of electronic equipment is available in Chapter 3.

2.2.1 Adjustable Speed Drives

Reducing motor speed to match process requirements saves energy and improves process control. Adjustable speed drives (ASDs) are electronic controls that allow electric motors to be operated at fluctuating speeds. These controls manipulate electric current frequency to adjust motor speed.

TABLE 2.1. Energy Conservation Measures

Controls (Section 2.2)
Adjustable Speed Drives
Arc Furnace Controls
Energy Management Systems
Power Factor Controllers
Computer Controlled Machining
Robotics
Motors, Pumps, and Conveyors (Section 2.3)
High-Efficiency Motors
Pumps
Pneumatic Conveyors
Process Heating and Drying Technologies (Section 2.4)
Convection
Induction Heating
Radiant Technologies
Infrared (IR) Radiation
Microwave Radiation
Radio Frequency (RF) Radiation
Ultraviolet (UV) Radiation
Dehumidifiers (Section 2.5)
Desiccant Dehumidification
Heat Pump Dehumidification
Refrigeration Technologies (Section 2.6)
Cooling Towers and Chillers
Thermal Storage
Refrigeration Upgrades
Heat Recovery Technologies (Section 2.7)
Heat Recovery
Heat Pumps
Pinch Technology
Fabrication and Finishing Technologies (Section 2.8)
Electrochemical Machining
Induction Heating (Hardening, Welding)
Lasers (Cutting, Hardening, Welding)
Water-jet Cutting
Separation and Concentration Technologies (Section 2.9)
Electrolytic Separation
Freeze Concentration
Membranes
Energy Systems (Section 2.10)
Insulation
Compressed Air Systems
Lighting Upgrades
Renewables
Wastewater

Moses et al. (1989) identifies ASDs as the most efficient means of capacity control for centrifugal fans and pumps. In many industrial processes, this type of control can replace existing systems that rely on mechanical reductions in motor speed using devices such as gears, belts, pulleys, and clutches or systems that control gas or liquid flows using dampers, vanes, or throttling valves.

Energy savings and improvement in process control are persuading many industrial plants to install ASDs and the use of ASDs is well established in applications involving pumps and fans. In the food processing industry, ASDs can be used to control refrigeration pump motors to deliver coolant in volumes required to match outdoor temperature fluctuations and other factors (Eilers 1990).

Retrofitting existing motors is quite effective and can be done easily in most cases. ASDs are more compact than mechanical or hydraulic motor controls, and need not be mechanically coupled to the motor (Nadel et al. 1991). However, detailed information and analysis is required. "In-house" designs not reviewed by experienced personnel can lead to serious problems, even accidents, and should be avoided (Ebasco and EA-Muellar 1990, p.3).

Ebasco and EA-Muellar (1990) report that in most cases, existing motors cannot be operated at rated horsepower without providing more cooling. Further, in virtually every case, the increased heat caused by ASDs will shorten the life of existing motors.

Nadel (et al. 1991) states manufactures recommend not running motors at 10% to 15% of rated speed because of heat and irregular rotation. At the other end of the performance spectrum, ASDs can be used operate motors at up to twice their rated speed. However, an existing motor's bearings and rotors may not handle the additional stress. The ASD itself will produce heat, but should be adequately cooled by its own systems in areas with normal temperatures.

Potential Environmental Effects

1. Systems requiring fast responses to control signals are likely to need forced ventilation or the installation of a larger motor to control heat. Cluttered environments or high dust or vapor concentrations may preclude the use of cooling fans (SJO, Shapiro, and Synergic 1984, p.32).

2. The use of ASDs may contribute to occupational exposure to low level electromagnetic fields (EMFs). Some researchers suspect that health effects may be related to EMF, but evidence is still preliminary and inconclusive (see Chapter 4). Nadel (et al. 1991) states that harmonic and electromagnetic interference occurs only in large ASDs, over 200 hp.
3. As more ASDs are used, utilities may require the installation of harmonic filtering. Electromagnetic interference caused by harmonics and electrical noise can upset computer equipment, control systems and instrumentation; overheat motors; and interfere with telephones and other electronic equipment. Laboratory tests have shown interference to radio reception broadly across the AM band (Wallace et al. 1989, p. 20). The cost of filters can be substantial. Adding filters to a system to meet Federal Communications Commission specifications for electronic data processing equipment may increase costs by 20%.
4. With either ASDs or conventional speed controls, noise and vibration may be a serious problem. Chapter 4 discusses the occupational impacts of noise and vibration. Vibration on retrofits may be helped by filtering the output. ASDs may cause vibrations at particular frequencies; band filters can be used to avoid specific frequencies to eliminate the vibration. Eliminating vibration in conventional units may be more difficult.

Earlier Bonneville-sponsored work suggests that ASDs using solid state components produce relatively low noise levels that would not be a factor in industrial settings (SJO, Shapiro, and Synergic et al. 1984, pp. 31-32). But ASDs may have an indirect effect on the noise level of the machinery to which they are applied. For example, doubling a motor's speed can increase noise by 3 to 10 dB(A).

Noise in conventional units usually comes from mechanical parts, especially friction clutches and dampers. These noises should subside with the use of ASDs. Fans that run at low speeds over long periods of time with ASDs also typically produce less noise than those found in conventional systems (Ebasco and EA-Mueller 1990). However, the electronics of an ASD may be quite noisy. So, if a conventional drive being replaced is quiet, the ASD may increase noise levels. Wallace, Spee, and Martin (1988, p. 24) found in laboratory tests that ASD noise increased proportionally to the difference between rated fan speed and operating speed. These researchers also found that under test conditions, subjects exposed to ASD noise for 8 hours reported that they would have difficulty working full time in similar environments (Wallace, Spee, and Martin 1988, p. 9-1). Hearing conservation programs may mitigate noisy work environments. These programs are described in Chapter 4.

5. To the extent that adjustable speed drives can eliminate throttling valves as a means of controlling flow rate in hazardous chemical or waste streams, there may be an incremental reduction in the risk of an

accidental release to the environment. But this effect is difficult to quantify and is not likely to be significant.^(a)

2.2.2 Arc Furnace Controls

Electric arc furnaces are used in high-temperature melting applications such as steel and semiconductor manufacture (see Chapter 3). Microprocessor-based arc furnace controls maximize electric arc performance and carbon balance and distribution to reduce electrode consumption, minimize furnace wall refractory wear, and shorten meltdown times. For example, in mini-mill production of steel, the systems control the length and intensity of the arc and help to calculate the best mix of scrap for a desired product (Sochacky and Gaillot 1983; Goins 1983; and Gregory, Ridley, and Weston 1983). These systems essentially replace operations that otherwise would occur manually or using other types of controls.

Potential Environmental Effects

1. No information of the environmental effects of arc furnace controls was found in the literature reviewed. However, because furnace operation is likely to be more efficient in terms of material and energy requirements, arc furnace controls may have an overall beneficial effect.
2. Proper control of arc may also decrease potential ozone formation, which is often associated with electrical arcs. Ozone is listed by the U.S. Environmental Protection Agency (EPA) as a criteria pollutant. The health effects of ozone are discussed in Chapter 4.
3. Dust produced by arc furnaces is classified as hazardous by the EPA (Douglas 1989). Controls may affect dust generation.

2.2.3 Energy Management Systems

Energy management systems control the heating, ventilating, air-conditioning, lighting, and other energy-consuming equipment in a building or process. An energy management system may encompass more than the energy-system control and is sometimes called a direct digital control system.

Direct digital control replaces conventional controls with electronic sensors and microprocessors (Williams and Bechard 1987). The direct digital control can work with pneumatic valves or electronic devices. These systems

(a) Personal communication with R.S. Butner, Senior Research Scientist, Pacific Northwest Laboratory, Richland, Washington.

provide precise, reliable, and flexible centralized control. However, the systems entail greater maintenance than conventional controls, and operators must be highly trained to understand all process operations. One reason that more maintenance is needed in computerized systems is that failed parts cannot be ignored. In a conventional system a failed controller is often ignored or is inefficiently locked open or closed. With a direct digital control or energy management system, if a control fails the system stops operating. It must be fixed for the process to continue.

In the food service industry, an energy management system is frequently employed to control refrigerators and freezers. The system consists of a mini-computer and software; computer peripherals; and sensors to measure pressure, temperature, humidity, electrical current, and power at various points throughout a plant. The energy management system reduces energy consumption in freezer applications by

- increasing suction pressure and/or reducing discharge pressure when permissible to minimize pressure rise in the compressors
- controlling the defrost cycle according to need rather than at fixed intervals
- limiting coil fan operation as permissible
- sequencing compressor operation so that a minimum of compressor power is used to meet cooling needs
- monitoring and recording equipment operating conditions to detect and repair malfunctioning equipment (Spanner, Dixon, and Fishbaugher 1990).

Analyses of the energy savings from an energy management system installation in one food processing and storage facility resulted in estimated energy savings of 23%. This estimate is based on end-use consumption data (Spanner, Dixon, and Fishbaugher 1990).

Specific energy controls that may be applied to space heating and cooling include the following:

- *Temperature Setup/Setback.* Minimizes the time that space heating and cooling equipment is operated when the plant is not operating.
- *Time-of-day Timeclock.* Starts and stops equipment operation at predetermined times.

- *Duty Cycling*. Periodically shuts down equipment not essential to maintaining the plant environment or to critical plant functions.
- *Supply Air Temperature Reset*. Changes the supply air setpoints to match air-handling unit output to the space load.
- *Hot/Chilled Water Supply Temperature Reset*. Matches hot or cooled water supply setpoints to the actual equipment load rather than to peak load.
- *Ventilation Purging*. Uses outside ventilation air, often during unoccupied periods, to meet cooling loads and condition the space prior to occupancy.
- *Economizer Cooling*. Uses outdoor air when temperature and humidity conditions permit, to cool indoor spaces.
- *Deadband*. Establishes a deadband between cooling and heating to prevent the simultaneous supply of hot and cold air.

Potential Environmental Effects

1. Since these systems often control equipment that is needed to provide ventilation or lighting, it is important that the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH) standards and guidelines be met at all times to protect worker safety. An energy management system may provide a means of improving ventilation and lighting conditions through automation, but care must be taken to program the controls properly.
2. An energy management system may shut off heating, ventilation and air conditioning systems during condensing operations (Dolan 1989). A shut-off at this time may allow condensate to pool in pans and to wet other surfaces. Such conditions could lead to microbial growth and indoor air contamination.
3. An energy management system can have a beneficial impact on process control and the resultant product quality. This can result in direct waste reduction benefits if less product is rejected (and sent to waste) for quality reasons. This would be especially true in industries in which quality is influenced by the presence of thermally labile materials that can be adversely affected by temperature deviations, such as food, paper, chemicals, and electronics industries.

2.2.4 Power Factor Controllers

A power factor controller (PFC) is a power electronics device that reduces voltage to a motor during periods of reduced motor torque requirements. In exceptional applications, energy savings can be 10% or more of energy used (Cohn 1982). Average savings will probably be less than 10%. A

PFC does not save energy when used with an energy-efficient motor. Since PFCs can be used as starters, Knudson Engineering (1989) predicts that PFCs will only be applied in the next ten years when a starter fails. Furthermore, Knudson reports that almost all PFC manufacturers have stopped trying to sell the device for energy savings, since the payback usually does not justify a PFC on energy savings alone.

Potential Environmental Effects

No information on the environmental effects associated with power factor controllers was found in the literature reviewed.

2.2.5 Computer-Controlled Machining

Computer controls can be applied to individual workstations, to an entire process or series of machines, or to an entire factory. In many of these applications the nature and function of tools do not change, but the methods of control have changed dramatically. One benefit of computer-controlled machining is the flexibility it provides in allowing changes in products without retooling (RDC and BCD 1988). These systems are also referred to as "flexible manufacturing systems" (FMS).

Flexible manufacturing systems combine several production technologies to help manufacture a wide variety of products as demand warrants. The products are manufactured by machines rather than workers. Although the major applications of flexible manufacturing systems have been in metal working, the systems are applicable to any batch manufacturing process where a variety of parts are produced or the demand for specific products fluctuates. This approach may be used in conjunction with robotics and other conservation measures discussed in this report, such as water-jet cutting and lasers. Industries with potential applications for flexible manufacturing systems include fabricated metal products, industrial and commercial machinery, computer equipment, electrical and electronics equipment, and transportation equipment.

Computer controls are the heart of the process. Programmable controls implement local functions such as sequencing, timing, counting, arithmetic and logic operations. Computer controls can store and edit programs at the machine site. A central computer can control routing, load balancing, and

scheduling, and download programs to other computer controls. In a few applications, computer controls have been linked with computer aided design systems to allow for systematic and direct control from the design stage to machining.

Potential Environmental Effects

1. Measures should be taken to ensure that workers are well informed about changes in production runs. With flexibility may come uncertainty about the placement and movement of mechanized equipment. Safety zones must be clearly designated with appropriate barriers and automatic kill switches.
2. Some researchers suggest that the interaction of workers and automatic controls may cause health problems that could impact plant operating efficiency. For example, Tsuchiya (1987) reports that automated controls and robots may result in two types of stress:
 - cognitive stress, arising from trying to handle too much poorly understood information
 - psychic stress from anxiety; the fear of being unable to respond properly, especially during an emergency.

Solutions to this problem are characterized by better design and implementation of technical layout, careful representation to workers of the functional state of the process, and training and retraining of controllers.

3. Many control technologies are based on recent advances in microprocessor technology. An environmental concern common to all these systems is electromagnetic radiation. As with other electronic equipment, computerized controls may emit electromagnetic fields. There is a great deal of uncertainty surrounding the health effects associated with these fields. Health effects may vary considerably depending on exposure to specific frequencies, duration of exposure, and other factors. A more thorough discussion of electromagnetic fields is given in Chapter 4.
4. Visual display terminals (VDTs) typically make up the interface between workers and automated processes. Potential affects on pregnant women are of concern. To date the evidence linking VDT operation with spontaneous abortion or congenital birth defects is not conclusive (McDonald et al. 1987). However, studies have raised the concerns of consumer groups and labor unions over reproductive effects. Canada and Sweden have established standards.
5. Eye strain and fatigue are problems that may result from long periods of VDT operation. Care should be taken to install computer systems in accordance with health and safety guidelines, such as those provided by

the Oregon Department of Insurance and Finance, Occupational Safety and Health Division (OR-OSHA 1990).

6. It is difficult to predict the types of impacts that computer controls will have on specific waste streams and occupational settings. In general, the controls will increase efficiency, thus reducing total material inputs, wastes, and emissions. If computer equipment is adapted on a large scale, it may require changes in plant space conditioning and air filtering may be needed in some settings.

2.2.6 Robotics

Spot welding and materials handling in the automotive and heavy machinery industries are currently the primary industrial uses of robots in the United States (EPRI 1984). Thirty years ago, the first robots were introduced to manufacturing in the United States, where they were primarily used in repetitive, uncomfortable, and hazardous tasks (Quazi 1991). In the 1980s robots began operating with various forms of sensory ability. The next generation of robots, currently in the research stage, is likely to incorporate human-like intelligence. Quazi estimates the following applications of robots in U.S. industry.

welding	38%
material handling	20%
machine loading/unloading	15%
casting	12%
printing and finishing	8%
assembly	6%
other applications	1%

Actual and potential uses of robotics and automation in the food service industry include batch processing and packaging, evisceration and deboning, fruit and vegetable canning and inspection, tomato paste manufacturing, grain milling, and sweetener manufacturing. Many of the conservation measures discussed in this report may include a robotics component. For example, lasers and water-jet cutters are often robot and computer controlled.

Current robot applications may result in an increase in electricity demand and consumption. However, robots are becoming more compact, mobile, versatile, and electrified. It is difficult to predict the generic impacts of robots on electricity consumption. Even where electricity consumption increases, robots may allow for more flexible scheduling to allow for work to be performed during off-peak periods (EPRI 1984).

Potential Environmental Effects

1. Robots should have appropriate controls to disengage when safety zones are violated by workers and workers should be trained in the safe coexistence with robots. Even trained workers have been known to avoid the obvious dangers of moving mechanical arms, only to be crushed when a robot base repositioned itself (Keyserling 1988, p. 109). Seemingly dead robots may be awaiting input signals to begin operating (Quazi 1991). This problem may become more pronounced as robots become more mobile. Quazi (1991) describes three risk levels associated with worker proximity to robot work spaces. A high-risk situation occurs when workers and robots share a work space; medium risk is present when workers have access to, but are not required to be near a robot; lowest risk exists when robots work independently of human contact and only authorized persons have access to the robot's vicinity.
2. Increased automation may reduce repetitive motion disorders if manual workers are replaced on assembly and production lines.
3. Robots may reduce direct human exposure to hazardous work environments but workers in the area may still be exposed to unshielded or unventilated hazards, such as arc welds or paint fumes.
4. In the food service industry, robots can decrease human exposure to bacteria (Quazi 1991).
5. At its best, robotics can relieve humans of dangerous and repetitive tasks. However, the use of robots may also lead to the introduction of automation in a form that takes away workers use of their minds or skills, leading to alienation and frustration, which ultimately could affect productivity (Tsuchiya 1987). As was mentioned in the previous section, mitigating cognitive and/or psychic stress due to automation requires better design and implementation of technical layout, careful representation to workers of the functional state of the process, and training and retraining of controllers.

2.3 MOTORS, PUMPS, AND CONVEYORS

Energy conservation measures for motors, pumps, and conveyors are described in this section. Other sections with relevant information include section 2.2 for information about control technologies, Section 2.7 for information on heat recovery from wastewater streams, and Section 2.2.3 for information about energy systems.

2.3.1 High-Efficiency Motors

Electric motors transform electrical energy into mechanical energy in the form of rotating shaft power (Argonne 1980). This power is used to drive

industrial machinery, such as pumps, fans, compressors, and materials-handling equipment, or further modified to provide reciprocating power. Motors account for over 75% of total industrial electricity consumption and over 90% of consumption in the pulp and paper industry (Montgomery 1989; Argonne 1980). Because of the size of the load attributed to electric motors, these devices may be the single most important target for conservation. Three conservation strategies include motor replacement, rewinding, and controls. Controls are discussed in Section 2.2.

The four basic components of a motor are a stator (field) assembly; a rotor (armature) assembly; an enclosure, which includes bearings, a lubrication system, and other mechanical/electrical assemblies; and a shaft. Motor action is created by the flow of current in two sets of windings, which develops torque on the rotor in a single direction. Alternating (AC) or direct current (DC) may be used to excite either or both windings.

Motors are divided into two major families: AC and DC. Within each family, they are grouped into subcategories according to various operating and physical properties. There are literally hundreds of thousands of types of motors; however, three basic types include AC induction/asynchronous motors, AC synchronous motors, and DC motors (Nadel et al. 1991). The National Electrical Manufacturers Association (NEMA) has standardized definitions and ratings that specify expected and/or minimum performance criteria for both AC and DC motors. The energy efficiency of a motor is the ratio of the mechanical power output to the electrical power input (McCoy, Litman, and Douglas 1990, p. 5). Design changes, better materials, and manufacturing improvements can reduce motor losses, making the motors more energy efficient.

In field tests, Lobodovsky, Ganeruwal, and Gupta (1989) found that a large number of motors are operating at loads far below their rated size. These oversized applications may be suitable for motor replacement. In addition, low-efficiency motors and motors needing repair may be candidates for replacement or rewinding.

Energy-efficient motors are generally from 0.7% to 4.0% more efficient than their standard counterparts (Argonne 1980). In some cases, increases in efficiency may be as high as 10% (SJO, Shapiro, and Synergic 1984). This

range varies depending on manufacturer, motor capacity, and motor speed. Argonne (1980) and Nadel (et al. 1991) identify the following areas of motor efficiency loss and technical changes to reduce the losses:

- *Friction and Windage.* Proper maintenance of bearings and design of smaller, more efficient fans reduces friction losses and improves air circulation through the motor. In a 50-horsepower motor at 3,600 rpm, Montgomery (1989) found these losses to account for about 15% of total losses. These losses are not normally affected by rewinding, but may be if too much grease is applied or poor bearings are installed.
- *Stray Load Losses.* These are heating and miscellaneous losses related to motor geometry and account for about 10% to 15% of total losses (Nadel et al. 1991, Montgomery 1989). Rewinding may contribute to these losses through damage to the stator or rotor cores.
- *Core losses.* These are associated with energizing the motor's magnetic field and account for about 25% of total losses in our example. Losses increase as load diminishes. At no load, core losses account for 60% of losses in the motor used for comparison. Steel gauge and grade selections can reduce losses. Rewinding may impact these losses by damaging insulation or changing motor geometries. The insulation will not be damaged if winding burn-out ovens are carefully controlled. A study conducted by General Electric (as reported in Montgomery 1989) found a nationwide average of 32% degradation in core losses from rewinding. A core loss test is available to screen motors that should not be repaired and verify the effects of rewinds and other repairs. In a high-quality rewind these losses will be diminished.
- *Electrical.* Electrical losses occur in the stator and rotor. These losses are directly related to winding, and account for 50% of losses in our example. If different gauge wire is installed, or fewer turns are used, efficiency may be degraded and there will be an increase in the electric field. If rewinding is done using the same wire size and configuration, there should be no degradation.

The key differences between energy-efficient and standard motors are that energy-efficient motors include more copper windings, use copper wire instead of aluminum wire, and use better grades of silicon steel in laminations (Argonne 1980).

Potential Environmental Effects

1. Upgrades will result in increased consumption of copper and silicon steel raw materials. The literature did not indicate the severity of this impact.

2. The installation of energy-efficient motors will not alter industrial processes or their waste streams. However, processes may require adjustment to accommodate increased motor speed (SJO, Shapiro, and Synergic 1984). Because of the change in speed, ventilation systems receiving new motors may require adjustment to continue meeting OSHA standards.
3. Energy-efficient motors operate more quietly and emit less electromagnetic radiation than standard motors and will thus improve the occupational environment (SJO, Shapiro, and Synergic 1984). Chapter 4 discusses the health hazards associated with noise and electromagnetic radiation.
4. Based on the literature review supporting this document, it does not appear that motor rewinding results in efficiency improvements, and may result in efficiency degradation. In addition to efficiency degradation, there is the possibility of increased electromagnetic radiation.
5. Rewinding often involves combustion or solvent processes to remove old windings and insulation. These processes will result in combustion pollutants that will vary by fuel type. The processes may create hazardous waste generation if solvents are used (see Chapter 4).
6. Concerns have been expressed that motor capacitors installed prior to 1978 may contain polychlorinated biphenyls (Baechler, Foley, and Jarnagin 1990). The literature surveyed contains no evidence to prove or disprove this concern.
7. Energy-efficient motors are likely to operate at lower temperatures. These lower temperatures will extend the life of lubricants and insulation. Improved lubrication, and the point that energy-efficient motors tend to have better bearings, will extend the life of the bearings. Similarly, insulation degradation leads to the degradation of windings. Winding and bearing failure are two key causes of motor failure. Thus, lower temperatures will extend the life of the whole motor (Nadel et al. 1991).

2.3.2 Pumps

Pumps are used in industrial processes with considerable quantities of cooling water or process fluid. A pump uses mechanical energy to raise a liquid to a higher level against gravity, or to overcome the effects of pipe friction in a circulation system (Argonne 1980).^(a) The thousands of end-

(a) The term pump may be applied to fluid-handling units, gas compressors, and vacuum pumps. This definition applies to fluid-handling units only.

classes of industrial pumps can be grouped into two major classes: dynamic and displacement pumps.

In dynamic pumps, energy is added continuously to raise the velocity of the fluid within the machine to a level higher than at the discharge. Displacement pumps apply force to the movable boundaries of an enclosed fluid until it is discharged into a region having a higher pressure. Centrifugal pumps are common dynamic pumps; rotary gear pumps are common displacement pumps. Argonne (1980) concluded that standard pumps were already efficient in terms of intrinsic losses, and that process changes would result in the greatest savings. Intrinsic pump inefficiencies stem from internal leakage (volumetric losses), flow anomalies (hydraulic losses), and frictional losses. The key for energy conservation is to find the right pump for the job.

Potential Environmental Effects

1. In the future, the chemical industry may use more seal-less (canned or magnetically coupled) pumps for hazardous fluid pumping in order to prevent accidental hazardous releases that occur when pump seals leak or fail. These pumps often have slightly lower energy efficiency due to the use of magnetic coupling to link the drive with the pump impeller.^(a) Thus, the most energy-efficient pumps may not be appropriate for installation in hazardous or toxic chemical or waste streams.
2. To the extent that adjustable speed drives can eliminate throttling valves as a means of controlling flow rate, there is an incremental reduction in the risk of an accidental or non-point source release of pollutants to the environment.

2.3.3 Pneumatic Conveyor Applications

The American National Standards Institute (ANSI) defines a conveyor as a horizontal, inclined, or vertical device for moving or transporting bulk materials, packages, or objects, in a path predetermined by the design of the device, and having fixed or selected points of loading and discharge (McElroy 1980, p. 172). Common types of conveyors are belt, slat, apron, chain, screw, bucket, pneumatic, aerial, portable, gravity, live roll, en masse, flight, mobile, and vertical conveyors.

(a) Personal communication with R.S. Butner, Senior Research Scientist, Pacific Northwest Laboratory, 6 March 1991.

A pneumatic conveyor consists of an arrangement of tubes or ducts through which solid objects, such as cash, mail, and other small items or grain, dust, and similar bulk materials, are transported by means of compressed air or vacuum (McElroy 1980, pp. 180-181). Solid objects are conveyed through a tubing system at relatively high velocity; an example would be the conveyance system used at the drive-up window of a bank. Bulk material mixes with the compressed air and flows through the system much like a liquid. Common applications of these systems in the Pacific Northwest include pulp and paper mills and lumber mills.

Two potential conservation measures for pneumatic conveyers are the installation of variable speed drives and the reengineering of systems.^(a) A variable speed drive allows the fan to match operating levels with load requirements. For example, a variable speed drive would allow a fan to operate at varying levels depending on the number of machine areas being served at a particular time. In a demonstration project in the wood products industry, variable speed drives resulted in energy savings ranging from 27% to 40% (CHAI 1990a p.1). CHAI estimates that total savings in pneumatic conveyers with variable speed drives will range from 30% to 40%.

Reengineering techniques for pneumatic conveyors include installing storage bins to smooth materials flow, improving aerodynamics, changing pipe size, changing systems from low to high pressure, and converting from a push-through to a pull-through system (CHAI 1990b). Another possibility is to switch from pneumatic to mechanical conveyers. A belt or chain conveyor will often move material for less than 30% of the energy required by a pneumatic system (CHAI 1990b).

On a per-unit-of-production basis, pneumatic conveyers require from 12% to 25% of the total energy used in various mill types. Over the region, conservation measures in pneumatic conveyers may amount to over 253 million kWh/year.

(a) Motor speed can be controlled using mechanical and electronic devices. See Section 2.2 on control technologies.

Potential Environmental Effects

1. In wood products mills, pneumatic conveyers tend to break up hogged material (specifically bark) as it moves through the system (CHAI 1990a, p. 30). Boilers designed to burn large pieces of bark allow dust to become airborne and leave the boiler as particulate matter. A belt conveyer will produce substantially less dust in the boiler than a pneumatic system, thus reducing particulate emissions. However, open belt conveyers may contribute to indoor dust levels.

In a pulp and paper mill Bechtel (1984) concludes that, with proper design and control measures, air emissions from a mechanical conveyer system would be equal to, or better than, a pneumatic system, and indoor air quality and work-place health and safety impacts would be minimal.

2. Conversion to belt conveyers may result in increased ambient noise levels along the beltway and in surrounding areas (Bechtel 1984, pp. 5-32). Open belt conveyers may increase dust concentration in the indoor air during operation. Dust may interfere with vision and increase the risk of fire in the immediate and adjacent areas surrounding the belt conveyor. In certain applications, this dust may be toxic. For example, in lumber mills the dust may be toxic if it is from wood treated with herbicides or preservatives (Bechtel 1984, pp. 5-33). Arsenic compounds, creosote, and pentachlorophenol are common wood preservatives (EPA 1984). Belt conveyors may be enclosed to prevent fugitive emissions (Bechtel 1984, pp. 5-18). The health effects associated with noise and dust are discussed in Chapter 4.
3. Conveyer belts often operate at high speeds and present mechanical safety hazards, requiring belt guards, a start-up alarm, and guarded passways for employees (Bechtel 1984, pp. 5-17). Conveyers may block employee traffic and materials movement, requiring crossovers at aisles and passageways. Passover aisles or guards will protect personnel from falling materials. Loose material that accumulates may pose an additional fire hazard. Regular housekeeping and maintenance can mitigate this risk. Belt conveyors may be enclosed to prevent fugitive emissions. Open hoppers and chutes with an open floor or open-sided work platform require standard protection devices.
4. Special hazards associated with pneumatic conveyors have to do with suction and pressure environments. Precautions must be made to keep contaminated air or materials from entering the conveyor tube and being transported to other areas.
5. In mining operations, vast quantities of ore must be transported. According to the Center for Metals Production, electric conveyers and trolley-assisted trucks would reduce costs and improve productivity in mines over the use of diesel-fueled trucks (Bush 1989). Replacing diesel-fueled trucks underground would also improve working conditions and reduce ventilation requirements for truck exhausts.

2.4 PROCESS HEATING AND DRYING TECHNOLOGIES

An oven or dryer is a device in which heat is transferred directly or indirectly to a workpiece for the purpose of changing its physical or chemical characteristics. Aluminum steel or alloy steels are used in the construction of industrial ovens, which operate at temperatures ranging from 120°F to 1200°F. This distinguishes industrial ovens from industrial furnaces, which are built of brick or ceramic material and operate at temperatures above 1200°F. The source of energy for these devices is typically fossil fuel.

The combustion products in direct-fired ovens contact the workpiece. In indirect-fired ovens the combustion products are kept separate from the workpiece by a heat exchanger or an intermediate fluid, such as water or steam. Heat in ovens or dryers can be transferred to the workpiece by either conduction, convection, or radiation. Heat transfer by conduction requires direct contact between the heat source and the workpiece. Convection refers to heat transferred through warm air currents (see Section 2.4.1). Radiant heating transfers energy using electromagnetic waves (see Section 2.4.3). For radiant heating, drying, and curing applications, the most applicable portion of the electromagnetic spectrum is infrared radiation.

2.4.1 Convection

Perhaps the most common conventional technology in industrial ovens is convection heating. Convected heat warms the air that surrounds a workpiece before it reaches the workpiece. Because of the insulating effect of this boundary of air, natural convection heating becomes slow and increasingly inefficient as production rates increase. Forced convection directs heated air at the workpiece with fans. The forced air breaks up the boundary layer, but requires enclosures and air-handling equipment. Faster forced convection heating results in higher air velocity that requires higher oven heating losses and risks possible damage to delicate workpiece surfaces.

Potential Environmental Effects

Most convection ovens are heated with natural gas. This combustion process results in air pollutants such as oxides of nitrogen and carbon dioxide. The health effects of these pollutants are discussed in Chapter 4. Natural gas is extracted from the earth in on-shore and off-shore wells. Impacts from these operations include air and water pollutants that result from both drilling and extraction (DOE 1983). The processing and transporting of natural gas may result in multiple-fatality accidents (ADL 1985).

2.4.2 Induction Heating

Electromagnetic induction, or induction heating, is a way to heat electrically conductive materials such as metal. The source of the energy is an induction coil. A flow of alternating current through these coils generates a magnetic field, which then creates electrical currents that dissipate energy, and thus heat a workpiece.

Induction heating is used for hardening and welding in metals fabrication processes. The most significant difference between induction heating and traditional techniques, is that induction heat is generated within the workpiece. Thus, induction processes do not require a furnace enclosure or large working area. Applications of induction heating and potential environmental effects are discussed in Section 2.8.2.

2.4.3 Radiant Technologies

Radiation falling on an opaque surface is immediately absorbed and transformed into heat. In radiant heating applications, radiant energy is transferred from a heat source to a workpiece in the form of electromagnetic waves. The electromagnetic spectrum is made up of energy-bearing waves ranging from DC current at 0 Herz to high-frequency cosmic rays at around 1×10^{22} Herz.^(a) The spectrum is divided into different segments, including power frequencies, radio, television, visible light, and X-rays (see Figure 2.1).

(a) Electromagnetic radiation is characterized by frequency measured in Herz (cycles per second) and wavelength usually measured in meters. Frequency and wavelength are inversely proportional. Low-frequency radio waves, for example, have wavelengths on the order of 100 meters whereas high-frequency microwaves have wavelengths of hundredths of a meter.

FIGURE 2.1. The Electromagnetic Spectrum

Non-ionizing radiation, which includes infrared (IR), radio frequency (RF), microwave and ultraviolet (UV) waves, describes that portion of the spectrum that transfers energy to objects in the form of heat. These radiant energy sources can be used to replace or enhance conventional heating, drying, and curing techniques. Since different frequencies have different properties, these energy sources are discussed separately in the following sections. Laser radiation, an amplified form of nonionizing radiation, is discussed in Section 2.8.3.

The application of electromagnetic radiation to industrial processes raises the question of increased worker exposure to electromagnetic fields. This literature review found little published data about electromagnetic discharges from these industrial heating and drying technologies. Except for microwaves and radio frequency waves, exposure to these fields is not regulated. There is no consensus on whether regulations are needed for low-level exposure, such as that from electrical transmission and circuits. The potential health effects of electromagnetic fields is discussed in Chapter 4.

Many of the radiant technologies can be viewed as waste reduction techniques for the management of hazardous wastes. The radiant technologies can be applied to special inks and paints to minimize the use of solvents and solvent emissions, which are often classified as air toxics.

However, in many cases, the new techniques replace combustion processes. Thus, rather than conserving electricity, these techniques may broaden the market for electricity. The trade-off is between the reduction of combustion pollutants and toxic pollutants at the end-use with an increase in environmental impacts from electricity production. The extent of reduction in combustion pollutants is dependent on the process type and size being replaced. Impacts from electricity generation would depend on generation resources used to meet the increased peak and off-peak load and the load of the new end-use.

2.4.4 Infrared Radiation

Infrared radiation is the part of the electromagnetic spectrum between visible light and radio waves. IR frequencies range from 3×10^{11} to 3.8×10^{14} Herz. IR applications include drying and curing. In drying, IR may be

used for both water- and solvent-based paints and inks. In general, any heat treatable coating can be processed with IR. Shortwave infrared radiation can be used to cure coatings requiring heat treatment. In a conventional oven, paints must be dried slowly to avoid the formation of a surface skin, which causes blistering. Infrared radiation dries paints from the inside out, thus avoiding this problem.

Infrared radiation works well for curing powders that melt to form a coating. In conventional convection ovens, the powders may be dislodged by moving air. IR curing is accomplished without forced air flow. An overall process using IR radiation may include shotblasting to clean the substrate, electrostatic spraying of a dry powder coating, and conveyance through an IR curing oven. Conventional heat treating methods rely on solvent-based cleaning, spray-on paints, and a gas-fired convection oven for curing.

Potential Environmental Effects

1. Some IR curing systems use coatings with solvents as carrying agents, which may emit volatile organics into the atmosphere. The health effects of solvents are discussed in Chapter 4. Since solvent vapors may be explosive at high concentrations, there must be adequate air flow in the ovens to prevent accumulation.
2. In some conventional applications more paint is lost to the atmosphere than is applied to the product. Thus, volatile organic emissions from paints and solvents can be substantial. In addition, the gas-fired oven emits some combustion gases regarded as criteria pollutants and greenhouse gases by the EPA. Reducing or eliminating these emissions would have positive environmental results.
3. The primary biological effect of over-exposure to IR radiation is skin burns, although the sensation of heat should alert those being affected. The lens of the eye is especially vulnerable because damage may occur before heat is detected. Control of IR radiation includes the shielding of sources, filtered eye protection, and increased worker distance from sources to reduce intensity.

2.4.5 Microwave Radiation

Microwaves are the portion of the electromagnetic spectrum between 300 and 300,000 MHz. Microwaves uniformly heat nonmetallic substances that are not good conductors of heat or electricity. Microwaves are used in industrial operations, such as heating, welding, and melting of metals; the processing of wood and plastic; and the creation of high-temperature plasma. Benefits of

microwave processing include increased production, decreased energy consumption, and reduced material loss, as well as space and labor savings.

Magnetron tubes set up electromagnetic fields that are manipulated to form microwaves. Magnetron tubes require frequent maintenance, having a typical lifetime of 6,000 hours. Microwaves have a higher power density and generally heat faster than RF waves (see Section 2.4.6). However, RF systems achieve a slower, more uniform heat rate that is better suited for larger, thicker objects. The average microwave system is about 50 kW, as compared with a typical RF system, which is about 100 to 300 kW. Microwave applications need energy levels of 200 or less Btu per pound of product.

Potential applications are shown in Table 2.2. The most widespread application of microwaves is in the food service industry. Researchers in California are experimenting with the microwave drying of grapes and other fruits and vegetables (Douglas 1989).

Table 2.2. Industrial Applications and Products of Microwave Processing

<u>Drying</u>	<u>Cooking</u>	<u>Vulcanizing and Curing</u>	<u>Other</u>
grain products such as pasta grain insulation photographic film pharmaceuticals polymers	bacon poultry sausage dough roasted coffee roasted nuts	rubber polymerization of synthetic resins	plastics welding meat tempering food defrosting food pasteurization and sterilization dewaxing molds

Source: adapted from RDC and BCD 1988

Potential Environmental Effects

1. The heating effect of microwave radiation is dependent on the amount of energy absorbed by the subject. Heating tissue requires relatively high power densities, above 100 watts per square meter. Documented adverse human health effects from high power levels include cataract formation, testicular degeneration, and, at extremely high intensities, death from hyperthermia (Hu 1988). There is much more controversy over potential health effects caused by long-term exposure to microwaves at power

densities below the standard. Chapter 4 discusses these effects in more detail.

2. Microwaves can interfere with medical electronic devices such as some pacemakers. Shielding employed where workers are exposed to microwave radiation will generally protect pacemakers.
3. The use of microwaves for sterilization in the food industry has not yet been approved by the Food and Drug Administration because it has not been demonstrated that the technology uniformly sterilizes food products (Morris and Russell 1990). However, use of the systems is spreading in Europe.

2.4.6 Radio Frequency Radiation

Radio frequency waves are the portion of the electromagnetic spectrum between 2 and 100 MHz. RF waves, like microwaves, uniformly heat nonmetallic substances that are not good conductors of heat or electricity. Industrial RF applications include drying, heating, and curing. Because it does not expose products to high temperatures and can be applied quickly and uniformly, RF radiation often enhances product quality when compared to conventional techniques.

Radio frequency radiation is well-suited to heating dielectric, or non-conducting, materials such as water and works to heat a material from within, much like a microwave. RF (low-frequency dielectric heating) is generally used in place of the microwave process (high-frequency dielectric heating) for thicker materials. Applications include heating plastics and drying moist materials in the plastics, textiles, lumber, and paper industries. RF applications are shown in Table 2.3.

Example: Veneer Drying

Plywood is constructed of an odd number of individual pieces of veneer sandwiched and glued together with their grains running at right angles to one another. In the manufacture of plywood, common practice calls for veneer to be at about 8% moisture content, by weight, before gluing. All veneer must be dried prior to being assembled into a panel.

Table 2.3. Radio Frequency Industrial Applications in the Pacific Northwest

<u>Drying</u>	<u>Heating</u>	<u>Curing</u>
baked food products	plastic preheating	plywood glue
Particleboard	welding auto trim	furniture glues
veneer	welding containers	furniture finishes
lumber	welding furniture	grinding wheels
fiberboard	welding hospital bags	
ceiling tiles	welding sporting	
insulation materials	goods	
printing inks	welding tarpaulins	
adhesives	welding toys	

Source: adapted from RCD and BCD 1988

Drying traditionally takes place in forced hot air convection machines. Veneer travels through the dryer on conveyors. Controllers may adjust both the temperature of the dryer and the time that veneers spend in the unit. Controllers attempt to dry veneer in one pass through the drying unit, although nonuniform moisture content often forces more than one pass. Often redrying damages veneer and forces either downgrading or disposal.

Radio frequency dryers can be used as redryers in the veneer industry. RF drying can be more precisely controlled than conventional processes and veneers are packaged to avoid handling. Thus, products are less damaged.

However, while RF energy forces moisture to be released, it is also absorbed by wood fibers. The temperature of veneers may reach 280°F. Glues used to bond veneers are designed to work with veneers at a temperature of about 100°F. Higher temperatures may cause product failure. Allowing excessively hot veneers to cool may require up to four days time in hot weather. In addition, cooling requires warehouse space with adequate ventilation. This may create occupational hazards for workers handling high-temperature materials and sorting and handling materials in the limited spaces typically found at the dry end of primary dryers.

One hypothetical technique for cooling veneers is to employ an RF dryer/cooler/sorter that uses forced outside air to promote heat transfer. Spent air would be exhausted outside the plant. A hypothetical case study

found that RF veneer drying used to full capacity could reduce costs by over 19% in one mill (CHAI 1988, p.6).

Example: French Fries

Another example of combining RF and conventional technologies is in the food processing industry where RF could help to efficiently reduce moisture content in french fries, a major Northwest food product (*Food Engineering* 1990). The conventional process uses convected air to evaporate surface moisture from blanched potatoes. However, heat conducts to the inside of the french fry slowly, degrading the product's surface layers before the inside is dry. The combined RF/convection process, which has been tried in Europe, uses much lower temperatures and evaporates surface moisture at the same rate that moisture from the interior is driven to the surface, thus preserving product integrity.

Potential Environmental Effects

1. As with microwaves, RF devices can interfere with medical electronic devices such as pacemakers. Shielding should be employed where workers are exposed to RF radiation.
2. RF radiation at high power densities can produce thermal effects, e.g. burns. This is normally not a problem at the power levels and frequencies used for these RF drying and curing applications. Like microwaves, RF exposures are regulated to protect against heating effects (Hu 1988, p. 278). There is debate over what if any health effects may result from exposure to low-level RF fields. This is discussed further in Chapter 4.

2.4.7 Ultraviolet Radiation

Ultraviolet radiation designates the portion of the electromagnetic spectrum between visible light and the X-ray band. UV frequencies range from 8×10^{14} to 1.5×10^{15} Herz, and are divided into UV-A, UV-B, and UV-C bands. UV radiation is used to cure specially formulated, non-heat-treatable coatings that cannot be treated with IR radiation. The most common sources of UV light are medium-pressure mercury vapor lamps. Either microwave energy or an electrode may be used as energy sources.

Ultraviolet radiation can be used in combination with receptive inks and varnish to produce tough, glossy finishes for virtually any coated, printed,

or bonded product. Applications include electronic components, plastic cups and tubes, printed labels and tags, furniture, and cans. The inks and varnish cure in less than a second, once exposed to UV radiation (RDC and BCD 1988). UV curing can be faster and consume less energy than both thermal and infrared ovens. This allows for faster product lines and there is no danger of damaging cans, or other heat sensitive products such as circuit boards, from overheating as in a conventional gas-fired convection oven (CMF 1987b).

Many UV curing systems incorporate low-solvent/high-solids coatings, which can be cured at low temperatures. Ultraviolet light is unable to penetrate thick coatings; however, new cationic-curing mechanisms are overcoming this limitation. New techniques are being developed that permit UV-curing of three-dimensional objects.

Potential Environmental Effects

1. The skin and eyes absorb ultraviolet frequencies and are vulnerable to injury, primarily due to UV-B radiation. Prevention requires the isolation of high-intensity sources and the use of goggles and other shields with proper filters. Shields to contain UV radiation are part of coating/curing systems installed by manufacturers. Microwave-powered UV lamps should be interlocked with a detector to protect against microwave radiation leaks. Health effects associated with UV radiation and microwaves are discussed further in Chapter 4.
2. UV radiation can also contribute to photochemical reactions. For example, UV radiation from arc welding can convert small amounts of oxygen and nitrogen into ozone and nitrogen oxides. These substances are respiratory irritants and may damage lung tissue. They are designated as criteria pollutants by the EPA in the ambient environment. At certain wavelengths, UV radiation can decompose certain solvent vapors into toxic gases. Control of these hazards requires local exhaust ventilation and isolation of high-intensity UV sources from solvent processes.
3. UV coatings do not cure by evaporation and contain no solvents. Thus volatile emissions may be reduced. Because finishes are cured with UV radiation instead of conventional gas-fired convection ovens, hot surfaces are reduced, thus improving the working environment. Ultraviolet curing also eliminates combustion pollutants, but the impacts of electricity generation must be taken into account.
4. Several studies of UV-cured printing inks have found they cause dermatitis in exposed workers. There is also some evidence that UV-cured inks containing dipropylene glycol methyl ether have caused bone marrow damage (see Chapter 4).

2.5 DEHUMIDIFIERS

Dehumidifiers remove water vapor from the air. Two potential energy-efficient technologies include desiccant and heat pump applications.

2.5.1 Desiccant Dehumidification

The major applications of desiccant dehumidifiers in the industrial sector are for space conditioning, refrigeration, and freezing (Relwani, Moschandreas, and Thomas 1990). Desiccant dehumidification has long been the dominant technology for applications requiring low dew-point control, which is a cold, dry environment (Dolan 1989).

The main components of desiccant dehumidification systems are a desiccant wheel, a regeneration heat exchanger wheel, and an air heater with fans. The desiccant wheel is made up of a mixture of particles that remove moisture from the air. A common compound for this purpose is silica gel bonded to an aluminum substrate. Other compounds include alumina, bauxite, and molecular sieves. The desiccant will give up its moisture when heated. Thus the desiccant wheel rotates through ambient-temperature and heated zones. In the ambient zone the desiccants take on moisture (adsorption). In the heated zone the desiccants give up moisture (desorption) so that the wheel can again go through the cycle. This desorption process is referred to as regeneration. When the desiccant wheel takes on moisture the air that is left is dryer and warmer than ambient air. This warm, dry air is blown through the rotary heat exchanger that uses air exhausted from the room to cool the dehumidified air.

A desiccant dehumidifier may be used in conjunction with air conditioning systems for total space conditioning. This combination increases efficiency (Dolan 1989; Griffiths 1989). Another approach is to add moisture to dried air that has been cooled in a heat exchanger. The moisture will further drop the temperature of the air. Desiccant dehumidifiers are capable of drying air to dew points well below the capability of standard electric air conditioners. Thus, lower humidity levels can be maintained. Further, a desiccant system requires less processed air than a conventional system, resulting in a need for smaller fans, coils and ducts. This reduced scale results in lower first costs.

One means of improving the energy efficiency of desiccant dehumidifiers would be to replace conventional heaters with IR heaters. Infrared radiation applications are discussed in Section 2.4.4.

Applications for space conditioning are found in the food, drug, and electronics industries (Relwani, Moschandreas, and Thomas 1990). These industries manufacture many specialty products, such as hard candy and granular products that require dry mixing or packaging processes. In the food industry, powdery products such as flour and cocoa must be handled in dry environments. Potato chips, macaroni, coffee, and other hygroscopic materials, which are sensitive to moisture and require only a small amount of water vapor to congeal, spoil, or cake in the package. In the electronics industry, moisture can cause product failure if it is sealed into the casing during manufacture. Dry packaging is also a concern in industries such as chemical and paper manufacturing. Another application where dry air with a low dew point may be needed is in plastics molding, where condensation forming on the die will ruin the plastic product. Some drying applications may need warm, dry air to dry a product in the shortest possible time.

The food industry requires refrigeration to preserve the quality of products during storage, processing, and transportation. Desiccant dehumidifiers can be used to remove moisture released from refrigerated or frozen food products, thus eliminating the need for defrosting and removing the latent heat given up by the products.

Possible Environmental Effects

1. Conventional systems may flood during condensing operations (Dolan 1989; Griffiths 1989). Since desiccant systems remove water vapor without condensation, they reduce the possibility of microbial growth and indoor air contamination. However, dehumidification can produce an uncomfortable working environment if humidity levels are less than 30%.
2. Desiccant-based systems are also potential alternatives to refrigeration equipment that uses CFCs. However, this approach is limited to applications where ambient wet-bulb temperatures are always low enough to ensure the effective use of evaporative coolers.
3. Eutectic salts, including calcium chloride, silica gel, and other hygroscopic chemicals, are used in some desiccant dehumidifiers. These chemicals may cause dermatitis in exposed workers.

2.5.2 Heat Pump Dehumidification

The largest single application of closed-cycle dehumidification heat pumps is for lumber drying (RDC and BCD 1988). These systems work in much the same way as a residential heat pump unit. For lumber drying, the equipment is modified and the dehumidification capability of the heat pump is optimized. Drying occurs in a sealed chamber using a combination of heat and fans to drive the moisture out of the wood. Some studies have shown that heat pump dehumidification kilns require about 750 Btus per pound of water removed, compared to 2,000 Btus required by conventional dry kilns (Wilson 1990). Heat pumps and associated environmental concerns are discussed in Section 2.7.2. The potential environmental effects of chlorofluorocarbon-based refrigerants are discussed in Section 2.6.3.

2.6 REFRIGERATION AND COOLING TECHNOLOGIES

Refrigeration systems provide cooling for processes, storage, and space conditioning. This section addresses chilled water systems, often used for space conditioning, and refrigeration systems for freezing and cooling. Other sections that may address these areas include Section 2.2 on controls, Section 2.10.1 on insulation, Section 2.7.1 on heat recovery, Section 2.7.2 on heat pumps, and Section 2.5 on dehumidification.

2.6.1 Cooling Towers and Chillers

A cooling tower is a structure over which water is circulated for cooling. The water is cooled by evaporation into the air. A chiller is a refrigeration machine that cools water. Cooling tower and off-line chiller conservation measures should be evaluated and installed in a systematic manner. Some conservation measures may counteract others if not properly coordinated. Section 2.6.3 on refrigeration upgrades describes measures that may be applicable to chillers.

With central chilled water systems the following areas may offer energy and cost savings: chilled water reset, condenser water reset, chiller sequencing, variable chilled water pumping, and chilled water storage (Gidwani 1987). Chilled water reset refers to raising the return chilled water temperature. Higher temperatures will adequately meet loads under most

circumstances because the systems are designed for extremes. For each 1°F rise in chilled water supply temperature, there is a 1% to 1.5% increase in the coefficient of performance (COP). Chilled water storage systems are described in Section 2.6.2.

Modern chillers can tolerate a wide variation in condenser water temperature. As ambient wet bulb temperature drops, condenser water can also drop. Gidwani (1987) reports that for each degree decrease in condenser water temperature, there is about a 1% increase in chiller efficiency. Burger (1988) states that every 1°F decrease in temperature results in a 3½% savings in compressor energy consumption. These savings more than compensate for any additional fan horsepower required because of increased fan operation. As shown in Figure 2.2, screw-type chillers show the greatest increase in COP, while the centrifugal type has the least improvement.

Centrifugal and absorption chillers operate most efficiently in the middle to upper range of their design capacity. As loads increase or decrease in a central system, the number of chillers operated and the size of the chillers used should be selected to maximize total chiller efficiency. Chiller sequencing decisions can be made manually or through automatic controls, such as an energy management system (see Section 2.2.3).

Standard centrifugal pumps provide nearly the same flow under all load conditions. Variable volume pumping supplies only enough cooled water to meet the cooling load. Energy savings come from reduced motor operations (Walz 1989). Control techniques include variable voltage, eddy current clutch, and hydraulic clutch and can be on the order of 60% to 80%. Adjustable speed drives are described in Section 2.2.1.

Fonstad (1988) demonstrates that fan control is one means of saving energy in cooling towers. Reduced fan speed also decreases noise emissions from fans and reduces freeze-up during cold weather. Methods of providing fan control include the following:

- manually or automatically turning fan motors on and off - this approach carries the penalty of electrical surges each time the motor is started

FIGURE 2.2. Effect of Condenser Temperature on Chiller Coefficient of Performance (Source: Gidwani 1987)

- using two-speed motors - a 50% reduction in motor speed amounts to an 85% savings of energy; abrupt changes in motor speed result in electrical surges but not as severe as off/on operation
- multiple cooling tower sequential operation may be used in large systems; these are not as effective as motor control
- dampers - continuously modulate air flow but are not as effective as motor controls and should not be used in freezing weather
- variable pitch propeller fan - operates with pneumatic controls to automatically adjust fan pitch, can be used with two-speed motors to increase efficiency, difficult to retrofit
- adjustable speed drives (see Section 2.2.1) - 80% more efficient than on/off cycling, 50% more efficient than two-speed fan cycling, and 25% more efficient than variable pitch propellers; system can be remotely located and eliminates power surge problem.

Modern cooling towers take advantage of improved design features that may be suitable for retrofit. Specific features include aerodynamically efficient air inlet louvers, light-weight polyvinyl chloride (PVC) fill material, high-efficiency nozzles, and drift eliminators (Schroepfer 1988). Fan technologies are discussed above.

Potential Environmental Effects

1. By design, cooling towers and chillers are typically wet dark places providing excellent environments for the growth of microorganisms (Baechler, Hadley, and Marseille 1990). Energy conservation measures that reduce growth mediums or involve inspections and cleaning are likely to improve indoor air quality.
2. Asbestos cement has been used as fill material in some cooling towers (Schroepfer 1988). Caution must be taken in change-outs to ensure that asbestos fibers are not released to the environment and that workers are adequately protected.
3. Polyvinyl chloride (PVC), another fill material used in cooling towers, is a polymer made from vinyl chloride. Since the polymer is relatively stable, the primary hazards associated with PVC are during its manufacture. However, use and disposal of the material might pose problems if conditions allow the release of vinyl chloride. Vinyl chloride is a flammable gas listed by the EPA as a hazardous air pollutant and a human carcinogen (see Chapter 4).
4. Corrosion inhibitors used in non-contact cooling water circuits can contaminate blow down. Common types of corrosion inhibitors contain chromate salts, sometimes resulting in hexavalent chromium contamination and toxic material.

2.6.2 Thermal Storage

Thermal storage entails producing and storing the capacity for cooling at night, when energy costs are least, for use during the day (Schiess 1987). Thermal storage is used to reduce peak energy costs or to take advantage of incentives offered by utilities to reduce peak energy demand. Storage works best when cooling needs show a marked difference between peak and off-peak times (Gidwani 1987). Three principle techniques may be used.

- *Chilled water storage* is the simplest form of thermal storage. Water is stored in a large tank. More complex systems involve diaphragms of rubberized fabric, multiple tanks, and stratified chambers that prevent mixing of warm and cold water.
- *Ice storage* is typically about one-fifth the size of a chilled water system and relies on ice for thermal storage.
- *Eutectic salt storage* is about one-third to one-half the size of a chilled water system. In one system, eutectic salts are frozen at 47°F by passing chilled water from a conventional chiller through a storage container holding the salts encased in plastic bricks.

Potential Environmental Effects

1. All three storage systems involve environments that may promote the growth of microorganisms. These systems should be routinely inspected and cleaned to avoid standing water and microbial growth.
2. Eutectic salts include calcium chloride, silica gel, and other hygroscopic chemicals. Skin contact with some of these chemicals, or with their solutions can result in irritation.

2.6.3 Refrigeration Upgrades

Refrigeration system conservation measures encompass three broad approaches: insulation to avoid heat gain, improved control strategies, and compressor upgrades. Bonneville has identified screw compressors, discussed in this section, as an important refrigeration conservation measure. Insulation is discussed in Section 2.10.1. Energy management systems, adjustable speed drives, and other control technologies are discussed in Section 2.2. Heat recovery for refrigeration is discussed in Section 2.7.1

In screw compressors, intermeshing, screw-shaped rotors turn to trap and compress air. These systems operate more efficiently than conventional systems using reciprocating compressors. In a demonstration of screw

compressor technology in supermarkets, Borhanian, Toscano, and Lee (1986) found that this technology along with a computerized floating head control can deliver up to a 28% reduction in annual energy consumption, compared to a conventional system. The floating head control allows the compressor to adjust to the exact requirements of the refrigeration load.

Both single-screw and twin-screw compressors may be fitted with economizer cycles. An economizer can improve screw compressor efficiency by about 15% while increasing refrigerating capacity over 25% (American Society of Heating, Refrigeration, and Air Conditioning Engineers [ASHRAE] 1988). Economizers may not be effective below a certain percentage of capacity.

Some twin-screw compressors optimize the compressor's volume ratio. The greater the change in either suction or condensing pressure that a given system experiences, the more benefits are possible. Efficiency improvements as high as 30% are possible, depending on the application, refrigerant, and system operating range (ASHRAE 1988).

Potential Environmental Effects

1. There was no information on environmental effects associated with screw compressors in the literature reviewed.
2. Automatic controls, such as energy management systems, may cut off refrigeration systems while condensing. This shut-off may flood drip pans and other surfaces, allowing the possibility for microbial growth and indoor air contamination.
3. Refrigeration systems rely on a refrigerant for moving heat from one location to another. Currently, most of these refrigerants are chlorofluorocarbon (CFC)-based. CFCs are strongly linked with ozone depletion in the atmosphere and global warming. CFCs have life expectancies of over 100 years. Over this long time period, CFC molecules diffuse from the earth's surface to the stratosphere, where they break down under the sun's ultraviolet radiation. Once broken down, halogen chloride, found in all CFCs, disrupts normal stratospheric chemistry, causing ozone destruction. One free atom of chlorine may help destroy 100,000 ozone molecules (DOE 1989).

These molecules make up the so-called "ozone layer." The ozone layer normally acts as a protective shield for the earth against harmful ultraviolet radiation from the sun. Increased levels of ultraviolet radiation may result in increased melanoma skin cancers, crop damage, formation of cataracts, formation of lower atmospheric ozone and smog, and increased degradation of manmade materials.

CFCs are also powerful greenhouse gases. Greenhouse gases are compounds that may block radiated heat from the earth's surface, rather than allowing it to escape to space. This heat may alter the earth's climates, generally causing a warming of the atmosphere. The global warming potential of CFCs may be 10,000 times more severe than carbon dioxide. CFCs may contribute 10% to 15% to the greenhouse effect. Marseille and Baechler (1990) provide a more complete discussion of CFCs, their effects, and alternatives.

CFC substitutes are being developed; however, recent newspaper reports suggest that some of these substitutes might be toxic in laboratory animals (Naj 1991).

4. The use of ammonia in vapor compression cycle chillers is viewed as an alternative to CFC-based systems. Ammonia has a theoretical cycle efficiency that approaches the efficiencies of some CFCs at temperature ranges suitable for air conditioning. However, vastly different compressor and heat exchanger designs and materials are required. Ammonia's high toxicity raises serious concerns about these system's suitability for indoor installations (ADL 1990). According to the EPA, in 1987 industrial air emissions of ammonia were larger than emissions of any other air toxic (Durenberger 1991). The occupational hazards of ammonia and other refrigerants are described in more detail in Chapter 4.

2.7 HEAT RECOVERY TECHNOLOGIES

The heat recovery technologies discussed in this section are heat exchangers, heat pumps, and pinch technology. Heat recovery techniques may involve the use of energy management systems, which are discussed in Section 2.2.3.

2.7.1 Heat Recovery

Sources of heat in industrial plants range from ovens to refrigeration systems. Most sources are amenable to heat recovery devices. Potential applications of heat recovery in food processing industries include scalders, cooker vapor, refrigeration systems, condensate return, boiler stacks, spray dryers, potato chip fryers, cooking kettles, canning sterilizers, and baking ovens (ACEC 1985). In the fabricated metal products industry, examples include compressors, process cooling, drying ovens, heat pipes, and solvent removal ovens (ACEC 1987a). In cement making, kiln exhaust heat may be captured to predry kiln feed (ACEC 1987b).

In plants producing electricity, the device that converts fuel energy to mechanical energy, such as an internal combustion engine or a steam boiler-

turbine, can be used as a source of heat.^(a) These devices produce thermal energy through turbine steam, turbine exhaust, and engine jacket heat. The waste heat can be recovered in many ways and is usually converted to hot water or low-pressure steam. This process is often referred to as cogeneration. Pinch analyses, discussed in Section 2.7.3, may often make cogeneration uneconomical (PICO 1988).

A typical refrigeration machine with a water-cooled condenser rejects approximately 15,000 Btu per hour for each ton (12,000 Btu per hour) of refrigeration. An air-cooled condenser rejects up to 17,000 Btu per hour. At these levels, up to 5,000 Btu per hour can be recovered.

A chiller's condensate heat is usually rejected to the ambient air or to cooling water. This heat can be recovered if it is needed for space or water heating. A chiller can be modified so that condensate heat is sent to a heat exchanger rather than the cooling tower. The recovered heat is about 100°F to 130°F.

Large quantities of heat are exhausted in the condensate return of many steam systems. This heat can be used to heat water. But the heat recovery should be evaluated to determine that the amount of energy required to reheat the condensate does not offset the heat-recovery savings.

Wastewater is another potential source of heat. Processes that use large quantities of hot water, which is then discharged down drains, are good candidates. Water entering the heat exchanger must be prefiltered and the exchanger must be easy to clean. If the plant's discharge water temperatures are elevated, heat recovery may reduce discharge temperatures, thus reducing waste heat emissions. Waste heat is a form of water pollution.

A heat recovery system of this type was installed in a potato processing plant in Washington.^(b) The system recovers heat from water heated to 170°F

(a) Much of the description of heat recovery techniques is taken from PNL 1989.

(b) Spanner, G.E. and G.L. Wilfert. 1990. "Letter Report: Impact Evaluation of an Energy Savings Plan Project at Lamb-Weston, Inc." Prepared for the Bonneville Power Administration by Pacific Northwest Laboratory, Richland, Washington.

and used to blanch sliced potatoes. The recovered heat is used to preheat incoming cold water (62°F) to 140°F, thus saving over 4 million kWh per year, about 2% of the plant's total electrical consumption.

The quantity of sensible heat available from flue products of a modern properly adjusted furnace or boiler burning oil or natural gas is about 10% to 15% of the rated output. This heat can be recovered with a heat exchanger to preheat combustion air, preheat water, or temper ventilation air. However, a careful evaluation is needed of this system's applicability. If the heat exchanger is reasonably efficient, it may reduce gas flow rates and temperatures. These reductions can lead to moisture condensation in the chimney or draft hood spillage, or both.

Heat may also be recovered from hot air. The characteristics of air-to-air energy recovery devices are shown in Table 2.4.

Potential Environmental Effects

1. A key environmental issue to address when selecting air-to-air energy recovery devices is the potential for cross pollution contamination. This problem arises when pollutants from one air stream mix with the noncontaminated air of the other.
2. By its nature, heat recovery involves working with hot gasses or liquids. These hot environments involve some risk to workers (see Chapter 4).
3. Recovering heat from process waters can reduce waste heat emissions.
4. Care must be taken to ensure that pollution control equipment is not adversely affected by heat recovery systems for flue gasses and that pollution discharge levels do not increase.

TABLE 2.4. Characteristics of Air-to-Air Energy Recovery Devices

Type Exchange	HVAC Applications	Exhaust to 250°F Supply -20° to 110°F	Exhaust 250° to 800°F Supply -40° to 500°F	Exhaust 800° to 1200°F Supply -40° to 500°F	Exhaust 1200° to 1800°F	Sensible Heat Recovery	Total Heat Recovery	Remote Airstreams	Possible Cross Contamination	Corrosive Gases Permitted (special construction)	Air-to-Air	Air-to-Liquid-to-Air
Rotary wheel												
Metallic	X	X				X			(a)	(b)	X	
Hygroscopic	X	X				X	X		(a)		X	
Ceramic			X	X	X	X			(a)	(b)	X	
Fixed plate	X	X	X	X	X	X				X	X	
Heat pipe	X	X	X	X		X				X	X	
Run-around coil	X	X	X			X		X		X		X
Multiple tower	X	X				X	X	X	(c)			X
Thermosiphon	X	X	X	X		X		X		X		X
Dry air cooler	X					X	(d)				X	

(a) Can be limited to less than 1% with a purge section.

(b) When used in process-to-process applications where cross-contamination can be tolerated.

(c) Gaseous cross-contamination can occur.

(d) Has evaporative cooling capabilities.

Source: PNL 1989.

2.7.2 Heat Pumps

Heat pumps can be used to transfer heat from one part of a process to another.^(a) Industrial process heat pumps receive process heat, elevate its temperature, and return it for process use. Heat pumps offer industries the ability to upgrade low-temperature heat and recycle it back into the process. Heat pump cycles may be closed, open, or semi-open.

Closed-cycle heat pumps use a refrigerant to transfer heat from a low-temperature source, elevate the temperature, and deliver it back to a process. An evaporator absorbs heat from the source, thus vaporizing the refrigerant. A compressor increases the pressure and the heat of the refrigerant. The refrigerant then passes through a condenser, where heat is transferred back to the process.

Closed-cycle heat pumps are used in industries with relatively low temperature requirements, such as food processing industries, electroplating and electrolytic processes, sewage treatment and water purification facilities, and pharmaceutical industries and in applications where hot-water-driven absorption chillers are used. A common example of a closed-cycle heat pump is the dehumidification heat pump used for lumber drying (see Section 2.5).

An open-cycle system, often called mechanical vapor recompression, uses the materials being processed directly as the working fluid, rather than transferring heat through a refrigerant. The cycle eliminates heat exchangers and their heat-transfer inefficiencies. A process material, such as wastewater, is delivered through an expansion device to a flash chamber where part of the material is vaporized and flows to a compressor. The compressor raises the material's temperature and pressure. The heated material is then transferred back to the process. The working fluid must be compatible with the compressor.

Most industrial process heat pumps now in use are open-cycle systems. These systems are used in industries where large quantities of water vapor are produced in evaporation, distillation, and drying processes. In the food

(a) Much of this discussion of heat pumps is taken from RDC and BCD (1988).

industries, installations are in place for the production of milk products, sugar, distilled spirits, and in grain drying and starch production. Installations are also used in the petroleum, textile, and chemicals industries. In a petroleum refinery, a heat pump can transfer heat from the top of a distillation tower to the bottom, thereby eliminating a fuel-burning reboiler and reducing air pollution (Douglas 1989).

A variation on the open-cycle system is the semi-open system. In these systems, the process fluid is vaporized using waste heat from a conventional heat exchanger, then compressed to deliver heat back to the process. Semi-open cycle systems are primarily used to recover heat from contaminated streams. Thus, the heat exchanger must be compatible with corrosive and erosive fluids.

Potential Environmental Effects

1. Chlorofluorocarbons are often used as refrigerants in closed-cycle systems. The environmental effects of refrigerants are discussed in Section 2.6.3 on refrigeration upgrades.
2. To the extent that they eliminate fuel-burning equipment, heat pumps may reduce air pollution.

2.7.3 Pinch Technology

The term "pinch technology" is used to designate an analytical technique used by plant managers and process engineers to identify heat sources and energy consumption measures. Pinch technology tracks heat and materials flow for all process streams in an entire plant to design optimum heat and power systems to supply process needs. Pinch refers to the thermodynamic limits to heat recovery and thermal energy efficiency available in a given system (Linhoff 1990).^(a) The idea is to optimize the energy efficiency of the total system. The technology exploits interactions among unit operations, and identifies process changes, operating conditions, or equipment selection that will be the most beneficial to the system as a whole.

(a) The technique graphs composite hot and cold target curves for a plant. The area where the two curves approach each other is known as the "pinch" (PICO 1988).

Prior to designing heat recovery systems, pinch analyses help determine what process characterizations are possible to achieve energy savings. Pinch technology recommendations result in energy savings of about 25% to 40%, depending on the process (PICO 1988).

Examples of recommendations resulting from pinch analyses are summarized below (PICO 1988). These recommendations are closely related to specific energy efficiency measures such as heat recovery and energy management systems (see Section 2.2.3 on energy management systems and Section 2.7.1 on heat recovery).

- In a paper mill producing tissue, recommendations included waste heat recovery at three points in the mill's processes, recovery and recycling of 50% of the wastewater, reduction of water consumption by 50%, downsizing or increasing efficiency of equipment, and shifting electrical loading. These recommendations reduced steam consumption by 25%, sewer costs by 50%, water costs by 50%, and electricity costs by 10%.
- At an edible oil processing plant, recommendations included installing a high-pressure water system to transfer heat, replacing cooling water with heat exchangers to transfer heat, modifying process sequences to facilitate heat transfer, and removing excess equipment. These recommendations resulted in a reduction in heat consumption of 80% and a plant capacity increase of 15%.

Potential Environmental Effects

1. As an analytic tool, pinch analyses does not result in impacts in its own right. Equipment and techniques employed based on the analyses may result in impacts depending on specific applications.
2. Energy savings are often accompanied by reduced fuel combustion, resulting in fewer combustion pollutants.
3. To the extent that they eliminate fuel-burning equipment, heat pumps may reduce air pollution.

2.8 FABRICATION AND FINISHING TECHNOLOGIES

This section discusses several electric technologies that are applicable to the cutting, hardening, and welding of metals and other materials. Alternatives to conventional machining processes include electrochemical machining, and laser and water-jet cutting. Lasers and induction heating technologies can be used to harden metals, replacing conventional techniques that rely on high temperatures.

2.8.1 Electrochemical Machining

The electrochemical machining process is similar to the electroplating process, only in reverse (Burgess 1981; RDC and BCD 1988). Material is removed and carried away rather than being deposited on a workpiece surface. In electroplating, metal is deposited on the workpiece (cathode) from a solid piece of plating stock (anode or electrode) using a DC electrolytic bath operating at low voltage and high amperage. In electrochemical machining, this process is reversed with the workpiece being the anode. The cutting tool, or cathode, is designed to cut a particular size and shape of hole in the workpiece. Electrolyte is pumped through the close space between the tool and the workpiece. As the DC current flows, metal particles, heat, and hydrogen are swept away by electrolyte.

This process is fast, produces an excellent surface finish, does not produce burrs, and causes little tool wear. The technique is widely used for cutting irregularly shaped holes in hard metals. The hole produced in the workpiece is nearly identical to the electrode's shape. The workpiece must be conductive, and large lots are usually required. Because of the quality of the surfaces produced, other operations may be eliminated, such as turning, milling, drilling, and deburring.

The largest user of this technology has been the aerospace industry, which needs parts with complex shapes made from high-strength metals that are difficult to machine. This technology has also been used to manufacture medical instruments, automotive parts and components, appliance parts, computer components, nuclear reactor parts, and rifle gun barrels.

Potential Environmental Effects

1. This process releases hydrogen, thus local exhaust is needed to avoid flammable concentrations (see Chapter 4). The equipment normally operates at low DC voltage and high current and does not present an electrical hazard.
2. Electrolytes used in electrochemical machining include inorganic salt solutions and acids. Metals dissolved by salt electrolytes form a sludge that must be removed by filtering, settling, or centrifuging. About 100 cubic inches of sludge are produced for each cubic inch of metal removed from the workpiece. This sludge is likely to be classified as a hazardous waste and must be properly documented and disposed of. Most electrolytes are corrosive and some are explosive. Electrochemical machining

equipment should be installed away from other equipment on an acid-resistant floor, and machine components and surrounding surfaces should be regularly cleaned.

Compared to conventional machining techniques, this technology is more likely to generate spent acids, etching solutions, and metal-bearing wastes. While these wastes can be treated and minimized, they are all problematic wastes (see section on wastewater treatment). Conventional machining instead generates spent cooling and cutting fluids, which are mostly non-hazardous and can be recycled, and metal dusts and fumes. Oils containing heavy metal contaminants are regulated as hazardous wastes in Washington (Dawson 1989). Spent metal working fluids must be treated before recycling or disposal (Hunt 1988).

3. In general, exposure by skin contact or inhalation to acid bases and salt solutions can cause health effects including burns and skin and respiratory irritation (see Chapter 4).

2.8.2 Induction Heating (Hardening, Welding)

As was described in Section 2.4.2, induction heating systems use an induction coil to generate a magnetic field. This field creates an electrical current in the metal workpiece, thus heating the workpiece from within. This process requires careful design of the coils and selection of the power supply frequency and power density levels to match the heating pattern, rate, and uniformity with the workpiece and end product. Induction heating is used for heat treating (hardening) and welding metals.

Because induction generates heating within the workpiece, the overall efficiency is much higher than that of gas-fired methods. Induction heating efficiencies may be as high as 80%. In an economic comparison of induction and gas-fired-furnace systems, the Center for Metals Fabrication (1987a) listed comparative efficiencies of 60% and 15% respectively.

In general, higher frequency power sources (100 kHz to 10 MHz) are used for surface hardening. Hardening an entire workpiece, rather than just the surface, can be done with lower frequencies of 60 to 1,000 Hz.

Potential Environmental Effects

Induction heating relies on electromagnetic fields to generate heat in a workpiece. Because the workpiece is not necessarily designed to shield these fields, workers may be exposed. Potential health effects of electromagnetic fields are discussed in Chapter 4.

2.8.3 Lasers (Cutting, Hardening, Welding)

LASER is an acronym for Light Amplification by the Stimulated Emission of Radiation. A laser is essentially a source of high-intensity light that is produced by passing electrical energy through a lasing medium (CMF 1986). Two different types of lasers, gas and solid state, are used for metal working. The lasing medium in gas lasers is carbon dioxide (CO₂) mixed with helium and nitrogen. In solid state lasers the lasing compound is yttrium-aluminum-garnet (YAG) crystal-containing neodymium ions. The two types are typically referred to as CO₂ and YAG lasers.

Laser light waves travel in only one direction, unlike waves from an ordinary light bulb, which spread out in all directions. Furthermore, lasers, unlike ordinary light, are coherent; that is, they emit monochromatic waves that are in phase with each other. The unidirectional and coherent laser beam can be focused onto a spot only 0.005 inches in diameter (about the size of a human hair) with an energy density of megawatts per square inch.

Laser processing has three major industrial applications: cutting, welding, and surface hardening. Bonneville has selected laser cutting and hardening as potential conservation measures.

Laser systems cut many different materials fast and accurately. The laser's biggest advantage as a cutting tool is its ability to be adapted to cutting various products without retooling (RDC and BCD 1988). If exactly the same area is to be hardened using induction heating and lasers, the laser is the less energy efficient of the two, with the laser using up to 20 times more energy than an induction heating process (RDC and BCD 1988). However, if only a small surface area requires treatment, the laser can be designed to treat these small areas at an energy usage rate competitive with induction heating.

Potential Environmental Effects

1. Waste streams can be reduced because precise metal treatment leads to less distortion and scrap (RDC and BCD 1988). Alternatives to laser hardening, such as gas carburization, require solvents as part of the process. Lasers eliminate this need and thus potentially reduce hazardous waste generation.
2. Intense laser beams can cause eye damage and burns. Operators should wear safety glasses, and the work cutting area should be enclosed to

prevent accidental exposure. It is uncommon for a laser to hit the human eye directly; diffuse reflected light is the most common type of laser-related eye hazard (Tanner 1990). Precautions must be taken to minimize diffuse, reflected radiation.

3. Lasers may also increase fire risks, cause skin burns, and result in toxic fumes when cutting materials such as lead and plastic (health effects are described more fully in Chapter 4). Installations should be isolated wherever possible, and the laser beam should terminate in a material that is nonreflective and fireproof (Hu 1988).

2.8.4 Water-Jet Cutting

Water-jet cutting uses a highly pressurized stream of water to erode or cut a workpiece. Water jets are capable of cutting nearly any material at most thicknesses. Water jets are widely used in aerospace, automotive, electronics, and other industries to cut materials such as titanium aircraft components, printed circuit boards, automobile dashboards and diapers. Water jets are often used on composites and plastics that cannot tolerate heat, mechanical damage, or delamination.

In a water-jet system, water is initially filtered to remove impurities, then pumped through an intensifier, a high-pressure pump that produces pressures as high as 60,000 pounds per square inch. The water is forced through a constricting orifice, usually a synthetic sapphire ranging from 0.003 to 0.020 inches in diameter. Water exits the orifice at velocities of up to 3,400 feet per second, three times the speed of sound. The water flows in a coherent jet, resulting in clean cuts with a kerf often no wider than the stream itself. The jet may use pure water or an abrasive may be added, such as garnet, silica, or zirconium. Abrasives are used to cut thicker, harder materials. The systems are used to cut completely through a workpiece, and are not now capable of partial cuts.

As the stream passes through the workpiece, a catcher traps the water and eroded particles. The water jet carries away eroded material and abrasives, practically eliminating dust and pollutants at the workpiece. Water jets can be designed to cut vertically or omnidirectionally. Large catching tanks under the cutting table are used with vertical systems. For omnidirectional systems, tube-like catchers move with the nozzle. The water then flows to a

settlement tank, separating the eroded particles. The systems require about 0.2 to 1.0 gallons of water per minute.

Potential Environmental Effects

1. Omnidirectional systems should be fully enclosed to protect against the jet stream, noise, and dangers inherent in a high-pressure system.
2. Abrasives used with water-jet cutting may include garnet, silica, and zirconium. Airborne particles may pose a health hazard, although major exposures are primarily associated with abrasive manufacture. The health effects associated with zirconium abrasives do not appear to be significant. Chapter 4 discusses the health effects associated with machining operations.
3. Water consumption may limit operations in water-short areas.

2.9 SEPARATION AND CONCENTRATION TECHNOLOGIES

Separation and concentration technologies are heavily used in the so-called process industries, including food processing, pulp and paper, chemicals, and petroleum refining, and in mining ore-processing operations. Applications include the concentration of fruit juices, beer, and wine in the food processing industries; concentration of black liquor in the pulp and paper industry; fractionation and solvent extraction of hydrocarbons and derivatives in the petroleum industry; and ore refining in mining. Commonly used separation and concentration techniques include evaporation and distillation, condensation, solvent extraction, centrifugal separation, and filtering.

Separation and concentration can be a very effective waste treatment technique. Membrane, electrolytic recovery methods, and other wastewater treatment alternatives have a high potential impact on the metals finishing processes used in a number of industries. Many of the wastes from these processes are liquid, metal-bearing wastes. For example, some membrane systems permit nearly complete recovery of spent plating solutions, with reductions of over 90% in waste generation.^(a) In the process industries, improved filtration and membrane technologies can reduce waste generation

(a) Personal communication with B.S. Butner, Senior Research Scientist, Pacific Northwest Laboratory, Richland, Washington, 6 March 1991.

through more efficient materials separation, reduced thermal effects, and reduced material losses to effluent streams.

In a study of the economic feasibility of separation and concentration technologies, Scientific Applications International (SAI 1989) estimated that reverse osmosis, a membrane technology, is over six times more cost effective than conventional waste treatment techniques. Table 2.5 shows SAI's findings for seven technologies.

TABLE 2.5. Economic Ranking of Separation and Concentration Technologies

<u>Technology</u>	<u>Advantage Ratio^(a)</u>
Reverse Osmosis ^(b)	6.42
Heat Pump Evaporation ^(c)	2.56
Ultrafiltration ^(b)	1.06
Freeze Concentration	2.13
Ion Exchange ^(d)	4.17
Electrodialysis ^(b)	1.07
Electrolysis	1.27

Source: adapted from SAI 1989

- (a) The advantage ratio is the ratio of the cost of conventional technology to that of the separation and concentration technology.
- (b) Membrane technology.
- (c) See Section 2.7.2 for information on heat pump processes.
- (d) Ion exchange is a sorption process in which dissolved salts replace ions on a resin surface.

2.9.1 Electrolytic Separation

The most widespread use of this technique is in the production of aluminum from bauxite. Other applications include extraction of other metals from ores, production of chlor-alkali, and purification of wastewater. The electrolytic process is based on the principle of attraction of oppositely charged electrical species. In a basic electrolytic cell, a DC voltage is passed through a molten or aqueous electrolyte containing metallic ions. This operation works much like electroplating in that metal is plated out of solution onto a cathode.

In metal finishing, the recovery units are designed to recover metals from very dilute solutions (Hunt 1988). The process can be used to recover metals from waste streams. Pure metals can be removed from the cathodes and sold for reclamation. Extracting metals from metal finishing wastewaters allows for reuse of the water in finishing processes. Electrolytic separation and other recovery techniques are summarized in Table 2.6.

Potential Environmental Effects

Electrochemical processes typically involve the use of corrosive solutions. Depending on the application, the chemicals used may include inorganic acids, inorganic bases, and oxidative salts. In general, exposure to acid bases and salt solutions can cause skin and respiratory irritation. In addition, spent process chemicals may have to be disposed of as hazardous wastes.

2.9.2 Freeze Concentration

Freeze concentration replaces heat evaporation in preparing certain foods and in treating wastewater. In freeze concentration, heat is removed from a mixture until one or more of the components crystallize. The crystals are then separated from the mixture using mechanical methods, such as a centrifuge or sedimentation tank. The separated crystals are typically very pure, with contamination coming only from the liquid adhering to the crystal surface.

Barron (et al. 1987) found that most of the best opportunities for freeze concentration process applications are within four industry groups: food, pulp and paper, chemicals, and petroleum refining. Specific applications are listed in Table 2.7.

Another application for freeze concentration technology is wastewater treatment. In some instances, this technology can completely reduce hazardous wastes from the waste stream. This technology has been applied to processing mining wastewater and cooling tower blow down. The greatest potential for freeze concentration technology is in the treatment of hazardous wastes, particularly aqueous solutions containing metals, reactive ions, or organics. These waste streams are generated by electroplating and circuit board manufacturing (SAI 1989).

TABLE 2.6. Summary of Recovery Technologies

Technique	Advantages	Disadvantages
Electrodialysis	<ul style="list-style-type: none"> • Achieves higher concentration than reverse osmosis or ion exchange • Energy efficient • Organics not concentrated • Inorganic salts transport at different rates, minimizes return of unwanted inorganics 	<ul style="list-style-type: none"> • Feed must be filtered • Membrane sensitive to flow distribution, pH, and suspended solids • Equipment uses multi-cell stacks, incurs leakage • Chemical adjustment of recovered material • Membrane life uncertain
Electrolytic Metal Recovery	<ul style="list-style-type: none"> • Recovers only metals • Results in salable, nonhazardous product • Energy efficient • Low maintenance 	<ul style="list-style-type: none"> • Solution concentration must be monitored • Fumes may form and may require hood scrubbing system • Solution heating encouraged to maximize efficiency
Evaporators	<ul style="list-style-type: none"> • Established and proven technology, very reliable • Simple to operate • Widely applicable • Can exceed bath concentration 	<ul style="list-style-type: none"> • Some units are energy intensive • Multi-stage countercurrent rinsing essential • Returns bath and impurities • Additional treatment may be needed to control impurities • May require pH control
Ion Exchange	<ul style="list-style-type: none"> • Low energy demands • Handles dilute feed • Returns metal as metal salt solution 	<ul style="list-style-type: none"> • Requires tight operation and maintenance--equipment complex • Limited concentration ability • May require evaporation to increase concentration • Excess regenerate required • Feed concentration must be closely monitored
Reverse Osmosis	<ul style="list-style-type: none"> • Achieves modest concentration • Small floor space requirement • Less energy intensive than evaporation 	<ul style="list-style-type: none"> • Limited concentration range of operation • Fouling of membranes due to feeds high in suspended solids; feed must be filtered • Membrane sensitive to pH • Some materials fractionally rejected • May require further concentration

TABLE 2.7. Freeze Concentration Applications

<u>Food Industry</u>	<u>Kraft Pulp and Paper</u>	<u>Chemicals</u>	<u>Petroleum Refining</u>
beet sugar	black liquor	caustic	crude
cane sugar		soda/chlorine	distillation
milk and whey		alumina	vacuum
wet corn		ethylene/	distillation
milling		propylene	reforming
fruit juices		phosphoric acid	hydrotreating
beer and wine		BTX ^a	naptha
fats and oils		sodium chloride	fractionation
		styrene	sour water
		industrial	stripping
		alcohol	light ends
			processing

Source: adapted from Barron et al. 1987.

(a) BTX = benzene, toluene, xylene fractionation

Potential Environmental Effects

The use of freeze concentration as a wastewater treatment will result in positive environmental effects. No negative effects were identified in the literature reviewed for this report.

2.9.3 Membranes

Membrane processes use electric pumps to force liquid mixtures through a permeable barrier that filters out selected contaminants at the molecular level. Membranes are made from a variety of materials including cellulose esters, polyvinyl chloride, cellulose acetate, polycarbonate, polyamides, polysulfone, polyolefins, and vinyl chloride. Four principal types of membrane processes are used in industry: reverse osmosis, ultrafiltration, separation, and electrodialysis. The principles are similar for each of the processes. Differences lie in the level of pressure used to force fluids through the filters, and in the selection of membranes of different compounds and sizes.

Membranes have been used commercially for 15 years in such applications as clarifying fruit juices, desalinating seawater, and separating cheese whey. The major industrial applications of membranes include water purification,

industrial waste clean up, food processing, and ultrapure chemical production. Industries showing the greatest potential to use membrane processes are producers of dairy products, pulp and paper products, chemical and petroleum products, corn sweeteners, and textile products; and industries engaged in beer, wine, and juice sterilization, wastewater treatment, and biotechnology and pharmaceutical sterilization.

Membrane technology provides an alternative to energy-intensive evaporation and distillation used in the chemicals and petroleum industries. Unlike these processes, membranes involve no phase changes, such as from a liquid to a gas, and thus do not require heat to work. Membranes do require electrical energy to run pumps or compressors. In the food industry, filtration can replace heat treatment to cold-pasteurize or cold-sterilize foods and beverages (Morris and Russell 1990).

Potential Environmental Effects

1. Chemical polymers used in the manufacture of membrane filters may include cellulose esters, PVC, cellulose acetate, and polymers of amides, sulfone, and olefins. These polymers are relatively stable and do not in themselves pose hazards. However, wastes are produced in their manufacture and noxious chemicals could be released from the membranes if they burn. Vinyl chloride, used in the manufacture of PVC, is listed by the EPA as a priority hazardous air pollutant and is a human carcinogen (see Chapter 4).
2. Membrane filters may have to be disposed of as hazardous wastes if they are contaminated by hazardous or corrosive materials. Filters used in plating and similar operations using hazardous materials could pose a significant waste treatment problem.^(a)

2.10 ENERGY SYSTEMS

Several systems offer energy conservation potential: insulation systems for buildings and process equipment such as pipes, tanks, and kilns; compressed air systems; lighting systems; renewable energy systems that use waste products; and wastewater treatment systems.

(a) Personal communication with B.S. Butner, Senior Research Scientist, Pacific Northwest Laboratory, Richland, Washington, 6 March 1991.

2.10.1 Insulation

Insulation as a conservation measure is commonly used in residential, commercial, and industrial settings. Insulation reduces heat loss or gain by increasing a building shell's resistance to heat flow or conduction. In simple terms, insulation blocks the flow of heat from a warmer to a cooler space. Thus, insulation is important as a means to keep warmth out of refrigerated spaces, and keep warmth in heated spaces.

In most industries insulation is applied to the shell around heated or cooled spaces, hot water pipes, and steam lines. Examples of applications in the food industry are the insulation of a scalding tank and the covering of open cooking kettles (ACEC 1985). An example in cement making is the insulation of cement kilns (ACEC 1987b).

Potential Environmental Effects

Environmental concerns involving insulation include increases in fire hazards, exposure to synthetic and natural fibers, emissions of volatile organic compounds, and effects on the ozone layer.

1. Although no conclusive evidence has yet linked fiberglass fibers to respiratory effects similar to those caused by asbestos exposure, the issue is controversial (see Chapter 4). If a conservation program results in increased worker, installer, energy auditor, or inspector exposure to these fibers, the program may result in an increased risk of lung cancer, although it is not now possible to calculate the impact.
2. The effects of human exposure to asbestos are well-documented (see Chapter 4). If insulation upgrades result in the disturbance of existing asbestos, workers should comply with all applicable OSHA, EPA, and state regulations. The work area must be isolated, workers must be adequately protected, and the asbestos must be properly disposed of.
3. Both plastic foam and cellulose insulations may present potential fire hazards. Plastic foams burn in different ways from typical building materials such as sheetrock and lumber. For example, rather than burning in place under test conditions, polystyrene melts (Rose 1987). Depending on how polystyrene fire test results are interpreted, the smoke produced by the melted plastic may exceed code requirements (Rose 1987).

The fire hazard issue surrounding cellulose insulation relates to the staying power of the insulation's fire retardants. Studies suggest that these retardants may leach away under extremely humid conditions, may slough off if not adequately bonded, or may evaporate as temperatures

rise (Lawson 1984, p. 24). However, other studies suggest there is no cause for alarm (Cutter Information Corporation 1988, p. 182).

A study conducted for the California Public Utility Commission concluded that there were not a significant number of fires in California associated with either loose-fill insulation or California- or utility-sponsored insulation programs. The study found that heat-producing devices and electrical short circuits were the major contributing factors in insulation-related fires. An earlier study found that both cellulose and urea formaldehyde insulation can corrode electrical conductors and that the problem seems to increase at higher humidities (Clifton, Beausoliel, and Meese 1982). In this respect, cellulose insulation may contribute to fire and shock hazards. Bonneville concluded in the New Homes EIS (1988) that properly installed cellulose insulation does not pose a serious fire hazard.

4. The potential emissions of volatile organic compounds from energy-efficient building materials is discussed in great detail in the report, Indoor Air Quality Issues Related to the Acquisition of Conservation in Commercial Buildings (Baechler, Hadley, and Marseilles 1990). A companion document discusses health effects from the emitted chemicals (Stenner and Baechler 1990).
5. Rigid foam insulation types containing CFCs have recently become popular in building construction. Primarily, these insulations are used in masonry cavity walls, prefabricated panel walls, low slope roofs, and in the construction of a building's HVAC and refrigeration systems. The primary types of rigid foam insulation used for these applications include extruded polystyrene, polyisocyanurates, and phenolics.^(a) In rigid foam insulation, the "blowing agent" used in the foaming process becomes a captured gas within the cells of the product, contributing in part to the product's structural characteristics. Thus, release of the blowing agent gas into the atmosphere does not occur at the time of use, but gradually over a period of years. Because of the very low thermal conductivity of CFC-11 and CFC-12, CFC blowing agents exhibit superior insulating properties compared to other readily available blowing agents, and thus are being widely used.

There is no residual demand for CFCs after production of the insulation is completed, and recycling or reclamation of refrigerants from scrapped insulation is not deemed practical. However, rigid insulation employed in construction may slowly emit CFCs for up to a hundred years (Khalil 1986). Thus, current and near-term construction may establish a reservoir of CFC that will contribute to ozone depletion for some time. Alternate blowing systems are discussed in Marseilles and Baechler (1990).

(a) K. R. Taylor. 1987. Issue Paper: The Use of Fluorocarbons in Rigid Foam Insulations. Pacific Northwest Laboratory, Richland, Washington.

2.10.2 Compressed Air Systems

For additional information also see Section 2.1 on controls, 2.3.1 on motors, and 2.7.1 on heat recovery.

One study suggests three types of conservation measures for compressed air systems: strategy measures, capital measures, and maintenance measures. A listing of these measures is given in Table 2.8.^(a)

Conservation measures applied to compressed air systems may result in savings of up to 35%.^(b) These measures are primarily directed at stopping leaks in air lines and proper maintenance of motors and other equipment.^(c) Reduced air leaks result in less demand for compressed air. Less demand and proper maintenance result in reduced motor operation and electricity consumption. In some instances compressors may provide redundant operations and may be eliminated or placed on a timer.

TABLE 2.8. Air Compressor Energy Conservation Measures

<u>Strategy Measures</u>	<u>Capital Measures</u>	<u>Maintenance Measures</u>
<ul style="list-style-type: none">- educate employees- design properly- use lowest loads- use lowest pressure- size properly- reduce pressure when not needed- separate compressor for small loads- use blow-off nozzles- properly size pipes- control system load- schedule compressor use- use cold air supply	<ul style="list-style-type: none">- add multiple pressure levels- use variable speed drives- use compressor controls- recover heat- properly size receiver- use distribution system as receiver- replace clean-off blowers	<ul style="list-style-type: none">- fix leaks- open air supply- do preventative maintenance- put indicator lights on air valves to spot trouble- use plug-in solenoid valves- use replaceable gland packing for cylinders- isolate use stations- use air supply filters- maintain dry air stream

(a) Carroll, Hatch & Associates, Inc. 1990. "Draft Report to Bonneville Power Administration on Industrial Compressed Air Energy Efficiency: Phase 1, Task 1, Draft Report," Portland, Oregon.

(b) *An Industrial Compressed Air System Energy Efficiency Study*, Statement of Work. March 15, 1990. Bonneville Power Administration, Portland, Oregon.

(c) Personal Communication with Brad Miller, Mechanical Engineer, Bonneville Power Administration, 24 April 1991.

Potential Environmental Effects

Reduced motor consumption associated with conservation measures reduces noise levels in the vicinity of the compressor equipment. Reduced equipment operations may also reduce oil consumption. Thus, conservation measures applied to compressed air systems tend to result in positive environmental effects.

2.10.3 Lighting Upgrades

Lighting upgrades include efficiency improvements to interior and exterior lighting systems. Typical measures include the removal of excessive lighting, installation of efficient ballasts and bulbs, and improved lamp reflectors and controls. Some of the savings from lighting measures come from decreased air-conditioning loads because inefficient lighting systems produce waste heat that must be removed from buildings.

Many types of lighting controls automatically manage lighting systems. Controls can lower light levels, schedule system operations, and respond to the availability of natural light, and the presence of occupants (Verderber 1988). Control strategies are summarized in Table 2.9.

Environmental concerns have not been identified for control techniques. However, it is important that lighting controls and sources maintain adequate light levels, color rendition, and lack of flicker for a safe and comfortable work environment. In a survey of office workers, good lighting was rated by the most people as the most important factor affecting a comfortable office (Khosla and Bachner 1986).

Potential Environmental Effects

Bonneville has established policies to address the environmental concerns associated with lighting upgrades. These are summarized below.^(a)

1. Indoor applications of high-pressure sodium (HPS) lamps shall be limited to buildings such as warehouses, and parking garages that need warning signs and danger signals illuminated by light sources with good color

(a) Additional information can be found in Bonneville's *Environmental Requirements for Existing Commercial and Institutional Buildings* (8PA 1986).

TABLE 2.9. Lighting Control Equipment

<u>System</u>	<u>Application</u>	<u>Strategy</u>
Static:		
Delamping	Retrofit	Method for reducing light level 50%.
Impedance Monitors	Retrofit	Method for reducing light level 30% to 50%.
Dynamic:		
Light Controllers		
Switches/Relays	Retrofit, Renovation, New Construction	Method for on-off switching of large banks of lamps.
Voltage/Phase Control	Retrofit, New Construction	Method for controlling light level continuously 50% to 100%
Solid-State Dimming Ballasts	Renovation, New Construction	Ballasts that operate fluorescent lamps efficiently and can dim them continuously (100 to 10%) with low voltage.
Sensors:		
Clocks	Retrofit, Renovation New Construction	System to regulate the illumination distribution as a function of time.
Personnel	Retrofit, Renovation New Construction	Sensor that detects whether a space is occupied by sensing the motion of an occupant.
Photocell	Retrofit, Renovation New Construction	Sensor that measures the illumination level of a designated area.
Communication:		
Computer/Microprocessor	Retrofit, Renovation New Construction	Method for automatically communicating instructions and/or input from sensors to commands to the light controllers.
Power-Line Carrier	Retrofit, Renovation New Construction	Method for carrying information over existing power lines rather than dedicated hard-wired communication lines.

Source: Adapted from Verderber 1988.

rendition. These are areas with low-visual-demand activity and short-duration occupancy patterns. HPS lamps may be used in high-bay areas that have warning signs as above and are also equipped with one incandescent, fluorescent, or metal halide fixture for each HPS fixture. Special wiring is needed to reduce the stroboscopic effect in areas with rotating machinery. These procedures are in basic agreement with those outlined in the 1982 EA and FONSI, but have been refined based on new information (W.S. Fleming & Associates 1987).

2. Low-pressure sodium vapor lights are not to be installed indoors because of the unpleasant monochromatic light produced.
3. One area not addressed in Bonneville's environmental requirements is fluorescent light ballasts contaminated with polychlorinated biphenyls (PCBs). The proper disposal of PCB-contaminated ballasts is an environmental issue that emerged at Bonneville from the Industrial Lighting Incentive Program. Bonneville then established procedures to suit the relatively small-scale lighting program, which served only one utility and generated a total of four barrels and one undefined box of PCB-contaminated ballasts. In October 1986, Bonneville issued interim guidance for PCB handling and disposal to be followed until the method of disposal used in the lighting program could be evaluated for future use. An evaluation of the PCB disposal process used in the Industrial Lighting Conversion Program is contained in the Program's environmental appraisal (BPA 1989).^(a)

2.10.4 Renewables

The current renewable energy contribution to industrial energy use comes primarily from wood and wood wastes. Waste products may be either burned directly or converted to methane and burned as a substitute for piped natural gas. Woody biomass is easily burned directly. Both the pulp and paper and forest products industries meet a substantial and growing portion of their energy needs from process by-products. For instance, in 1987 the pulp and paper industry derived 56% of its energy needs from wood wastes and residues including spent pulping liquors and solids, hogged fuel, and bark. This was up from a 40% wood waste energy share in 1972 (INEL et al. 1989).

Geothermal energy is used for low-temperature direct heat applications in industry, such as enhanced oil recovery, crop drying, and agriculture.

(a) Additional information about the environmental effects and disposal options of PCB-laden ballasts is discussed in Baechler, Foley, and Jarnagin (1990).

Solar thermal processes can provide industrial process heat. The Solar Energy Research Institute has developed special optical devices to intensify the sun's power up to 2,500 times (*Chemical Engineering* 1990). The concentrator has produced temperatures up to 2,400°C. A unit that is 12 times more powerful is expected in the fall. These devices may be capable of replacing lasers and arc lamps for melting, evaporating, and hardening metals. Another application is the detoxification of hazardous wastes by exploiting solar heat, as well as the sun's high-energy photons, to decompose and destroy toxic chemicals.

Other wastes may be converted to methane and used as a substitute for natural gas. Currently, the primary nonconventional source of gas is from the anaerobic digestion of municipal solid wastes in landfills. Other potential sources of biogas are digester gases, agricultural wastes, woody materials, and solid wastes.

Potential Environmental Effects

The environmental effects of renewable energy systems depend on specific applications, technologies, and sites. Generic effects for many systems are discussed in Baechler, Fickeisen, and Hendrickson (1990).

2.10.5 Wastewater

Most measures for conserving electricity in wastewater treatment have been discussed in earlier sections about heat recovery, pumps, motors, and membranes. This section addresses measures for conserving water. Reduced water consumption will result in reduced water pumping and the treatment required.

Most water conservation techniques are simple, inexpensive, and well known. Hunt (1988) reports that the metal finishing industry could reduce water consumption up to 50% by using proper rinse tank designs, flow controls, and countercurrent rinsing, and reusing rinse water where possible. These measures must be carefully applied to avoid product degradation, but can be instituted as part of an overall waste reduction program.

Potential Environmental Effects

Reducing and recycling wastewater may in some cases require additional energy consumption. Overall environmental effects will be positive.

3.0 INDUSTRY PROFILES

This chapter profiles the nine major electricity-consuming industries in the Pacific Northwest. Industries were selected based on a Bonneville list of the 101 largest industrial electricity users served by public utilities in the Pacific Northwest. The profiles describe selected production processes, equipment employed, energy requirements, waste streams, and occupational hazards for each industry.

The profiles can be used to identify major energy-consuming industrial processes in order to pinpoint where energy conservation measures might be applied. Similarly, they can be used to identify the current environmental and occupational hazards associated with those processes in order to assess the impacts of energy conservation measures.

3.1 INDUSTRY SELECTION AND SOURCES

The starting point for the industry profiles was Bonneville's list of the 101 largest industrial electricity users served by public utilities in the Pacific Northwest (see Appendix A, Table A.1). The establishments on this list represent approximately 80% of the industrial electric load provided by public utilities in the Pacific Northwest. The list ranks plants according to energy consumption and indicates the major industry group of each plant as designated by two-digit SIC code.

3.1.1 Industry Selection

On the list are representatives of 11 major industry groups, all of which, except for mining, belong to the manufacturing sector. These 11 industry groups were consolidated to nine for the purposes of the profiles. Representative sectors or subindustries within each major group, which are designated by four-digit SIC code, were identified. Appendix A discusses some problems with the Bonneville list, describes how the specific industries were identified, and defines the major industry groups profiled in this chapter.

Whenever possible, Northwest industries not already described in other Bonneville reports were selected for coverage in the profiles (see Battelle 1984; Bechtel 1984; and SJO, Shapiro, and Synergic 1984). It should be noted

that the industries profiled here are not necessarily the largest Northwest industries in terms of number of plants or output. For example, transportation equipment (SIC 37) is the largest Northwest industry in terms of number of employees.^(a) However, this industry by itself accounts for only 5.1% of total electricity consumption according to the Bonneville list, which makes it the fifth largest electricity consumer in the region (see Appendix A).

3.1.2 Sources

The industry profiles are based on a variety of primary and secondary sources which are described in Appendix D. Appendix D also contains a contact list for primary sources. There does not appear to be any primary or secondary source that maintains and updates industrial profile information per se. Agencies such as the U.S. Environmental Protection Agency (EPA) and the National Institute of Occupational Safety and Health (NIOSH) have published comprehensive industry profiles designed to permit energy conservation and environmental impact analyses (EPA 1977; NIOSH 1987a). Unfortunately, these documents are old and hard to find. Similarly, Bonneville reports that have included profiles and environmental impacts for specific industrial sectors in the Pacific Northwest are old and have not been updated (Battelle 1984; Bechtel 1984; and SJO, Shapiro, Synergic 1984).

3.2 OVERVIEW OF PROFILES

Profiles for the nine industry groups representing the major electricity-consuming industries in the Pacific Northwest begin in Section 3.3 in order of SIC code. They are

- metals mining (SIC 10)
- food and kindred products (SIC 20)
- lumber and wood products (SIC 24)
- paper and allied products (SIC 26)
- chemicals and allied products (SIC 28)
- petroleum and related industries (SIC 29)
- stone, clay, and glass products (SIC 32)
- primary metal industries (SIC 33)
- metals fabrication and finishing (SICs 34, 36, and 37).

(a) A single company, The Boeing Company, accounts for most of these employees (Weisman, Harrison, and Shorett 1990, p.34).

These major industry groups are further described in Appendix A.

Each industry profile provides an overview of basic production processes, equipment, energy requirements, waste streams, and occupational hazards. The remainder of this section gives some background information on each of the subsections in the profiles.

3.2.1 Processes

Each profile describes major production processes for the industry and gives a process flow diagram. Whenever possible, the profiles cover processes that are common across industries within a major group as well as any that are specific to selected four-digit SIC industries represented on the Bonneville list. In most cases, processes vary widely across manufacturing sectors within a major group so the process flow diagrams are generic. More detailed process flow diagrams showing major process steps and energy and materials inputs and outputs have been produced using PNL's INDUST database (Moore and Wilfert 1987).

It is important to note that certain generic processes--such as materials handling, pollution abatement, and waste treatment processes -- which are common to many industries, are not included in the process descriptions. These generic processes can be briefly described as follows:

- Materials handling processes include raw materials transport and storage, transfer of intermediate products and materials between different processes, packaging, transport, and maintenance. Materials handling equipment includes blocks and tackles, cranes, hoists, conveyors, elevators, in-plant rail systems, trucks and other transfer vehicles, feeders, pumps, and piping systems. This equipment is discussed to some extent in the previous chapter under motor-drive systems (Section 2.3).
- Common air pollution control techniques include incineration, filtration (bag houses), electrostatic precipitation, and wet scrubbing. With few exceptions, air pollution control processes are not discussed in this report.
- Common wastewater treatment processes include chemical treatment, evaporation and distillation, electrolytic separation, and dewatering. These are primarily separation and concentration operations, which are discussed in Section 2.9 of the previous chapter. The discussions of wastewater in this chapter are limited to process water and do not cover generic waste streams such as surface runoff or sanitary sewage.

3.2.2 Equipment

The profiles list generic equipment, such as ovens, as well as industry-specific equipment, such as veneer kilns and coke ovens. The equipment lists do not attempt to be comprehensive but rather are a means of identifying the applicability of possible energy conservation measures. In some cases equipment lists were taken from the PNL INDUST database, which lists general types of equipment used by selected four-digit SIC codes (Moore and Wilfert 1987). Pollution abatement and waste treatment equipment, which may be extensive for particular types of plants, are not generally included in the equipment lists. However, in many cases these types of equipment are major energy consumers, for example, incinerators.

3.2.3 Energy Requirements

Each profile discusses energy requirements for the industry. These brief discussions identify the most energy-intensive processes within the industry and give an indication of the overall energy intensity of the industry. They do not report energy statistics. A single source of current process-specific energy requirements for all the industrial segments covered here was not found, although various Electric Power Research Institute (EPRI) reports give electricity use statistics for industrial processes (RDC and BCD 1988; RDC 1990). Bonneville's Industrial Sector Conservation Supply Curve (ISCSC) Database gives 1985 end-use breakdowns, by process, for eight manufacturing industries in the Pacific Northwest. These end uses are shown in Table 3.1 (Ciliano, Heidell, and Dee 1988).

According to national statistics on total energy consumption, chemicals and allied products, petroleum and coal, primary metals, paper and allied products, food and kindred products, and transportation equipment are the six largest consumers of energy.^(a) In order of electricity consumption, the top six U.S. industries are chemicals, primary metals, pulp and paper, food, petroleum, and transportation (RDC and BCD 1988). Table 3.2 gives electricity

(a) This ranking is from the PNL INDUST database and is based on data from the 1985 U.S. Census of Manufactures (Moore and Wilfert 1987). Rankings vary from source to source for electricity consumption. The most recent electricity consumption figures were found in RDC (1990), which used the 1986 U.S. Census Bureau Survey of Manufacturers data.

TABLE 3.1. Electric Load Sharedowns by Industry

Industry	Motors	Heating ^(a)	Lighting	A/C	Compression	Refriger- ation	Electro- chemical	Total
Food and Kindred Products (SIC 20)	66	0	8	5	0	20	0	100%
Lumber and Wood Products (SIC 24)	92	0	4	2	2	0	0	100%
Paper and Allied Products (SIC 26)	94	0	5	1	0	0	0	100%
Chemicals and Allied Products (SIC 28)	25	54	6	2	4	1	7	100%
Petroleum and Related Industries (SIC 29)	56	36	6	2	0	1	0	100%
Stone, Clay and Glass Products (SIC 32)	77	11	8	4	0	0	0	100%
Primary Metal Industries (SIC 33)	18	5	5	1	0	0	70	100%
Transportation Equipment (SIC 37)	70	7	16	5	2	0	0	100%

Source: Bonneville ISCSC Database (Ciliano, Heidell, and Dee 1988, p. II-34).

(a) There was no electric space heating in any of the industries.

TABLE 3.2. Energy Consumption by Northwest Industries in Kilowatt-Hours

Industry	Process Electric (kW-h)	Facilities ^(a) Electric (kW-h)	Total Electric (kW-h)	Total Energy Use
Food and Allied Products (SIC 20)	5,493	833	6,326	14%
Lumber and Wood Products (SIC 24)	11,212	717	11,928	30%
Paper and Allied Products (SIC 26)	42,148	2,866	45,015	18%
Chemicals and Allied Products (SIC 28)	16,654	1,552	18,206	56%
Petroleum and Related Industries (SIC 29)	4,801	372	5,173	9%
Stone, Clay, and Glass Products (SIC 32)	1,099	154	1,252	9%
Primary Metal Industries (SIC 33)	59,311	4,108	63,419	86%
Transportation Equipment (SIC 37)	2,897	747	3,644	51%

Source: Bonneville ISCSC database (Ciliano, Heidell, and Dee 1988).

(a) Facilities includes lighting and space conditioning.

and percent total energy consumption figures by industry group for eight industry groups in the Pacific Northwest.

Based on the Bonneville list, the top electricity users in the Pacific Northwest by major industry group are paper and allied products, chemicals, primary metals, and metals fabrication and finishing. Table 3.3 gives the electricity use figures compiled from this list. The paper and allied products industry is by far the largest consumer of electricity, accounting for more than half of total consumption. This ranking is slightly different from other electricity estimates for the Pacific Northwest, such as those in Table 3.2, which include all plants in the region.^(a) The Bonneville list only includes plants served by public utilities in the Bonneville service area. However, the 101 plants on the list account for 80% of the industrial load in the Pacific Northwest provided by public utilities.

3.2.4 Waste Streams

Each profile describes major process-related waste streams.^(b) Waste streams are divided into three general types: air, water, and solid wastes. The designations "toxic" and "hazardous" are defined by federal legislation such as the Clean Air and Water Acts and the "Community Right to Know Act" (see Chapter 5). Toxics may be air, water, or solid pollutants. Generally, hazardous wastes are solid wastes. The states of Oregon and Washington define several additional categories of hazardous wastes not covered by federal regulations (Stokes et al. 1989). Chapter 5 describes the existing regulatory framework for controlling waste streams. Appendix B contains air emission and water discharge data for the four states in the Bonneville service area. This

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- (a) The energy estimates in the ISCSC database are based on the total number of Northwest plants in each major industry group in the Dunn & Bradstreet Major Industrial Plant Database (MIPD). Aluminum plants, which account for a large share of electricity consumption in the primary metals major industry group, are direct-service customers and, therefore, not included on the Bonneville list (RDC and BCD 1988, Section 4.1.33).
- (b) The descriptions of waste streams and occupational hazards associated with each industry are based on readily available information. In many cases the sources used for this information were the same sources from which process descriptions were derived.

TABLE 3.3. Top Electricity-Consuming Industries in the Bonneville Service Area

<u>Industry</u>	<u>Number of Plants^(a)</u>	<u>Electric Use (aMW)</u>	<u>Percent Total Electric Use^(b)</u>
Paper and Allied Products (SIC 26)	19	903.6	58.4%
Chemicals and Allied Products (SIC 28)	6	160.0	10.3%
Lumber and Wood Products (SIC 24)	44	123.1	7.9%
Primary Metal Industries (SIC 33)	5	93.6	6.0%
Metals Fabrication and Finishing (SICs 34,36, and 37)	5	91.4	5.9%
Metals Mining (SIC 10)	4	62.0	4.0%
Stone, Clay, and Glass Products (SIC 32)	3	46.1	3.0%
Food and Kindred Products (SIC 20)	12	39.0	2.5%
Petroleum and Related Industries (SIC 29)	3	29.7	1.9%
TOTAL	101	1548.5	99.9%

(a) Number of plants on Bonneville list of the 101 largest industrial electricity users served by public utilities in the Pacific Northwest.

(b) Does not add up to 100% due to rounding error.

information was taken from air and water discharge permits and statistics compiled by state regulatory agencies.

It is not surprising that the major industrial consumers of energy are also major sources of environmental pollutants. According to the 1988 EPA Toxic Release Inventory, the U.S. chemical and primary metals industries are the largest producers of toxics discharged into the nation's air, land, and water (D'Innocenzio 1990b). The major federally regulated hazardous waste streams in the Pacific Northwest are metals, corrosives, ignitable wastes, and electroplating sludges (Stokes et al. 1989). The largest industrial producers of hazardous wastes in the region are primary metals, transportation equipment, and chemicals manufacturers.

The largest manufacturing consumers of water nationwide are primary metals, petroleum products, chemical and allied products, pulp and paper, and food processing (RDC and BCD 1988, p. 3.11). These industries would be expected to be major generators of wastewater as well. In the food industry, for example, most of this water ends up as industrial wastewater, high in dissolved organic matter such as protein, fat, lactose, fermented starches, sugar, and suspended solids. Food processing operations also generate large amounts of solid wastes.

3.2.5 Occupational Hazards

The profiles identify common occupational safety and health hazards in each industry, for example, chemical exposure, excess noise, vibration, heat, and other physical hazards, such as radiation. In general, the industry profiles do not discuss hazards associated with materials handling and maintenance operations. This chapter concentrates on identifying the hazards associated with specific processes rather than on detailed health effects. Chapter 4 describes specific health effects associated with common hazards and lists exposure limits established by OSHA, EPA, and others. Appendix C contains national and regional statistics on occupational injuries and disease, giving some idea of the relative riskiness of the different industries and processes profiled in this chapter.

3.3 METALS MINING (SIC 10)

The metals mining industry comprises companies engaged in mine exploration and development as well as the production of metal ores and concentrates. Mills or concentrators, at the mine or at a separate location, employ a variety of physical processes to separate metals from contaminants. The resulting metal concentrates may be subject to further smelting and refining at plants classified under SIC 33 (primary metals). The metals mining industry group also includes the production of bullion, ingots, and pellets at the mine or mill site.

The Bonneville list of major industrial electricity users includes a gold mine (SIC 1041), a molybdenum mine and concentration mill (SIC 1061), and two mining operations that could not be identified. This section briefly surveys mining and concentrating processes and discusses techniques commonly employed for the major metals mined in the Western United States.

3.3.1 Processes

The major processes in this industry are exploration and mine development, mining, ore dressing and beneficiating, and, in some cases, smelting and other refining techniques (see chapters on mining in Burgess 1981; Cralley and Cralley 1982; Ferguson and Roy 1982; Northern Miner Press 1979). Figure 3.1 is a process flow diagram for a generic mining operation. Exploration may include drilling, sampling, and assaying operations. Mine development techniques vary widely. For example, soft copper ore deposits are usually surface mined with bulldozers and other excavation equipment. Hard-rock mining usually requires drilling and blasting, and underground mine construction can require laying of track, installation of ventilation and electrical systems, air and water lines, roof supports, and concrete operations.

In addition to the above activities, ore recovery entails loading and transport of the ore and waste rock. In underground mining, the orebody or vein is drilled and blasted. The ore is then transported through stopes, chutes, and rises; crushed underground; hoisted from the depths; crushed again on the surface; and conveyed to the mill for recovery processing.

FIGURE 3.1. Process Flow for Metal Mining (SIC 10)

Dressing or beneficiating techniques remove impurities from the ore. The process can be as simple as washing and screening the ore, but may include crushing and grinding and more complex milling and concentrating techniques such as sintering, leaching, and magnetic concentration. Froth flotation is a concentrating process in which the crushed ore is mixed with oils and chemicals to form a pulp. Flotation reagents are added to the pulp which is then agitated, causing bubbles containing sulfide ores to float to the top.

With the exception of gold, platinum, some silver, and minor amounts of copper, all metals exist in nature in the oxidized state. Thus, the processing of base metals is usually more complex than gold dressing. Sintering is a process used to reduce the sulfur content of ores. Smelting is a thermal process in which chemical reactions produce liquid metals from the ore. Gold and iron ores, for example, are smelted and cast at the mine or mill site to produce bullion, ingots, and pellets.

Specific mining and beneficiating techniques for common minerals are as follows (Bush 1989):

- Bauxite is commonly mined in open pit mines. Draglines, scrapers, and shovels are used for stripping. Processing usually consists of crushing, washing, and drying. Beneficiating is not usually required. Alumina is recovered by the Bayer process and then reduced electrolytically in fused salt.
- Open pit mining of copper predominates in the West. The ores, which usually are sulfates and mixed base-metal sulfates, require crushing, grinding, and flotation. Leaching is used to concentrate oxide ores. The concentrates are smelted to produce copper, which is then electrowinning. Electrowinning is used for the leachant obtained from oxide ores.
- Most Western gold mines are underground lode mines with some open pit or placer mines. The most common recovery method is cyanide leaching, followed by zinc dust or carbon precipitation. The gold is then recovered electrolytically and remelted.
- Most iron ore is mined by open pit techniques, although there is limited underground mining. The ore is generally concentrated by crushing, grinding, flotation, and magnetic separation. A large portion is pelletized before shipping.
- Most lead is mined in underground operations with a small amount produced in open pits. The ore is crushed by jaw and gyratory crushers and ball mills and concentrated by flotation.

- Molybdenite ores are mined by both underground and open-pit methods (Ferguson and Roy 1982). The ore is crushed, milled, and concentrated by flotation.
- Silver is mined by open pit and underground techniques. Concentration is by flotation, cyanidation, melting, and electrolytic refining.

3.3.2 Equipment

Equipment used in mining includes the following: drills, draglines, trucks, haulers, loaders, skips (railway cars), shovels, conveyors, jaw crushers, tanks, pumps, mills, conveyors, separators, filters, agitators, flotation tanks, furnaces, and generators.

3.3.3 Energy Requirements

The metals mining industry ranks sixth on the Bonneville list in terms of total electricity consumption (see Table 3.3). Crushing and grinding operations are major consumers of electricity in the mining industry (Bush 1989). Since the richness of the ore mined is low for many metals, considerable quantities of ore must be transported. Solvent extraction and electrowinning of copper require considerable expenditures of power. Thermal beneficiating techniques such as sintering and smelting, although not used for all metals, are energy intensive.

3.3.4 Waste Streams

Since most metals are extracted from sulphide ores, mining and milling operations may release sulphur dioxide into the atmosphere and sulfuric acid and sulfates into groundwater and streams (Northern Miner Press 1979). In addition to stack gases from refinery operations (usually smelting), the major atmospheric waste streams are dust from mining and concentrating operations and exhausts from diesel-powered equipment, both under and above ground. Underground diesel-powered equipment is fitted with scrubbers to remove exhaust fumes. Tailings from mills or concentrators are usually disposed of in impoundments; windblown dust from old, inactive impoundments may be an additional pollutant source in some cases.

Wastewaters include mine drainage and mill effluent in tailings and process waters. The drainage water of metal mines tends to be slightly acidic

and to contain sulfates of iron and other metals. Drainage water is usually neutralized with lime, and can be treated with membranes or other separation technologies to reduce its metal content. Milling operations use large quantities of water that may contain traces of the various reagents used in concentrating the metals, for example, cyanide used in dissolving gold.

The EPA classifies several categories of hazardous wastes associated with mining operations, including surface-impounded solids from lead facilities (Bush 1989; Stokes et al. 1989). The others are primarily associated with refining activities such as copper smelting.

Noise pollution from open pit mining may be a problem for surrounding communities.

3.3.5 Occupational Hazards

The major occupational exposures in mining are dust, noise, temperature and humidity extremes, vibration, poor lighting, mine gases, blasting fumes, and diesel exhaust (see chapters on mining in Burgess 1981; Cralley and Cralley 1982). Metal dusts can pose exposure hazards, particularly for toxic metals such as lead. Molybdenum is a neurotoxin; molybdenite dust, which is relatively benign, can be irritating and, in sufficient concentrations, can be hazardous (Ferguson and Roy 1982). In certain mines, workers may be exposed to additional mineral hazards such as silica dust, asbestos fibers, or radioactive particles that may cause lung disease.

Hard-rock mining, particularly underground mining, can expose workers to extremes in noise associated with drilling, ventilator system and equipment operation, crushing, loading, and unloading ore. In some operations, cold and heat stress are additional hazards.

Drilling and blasting generate dust. Blasting fumes include carbon monoxide and oxides of nitrogen. Blasting and mining operations may pose various additional risks such as burns and injury from explosions and cave-ins. Diesel exhaust may expose workers to carbon monoxide, oxides of nitrogen, and particulates. Diesel exhaust has been shown to cause cancer in animals and limited epidemiologic evidence suggests an association between occupational exposure to diesel exhaust and lung cancer (NIOSH 1988). Pneumatic conveyors used in underground mining are a major source of dust.

In beneficiation operations, crushing, which is a dry process, generates dust; grinding, a wet process, can be extremely noisy. Flotation may expose workers to reagents and fumes. Sintering and smelting may expose workers to metal dusts and fumes and combustion gases.

3.4 FOOD AND KINDRED PRODUCTS INDUSTRY (SIC 20)

The food and kindred products industry (SIC 20) is the largest and most geographically dispersed sector in U.S. manufacturing (PICO 1991). The trend in the United States is toward increasing levels of processing in food products, with a resulting increase in process complexity and energy use. A large number of the food-processing plants in the Pacific Northwest, as reflected in the Bonneville list, produce preserved fruits and vegetables, including frozen, dehydrated, and canned goods. Frozen and dehydrated fruit and vegetable plant processes (SICs 2034 and 2037) are only briefly covered here, as they are the subject of other Bonneville reports (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984). This section briefly discusses common food industry processes, then profiles meat packing (SIC 2011), cheese products (SIC 2022), and canned fruits and vegetables (SIC 2033), all of which are represented on the Bonneville list.

3.4.1 Processes

The manufacturing processes used in this industry group are extremely diverse. Figure 3.2 is a process flow diagram for a generic food processing operation. Some common processes are cooking, drying, liquid heating, refrigeration, cooling, freezing, sterilization, separation and concentration, and thawing (RDC and BCD 1988, Section 3.1.20; RDC 1990). Cooking techniques, including baking and frying, use hot water, steam, gas or electrical ovens, fryers, and atmospheric cookers. Most drying processes apply warm or heated air (typically gas-fired) to the food. Other drying techniques include sun drying, spray drying, agglomeration, freeze drying, drum drying, and microwave-assisted drying. Liquid heating is used in a variety of food processing and cleaning operations, for example, hot-water scalding of poultry, pasteurization of dairy products, and juice processing.

FIGURE 3.2. Process Flow for Food and Kindred Products (SIC 20)

Refrigeration, open air, and water cooling processes apply low or sub-freezing temperatures to food in order to retain freshness. Freezing techniques include air freezing, fluidized bed freezing, plate freezing, liquid-immersion freezing, freeze drying, and cryogenic freezing. Concentration techniques remove all or most of the water from a food product prior to freezing and packaging.

In addition to drying and freezing, food preservation techniques include pickling and sterilization. New storage and sterilizing processes include ultrahigh-temperature (UHT) sterilization, used in the dairy and aseptic-packaging industries, cold sterilization using filtration systems, microwave sterilization, and rapid chilling (Morris and Russell 1990). The sterilization techniques reduce or eliminate the need for refrigeration and dramatically increase product shelf life.

Meat Packing

After slaughtering, the hair and/or hide is removed from the carcass (ACEC 1985). Techniques used are washing, scalding, singeing and polishing, and skinning. Techniques may include the application of short-term, high-temperature cooking using steam and hot water and/or mechanical techniques. The carcass is then eviscerated and trimmed. The meat is chilled to prevent spoilage, cut and deboned, cured, smoked or cooked, and packaged. Blood products are processed, as are unused or inedible portions of the meat products which are rendered (usually cooked), then either dried and sold as by-products or disposed of.

Dairy Processing

Raw milk is first clarified and separated to remove suspended matter and separate the cream (ACEC 1985; EPRI 1990). It is then heated to high temperatures in a pasteurizer to kill disease-producing organisms, pumped through a series of valves in a homogenizer to reduce the size of the fat globules, and cooled. In cheese production (SIC 2022), the milk is first coagulated using enzymes and lactic acid to produce curd and then aged or ripened using bacteria and molds to ferment the curd. Large quantities of water and water-soluble milk constituents are separated from the solid parts during cheese

production. The liquid residue is known as whey. Whey is further processed in dryers or evaporators to recover by-products or prepare for waste disposal.

Prepared Fruits and Vegetables

Processing steps for canned, dehydrated, and frozen fruits and vegetables are similar and include preparation (e.g., sorting and trimming), washing; peeling; cutting; cooking; canning, dehydrating, or freezing; and packaging.

Canning-specific processes are filling, sealing, retorting, and cooling. Retort machines combine high heat and pressure to produce a sterile product. Dehydrating may take the form of sun drying or artificial dehydration. For example, potato dehydration facilities usually use a flash dryer and then a fluidized bed dryer.

3.4.2 Equipment

Equipment used in meat packaging includes the following: boilers, compressors, dryers, coagulators, centrifuges, cookers, cutters, refrigerators, rendering equipment, saws, and scalders.

Equipment used in dairy processing includes the following: high-speed centrifugal machines, separators, pasteurizers, vats, homogenizers, boilers, compressors, refrigerators, evaporators, whey driers, and spray dryers.

Equipment used in preserved fruit and vegetable processing includes the following: washers, peelers, cutters, cookers, coolers, retorts, dryers, freezers, boilers, compressors, and refrigerators.

3.4.3 Energy Requirements

The food and kindred products industry ranks eighth on the Bonneville list in terms of total electricity consumption (see Table 3.3). Food operations require significant expenditures of energy (RDC and BCD 1988; RDC 1990). Most of the energy for process heating is used to generate steam. In addition to direct processing requirements, supplementary and preparatory procedures need energy for sterilization and cleaning of equipment and containers. Waste treatment and disposal, and the recovery and treatment of byproducts, also require energy.

According to EPRI, the food processing industry is the nation's fourth largest manufacturing consumer of electricity, after chemicals, primary metals, and pulp and paper (RDC 1990, p. 1.9). The industry accounted for about 7% of the manufacturing sector's total electricity consumption in 1986. In general, refrigeration, cooling and freezing, and materials processing (e.g., cutting and mixing) rely heavily on electricity, whereas natural gas and other fossil fuels are used widely in cooking and drying processes. Power motor-driven equipment (pumps, fans, and compressors), materials handling equipment (conveyors), and materials processing equipment (mixers and grinders) account for most of the electricity consumed (RDC and BCD 1988). The remainder is used for lighting.

3.4.4 Waste Streams

Food wastes are generally non-hazardous, but can constitute up to 50% of the raw food product coming into the plant (Bechtel 1984, p. 5.2; see also ACEC 1985; EPA et al. 1972; Battelle 1984; SJO, Shapiro, and Synergic 1984). Wastes include dirt and other wash residue, water-soluble components of foods (from washing), culls, and other reject materials. Food processing plants, particularly freezing and canning operations, consume large amounts of water for preparing and cleaning the raw material and keeping the plants clean. Certain effluents may be reused with no or minimal treatment, but the industry as a whole discharges large amounts of liquid wastes. In addition, processes such as blanching (water or steam), frying, and cooling release considerable amounts of vapor into the air. Stricter enforcement of the Clean Water Act is expected to result in increasing pretreatment and recycling of wastewater by food processors (Ross and Valentine 1991).

Meat packing house wastes typically are high biological oxygen demand (BOD) wastes with a high grease and solids content, and variable pH and temperatures (ACEC 1985). Depending on the product, waste streams may include salt brines, effluents from pickling and curing operations, and gas emissions from smoke-house operations. Slaughtering and rendering require large amounts of steam and hot water, which are wastewater sources. Odor is often a problem for rendering plants.

Whey from the manufacture of soft (cottage) or hard cheese contains high concentrations of BOD and total solids, particularly lactose, milk fats, and milk proteins (ACEC 1985; Goldsmith et al. 1972; Harper and Blaisdell 1972). The whey can be evaporated and dried to recover solids for incorporation in foods, animal feeds, or the manufacture of by-products. In some cases, diluted whey sludge is spread or spray-irrigated over pasture or bare land.

The major waste stream associated with fruit and vegetable processing is solid wastes from peeling, pitting, and other processes (Rose et al. 1972; Parker and Skerry 1972; Bechtel 1984). Some of the solid wastes can be used as by-products, for example, for animal feed. Most vegetables and some fruits are blanched in water or steam before canning, drying, or freezing, resulting in additional wastewater. Wastewaters are high in BOD and develop odors rapidly.

3.4.5 Occupational Hazards

Potential health hazards to food processing workers include infections resulting from contact with animal products and wastes; exposure to various chemicals used in food preparation and sanitation; and risks of burns, cuts, and shocks. Workers may also be exposed to high temperatures due to processes such as cooking, sterilization, and pasteurization and low temperatures in facilities such as meat cutting rooms and freezing lockers (Bechtel 1984; Battelle 1984; Burgess 1981; SJO, Shapiro, and Synergic 1984). Meat packing plants, in particular, are characterized by high humidity and extreme temperature variations between work areas, which may result in heat or cold stress. Chemical additives to prevent browning or spoilage in preserved fruits, including sulfur dioxide, sodium sulfate, sulfurous acid, citric acid, and malic acid, can cause skin or respiratory irritation (SJO, Shapiro, and Synergic 1984, p. C.6). Refrigerant leaks may expose workers to ammonia or other chemical hazards.

Food processors are among those groups at risk for carpal tunnel syndrome (CTS) and other repetitive motion injuries (Bush 1991; Mintner 1989; OTA 1985, p. 127). Poultry and meat packers are at high risk because poultry and meat are repetitively cut by hand at extremely high line rates. A cumulative trauma incidence rate 75 times that of the food processing industry

as a whole has resulted in OSHA fining a number of meat packing companies (Mintner 1989).

Meat processors can be exposed to zoonotic diseases, such as anthrax or leptospirosis (Burgess 1981, pp. 186-187). Dermatitis is a common result of contact with irritants such as brine and various preservatives. "Meat wrappers' asthma" is a term used to describe respiratory symptoms in workers exposed to fumes and smoke from cutting the plasticized polyvinyl chloride film used to wrap meat. Slaughter room workers may be exposed to high levels of carbon dioxide, which may present an asphyxiant hazard. The use of fork lifts with internal combustion engines in meat lockers can pose a risk of carbon monoxide exposure.

3.5 LUMBER AND WOOD PRODUCTS (SIC 24)

The lumber and wood products industry group produces logs, rough and dressed lumber, and manufactured wood products ranging from boxes and moldings to golf club handles and prefabricated homes. Sawmills and planing mills (SIC 2421) produce wood chips and wood products, such as railway ties, softwood flooring and siding, and fence pickets. The hardwood and softwood veneer and plywood industries (SIC 2435, SIC 2436) manufacture products widely used in interior construction, for furniture, and in industrial applications such as transportation equipment. The wood preserving industry (SIC 2491) is engaged in treating lumber and timbers, plywood, posts, and other products to prevent decay and to protect against fire and insects.

According to the 1990 U.S. Industrial Outlook, the Pacific Northwest is the nation's primary supplier of softwood veneers (USCD 1990, Ch. 6). In addition to plywood and veneer mills, sawmills and planing mills are heavily represented on the Bonneville list. Common processes in these operations are discussed in this section. Sawmills and planing mills and veneer and plywood mills have been profiled in other Bonneville reports (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984).

3.5.1 Processes

The major processes in the wood products industry are logging, wood preparation, wood preservation, milling, and fabrication and finishing (Battelle

1984; Bechtel 1984; Kline 1982; SJO, Shapiro, and Synergic 1984; Standard & Poor's 1989). Figure 3.3 is a process flow diagram for a generic wood products operation. The exact processes vary according to the type of mill and end product; some plants may engage in only a single process or a few processes. Integrated wood products mills and plants may include tree farms and logging operations, lumber manufacture, and finishing operations.

Logging operations may include delimbing and cutting of logs in addition to tree felling. Wood preparation steps include debarking, sawing, and seasoning (drying). Often lumber is air dried outside in lumber yards for several months, then placed in drying ovens or kilns. Wood preservation may consist solely of drying. However, the manufacture of so-called preserved wood products generally consists of two steps: preconditioning the wood to reduce its natural moisture content and increase permeability, and treating the wood with a preservative (EPA 1980, p. 21.1-21.3). Common preconditioning techniques are seasoning or drying in open yards; kiln drying; steaming the wood at high pressure in a retort, followed by the application of a vacuum; heating the stock in a preservative bath under reduced pressure in a retort; and vapor drying. Common wood preservatives include creosote, pentachlorophenol (PCP), and various water-soluble inorganic chemicals, such as copper salts, chromium, and arsenic.

Milling, fabrication, and finishing processes vary widely. In lumber manufacture, the prepared logs are graded and planed. The manufacture of lumber is basically a continuous process in which raw materials are moved from one work station to another (Bechtel 1984, p. 5.10). In the manufacture of veneer and plywood, prepared logs are peeled into veneers of uniform thickness and dried. After drying, the veneer plies are trimmed, sorted, patched, assembled into an odd number of perpendicular layers, and a thermostating resin is applied. The veneer assembly is then sent to a hot press, where pressure and heat are applied to form plywood. Trimming, face sanding, and other finishing processes may be employed.

FIGURE 3.3. Process Flow for Lumber and Wood Products Processes (SIC 24)

Reconstituted wood products, such as particle board and fiber board, require different preparation, fabrication, and finishing processes. Particle board is manufactured from wood particles--flakes, shavings, or splinters--mixed with resin and other additives, formed, and pressed into a board. In, fiber-board manufacture, the wood is treated differently before it is pressed into boards.

3.5.2 Equipment

Equipment used in lumber processing includes the following: debarkers, chippers, hogs, grinders, hammer mills, drying kilns, surface dryers, veneer dryers, rotary dryers, fluidized bed dryers, tempering ovens, saws, knives, planers, lathes, presses, resin tanks, blenders, buffer, sanders, cookers, boilers, compressors, blowers, and turbine generators.

3.5.3 Energy Requirements

The lumber and wood products industry ranks third on the Bonneville list in terms of total electricity consumption (see Table 3.3). According to EPRI, sawmills, planing mills, fabricated millwork plants, and plywood plants dominate the industry group in terms of electricity use (RDC and BCD 1988). The drying of lumber is the most energy-intensive operation in forest products manufacturing (Wilson 1990).

3.5.4 Waste Streams

The primary source of air pollutants from sawmills and planing mills is combusted fuel used to produce heat for the drying kiln (SJO, Shapiro, and Synergic 1984, pp. 49-52; see also Battelle 1984; Bechtel 1984). Veneer dryers emit organic materials of two types: condensibles and volatiles. Condensable compounds consist primarily of wood resins, resin acids, and wood sugars. Gas-fired dryers are a major source of uncontrolled volatile organics (VOCs), including terpenes and natural gas components, such as unburned methane. The exact type and quantity of emitted organics depends on the wood species and dryer type. Dust from sanding, sawing, and other woodworking operations generates additional air pollutants.

Petroleum-based products, which are widely used as fuels and lubricants at wood products mills, may generate oily wastes. Adhesives, glues, and

patching compounds used in plywood and veneer manufacture include phenolic resins (made from phenol and formaldehyde), urethane, and styrene (SJO, Shapiro, and Synergic 1984, p. C.23-C.25). Fungicides and chemicals used in preserving wood products may be sources of concern. The EPA is considering whether to classify wood preserving wastes as hazardous under RCRA provisions (EPA 1984; USCD 1990, p. 6.13).

Process waters include log storage water sprayed on stored logs to prevent checking, veneer dry cleaning, and glue spreader washdown. Sawmills, planning mills, and veneer mills are not allowed to discharge wastewater, so that water must be recycled (SJO, Shapiro, and Synergic 1984, pp. 51-52).

Saw and planing mills generate large quantities of wood waste, including wood chips, hog fuel, and sawdust, much of which is used on site or sold as byproducts.

3.5.5 Occupational Hazards

The principle occupational hazard for sawmill and planing mill workers is exposure to wood dust, which may cause dermatitis, respiratory disease, and cancer (SJO, Shapiro, and Synergic 1984, pp. C.21-C.25). Cedar dust can cause a disease known as "cedar asthma." Veneer and plywood mill workers may be exposed to chemicals escaping from dryers, dusts, and vapors from adhesives and resins used in gluing and patching operations. Adhesives may include soybean and blood proteins, which can cause skin irritation and allergic reactions. Resins may expose workers to phenol, formaldehyde, urethane, styrene, epoxies, and organic amines used as catalysts. Dusts and mists of preservatives, such as creosote, pentachlorophenol, and inorganic arsenicals, pose additional exposure hazards (EPA 1984).

Wood products workers may be exposed to high noise or temperature levels and equipment operators may be at risk for burns and shocks. Workers using saws and other cutting machinery are at risk for amputations, cuts, and abrasions. Machining equipment such as lathes and refiners may expose workers to dust and larger particles, as well as fumes and mists of abrasives, cutting oils, and solvents (see Section 3.11 on fabrication and finishing processes).

3.6 PAPER AND ALLIED PRODUCTS (SIC 26)

The paper and allied products industry produces pulp, paper, paperboard, and converted paper and paperboard products, such as corrugated boxes, stationery, cups, and other retail products. Large integrated mills produce pulp and paper (SIC 2621) or pulp and paperboard at one location, whereas smaller, nonintegrated mills may produce only pulp, paper, or paperboard (SIC 2631). Pulp mills (SIC 2611) convert wood or other furnish into papermaking fiber (pulp). The majority of pulping operations in the United States use the kraft pulping method. Secondary fiber or recycle mills produce no pulp on site; most of the raw materials are derived from waste paper. The number of recycling and deinking mills is increasing.

There are numerous pulp and paper mills on the Bonneville list. This section profiles integrated pulp and paper manufacture (SIC 2621), discussing various pulping techniques. Other Bonneville reports have concentrated on kraft pulping (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984).

3.6.1 Processes

The major pulp and papermaking processes are wood preparation, pulping, papermaking, and converting (Battelle 1984; Bechtel 1984; EPA 1976, Vol. V; EPA 1980, Ch. 16; Kline 1982). Figure 3.4 is a process flow diagram for a generic pulp and papermaking operation. There is extreme variation in processes used across mills, depending on the fiber source and the type and quality of end product produced. The industry is considering changing several of its unit processes, particularly bleaching, because of increasing government regulation of process pollutants such as chlorine. Closed-cycle processes may be necessary to comply with air and water discharge limits that cannot be met by waste treatment alone (Samdani, Gilges, and Fouhy 1991). Deinking process changes will be required to produce high-grade papers from recycled fibers.

Wood Preparation

At integrated mills (SIC 2621) where pulp is produced on site, wood preparation may include debarking, washing, and chipping (Bechtel 1984; Kline 1982). Pulpwood may include whole logs and chips, with or without bark, or

manufacturing residuals, e.g., sawdust and shavings from a lumber mill. Recycle mills use waste paper as pulping stock.

Pulping

Pulping entails mechanically or chemically converting the cellulose source to a form suitable for further processing. There are a variety of mechanical, chemical, and combined pulping techniques. Mechanical techniques break up raw wood materials by directly grinding the stock. These methods produce slightly yellow paper of fair or low strength, and are used primarily on softwoods to produce printing and writing grades such as newsprint. Groundwood is the most common mechanical pulp. In thermomechanical pulping (TMP) and defibrated/exploded pulping, the logs are processed into chips, then treated with steam or chemicals prior to further mechanical refining. Thermomechanical pulping is the fastest growing pulp technology (RDC and BCD 1988).

In chemical pulping, cooking liquors digest the fiber source, dissolving the natural glues (lignan) in the raw wood materials without mechanical refining. Chemical and semichemical pulps are made from chips that are cooked in pulping liquors (alkaline, neutral, or acidic). The pulp is separated from the spent cooking liquor (black liquor), which is then recycled to reclaim the pulping chemicals. The recovery system includes evaporators to concentrate the spent chemicals and recovery furnaces or kilns to return the chemicals to their original forms. Wood components recovered from the cooking liquid during the process can be burned to produce steam for power production and process uses.

Chemical methods use softwoods, hardwoods, or a blend. The most common chemical process is kraft pulping, a sulfate process. Kraft pulping produces a stronger paper than an alternative technique, the sulfite method. Another reason kraft pulping is preferred is that kraft waste products are more easily reused than are sulfite wastes.

FIGURE 3.4. Process Flow for Paper and Allied Products Manufacture (SIC 26)

High-yield processes use a combination of chemical and mechanical processes. Chemical processes reduce yield since they dissolve some cellulose (Kline 1982, p. 33). Final yields may be only 50% of the initial weight of wood, whereas mechanical techniques can yield more than 90%. Current research is focused on extended and oxygen delignification processes that result in greater lignan removal without compromising pulp strength (Ferguson 1990; Samdani, Gilges, and Fouhy 1991). The remaining lignan, which turns brown during pulping, determines the amount of bleaching needed. Oxygen delignification reduces the bleaching required. Incorporating bleaching and coloring into the pulping process, rather than leaving them as add-on steps, would also reduce the amount of bleaching required. Researchers are investigating the potential use of fungi (phanerochaete chrysosporium) in pulping and waste treatment processes (Roy-Sole 1990). These fungi have the ability to dissolve lignan and toxic compounds such as phenols and dioxon.

After pulping, the stock is washed to remove chemicals, if used, and then screened, filtered, and refined to remove dirt and further break up the fiber bundles. Unbleached pulp is brown or deeply colored. In bleaching, the stock passes through soaking towers where chlorine and other bleaching agents remove additional lignan and brighten the fibers. Washing removes the bleaching chemicals.

Recycle Plant Processes

The pulping processes at recycle or deinking plants are slightly different than at plants using virgin furnish (Broeren 1990; Kennedy 1990; Kline 1982). Processes may include pulping, screening, cleaning, and deinking. Newsprint and coated paper are churned into a wet pulp mix in the pulper. Then, depending on the type of furnish and the end product, contaminants such as plastics, styrenes, hotmelts, and contact adhesives must be removed from the pulp. This is usually done by screening and cleaning while the contaminants are still in large pieces.

Deinking is achieved by combined mechanical and chemical action in the pulper, involving washing or flotation or both. For example, after washing, the pulp is pumped into the flotation chamber of a deinking tank where the ink rises to the surface to be skimmed off and piped to a waste treatment plant.

Washing systems remove the ink once it is in suspension. Some products require post-deinking treatment steps.

Deinked fiber is primarily used for tissue, newsprint, and fine paper. New mills are being built and existing mills are retooling to handle more recycled paper in response to rising wood chip prices and legislation mandating recycling. Several states are considering legislation that will require newsprint to have a 25% to 50% recycled fiber content (Sorenson 1990). The American Paper Institute has set an industry goal of 40% recycling by the end of 1995 (Carp 1991).

Papermaking

Some pulps must be beaten or further chemically treated to develop the desired paper or board characteristics. Stock preparation may include pulp blending, the addition of chemicals, and mechanical abrasion to increase the surface area. Common modification techniques include sizing, calendering, and pigment coating. Some of these steps can be done inside the paper machine. The most common papermaking processes use a paper machine called a Fourdrinier machine to produce a continuous sheet of paper.

Paper is made by depositing a layer of fiber from a dilute pulp-water suspension onto a fine screen of moving wire or filament. The water drains as the screen moves through the paper machine and the fibers form a wet mat or sheet. At the end of the machine, the sheet is lifted from the screen, passed through presses for mechanical removal of water, and then dried by evaporation in the steam-heated dryer. Other drying techniques include microwave and float drying, which uses air jets to suspend the paper through the drying zone where it is exposed to dry air (EPA 1976, p. 80).

Heavy paper or paperboard is usually produced on a multicylinder machine, in which forming cylinders build up the web layer by layer. After pressing and drying, the paper or paperboard is then wound, cut, and packaged.

Converting

The major types of paper products are newsprint, unbleached kraft paper used for grocery sacks, linerboard used to make corrugated boxes, paperboard used for milk cartons and disposable plates, tissue, uncoated paper used in

office and printing papers, and coated paper used for magazines and other color printing applications (Kline 1982; Standard & Poor's 1989, p. 879). Construction paper, gypsum, and insulation board are used in the manufacture of construction materials. Converting operations, in which intermediate products such as linerboard and paperboard are converted to consumer products, include corrugating, box making, folding, cutting, and forming.

3.6.2 Equipment

Equipment used in papermaking includes the following: debarkers, chippers, washers, digesters, batch and drum pulpers, grinders, centrifuges, deckers, blow tanks, filters, screens, beaters, refiners, diffusers, Fourdrinier machines, multicylinder machines, dryers, presses, lime kilns, slaker/caustecizers, recovery furnaces, evaporators, boilers, turbine generators, and conveyors.

3.6.3 Energy Requirements

The paper and allied products industry ranks number one on the Bonneville list in terms of total electricity consumption (see Table 3.3). In fact, the top five electricity consumers on the Bonneville list are pulp and paper mills. According to the 1989 Pulp and Paper Factbook, the pulp and paper industry is the fourth largest U.S. manufacturing consumer of energy, primarily for process steam and electric power (Mikulenska 1989). EPRI ranks the pulp and paper industry as the third largest U.S. industrial consumer of electricity, after chemicals and primary metals (RDC 1990, p. 1.9).

The availability of low-cost waste fuels, such as hog fuel, wood waste, and black liquor, has allowed the industry to supply a significant amount of its energy needs through co-generation. In the past, mills have relied primarily on steam turbines, but many are now switching to gas turbines and modified steam turbines and boilers.

Mechanical operations in pulp and paper processing that rely on electrical power include materials conveying, machine drive, pressing, and pumping. Kraft pulping and papermaking are the major electricity-consuming processes. Drying is a process often targeted for energy saving measures (EPA 1976, Vol. V).

Overall energy consumption varies with the grade of paper produced (Mikulenka 1989, p. 64). Newsprint made from thermomechanical pulping has high energy requirements per ton of production, which is generally supplied by purchased electricity and fossil fuels. Unbleached kraft linerboard has lower total energy requirements per ton than newsprint; half the energy may come from burning spent black pulping liquor.

Although recycled grades require less total energy per ton to produce than virgin paper and paperboard, they must rely entirely on purchased fossil fuel and electricity. Furthermore, purchased energy requirements for recycled newsprint are lower than for newsprint made by thermomechanical pulping, but higher for recycled linerboard than for kraft linerboard. New pulping processes designed to eliminate chlorinated organics may use more energy than conventional processes (Samdani, Gilges, and Fouhy 1991).

3.6.4 Waste Streams

The major waste streams at a pulp and paper plant are gases emitted during pulp preparation, effluents such as wastewater from wood preparation and pulping, and solid wastes from wood preparation and various chemical recovery systems (Bechtel 1984; Ferguson 1990; Kennedy 1990; Samdani, Gilges, and Fouhy 1991). Several Northwest pulp and paper mills have been listed by EPA as posing a serious cancer risk to humans through their air emissions (Kadera 1989). In 1989, according to the Oregon State Public Interest Research Group (OSPIRG), the three largest sources of toxic substances discharged into the environment in Oregon were pulp and paper mills (Laats 1991).

Pulp and paper mills emit sulfur dioxide and a group of compounds known as total reduced sulphur (TRS), which includes hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. Air emission sources include the digester, washer, evaporator, recovery furnace, kiln exhaust, and lime slaker vent. The primary air emission sources in the kraft pulp and paper industry are the recovery furnace and main power boilers (SJO, Shapiro, and Synergic 1984, p. 39). Odor from kraft pulp mills is also a significant air pollution problem (EPA 1976, Vol. V, p. 19).

Pulp and paper mills use large quantities of water, primarily in pulping operations. Dioxin and total organic chlorine are major problems for mills using chlorine bleaching. Chlorine bleaching produces a mixture of as many as 1,000 toxic compounds, including dioxins and furans, both known animal carcinogens (Kennedy 1990, p. 56). Special programs for the Columbia River have been established to reduce dioxin concentrations originating from pulp and paper mills. For the most part, pulp and paper wastewater is not classified as hazardous. However, amendments to federal hazardous waste laws may change this. For example, chloroform, a byproduct of the bleaching process, may be listed as hazardous (Ferguson 1990). In the future, all organic chlorides, phosphorous, metal ions, and chlorophenolics may also be regulated. As a result, many mills are shifting to chlorine dioxide and hydrogen peroxide for their pulp bleaching chemicals.

Solid waste generated from kraft pulp and paper mills includes lime solids, settling pond dredgings, wood and fiber wastes, and log pond dredgings. Sludges include fiber, clay filler materials, other chemical additives, and biological materials. Ink sludge can be dried and used as fertilizer. Recycle mills have the potential to generate hazardous sludges, since waste inks from older papers and boards may contain PCBs or heavy metals.

3.6.5 Occupational Hazards

The principal occupational exposures during pulping are to toxic gases associated with digesting and bleaching operations, including methyl mercaptan, hydrogen sulfide, sulfur dioxide, and chlorine gas (Burgess 1981, pp. 221-223; SJO, Shapiro, and Synergic 1984, pp. C.7-C.8). Paper coating and drying may also expose workers to various chemicals, including acrolein and other aldehydes formed by the atmospheric oxidation of linseed oil and solvent vapors. Acrolein is an eye, skin, and respiratory irritant. Lime exposure may occur during pulping and the subsequent lime processing in kraft pulp mills. Various processes may expose workers to high heat, humidity, and noise levels. Container board manufacture may expose workers to lead-based inks (Battelle 1984, pp. 7.3-7.4). High noise levels are associated with high-speed rollers, rotary knives, and impacting metal parts.

3.7 CHEMICALS AND ALLIED PRODUCTS (SIC 28)

The chemical industry manufactures a wide variety of products including industrial chemicals; intermediate products such as synthetic fibers and plastics used in further manufacture; consumer products such as drugs, cosmetics and soaps; and materials and supplies, such as paints, fertilizers, and explosives, used in other industries.

Chlor-alkali plants (SIC 2812) manufacture inorganic industrial chemicals such as chlorine, hydrogen, sodium hydroxide (caustic soda), and sodium chlorate from feedstocks of salt and brine. Fertilizer manufacturers produce a variety of solid and liquid fertilizer products containing one or more of the three essential plant nutrients--nitrogen, phosphorus, and potassium--as well as trace elements such as calcium and iron.

On the Bonneville list are producers of industrial inorganic chemicals, organic chemicals (SICs 2865 and 2869), and fertilizers. Nitrogenous fertilizers (SIC 2873), which are derived from ammonia, are profiled in this section. Organic and inorganic chemical plants, particularly chlor-alkali operations, have been covered in other Bonneville reports (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984).

3.7.1 Processes

The unit processes in chemicals manufacture are numerous and vary widely across different products (EPA 1980; Austin 1982a, 1982b; RDC 1990, Section 3.1.28; and Standard & Poor's 1990). Some common ones are heat transfer, size reduction (e.g., grinding), mixing (solids, liquids, gases), mass transfer (e.g., gas absorption and solvent extraction), humidification, drying, evaporation and crystallization, and phase separations. Phase separation techniques include filtration, screening, centrifugation, and sedimentation.

Nitrogenous Fertilizers

Ammonia is the primary raw material used in manufacturing nitrogenous fertilizers, which include urea, ammonium nitrate, ammonium phosphate, nitric acid, and complete mixed fertilizers (EPA 1976, Vol. XV; Standard & Poor's 1990, pp. C34-C37). Figure 3.5 is a process flow diagram for the manufacture of urea.

The first step in urea manufacture combines carbon dioxide and ammonia in a reactor vessel to produce ammonium carbamate, a large portion of which decomposes immediately into urea and water (Lynch 1982). The stream leaving the reactor consists of a mixture of urea, water, carbon dioxide, free ammonia, and ammonium carbamate which is separated in a recovery system. The solution is concentrated, crystallized, and dried. These crystals may be sold as is or used to make urea prills. Prills are made by spraying a concentrated urea solution into the air at the top of a tall tower. As the droplets fall, they solidify in the stream of air forced up the tower by a blower. Formaldehyde is sometimes added to improve prill quality. Some plants make granules instead of prills by using a rotating granulator. The cooled finished product is screened and bagged.

Nitric acid is produced by mixing liquid ammonia with preheated air and introducing it into a converter where the ammonia is oxidized, forming nitric oxide (Muranko 1982). This product is passed through heat exchangers and coolers to form nitrogen dioxide. The gases then pass to an absorber where nitrogen dioxide combines with water to produce nitric acid and nitric oxide. These reaction are performed at high temperatures and under high-pressure conditions.

Ammonium nitrate is manufactured by the neutralization of nitric acid with gaseous ammonia (Burgess 1981, pp. 184-185). The slightly acidic material is pumped to an ammoniator where additional ammonia is added. The resulting agglomerate, diammonium phosphate, is dried, screened, and cooled for packaging.

3.7.2 Equipment

Equipment used in fertilizer production includes the following: reactor vessels, concentrators, evaporators, dryers, melters, prill towers, blowers, ammoniators, granulators, mixers, screens, grinders, heat exchangers, pumps, compressors, boilers, conveyors, cranes, bucket elevators, and lift trucks.

FIGURE 3.5. Process Flow for Urea Manufacture (SIC 287)

3.7.3 Energy Requirements

The chemicals and allied products industry ranks second on Bonneville's list of electricity consumers in the Northwest (see Table 3.3). For the nation as a whole, the chemical industry group is the number one industrial energy consumer, with energy use highly concentrated in industrial chemical production (SICs 281 and 286) (RDC and BCD 1988, Section 3.1.28). In addition, chemical manufacturers are the nation's largest industrial consumers of electricity.

Chlor-alkali plants, which produce chlorine and caustic soda by electrolytic processes, dominate electrical consumption in the industry group. In other sectors, electricity is used primarily to run pumps, compressors, and instruments. Significant amounts of energy are required to control emissions of nitrogen oxides produced by the manufacture of nitric acid (EPA 1976, Vol. XV). Some plants may also produce the ammonia used in fertilizer production, which consumes large amounts of electricity.

3.7.4 Waste streams

According to EPA's 1988 Toxic Release Inventory, the chemicals manufacturing sector is the largest source of toxic pollutants released into the environment (D'Innocenzio 1990b). Chemicals manufacture is the third largest generator of hazardous wastes in the Pacific Northwest, after metals and transportation equipment (Stokes et al. 1989). Waste streams for chemicals manufacture include stack gases, spent or leaking process chemicals, process wastewaters, and pollution control wastes. Potential gas, liquid, and solid pollutants number in the hundreds and include volatile organics, solvents, corrosives, and heavy metals.

The manufacture of nitric acid causes significant emissions of nitrogen oxides. Dust, particularly that produced by the drying of mixed granular fertilizers, is an additional source of air pollution. Ammonia leaks are a potential pollutant source in the manufacture of all nitrogenous fertilizers. According to the Oregon Department of Environmental Quality, the top two dischargers of wastewater in the state are a chlorine manufacturer and a

fertilizer manufacturer.^(a) Discharges from the latter include organic nitrogen, ammonia nitrogen, oil, and grease.

3.7.5 Occupational Hazards

The potential health and safety hazards associated with chemicals manufacture are numerous (Hoffman and Maser 1985). Because of the number of catastrophic accidents in the petroleum and chemicals industries, the Occupational Safety and Health Administration (OSHA) has proposed new and more stringent safety standards covering a wide variety of potentially hazardous chemicals and processes used in these industries (Corbett 1990). Many of the largest U.S. chemical companies have facilities on EPA's list of plants whose use of toxic, flammable, and explosive chemicals represents high risks to workers (Chemical Engineering 1990).

The principle safety hazards are fires and explosions. Other hazards include extremes of temperature, risk of burns, and high noise levels in some processes. The risk of cancer and other serious diseases among chemical workers is excessive.

Leakage of ammonia, a strong respiratory irritant, is the primary health concern in the manufacture of urea (Lynch 1982). Exposure to urea dust and formaldehyde may also be hazardous. All nitration reactions are potentially hazardous because of the explosive nature of the end products and because most nitrating agents are also strong oxidizing agents. All the chemical reactions involved in nitric acid production are exothermic, posing explosion and heat hazards. Nitric acid production may expose workers to nitric acid mists, fumes, and dusts as well as to nitrogen oxide (Muranko 1982). Ammonium phosphate production may expose workers to fluorides, ammonia, and phosphate dusts. The resulting health effects include corrosion to skin, eye, and other tissues, and respiratory tract irritation, which may result in pulmonary disease.

(a) Personal communication from the Water Quality Division, Oregon Department of Environmental Quality, to M. Baechler, May 1991.

3.8 PETROLEUM REFINING AND RELATED INDUSTRIES (SIC 29)

This industry group includes the refining of crude oil and production of finished products together with the manufacture of asphalt and miscellaneous products such as lubricating oils from purchased materials. Petroleum refineries produce a wide variety of finished products, such as propane and butane, motor and aviation gasoline, jet fuel, diesel oil, heating oil, lubricants, waxes, and asphalt. Intermediate, unfinished refinery products are sold to petrochemical plants as feedstocks for the manufacture of plastics, resins, synthetic fibers, fertilizers, pesticides, cleaning agents, and other consumer goods.

There are two oil refineries (SIC 2911) and an asphalt manufacturer (SIC 2951) on the Bonneville list. Refineries are profiled in this section as well as in other Bonneville reports (Battelle 1984; SJO, Shapiro, and Synergic 1984).

3.8.1 Processes

Figure 3.6 is a process flow diagram of a generic refinery operation. Crude oil is a mixture of carbon, hydrogen, sulphur, nitrogen, and oxygen, with traces of iron, vanadium, nickel and other metals, and is almost always contaminated by water, inorganic matter, or gas (Northern Miner Press 1979; Battelle-Columbus 1986a, pp. 2.86-2.95; McGraw-Hill 1987; RDC and BCD 1988, Section 3.1.29). Most of the water and gaseous and solid impurities are removed by well-site separators before the crude oil is sent to refineries. At the refineries the volatile hydrocarbons are separated from each other and the crude is converted to commercial products by molecular cracking, molecular rebuilding, and solvent finishing.

Although the processes at a specific refinery will vary depending on the composition of the crude oil feedstock and the types of end products produced, in general they employ three basic operations: physical separation, chemical conversion, and treating and finishing.

Distillation is the primary separation procedure, although topping, skimming, absorption, stripping, and extraction procedures may also be used. The crude oil is heated and initially separated (fractionated) in a distillation tower. The heavier components drop and lightest components come

FIGURE 3.6. Process Flow for Petroleum Refining (SIC 2911)

off at the upper cooler levels of the tower. Since the various hydrocarbons in the crude have different boiling points, distillation produces basic product groups such as gasoline, kerosene, lubricating oil, and fuel oil.

In order to increase the output and quality of specific products, the hydrocarbons may be converted using heat, pressure, and suitable catalysts to rearrange the molecules in the compound. Cracking processes convert larger molecules into small molecules by heating the compounds to temperatures high enough to crack them. Cracking techniques include coking (thermal cracking), catalytic cracking, and hydrocracking. Catalytic cracking is the most common technique. Hydrodesulfurization reduces the sulfur content of distillate streams prior to reforming.

Other conversion and reforming techniques include polymerization, alkylation, isomerization, and catalytic reforming. Alkylation, for example, increases the number of carbon molecules and produces highly branched paraffins with high antiknock (octane) ratings and good stability.

Various treating and finishing techniques, including chemical sweetening (desulphurization), acid, clay, and solvent treatment, may be employed to stabilize and upgrade certain products.

Lube oil and asphalt production are common refinery operations that have their own set of processes.

3.8.2 Equipment

Equipment used in petroleum refining includes the following: topping units, atmospheric stills, vacuum stills, catalytic crackers, hydrocrackers, cokers, desalters, sour water strippers, refiners, reformers, Claus plants, API separators, boilers, compressors, furnaces, and turbine generators.

3.8.3 Energy Requirements

Petroleum and related industries rank ninth on the Bonneville list in terms of total electricity consumption (see Table 3.3). The petroleum industry is the nation's fifth largest consumer of electricity among manufacturing industries (RDC and BCD 1988, p. 3.1.29.2). The industry's energy consumption is expected to rise largely because of increasing demand for higher-quality products from lower-quality crudes. The petroleum refining

industry is extremely energy intensive and refineries operate on a 24-hour basis (RDC and BCD 1988, Section 3.1.29). Processing steps demand a great deal of mechanical energy for pumping and compression. Fossil fuels are used for process heaters and boilers and as feedstock in the manufacture of the hydrogen used in hydrocracking and hydrotreating processes. Electricity is primarily used for pumps, mixers, air coolers, and miscellaneous process applications.

3.8.4 Waste Streams

Catalytic cracking emits significant quantities of total suspended particulates (TSP), sulfur dioxide, and nitrogen oxides (Corbett 1990; EPA 1980, Chapter 14; SJO, Shapiro, and Synergic 1984, pp. C.8-C.12). Crude oil contains large amounts of sulfur. During refining processes sulfur is converted to hydrogen sulfide and mercaptans (foul-smelling sulfur-containing compounds). These are in turn extracted and converted--refineries operate Claus plants to recover sulphur from residue gases. Other sources of air emissions are combustion systems supplying process steam and heat, utility boilers, and heaters (SJO, Shapiro, and Synergic 1984, pp. 41-43).

Water use at refineries is primarily for steam generation and heat transfer (EPA 1976, Vol. IV; EPA 1980, Ch. 14). The major sources of refinery wastewater are cooling water blowdown, boiler blowdown, and process water. Raw wastewater is defined by the industry as the effluent from the American Petroleum (API) separator, which is used to recover product/raw materials prior to final treatment (EPA 1980, p. 14.4). The wastewater may contain free oil, dissolved hydrocarbons, sulfur and nitrogen compounds, coke and inorganic particulates. Refinery wastewater has both high chemical (COD) and biochemical (BOD) oxygen demand. Chromium is the major constituent of concern (Dawson 1989).

The refining sector generates the major share of hazardous wastes in the petroleum industry (SJO, Shapiro, and Synergic 1984, pp. F.30-32; Stokes et al. 1989). Solid refinery waste is primarily in the form of oily sludge from storage tank sediment, settling tanks in wastewater treatment plants, biotreatment facilities, and bottom dredging of settling lagoons. Oily sludges are either treated and recycled into the refining process or disposed

of in landfills. The largest waste stream is spent lime from boiler feedwater treatment, the second is non-leaded tank bottoms. Filter clays are generated at those refineries producing lube oil. These wastes contain a variety of toxic constituents, including phenols, cyanides, heavy metals, and oil.

The EPA classifies five waste streams associated with refining as hazardous due to their lead and hexavalent chromium content: dissolved air flotation (DAF) float, slop oil emulsion solids, heat exchanger bundle cleaning solids, API separator sludge, and leaded gasoline tank bottoms (Corbett 1990; Stokes et al. 1989). Lead usually comes from the tetraethyl lead used as an octane fuel booster in gasoline. Hexavalent chromium usually originates in corrosion inhibitors used in cooling tower systems (Leeman 1988, p. 817).

Spent process catalysts, particularly fluid catalytic conversion catalyst (FCC) and hydrotreating catalyst, are additional sources of wastes. Spent FCC catalyst contains significant levels of heavy metals. Some refineries sell spent FCC catalyst to cement kilns which use them as a source of alumina (Corbett 1990; Dawson, 1989; Evanoff 1990, pp. 60-61)--the catalyst is chemically consumed in the cement-making process. Most spent catalysts are not currently classified as hazardous wastes but proposed amendments to RCRA may add them to the classified list (Corbett 1990).

3.8.5 Occupational Hazards

The principle hazards at refineries are fires and explosions, which account for the majority of refinery accidents and losses (Krembs and Connolly 1990). Because of the volatility of the materials involved in refining, there are significant risks of catastrophic accidents. The leading cause of these accidents is mechanical failure of equipment, with pumps and compressors thought to be responsible for a large number of fires and explosions. The Occupational Safety and Health Administration has proposed new and more stringent safety standards covering a wide variety of potentially hazardous chemicals and processes used in the petroleum and chemicals processing industries (Corbett 1990).

Workers are exposed to a number of potential chemical hazards, both from process chemicals and byproducts, including hydrocarbons, hydrogen sulfide,

carbon monoxide, phosgene catalyst dusts, additives and dyes, metals, and graphite particulates (Burgess 1981, pp. 211-216; Hobson 1982). For example, primary distillation may result in exposures to hydrogen sulfide and hydrocarbon vapors, including known carcinogens such as benzene. Further fractionation can cause dermatoses through skin contact. Coking operations expose workers to polynuclear aromatic hydrocarbons (PAHs), which are carcinogenic. The principle exposures in refineries occur during shutdown, maintenance, and startup procedures.

Significant noise exposure may exist due to pumps, blowers, burners, fans, flares, and steam and air releases. Abrasive blasting, welding, and cutting are common operations at refineries that may pose additional hazards (see Section 3.11 on metal fabrication and finishing).

3.9 STONE, GLASS AND CLAY (SIC 32)

This industrial group includes a variety of products made from brick, clay, cement, and glass. Hydraulic cement, made from limestone and alumina materials (clays and shales), is a cement that re-hydrolizes when water is added. When combined with water and aggregate, e.g., sand and rock, the cement acts as a binder to produce concrete. Portland cement is the most common form of hydraulic cement, accounting for the bulk of cement manufactured in the United States (SJO, Shapiro, and Synergic 1984, p. 43). Other types of cement are masonry, mixed, natural, and lime. Cement plants may be simply grinding mills, which produce cement from imported, purchased, or interplant transfers of clinker (calcinated limestone produced in the kiln), or they may produce clinker from raw materials and then grind the clinker into cement.

Of the three plants in this industry group, only one, a Portland cement plant, was identified as being operational. Hydraulic cement (SIC 3241) is profiled in this section and in other Bonneville reports (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984).

3.9.1 Processes

The three basic steps in cement manufacture are raw materials preparation, calcining, grinding, and finishing (ACEC 1987a; EPA 1976, Vol. X;

Powell 1982; RDC 1988, Chapter 6; Standard & Poor's 1989, p. B88). Figure 3.7 is a process flow diagram for hydraulic cement manufacture. The raw materials --sand, limestone, iron ore, and clay--are quarried by conventional means and transported to the cement factories. Plants are usually located near the source of raw materials because limestone is so heavy. Raw materials preparation involves crushing, grinding, and blending operations. Primary crushing is usually done at the quarry using a jaw or roll crusher. At the plant, the materials are sized, by secondary crushing and grinding screens, to pea-sized nodules.

There are two types of cement production: wet process and dry process. Some plants only crush and grind the raw materials, wet or dry, prior to calcining. Most plants pre-dry the limestone and clay prior to sizing and calcining. In the dry process, raw materials are dried and pulverized into a meal. In the wet process, water is added during grinding to produce a slurry. Water is then removed with filter pressing prior to feeding to the kiln.

The dry meal or slurry is fed to a rotary kiln where it is heated to temperatures as high as 2,900°F. In the kiln the mixture is dried, the limestone changes to lime, the alkalies vaporize, and any organic material is burned. This process is known as calcining and the fused kiln product is clinker. The clinker is air cooled and ground with gypsum to produce cement.

3.9.2 Equipment

Equipment used in cement production includes the following: jaw crushers, ball mills, roll mills, swing hammer mills, rotary driers, feeders, a calciner-kiln and auxiliaries, grinding and finishing mills, silos, bagging machines, fork lifts, conveyors, elevators, payloaders, a plant rail system, slurry pipelines, and pumps.

3.9.3 Energy Requirements

The stone, clay, and glass products industry ranks seventh on the Bonneville list in terms of total electricity consumption (see Table 3.3). Large quantities of fuel, primarily coal and natural gas, are required for clinker production (Battelle-Columbus 1986a, pp. 2.34-2.38). The kiln is the principal consumer of energy in the process, followed by crushing and grinding of raw materials. Electricity is primarily used for grinding operations.

FIGURE 3.7. Process Flow for Hydraulic Cement Manufacture (SIC 3241)

Most of the cement plants in the Northwest use the wet process, which requires additional thermal energy to dry the water-blended material.

3.9.4 Waste Streams

Air pollution due to particulates is a major concern in cement making processes (Bechtel 1984; EPA 1976, Vol. X, Appendix C; SJO, Shapiro, and Synergic 1984). The kiln and clinker cooler are the major cement dust sources, but most processing steps--e.g., raw material handling, crushing, milling, and transport--generate dust. Dust is generally controlled with cyclones, bag houses, and electrostatic precipitators. Kiln emissions contain combustion gases in addition to particulates. The solid particles in this gas are generally recovered and recycled back into the kiln. Some plants leach the recovered dust before recycling to reduce sodium, potassium, sulfates, and chlorides to produce a lower alkali clinker (Bechtel 1984, p. 5.44).

Most plants use process wastewaters as make-up feed water for the next batch (SJO, Shapiro, and Synergic 1984, p. F-37). The major source of wastewater in hydraulic cement manufacture is from the leaching of kiln dust, when this operation is performed (Bechtel 1984, p. 5.52). Leachate is high in pH and alkalinity and contains significant amounts of suspended and dissolved solids. Slurry discharges from wet process operations may contain high concentrations of suspended solids. The major source of wastewater in dry process plants is noncontact cooling water used to cool equipment and the finished cement. Blowdown from the cooling tower and scrubber effluent may generate wastewater when these units exist. Additional sources are plant cleaning and surface runoff from accumulated piles of discarded cement dust. In non-leaching plants, discarded dust is stored in piles or returned to the quarry.

Solid wastes include particulates that are separated from air streams prior to release into the atmosphere and are not recycled into the kiln. In plants where particulates are leached, solids are disposed offsite or used for soil conditioning (Bechtel 1984, p. 5.52). Cement kiln dust is classified as a moderately toxic waste by the state of Washington (Stokes et al. 1989). Since it can be used to stabilize metal bearing sludges, kiln dust is increasingly being recycled as a stabilization agent.

Temperatures in drying kilns are so high that the kilns are being used to incinerate hazardous wastes, which may create additional waste streams.

3.9.5 Occupational Hazards

The principal health hazard associated with cement manufacture is dust, the composition of which varies with the quartz content of the clay, shale, or slate used to form the clinker (Burgess 1981, pp. 175-177; Powell 1982). Cement dust has low toxicity but it is an irritant and can cause skin and respiratory problems. Hexavalent chromium present in the cement can cause skin irritation and is considered to be a human carcinogen (SJO, Shapiro, and Synergic 1984, p. 44). Special cement products may expose workers to silica, asbestos, or cristobalite, a biologically active mineral formed when diatomaceous earth is calcined. Chronic exposure to silica can result in silicosis, a lung disease.

The greatest risk of exposure to silica is associated with raw materials handling, particularly during quarrying and primary crushing and grinding operations. Exposure to the intermediate clinker also poses greater risk than the finished cement products. Cement manufacture requires extremely high-temperature operations. The dryers and the calcining kiln can potentially cause heat stress and burn hazards. The operation of crushers, fringers, and the rotary kiln present noise hazards. Routine firing of the kiln may expose workers to carbon monoxide and sulfur dioxide.

3.10 PRIMARY METAL INDUSTRIES (SIC 33)

The primary metals industries produce ferrous and nonferrous metals, including iron and steel, aluminum, copper, lead, zinc, and magnesium. Products include basic ores and scraps and finished products such as bars, sheets, wires, machinery, and auto parts. Iron and steel plants, including blast furnaces, steel works and rolling and finishing mills, and iron and steel foundries, make up the ferrous metals industries (SIC 331 and 332).

Some large, integrated steel operations mine and quarry their own materials and refine and process them to produce finished steel products. Others may perform only segments of the process. In steel production, arc furnaces provide an intense concentration of heat that enables the steel to be

produced quickly in small quantities from recycled scrap. The result has been a steady rise in "minimills," which compete directly with large, integrated mills for the high end of the steel market. In terms of size and output, many electric arc furnace companies are no longer truly minimills, although they continue to produce primarily lighter grades of steel, merchant bars, and rods (McManus 1990, p. 19). Electric arc furnaces are expected to account for 50% of U.S. steel production by the year 2000 (CMP 1988).

Foundries produce cast parts but, unlike iron and steel works and mills which may also have foundry operations, they do not manufacture the materials used in the manufacture of castings such as stoves, furnaces, plumbing fixtures, and automobile parts. Many plants classified under other major industry groups have foundry operations.

This section profiles iron and steel mills (SIC 3312), and nonferrous smelting, refining, and foundries (SICs 333 and 336). Iron and steel manufacturing are covered in other Bonneville reports as well (Battelle 1984; and SJO, Shapiro, and Synergic 1984).

3.10.1 Processes

The major processes in metals production are refining, reduction, smelting, melting, casting, forging, heat treating, and finishing (see RDC and BCD 1988, Section 4.1.33). Raw materials, such as iron ore, metallurgical coke, limestone, scrap, and coal, are fed into furnaces in which the metal ores are melted and refined to reduce impurities. Melting or smelting techniques are then used to reduce the purified metals into liquid (molten) metal and cast into molds to produce slabs, billets, and ingots. Smelting is a thermal process in which chemical reactions produce liquid metals from the ore. The solid metal is then worked, with or without heat, to obtain desired properties such as strength, softness, and ductility. Forging is a metal-forming process in which heated metal is formed into desired shapes using compressive force, with or without dies. The metals are then prepared for market by finishing, which can include a variety of surface protection or modification steps such as the application of coatings, heat treating, plating, and polishing. Finishing processes are discussed in more detail in Section 3.11.

Iron and Steel

Steelmaking is the process of removing impurities and adding alloying elements to the pig iron produced in blast furnaces. Figure 3.8 is a process flow diagram for iron and steelmaking. Integrated steelworks with ore-to-metal operations may include mining and quarrying processes as well as coke and iron production (Standard & Poor's 1988). The major processes in the production of steel are ironmaking, steelmaking, casting and semifinishing, reheating, and final finishing (Battelle-Columbus 1986; Burgess 1981; CMP 1988; Webster 1982).

Coke, a mass consisting primarily of carbon, is made by distilling bituminous coals in a coke oven. Coke serves as the primary fuel and an oxygen-reducing agent in the production of iron in a blast furnace. In ironmaking, iron-bearing materials (such as pellets or iron ore sinter), limestone, and coke are first heated in a blast furnace to melt and refine the iron. The molten iron is then cast into pig iron, made into cast iron products, or used in steelmaking operations. Newer direct-reduction techniques produce iron pellets in an electric arc furnace, bypassing the blast furnace processes.

Three basic techniques are used to produce steel ingots or castings from pig iron or scraps: open hearth, basic oxygen, and electric furnace. The open hearth furnace melts the iron or scrap in a direct flame. In the basic oxygen furnace, which is used for the majority of steel production in the United States, iron is blasted with almost pure oxygen to burn off excess carbon and eliminate other impurities. Alloying elements can be added to the basic carbon steel after the molten steel is tapped into the ladle. Ladle refining furnaces are miniature electric furnaces that purify and reheat molten lead. An electric arc furnace can melt scrap or direct-reduced pellets. Alloying elements are added directly to the molten steel in the furnace. The molten steel is then cast in molds to produce ingots. Additional refining may be done in the ladle.

FIGURE 3.8. Integrated Iron and Steel Industry Processes (SIC 3312)

The cast ingots are reheated and shaped into semi-finished products, such as slabs, billets, and blooms, which are then processed through a rolling mill and forge to produce a range of finished products. Continuous casting is a new method that allows the molten steel to be cast directly into unfinished products, bypassing the intermediary steps of ingot casting and reheating. Finally, the steel may be hardened by heat or induction treatment, be annealed, or receive specialized surface treatments such as tin-plating or painting.

Minimills begin with scrap metal that is melted in electric arc furnaces, eliminating the ironmaking processes employed at traditional steel mills (McManus 1990). In the past, electric arc furnaces were used primarily for the production of lower-quality products such as bars, wires, and structural shapes for light construction. Now continuous casting allows minimills to cast thin slab steel that can be made into finished products without the need for the expensive hot strip mills used by larger operations to roll slab into sheet and strip.

Foundries

Foundries, which include jobbing and captive operations, produce metals castings. Foundry processes consist of making molds, preparing and melting the metal, pouring the metal into molds, cleaning the casting, and in the case of sand casting, reclaiming the sand for reuse (Battelle-Columbus 1986b; CMP 1989; Oman 1988). The metals, e.g., scrap iron and steel, recycled copper, aluminum, lead, and zinc, are mixed with flux and refractories, such as clay or silicon, in a furnace. Iron foundries melt pig iron and scrap in a furnace called a cupola. Other melting furnaces include electric arc and induction furnaces. The molten metal is poured into molds made of sand, metal, plaster, or ceramics. In addition to sand casting, modern techniques include die, centrifugal, and electroslog casting, which uses electrodes instead of a furnace to melt the metal. Once the casting has hardened it is separated from the molding materials, cooled, cleaned, and finished.

Nonferrous Smelting

With the exception of gold, platinum, some silver, and minor amounts of copper, all metals exist in nature in the oxidized state (Northern Miner Press

1979). The ore and concentrates from mines and quarries are shipped to smelters, hydrometallurgical works, and refineries for reduction and recovery of the metals from the ore minerals. Smelting is a thermal process that removes the chemical link between the metal and oxidizing impurities.

For example, copper ore is usually concentrated by froth flotation at the mine then shipped to a smelter for reduction and electrolytic refining (see Section 3.3). At the smelter, the concentrates are first roasted to burn off some of the sulfur (Burgess 1981; Dungey 1982; Northern Miner Press 1979). The resulting calcine is mixed with fluxes and fed into a reverberatory furnace (some nonferrous smelters use a blast furnace) to form a copper/iron matte, then sent to a converter where the iron is fully oxidized and mixes with the fluxes to form a slag. The slag, which floats on top of the heavier copper blister, is topped off and returned to the reverb to recover any remaining copper. The copper blister is cast into shapes known as anodes. The anodes are further refined electrolytically either at the smelter or shipped to an electrolytic refinery for purification to commercial specifications.

3.10.2 Equipment

The equipment at iron and steel mills and foundries includes the following: coke ovens, charge buckets, cranes, blast furnaces, electric arc furnaces, basic oxygen furnaces, ladle furnaces, rolling mills, conveyors, annealing furnaces, cupolas, grinders, shakers, and casting and machining equipment.

The equipment used in nonferrous smelting includes the following: multiple hearth roasters, fluid bed roasters, reverberatory furnaces, electric furnaces, converters, and electrolytic refiners.

3.10.3 Energy Requirements

Primary metal industries rank fourth on the Bonneville list in terms of total electricity consumption (see Table 3.3). The industry group as a whole is the second largest industrial user of electricity in the United States (RDC 1990, p. 1.9). The iron and steel industry accounted for more than half of the total energy consumed and more than a third of electricity consumed by the industry group (RDC and BCD 1988, Section 4.1.33). Most electricity consumption is associated with the melting of metals, although increasingly

electricity is being used for other processes such as forging and heat treating. Rolling mills, which produce products of desired dimensions, contain hundreds of electric motors, some as large as 6,000 kilowatts (8,000 horsepower) (CMP 1988).

The majority of Northwest steel works use arc furnaces to melt steel scrap. Because they start with steel scrap, minimills consume much less energy than integrated mills that convert iron ore to iron in blast furnaces before making the steel. Although they reduce the total energy consumed in the manufacture of steel, arc furnaces consume about six times more electricity per ton of steel produced than do conventional furnaces (RDC and BCD 1988, p. 4.1.33.5). However, techniques such as scrap preheating can reduce total power requirements substantially. Mills have reported savings ranging from 35 kWh to 80 kWh per ton of steel produced (McManus 1990, p. 26).

3.10.4 Waste Streams

According to EPA's Toxic Release Inventory, primary metals manufacturers are among the nation's top industrial producers of toxic pollutants discharged into air, land, and water (Abrahamson 1990). Among the most toxic substances generated by the industry group are trace metals, such as copper, manganese, and zinc (D'Innocenzio 1990b). In the Pacific Northwest, metals manufacturing is the largest generator of hazardous wastes, followed by the transportation equipment and chemicals industries (Stokes et al. 1989). Primary and secondary metals together account for almost one-third of the hazardous wastes generated in the region.

Iron and Steel Mills and Foundries

The major atmospheric waste streams from iron and steel manufacture are stack gases and dusts (EPA 1976, Vol. III.) Coke ovens are major producers of airborne toxics. Electric arc furnace (EAF) dust, containing zinc, lead, chromium, cadmium, mercury, and other pollutants produced when nonferrous metals volatilize off the molten steel, is classified as hazardous (Dawson 1989). Lead and zinc are of particular concern. New waste disposal systems for arc furnace dust recycle the waste oxides back into the arc furnace (McManus 1990).

The major wastewater sources in electric arc furnace operations are non-contact cooling water and the fume collection cooling scrubbing system (EPA 1980, Chapter 6; SJO, Shapiro, and Synergic 1984, p. F.43). Pickle liquors generated by steel finishing operations--solid sludges and wastewaters containing acids, oil and grease, chromium, nickel and lead--are also classified as hazardous (Dawson 1989).

Proposed amendments to RCRA would classify scrap metals containing significant quantities of metals such as cadmium and lead as hazardous (D'Innocenzio 1990a).

Foundries are major consumers of waste materials including metal scrap and manufacturing residues such as asphalts, sugars, and cellulose (Oman 1988). Foundry wastes include spent refractories, slag, bottom drop, and sweepings from cupola operation, and either baghouse dust or wet sludge. Wastewater sources are noncontact cooling systems and water used in air pollution scrubbing systems.

Nonferrous Smelting

Base metal smelters and refineries produce sulphur dioxide gas from sulfide ores, some of which is recovered and converted to sulfuric acid; the rest is discharged into the atmosphere. For example, in copper smelting the flu gases from roasters, sintering plants, blast furnaces, reverberatory furnaces, and converters are generally passed through electrostatic converters to recover particulate dusts, which may be processed further to recover metals. New technologies are being developed to permit environmentally cleaner processing of metals such as lead and zinc (Parkinson 1990).

A great deal of water is used in refining processes, in gas scrubbers, and purification cycles of electrolytes, which may generate wastewater containing heavy metals.

3.10.5 Occupational Hazards

Coke oven workers are exposed to a variety of particulates, gases, and vapors including known carcinogens such as benzo(a)pyrene, benzo-fluoranthene and chrysene (Burgess 1981, pp. 194-205; Webster 1982). The cancer mortality rate for coke oven workers is greater than expected. The volatile byproducts

of coke production are piped to a chemical plant for separation and treatment. Processing these chemicals may pose additional risks, particularly where the chemicals are removed from the system and during maintenance, but risks are primarily associated with leaks and accidents. Because the chemicals are extremely hot when leaving the coke oven, they may pose burn hazards.

Carbon monoxide, produced by the reaction between burning coke and iron oxide, is a major hazard in all areas of blast furnace operation, as are heat and noise. Workers may also be exposed to metal fumes, free silica, sulfur dioxide, and radiation from capsules used to monitor blast furnace operations. Lime used in the basic oxygen furnace may cause eye and skin irritation.

The major occupational hazard associated with melting scrap iron and steel in electric arc furnaces is exposure to iron oxide dust (SJO, Shapiro, and Synergic 1984, pp. C.15-C.17). Scrap metals, particularly scrap imported from other countries, may be contaminated with radiation, creating an additional hazard. Electric arc furnaces generate high levels of noise.

Sintering plants may be extremely dusty and have significant noise levels. Fumes and heat stress may be a problem during steelmaking processes and in final mill operations. The production of specialty products may allow additional exposures, for example to lead, chromium, and fluorides. Welding, plating, and painting operations are common processes in steelmaking plants that may expose workers to a variety of chemical and physical hazards, including dust and fumes of metals, abrasives, solvents, and fluxes. Melting, welding, and flame cutting may expose workers to eye and skin damage from infrared and ultraviolet radiation. Welding and electrical arcs may also generate ozone, a respiratory irritant. Other hazards associated with finishing operations are discussed in Section 3.11.

Sand casting can put foundry workers at increased risk for respiratory disorders, including silicosis and lung cancer (NIOSH 1986). Other chemical hazards include phenolic, urethane, epoxy and furan resins, core oils, and acid catalysts used in mold making. Chemicals in these materials include formaldehyde, ammonia, alcohols, phenols, phosphoric and sulfuric acid, and isocyanates. Partially cured resins can be sensitizers, resulting in skin or asthmatic reactions. Acrolein vapors from core oils can cause eye, skin, and

respiratory irritation. Foundry workers may also be exposed to high levels of heat, noise, vibration, and nonionizing radiation.

The major occupational exposures from nonferrous smelting, such as copper, are to sulfur dioxide and metal fumes, carbon monoxide from combustion processes, silica and metal dusts, which may include traces of arsenic and lead, heat, and noise (Burgess 1981, pp. 238-243; Dungey 1982). Electrolytic refining can expose workers to acids, solvents, arsine (a deadly gas), and high noise levels.

3.11 METALS FABRICATION AND FINISHING (SICs 34, 36, and 37)

Metals fabrication and finishing encompasses three major industry groups: fabricated metal products (SIC 34); electronics and electrical equipment (SIC 36); and transportation equipment (SIC 37). This grouping was common in the literature surveyed and is used by EPRI in its technical reports (e.g., RDC and BCD 1988). A wide variety of products is made by these industries, ranging from tin cans to aircraft engines, to televisions and household appliances. The materials and parts utilized come in a variety of shapes, sizes, and surfaces. The manufacture of some products requires the application of motive power; for others, a combination of chemicals and electricity is required.

The fabricated metal products industry group (SIC 34) produces metal cans for the industrial and commercial markets, general components for the automotive and other heavy equipment industries, and fabricated structural metal for the construction market. Unit metal finishing operations, such as electroplating, etching, and coating, are classified in this major group, regardless of the nature of the finished product (SICs 3471 and 3479). The electrical and electronic equipment industry group (SIC 36) produces a range of equipment and devices including household appliances, communications equipment, and electronic components. The transportation equipment industry group (SIC 37) produces transportation vehicles--consumer, commercial, and military--and the parts to maintain them.

On the Bonneville list are representatives of the fabricated metal products, electrical and electronic equipment, and transportation equipment industry groups. However, not all of the plants could be identified. This

section discusses common processes in the metal fabrication industries and profiles the electronic components (SIC 367) and aircraft manufacture (SIC 372) subgroups. Only aircraft assembly (SIC 3721) has been profiled in other Bonneville reports (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984).

3.11.1 Processes

Despite the wide range of products manufactured, these industries share many common production processes, including primary fabrication and machining processes and surface finishing and coating operations (Hunt 1988; RDC and BCD 1988, Ch. 5). Fabrication encompasses those primary processes involved in transforming a metal part to a final metal product. There are four basic methods of manufacturing metal components: casting, machining, joining, and deformation processes (Amstead, Ostewald, and Begeman 1987).

- Casting involves melting metals and pouring the molten metal into molds (see Section 3.10 on primary metals).
- Machining or metal cutting techniques include shaping, planing, milling, facing, broaching, grinding, sawing, boring, and drilling.
- Joining techniques include welding, brazing, powder metallurgy, and the use of mechanical fasteners and epoxies.
- Forging is the plastic deformation of metals into desired shapes and sizes by impact, pressure, or a combination of the two. Common forming techniques are rolling, stamping, and extrusion.

Many fabricated materials, components, or products are not suitable for final use and require further treatment. Finishing consists of a variety of surface protection or modification steps that produce specific characteristics such as corrosion resistance, absorptivity, and ductility (RDC and BCD 1988, Ch. 5). These processes may employ mechanical, electromechanical, and chemical methods. In general all finishing processes can be divided into three stages: 1) cleaning, preparation and/or pretreatment; 2) surface modification, coating deposition, or coating removal; and 3) post-treatment (Battelle-Columbus 1986b).

Parts fabrication may include various processes that are categorized as finishing techniques such as heat treating and coating. Similarly, finishing

processes may employ various fabrication techniques. Some of the most common finishing processes employed in the six industry groups are heat treating, electroplating, surface cleaning, machining, and coating (Hunt 1988).

- Heat treating methods are used to improve the strength, impact resistance, hardness, durability, and heat and corrosion resistance of metal alloys. In the most common procedures, metals are hardened by heating to high temperatures and then cooled rapidly. This may take place in air, in atmosphere furnaces, or in immersion baths.
- Electroplating involves the application of a thin metal coating of one metal upon another by electrodeposition. Parts are plated to prevent rust and corrosion, to enhance appearance or electrical properties, and to improve wearability. Common plating metals are brass, bronze, cadmium, chromium, copper, iron, lead, nickel, tin, and zinc. Precious metals such as gold, silver, and platinum are also widely used. Electroplating usually involves a number of process baths followed by rinse tanks. After plating, a part may undergo a series of post-treatments such as conversion coating. Prior to electroplating, parts may be cleaned and treated.
- Surface cleaning involves the removal of oil, grease, and dirt from the metal parts. A range of process solutions may be used including alkaline, acid, and solvent solutions. Alkaline cleaners are used in soak, spray, or electrolytic applications; acid cleaners are usually used in dip or soak processes; and solvents are used either as liquids or vapors. Rinse tanks may be used after each cleaning step. Abrasive blasting may be used to remove rust or surface coatings in preparation for further finishing.
- Machining is the process of removing stock from a metal workpiece by a cutting tool or abrasive material. A fluid is used to cool and lubricate the workpiece during the removal process. Machining may include turning, grinding, milling, drilling, firing, broaching, sawing, and shaping.
- Coatings, including paint, varnish, lacquer, and plastic, are applied by spraying, dipping, brushing, powder and roll coating. Spray painting is the most common coating application technique.

Electronic Components (SIC 367)

Common processes in electronic component manufacture are machining, metal forming, electrochemical operations, painting and coating, plastic thermoforming, cleaning, and drying (Foecke 1988). Figure 3.9 gives flow diagrams for printed circuit board (SIC 3672) and semiconductor manufacture (SIC 3674).

FIGURE 3.9. Process Flow for Printed Circuit Board (SIC 3672) and Semiconductor Manufacture (SIC 3674)

Printed circuit board manufacture begins by drilling holes in the fiberglass or plastic boards, which are laminated with copper foil, to provide points of attachment for components and the electrical pathways that make up the circuit. The boards are then plated with copper to create a continuous metal surface. Photolithography is used to create an image of the required circuitry on the boards. Solder plating is used to further refine the circuits. The photoresist is stripped and the exposed copper is etched, revealing the final circuitry. In some cases further solder plating and reflowing of the deposit is required.

Semiconductor manufacture (SIC 3674) begins with the fabrication of crystalline base materials, primarily silicon. The crystals are grown into an "ingot," which is sliced into wafers, polished, and cleaned with solvents. The wafers are then processed to form semiconductor devices. The wafer is oxidized, cleaned, and coated with a photoresist. The exposed portions of the wafer are then etched and doped with impurities, which modifies the electrical properties of the surface. The resist layer is stripped and the devices on the wafer are interconnected using metallization processes such as evaporation, vapor deposition, or sputtering. This sequence may be repeated several times to build up layers of circuitry. The individual chips are sliced from the wafer for use.

Aircraft Manufacture (SIC 372)

The manufacture of aircraft parts and subassemblies entails many common fabrication and finishing techniques, including machining, degreasing, electroplating, joining, and painting (Boeing 1989; Evanoff 1990). Figure 3.10 is a process flow diagram for aircraft assembly. Alloys and other materials must be degreased prior to surface finishing. Surface finishing, including chemical milling, etching, deoxidizing, and plating, is the largest operation in aircraft production. For example, chemical milling is used to remove aluminum from the metal surface and small steel parts are plated with various metals. Parts are then painted and preassembly and subassembly parts are cleaned prior to and during adhesive bonding or rivetting of parts. Subassemblies are painted in spray booths.

FIGURE 3.10. Process Flow for Aircraft Assembly (SIC 3721)

At aircraft assembly facilities, parts and subassemblies for the various aircraft models are riveted, glued, and welded prior to installation of wiring, plumbing, and control systems (Battelle 1984; Bechtel 1984; SJO, Shapiro, and Synergic 1984). Final assembly includes the closing up of parts by riveting and finishing. The aircraft is then spray painted, inspected, tested, and delivered.

3.11.2 Equipment

Metal fabrication and finishing equipment includes the following: furnaces, dryers, hammers, lathes, presses, drills, grinders, saws, welding gear, dies, stamps, molds, rolling mills, electrodeposition equipment, process tanks, rinse tanks, boilers, compressors, and conveyors.

Electronic components equipment includes the following: crucibles, saws, polishers, diffusion furnaces, dryers, epitaxial reactors, metallization equipment, and microscopes, as well as all the equipment listed above for metal fabrication and finishing.

Aircraft manufacture equipment includes the following: cutters, dryers, machining equipment, paint guns and sprayers, riveters, and welders, as well as all the equipment listed above for electronic component manufacture.

3.11.3 Energy Requirements

The metal fabrication and finishing industries rank sixth on the Bonneville list in terms of total electricity consumption (see Table 3.3.). Nationwide, these industries are not major energy consumers compared to other manufacturing sectors (RDC and BCD 1988). Electricity intensity for these industries is generally low. Primary fabrication processes that require heating, such as forging, bar drawing, and extrusion, are energy intensive, others are not. The energy required varies across individual finishing operations. For example, chromium plating is the most energy intensive electroplating process (Battelle-Columbus 1986b, p. 3.7).

Natural gas accounts for one-third of energy consumed by the fabricated metal products industries (SIC 34). Electricity is primarily associated with motor drives and process heating, including heating, heat treating, forming, and welding. Little melting is conducted by these industries.

Electricity accounts for nearly 40% of energy consumed by the electrical and electronic equipment industries (SIC 36). Electronic components and accessories dominate the other industry subgroups in terms of electricity consumption. Process heating that relies primarily on electricity includes melting and refining, curing of coatings, and sealing operations.

The transportation equipment (SIC 37) industries rely primarily on fossil fuels, which are used for the more heat-intensive operations. Electricity is used primarily for assembling processes.

3.11.4 Waste Streams

Metal finishing operations generate a variety of waste streams, many of which include toxic and hazardous pollutants (EPA 1980, Ch. 4; Hunt 1988; Nunno and Freeman 1987). Metal wastes come in the form of dusts, sweepings, scrap, and "drag out" (excess process material) in rinses and spent baths. Air emissions include fugitive releases of process chemicals and combustion products associated with space and process heating.

Most wastewaters from metal finishing operations are generated by rinsing between various process baths, which include plating baths, acid and alkaline cleaners, and post-treatment baths. Rinse waters may contain dilute concentrations of metals, oils, solvents, cyanide, and other process chemicals. Other sources of wastewater include dumps of process solutions, scrubber water, paint booth wastewater, spills, leaks, and cleanup wastes.

Oils are used widely in metal fabrication and finishing operations as metal-working fluids, lubricants, hydraulic fluids, and quenching oils. These oils may contain a variety of additives, including halogenated compounds, in addition to the basic petrochemical constituents, many of which are toxic.

Organic solvents--aliphatic hydrocarbons, halogenated hydrocarbons, and alcohols--are used in degreasing and cleaning operations to remove foreign substances from metal surfaces. Solvents such as xylene, toluene, methyl ethyl ketone, and acetone are also widely used in painting and stripping operations. Spent process solvents are a major source of wastes.

Electroplating and painting sludges, degreasing solvents, and corrosive wastes are classified as hazardous under RCRA (Stokes et al. 1989). Metals,

corrosives, ignitable wastes, and electroplating sludges are the four largest categories of federally regulated hazardous wastes in the Pacific Northwest. Oily wastes and paint booth sludges, which are classified as hazardous by the state of Washington, belong to the group of substances that make up the largest component of the region's hazardous wastes.

Electronic Components

The electronic components industries are major consumers of toxic and hazardous substances, including solvent chlorofluorocarbon (CFC 113) and methyl chloroform, which are both "greenhouse" gases (Hayes 1990). Halon is widely used by the industry for fire extinguishers. Chromate solvents are used to clean circuit boards after drilling. CFC solvents are used to clean printed circuit boards after fabrication and assembly. Vapor-phase soldering, which is used to mount components, can emit toxic vapors. Vapor degreasing operations can also produce toxic vapors. The industry also uses corrosive acids and toxic gases, such as arsine and phosphine.

Electronic components manufacturers have been responsible for creating numerous Superfund cleanup sites due to groundwater contamination by leaking underground storage tanks (LaDou 1984, p. 34; Geiser 1986). According to a study done for the EPA, of all the industry subsectors, semiconductor manufacture presents the greatest potential for impacts on the environment because of the organic and inorganic pollutants generated in the processes and the large volume of wastewater generated (Burckle and Corwin 1983, p. 2). Printed circuit board manufacture is a distant second in terms of potential impacts.

Aircraft Manufacture

The transportation equipment industry is the third largest generator of hazardous wastes in the Pacific Northwest, after metals and followed by chemicals (Stokes et al. 1989). The aerospace industry, which constitutes the majority of transportation equipment manufacturing in the region, generates a variety of air emissions and hazardous liquids and solids during the processing of aluminum, titanium, composites, and other materials into aircraft and system components (Evanoff 1990). Of particular concern is the industry's use of chlorofluorocarbons (CFCs) and organic solvents and its high

production of chromium-containing wastes. In response to increasing government regulation, companies such as Boeing have made reductions in the use and emissions of these chemicals a major corporate goal (Boeing 1989).

The majority of the waste streams are associated with parts manufacture and subassembly processes, particularly machining, plating, coating, painting, and stripping operations. For example, CFCs are used in vapor-degreasing operations, and as drilling coolants and mold-releasing agents. Solvents are used extensively in cleaning, painting, and electronics manufacturing. Plant maintenance, particularly plant washdown, can generate additional wastes. Very little wastewater or solid waste is generated by assembly operations (SJO, Shapiro, and Synergic 1984, p. 47). However, washing the airplanes generates large volumes of water containing phenols (Bechtel 1984, p. 5.59).

3.11.5 Occupational Hazards

Many finishing processes expose workers to chemical hazards, such as metal fumes and mists, and organic vapors and mists from process baths, paints, solvents, and thinners. The chemicals may be irritants or sensitizers, and may be toxic. As is discussed under primary metals (see Section 3.10.5), some metal dusts may be toxic and exposure even to non-toxic metal fumes can result in "metal fume fever." The potential chemical hazards in electroplating and coating operations are numerous and workers in these industries have shown an excess mortality rate for cancers of the esophagus and larynx (Burgess 1981, p. 33). Of particular concern is exposure to cyanide compounds and chromic acid mists which can cause respiratory irritation and cancer (Levy and Wegman 1988, p. 329). Solvents used in degreasing can cause skin irritation and defatting. Vapor degreasing can expose workers to toxic gases such as phosgene and chlorine (Levy and Wegman 1988, p. 89; Burgess 1981, pp. 20-33).

Coolants and cutting fluids used in machining operations can cause skin and respiratory irritation (Burgess 1981, pp. 86-95). Exposure to lubricating and cutting oil mists has been associated with increased cancer risks (Burgess 1981, p. 89). In addition to cuts, burns, electrical shock, and explosion hazards, welding and other cutting techniques may expose workers to intense visible and ultraviolet light, which may cause eye injuries (OTA 1985, pp.

109-113). Welding and brazing can expose workers to metal fumes and gases, such as ozone and oxides of nitrogen. Heat stress and noise can be significant hazards associated with heat treating, forging, and some machining operations. The use of furnaces can expose workers to carbon monoxide and other combustion gases.

Electronic Components

Electronics production and maintenance workers are exposed to numerous potential hazards including carcinogens, toxic metals and gases, and microwave and other nonionizing radiation (Geiser 1986; LaDou 1984; NIOSH 1987b). According to the Santa Clara Center for Occupational Safety and Health (SCCOSH), the scientific instruments (SIC 38) and electrical equipment (SIC 36) manufacturing industries rank first and third among industries most likely to expose workers to carcinogens.^(a) The incidence of occupational illness among semiconductor production workers is three times the national rate for all manufacturing workers (Geiser 1986, p. 108). Known or suspected carcinogens commonly used in electronics processes include arsenic, benzene, cadmium, carbon tetrachloride, and trichloroethylene (TCE).

Safety hazards include electric shock, and acid and thermal burns. Component assemblers are at high risk for developing carpal tunnel syndrome and other repetitive motion disorders (OTA 1985, p. 127). There is some evidence that microelectronics workers have a high incidence of respiratory disease caused by inhaling multiple toxic chemicals, fumes, and dusts (Ruffenach 1988). Studies of women microelectronics assembly workers suggest an association between exposure to solvents and an increased rate of spontaneous abortions (Huel, Mergler, and Bowler 1990).

Aircraft Manufacture

Workers involved in aircraft parts manufacture and subassembly can be exposed to all of the hazards involved in metal fabrication and finishing operations. Exposure to chromium has been a particular problem for workers. Degreasing and painting operations may cause skin irritation and defatting

(a) "Information Sheet on Electronics Industry Hazards," dated January 1981. Distributed by the Santa Clara Center for Occupational Safety and Health, San Jose, California.

from contact with solvents and thinners. The primary contaminants to which workers are exposed during final aircraft assembly are epoxies used in primers and isocyanates used in polyurethane finishes (SJO, Shapiro, and Synergic 1984, p. C-19). As is true for electronic component assemblers, aircraft assemblers are at high risk for developing carpal tunnel syndrome and other repetitive motion disorders (OTA 1985, p. 127).

4.0 INDUSTRIAL HAZARDS AND HEALTH EFFECTS

This chapter discusses common industrial hazards and the health effects associated with them. It provides background information to aid Bonneville in assessing the occupational health and safety impacts associated with the energy conservation measures discussed in Chapter 2 and the industrial processes discussed in Chapter 3.^(a) The first section gives an overview of the types of injuries and illnesses commonly found in industrial settings, including definitions and selected statistics. Sections 4.2, 4.3, and 4.4 are concerned with industrial hygiene and toxicology, including safety hazards and the health hazards associated with common workplace contaminants and physical agents. Section 4.5 discusses hazards associated specifically with materials used in the manufacture or operation of energy conservation measures from Chapter 2. These sections give exposure limits, when they exist, for the health hazards discussed.

4.1 OCCUPATIONAL INJURIES AND ILLNESSES

The primary public sources of national data on occupational injuries and illness is the Survey of Occupation Injuries and Illnesses conducted by the U.S. Department of Labor's Bureau of Labor Statistics (BLS) and individual state statistics on workers' compensation claims. An occupational injury is defined by BLS as any injury that results from a work-related accident or from exposure involving a sudden event in the work environment (BLS 1990, p. 1). An occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment (BLS 1990, p. 3). Included are acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact.

(a) This chapter does not provide in-depth discussion of control techniques for industrial hazards.

National and regional statistics on occupational injuries and illnesses are reported in Appendix C.^(a) These data are based on sampled surveys of employers and state records of compensation claims, thus they are not comprehensive. Occupational illnesses, which are often unrecognized or unreported, are underrepresented in these statistics.

4.1.1 Injuries

According to workers' compensation claims data, the most common type of injuries are sprains and strains; cuts, lacerations, and punctures; contusions and bruises; and amputations.^(b) The most commonly affected body parts are the back/trunk, hands and fingers. Overexertion is responsible for the majority of sprains and strains (which primarily affect backs). "Struck by" and "struck against" accidents account for most of the cuts, lacerations, punctures, cuts, and bruises.^(c) A large number of striking accidents involve hand and finger injuries. Common sources of injury are body motion, working surfaces (e.g., floors and steps), boxes and other containers, tools, machines, metal items (e.g., structural metal and fasteners), and vehicles. Motor vehicle accidents, striking accidents, falls, and electrocutions account for most work-related fatalities.

4.1.2 Illnesses

The most commonly reported diseases according to BLS and workers' compensation data are disorders associated with repeated trauma (conditions due to repeated motion, pressure, or vibration, e.g., carpal tunnel syndrome), which account for 48% of illnesses reported nationwide, followed by skin diseases and conditions, which account for 24% of total illnesses (BLS 1990). These proportions are reflected in state statistics. However, occupational

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- (a) Data were available for three of the four states in the Bonneville service area: Montana, Oregon, and Washington. Data for Idaho were unavailable.
 - (b) Extracted from the annual workers' compensation claims reports for Montana (1989), Oregon (1988), and Washington (1988) (MDLI 1989; ODIF 1990b; WDLI 1988b).
 - (c) The ANSI classification scheme for types of accidents is used for reporting accident data. This classification is described in Appendix C.

illnesses tend to be unrecognized, underreported, and, in many cases, are incompensable. Because some diseases manifest themselves weeks or years after occupational exposures, they may not show up in this data, which is heavily weighted toward immediate, visible effects such as skin irritations.

According to NIOSH, the 10 leading types of occupational injuries and diseases are occupational lung disease; musculoskeletal injuries; occupational cancers, other than lung; amputations, fractures, eye loss, lacerations, and traumatic deaths; cardiovascular diseases; disorders of reproduction; neurotoxic disorders; noise-induced loss of hearing; dermatologic conditions; and psychologic disorders (OTA 1985, p. 43). The NIOSH list incorporates epidemiological and other data sources not reflected in the BLS data. The remainder of this section gives a brief overview of the most common occupational disorders and diseases. Sections 4.4 and 4.5 discuss particular contaminants and physical agents associated with these diseases.

Cancer

An Office of Technology Assessment (OTA) list of "some" occupational cancer hazards includes 27 chemicals, and ionizing and ultraviolet radiation (OTA 1985, pp. 46-47). Table 4.1 lists occupational carcinogens for which evidence of human carcinogenicity is considered sufficient. There is considerable debate over the portion of overall cancers that are occupationally related (Letz 1988, pp. 40-41). The issue is complicated by a number of factors, including the long latency period for most cancers; the confounding effects of multiple work-place exposures and other health-related variables such as cigarette smoking; the lack of data on individual workers over their work life; and the lack of epidemiological studies for many contaminants. Furthermore, there is considerable debate over permissible occupational exposure levels for known or suspected carcinogens, even though carcinogens are thought to be non-threshold substances, to which no exposure can be presumed not to carry some risk of adverse effect (Stenner and Baechler 1990, Vol. 1, p. 2.3).

TABLE 4.1. Industrial Agents or Processes Associated with Cancer in Humans^(a)

Agent or Process	Cancer Type
4-Aminobiphenyl	Bladder
Arsenic and Trioxide compounds	Skin; lung, angiosarcoma, liver
Asbestos	Lung, mesothelioma, larynx, G.I.
Auramine (base yellow 2)	Bladder
Benzene	Leukemia (acute nonlymphocytic)
Benzidine	Bladder
Bis (Chloromethyl) ether (BCME) and chloromethyl ether	Lung
Chromium and compounds	Lung; nasal sinuses
Coke oven emissions	Skin; lung, urinary tract
Hematite underground mining	Lung
Isopropyl alcohol manufacture	Lung; larynx, paranasal sinuses
Mustard gas	Lung
β -Naphthylamine	Bladder
Nickle and compounds, nickle refining	Lung; nasal passages, larynx
Soots, tars, and mineral oils	Skin; lung, bladder, G.I.
Vinyl chloride	Liver (angiosarcoma); lung; brain
Boot and shoe manufacture	Nasal sinuses, lung, bladder, leukemia
Furniture manufacture	Nasal sinuses
Rubber manufacture	Multiple sites

(a) Based on classification by the International Agency for Research on Cancer (IARC) as carcinogenic to humans with sufficient epidemiologic evidence (Group 1) and by the National Toxicology Program (NTP) as known to be carcinogenic with evidence from human studies (Group a).
GI = gastrointestinal system.
Source: Letz (1988, p.41).

Thus, many contaminants and physical agents that are classified by EPA^(a) or even NIOSH as probable or potential carcinogens are not classified as occupational carcinogens by groups such as the International Agency for

(a) The Carcinogen Assessment Group (CAG) of the Office of Health Environmental Assessment in EPA's Research and Development Office lists chemical substances for which substantial or strong evidence exists indicating that exposure to these chemicals, under certain conditions, causes cancer in humans, or can cause cancer in animal species, which, in turn, makes them potentially carcinogenic in humans.

Research on Cancer (IARC) or regulated by the Occupational Safety and Health Administration (OSHA) as occupational carcinogens.^(a) Attempts to develop comprehensive "generic" regulation of occupational carcinogens at the federal level have not been successful (Epstein 1990, p. 57). The effects of exposure to specific contaminants are discussed in Section 4.4.

Cardiovascular Disorders

With the exception of sedentary versus physically active work, the occupational factors associated with increased risks of cardiovascular disorders are not well-known (Letz 1988, pp. 37-39). However, exposure to certain chemicals, e.g., carbon disulfide and carbon monoxide, is known to cause adverse cardiovascular effects such as hypertension and arrhythmias or to aggravate existing cardiovascular conditions. The effects of exposure to specific contaminants are discussed in Section 4.4.

Neurologic Disorders

Various metals and organic compounds are neurotoxins, causing physical and behavioral disorders (Baker 1988b, pp. 399-413; OTA 1985, p. 49). Lead and mercury are well-known occupational neurotoxins, as are organic solvents and some insecticides. Physical effects range from intoxication and impaired motor performance, which may be reversible, to permanent damage to the peripheral nerves and the brain. In many cases, effects can be subtle and nonspecific: symptoms may include slow response time, impaired hand-eye coordination, irritability, lack of concentration, continual emotional instability, and impaired short-term memory. In addition to being health hazards, by impairing motor and cognitive abilities, neurotoxin may increase the risk of workplace accidents. The effects of exposure to specific contaminants are discussed in Section 4.4.

Repetitive Motion Disorders

Repetitive motion disorders are a type of cumulative trauma associated with repeated, often forceful movements, usually involving the wrist or elbow

(a) For example, the Oregon Occupational Safety and Health Code section on carcinogens only lists 14 chemicals (OAR 437, Division 116). These substances are regulated in Subsections 19.1001 through 19.1101 of the federal OSHA Safety and Health Standards (29 CFR Part 1910).

(OTA 1985, p. 127-132). Workers on assembly lines and in other jobs that require repetitive strain-producing motions are at increased risk of developing such disorders. Carpal tunnel syndrome is a progressively disabling and painful condition of the hand caused by repeatedly flexing the wrist or applying wrist-finger force. Occupations and activities associated with carpal tunnel syndrome and other repetitive motion disorders are aircraft assembly, coke making, electronic assembly, meat processing, metal fabricating, and packaging (OTA 1985, p. 127). Repetitive motion, together with prolonged periods of work without breaks and poor working positions, contributes to the numerous back, neck, and shoulder complaints, and eyestrain, associated with video display terminal (VDT) operation (OTA 1985 pp. 135-139).

Methods for reducing the incidence of repetitive motion disorders include redesigning work stations, equipment, and hand tools. These measures can significantly reduce the awkward, forceful movements common to many jobs on assembly lines and in office work. Redesign of the work place and work stations may relieve many of the musculoskeletal and visual problems associated with VDT use.

Reproductive Disorders

Reproductive hazards may effect reproductive organs or the endocrine system, causing changes in fertility and sexual behavior in both exposed males and females, and affecting pregnancy outcomes (OTA 1985, p. 49). Depending on the hazard, exposure of either parent prior to conception, or exposure of the mother during pregnancy, can result in fetal damage and developmental effects.

Occupationally related reproductive disorders are not as well studied as other types of health effects (Hatch and Stein 1988). Dibromochloropropane (DBCP), a pesticide, has been shown to cause sterility in male workers. Some substances are known to be reproductive toxins, for example certain organic solvents and lead, but their effects have not been comprehensively studied in work-place settings. For example, lead is known to cause reproductive effects in women, including menstrual disorders, sterility, miscarriages, and stillbirths. However, in most cases reproductive effects are only suspected and their connection with occupational settings has not been established

(Hatch and Stein 1988, pp. 426-429). Suspected reproductive hazards include heavy metals, halogenated hydrocarbons such as PCBs, nonionizing radiation, and certain pharmaceuticals. The effects of exposure to specific contaminants are discussed in Section 4.4.

Exposure to nonionizing radiation, particularly power frequency fields (60 Hertz), has been suspected of causing reproductive effects (see Section 4.5.6). There has been concern over the potential effects on pregnant women of use of VDTs. However, to date, the evidence linking VDT operation with spontaneous abortion or congenital birth defects is not conclusive (McDonald et al. 1987).

Respiratory Disorders

Most occupational exposures to toxins are through inhalation of airborne contaminants, however, not all toxics cause respiratory effects. Those contaminants primarily associated with respiratory disorders include irritant gases (e.g., ammonia and nitrogen dioxide), dusts and fibers (e.g., asbestos and silica), and metal fumes and fluxes. Job-related respiratory disorders include irritation of the nose, throat, and lungs; allergic and immunologic responses; occupational asthma; fluid in the lungs; pneumonia and other diseases such as obstructive pulmonary disease; and cancers. Existing respiratory conditions may be aggravated by work-place exposures.

Many of the best-known and most severe occupational lung diseases are caused by occupational exposures to fibers and dusts, such as asbestos, cotton, and silica fibers, and coal dust. However, an increasing number of chemicals, for example, arsenic and chromate compounds, are being associated with respiratory disorders and lung diseases such as cancer (Proctor, Hughes, and Fischman 1988, Table 2.2). There is some evidence that chronic exposures to multiple chemicals in occupations such as microelectronics manufacturing is increasing the incidence of respiratory disorders and disease (Ruffenach 1988). The effects of exposure to specific contaminants are discussed in Section 4.3.

Skin Diseases

Various chemical, physical, and biological agents, and plant substances are known to cause occupationally related skin disorders (Arndt and Bigby

1988; OTA 1985, pp. 49-52). Those industries whose workers are at highest risk for occupational skin diseases include poultry dressing, meat packing, metal plating and polishing, frozen fruit and vegetable processing, and chemicals manufacturing (OTA 1985, p. 52). Skin irritations are largely reversible; 90% of all occupational skin dermatoses are contact dermatitis, including allergic responses (OTA 1985). Dermatitis simply means skin inflammation and applies to conditions such as redness, itchiness, blisters, and thickening, hardening, or flaking of the skin. More serious effects include defatting, caused by solvents for example, pigment disorders, and skin cancer. Absorption through the skin can cause permanent neurological, reproductive, and developmental damage and cancers. For substances with low volatility that can be absorbed through the skin, the skin can be the primary route of entry into the body. The effects of exposure to specific contaminants are discussed in Section 4.3.

Occupational Stress

Unlike most occupational hazards, which are usually task-specific, stress is associated with all work to some extent (Baker 1988a). The incidence of stress-related disorders is large and growing, as is the number of workers' compensation claims associated with job-related stress (Baker 1988a, p. 297). The health effects of stress are wide ranging and can be severe. Stress may contribute to the development of heart and cerebrovascular disease, hypertension, musculoskeletal disorders, and gastrointestinal ulcers and disease (Baker 1988a, p. 297). Stress may suppress the immune system and possibly contribute to the development of cancer. Stress is associated with anxiety, depression, neuroses, and alcohol and drug abuse.

Occupational stress may be mental or physical or a combination of both. Definitions of occupational stress vary widely, and may distinguish between types of stress, for example, environmental, musculoskeletal, psychomotor, perceptual, cognitive, and psychosocial stress (Ostberg 1987). There is some indication that job-related stress is shifting from environmental and physical to cognitive and emotional forms due to the combination of "quantitative overload with qualitative overload and lack of control" (Ostberg 1987, p. 17; Baker 1988a, p. 303). These attributes are increasingly common in industrial assembly lines and office environments and are associated with factors such as

excessive work loads, environmental pressure, repetitive work flow, and narrow job demands. Automation, through computer-controlled systems, alleviates physical fatigue but may increase monotony, alienation, and stress.

4.2 INDUSTRIAL SAFETY HAZARDS

The industrial hygiene field divides occupational hazards and effects into two types: health and safety. Health hazards cause diseases and other disorders that may not manifest themselves immediately following exposure to an occupational hazard. Safety hazards result in immediate trauma injuries such as lacerations, burns, and electrocution (Keyserling 1988) and are regulated separately by agencies such as OSHA^(a). These injuries usually are immediately apparent and can be directly linked to a well-defined accident or event. In some cases, safety hazards may result in cumulative trauma, such as chronic back pain and tendinitis. However, cumulative trauma disorders such as carpal tunnel syndrome are classified as occupational illnesses rather than as injuries. Table 4.2 describes common examples of trauma and their sources.

Safety hazards are generally associated with equipment, machinery, and physical plant features. Control of these hazards includes proper workplace design, regular maintenance, good lighting, properly designed equipment, etc. Safety hazards are only briefly discussed in this report because, with few exceptions, they are not impacted (caused, bettered or worsened) by the energy conservation measures discussed in Chapter 2.^(b) It should be noted that in addition to the health effects discussed in the next sections, many workplace contaminants pose fire and explosion hazards and may contribute to the risk of accident by debilitating or incapacitating workers.

(a) See OSHA Safety and Health Standards: 29 CFR Parts 1910.20 to 1910.999.

(b) When ECMs do impact safety, the relevant facts are discussed in the "Potential Environmental Effects" sections in Chapter 2. Safety hazards associated with specific industrial processes are discussed in the appropriate "Occupational Hazards" section of Chapter 4.

TABLE 4.2. Overt and Cumulative Trauma Associated with Work-Place Hazards

<u>Cause</u>	<u>Injury or Disorder</u>
Overt Trauma:	
Mechanical Energy	Lacerations, fractures, contusions, amputations, crushing injuries, eye injuries (struck by foreign objects), strains or sprains (overt)
Thermal energy	Burns, heat strain, cold strain
Chemical energy	Burns, asphyxiation, acute toxicity
Electrical energy	Electrocution, shocks, burns
Nuclear energy	Radiations burns, illness
Cumulative Trauma:	
Heavy lifting, prolonged sitting, awkward posture	Back pain
Frequent or repetitive forceful hand motions with awkward posture	Upper extremity cumulative trauma disorders (tendinitis, carpal tunnel syndrome, epicondylitis, degenerative joint disease)
Vibration	Raynaud's syndrome

Source: Keyserling (1988, p. 106)

4.3 INDUSTRIAL HEALTH HAZARDS

There are two basic types of industrial health hazards: contaminants (such as metals, dusts and fibers, and chemicals) and physical agents (such as noise, vibration, nonionizing radiation, and temperature extremes). This section gives background information on occupational exposures and exposure limits for toxic contaminants and physical agents.^(a) Section 4.4 discusses

(a) The primary sources for this information were Levy and Wegman (1988) and OTA (1985). Additional sources of information on specific contaminants include ACGIH (1989, 1990); Hamilton and Hardy (1974); Proctor (1988); SJO, Shapiro, and Synergic (1984, Appendix C); Stellman and Daum (1973); Stenner and Baechler (1990, Vol. I.).

the health effects associated with common contaminants found in industrial settings. Section 4.5 discusses the health effects and exposure limits for physical agents. Section 4.6 discusses additional hazards not specifically covered in Section 4.4 associated with materials used in the energy conservation measures presented in Chapter 2.

4.3.1 Toxic Substances

Toxicity is the ability of a substance to cause injury to biological tissue; the associated hazard is the likelihood that the substance will cause injury in a given environment or situation (Proctor 1988, p. 6). The severity and duration of the effects of toxic substances and physical agents may vary with route of entry, length of exposure, and concentration or exposure level. For example, in high enough doses, exposure to gases like carbon monoxide and hydrogen disulfide results in immediate death by asphyxiation. Lower doses and chronic exposures can result in central nervous system damage. Some contaminants are directly toxic, others are sensitizers.

Contaminants can enter the body through inhalation, absorption through the skin, or ingestion. The primary route of entry for occupational exposures is inhalation and many contaminants can cause respiratory irritation and disease. Gases, vapors, and mists that are highly fat soluble, as are many volatile organics, can cross from the lungs into the blood stream, causing systemic, reproductive, and developmental effects, and cancer. Some chemicals, particularly organic solvents, can be directly absorbed through the skin. For those substances with low volatility, this may be the primary route of entry into the body (Frumkin 1988, p. 198). Thus, skin contact with toxics can cause local and systemic effects. Ingestion exposures are primarily associated with eating or smoking with contaminated hands or in contaminated work areas. The amounts ingested usually have minor health impacts, with the exception of highly toxic substances such as lead, arsenic, and mercury (Proctor 1988, p. 5).

4.3.2 Exposure Limits

OSHA regulates some 500 toxic chemicals in the work place; more are regulated in some states.^(a) The American Conference of Governmental Industrial Hygienists (ACGIH) is the origin for many of the exposure guidelines enforced by OSHA. ACGIH has established exposure limits for chemicals and physical agents whose enforcement is not currently mandated to OSHA.^(b) Exposure limits are established for contaminants in isolation. Thus, they may or may not be adequate to protect workers against the effects of the complex mixtures of chemicals found in many industrial settings.

Furthermore, whereas the human health effects of certain substances, such as formaldehyde, have been well documented, for many contaminants little or no human data is available. In many cases, available research has to be extrapolated from animal research which usually entails extremely high exposure levels. The health effects at concentrations normally found in occupational settings can only be inferred from these studies.

The occupational exposure limits set for various contaminants give some idea of their toxicity. In addition, there are various toxicity rating scales, based on statistical analysis of experimental toxicological data. Some scales are based on the lethal concentration₅₀ (LC₅₀) and the lethal dose₅₀ (LD₅₀) (Proctor 1988, p. 6; Stenner and Baechler 1990, Vol. 1, p. 2.2). These are the atmospheric concentration (for inhalation) and dose (other exposure routes) expected to be lethal in 50% of the animals in a group of the same species. For noncarcinogenic health effects, the EPA provides risk assessment information in the form of oral and inhalation reference doses (RfDos and RfDis). A reference dose is a concentration to which a human

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- (a) OSHA Safety and Health Standards are contained in 29 CFR Part 1910. Oversight for worker health and safety in the mining industry belongs to the Mine Safety and Health Administration (30 CFR Parts 1-999).
 - (b) In states such as Oregon, ACGIH exposure limits may be reinforced under the so-called "General Duty" clause of the Occupational Safety and Health Code.

population may be exposed daily without appreciable risk of deleterious effects during a lifetime. These values are given when available.^(a)

Threshold Limit Values (TLVs)

There are three types of occupational exposure limits for airborne contaminants: the threshold limit value (TLV), the short-term exposure limit (STEL), and the ceiling limit. The TLV is a time-weighted average (TWA) representing the average concentration (in milligrams per cubic centimeter) for an 8-hour workday and a 40-hour work week to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.^(b)

The STEL is the maximum concentration of a toxic substance to which a worker should be exposed during a specified period of time, usually 15 minutes. STELs are specified where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. Ceiling limits are concentrations that should not be exceeded during any part of the working day. These are generally given for highly toxic substances.

In the following sections, exposure limits are given for selected chemicals and physical agents.^(c) OSHA limits are given when they exist; the State of Oregon (OR-OSHA) and ACGIH limits are given when there are no OSHA limits or the OSHA limits are higher. TWAs for airborne contaminants are usually specified in terms of milligrams per meter cubed (mg/m^3). For gases, TWAs are also specified in parts per million (ppm). STELs and ceiling limits, when they exist, are also given in the same units. The TLVs for physical agents discussed in Section 4.5 are expressed in units appropriate to the exposure, e.g., power density for nonionizing radiation.

(a) The source for RfDs is the EPA's Integrated Risk Information System (IRIS) online database.

(b) TLVs are also called permissible exposure levels (PELs) or simply TWAs.

(c) Except where noted otherwise, OSHA limits for air contaminants are from Tables Z.1-A, Z.2, and Z.3 of the Federal Occupational Safety and Health Standards (29 CFR 19.1000). The State of Oregon (OR-OSHA) limits are from the Oregon OSHA Interim Codebook for Airborne Contaminants (OAR 437, Division 2, Subdivision Z). ACGIH limits are from ACGIH (1990).

These exposure limits are only for inhalation exposures. They do not take into account possible absorption through the skin, mucous membranes or eyes (Proctor 1988, p.8). However, both OSHA and ACGIH specify whether skin absorption is likely for a given contaminant and thus should be protected against by the use of protective clothing and equipment, engineering controls, or work-place practices.

Carcinogenicity

The ACGIH indicates when airborne contaminants are either confirmed (A1) or suspected (A2) human carcinogens. The council recommends that worker exposure by all routes for these contaminants should be carefully controlled to levels as low as reasonably achievable (ALARA) below the TLV, when they exist.

The EPA provides carcinogenicity risk assessment information in the form of inhalation slope factors. These assessments are provided when available.^(a) Also known as carcinogenic potency factors, the values indicate the increased number of cancers associated with a particular dose or exposure to a contaminant. Risks are generally expressed as numbers from zero to one: E-4 indicates a risk of 1 in 10,000, E-5 indicates 1 in 100,000, and E-6 indicates 1 in 1,000,000. For example, the inhalation slope factor associated with exposure to benzene is $2.9\text{E-}2/\text{mg/kg/day}$. This means that there will be 2.9 cancers per hundred people exposed per milligram of benzene (dose) per kilogram of body weight per day for lifetime exposure.

4.4 COMMON CONTAMINANTS

Common contaminants found in many industrial settings include biogenic contaminants, toxic gases, dusts and fibers, metals, and chemicals. Since the majority of occupational exposures are by inhalation, the contaminants discussed in this section are primarily airborne contaminants. Section 4.6 discusses additional hazards associated with materials used in the manufacture or operation of certain energy conservation measures discussed in Chapter 2.

(a) The source for inhalation slope factors is U.S. EPA's IRIS database.

These materials may not be specifically addressed in this section, which focuses on individual chemicals.

Control measures for specific contaminants are not discussed. In general, control of exposure to work-place contaminants involves a combination of protective clothing and equipment, engineering measures, including the use of ventilation systems, hoods, air cleaners, etc., and proper design of workplace practices.

4.4.1 Biogenic Contaminants

Occupational exposures to infectious agents are most common among health-care professionals, workers who come in contact with animals or animal products, and workers involved in ground-breaking or earth-moving operations (Gantz 1988). Meat packers, for example, may contact zoonotic diseases from contaminated animal products and bulldozer operators may inhale spore-containing dust that can cause fungal infections of the respiratory system. Except for health care professionals, exposures to infectious agents are comparatively rare.

Recently, attention has focused on the health hazards associated with biogenic contaminants commonly found in indoor air (Baechler, Hadley, and Marseille 1990). Dust in indoor air can contain a wide variety of biogenic contaminants that may cause infectious disease and allergic reactions. These contaminants may originate outdoors and migrate inside, or they may be generated indoors. An example of biogenic contaminants that may potentially affect all workers in a given plant are the microorganisms that grow in space conditioning and thermal storage units, evaporative condensers and cooling towers. The health risks associated with these contaminants are uncertain.

4.4.2 Combustion Products

Combustion products are generated by boilers, furnaces, ovens, and diesel equipment. Of the major combustion products, carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide, and particulates are EPA criteria pollutants. Carbon monoxide is the product of incomplete combustion. Nitrogen dioxide is produced by high-temperature combustion processes. Sulfur dioxide results from burning sulfur-containing fuels. Benzo(a)pyrene is a polyaromatic hydrocarbon produced during combustion of coal, wood, diesel fuel, and tar.

Diesel exhaust has been known to cause cancer in animals and limited epidemiological evidence suggests an association between occupational exposure to diesel exhaust and lung cancer (NIOSH 1988). Other hazardous combustion products are associated with specific industrial processes. For example, coke oven emissions are listed by EPA as a hazardous air pollutant and are considered to be an occupational carcinogen. Infrared radiation can be an additional health hazard associated with high-temperature operations (see Section 4.5.4).

Benzo(a)pyrene

Benzo(a)pyrene is a constituent of coal tar pitch volatiles. It is a procarcinogen, which is metabolized by living cells into carcinogenic derivatives (Stenner and Baechler 1990, Vol. 1, p. 6.2). Chronic exposure may result in skin and respiratory cancer. Benzo(a)pyrene has been used as a surrogate for the carcinogenicity of smoke. However, there are numerous complex components found in smoke. Thus, benzo(a)pyrene is not representative of risks. The exposure limits for coal tar pitch volatiles are:

OSHA TWA 0.2 mg/m³; no STEL defined.

The EPA classifies benzo(a)pyrene as a probable human carcinogen. ACGIH classifies benzo(a)pyrene as a suspected human carcinogen and coal tar pitch volatiles as known human carcinogens.

Carbon Monoxide

Carbon monoxide reacts with the hemoglobin in red blood cells, thereby decreasing the oxygen-carrying capacity of the blood. It is a chemical asphyxiant that can cause headaches, dizziness, nausea, and, in high concentrations, death. Carbon monoxide can also affect the central nervous system and aggravate cardiovascular disorders. There is evidence that carbon monoxide causes fetal damage (Stenner and Baechler 1990, Vol. 1, p. 6.4). The exposure limits to carbon monoxide are:

OSHA TWA 35 ppm (40 mg/m³); no STEL defined

OSHA Ceiling 200 ppm (229 mg/m³).

Formaldehyde

Formaldehyde can cause eye and respiratory irritation, chronic respiratory disease, dermatitis (which may be delayed), headaches, and nausea. Eye injuries, ranging from minor discomfort to permanent loss of vision, may be caused by solution splashed in the eyes. Ingestion can result in severe pain, vomiting, and diarrhea. After absorption, formaldehyde depresses the central nervous system, causing symptoms similar to alcohol intoxication. Exposed women workers have experienced menstrual disorders and secondary sterility (Stenner and Baechler 1990, Vol. 1, p. 3.21). Formaldehyde is an allergen and generally aggravates medical conditions. All aldehydes have strong, unpleasant odors that may cause worker stress. The exposure limits for formaldehyde are:

OSHA TWA 1 ppm; STEL 2 ppm.

Because of its high toxicity, formaldehyde is regulated under a different subsection than other air contaminants (see 29 CFR 1910.1048). The ACGIH and the EPA list formaldehyde as a suspected human carcinogen with an inhalation slope factor of $4.5E-2/\text{mg/kg/day}$. Studies have found significant increases of lung and nasopharyngeal cancers in exposed workers and a possible association with leukemia and abnormal brain and colon tumors (Stenner and Baechler 1990, Vol. 1, p. 3.22).

Hydrogen Sulfide

Hydrogen sulfide can cause eye and respiratory irritation, headache, dizziness, lack of appetite, nausea, diarrhea, and loss of muscle control. The exposure limits for hydrogen sulfide are:

OSHA TWA 10 ppm (14 mg/m^3); STEL 15 ppm (21 mg/m^3).

Mercaptans

Mercaptans are extremely noxious derivatives of hydrogen sulfide (the scent of a skunk is a mercaptan). Their odor alone can cause nausea and vomiting in exposed workers (Stellman and Daum 1973, p. 237). Mercaptans reduce the oxygen-carrying capacity of the blood and chronic exposure may cause blood damage. They are central nervous system depressants. High concentrations can cause respiratory irritation and death by respiratory

paralysis. When heated, mercaptans release sulfur dioxide (see below). The exposure limits for ethyl and methyl mercaptan are:

OSHA TWA 0.5 ppm (1 mg/m^3); no STEL defined.

Nitrogen Dioxide

Nitrogen dioxide can cause headaches, dizziness, weakness, conjunctivitis, corneal ulcerations, skin irritation, chest pains, difficult breathing, cough, asthma, and tracheobronchitis. Like carbon monoxide, it reduces the oxygen-carrying capacity of the blood and it is a respiratory irritant, similar to ozone, that may cause acute and chronic changes in the small airways and lungs. The exposure limits for nitrogen dioxide are:

OSHA STEL 1 ppm (1.8 mg/m^3); no TWA defined.

U.S. EPA lists a chronic oral exposure reference dose for nitrogen dioxide of $1\text{E}+0 \text{ mg/kg/day}$.

Sulfur Dioxide

Moderate exposure to sulfur dioxide can cause bronchoconstriction with increased pulmonary resistance. Chronic exposure may result in an altered sense of smell, chronic bronchitis, or nasopharyngitis. Acute overexposure may result in chemical bronchopneumonia and death. The exposure limits for sulfur dioxide are:

OSHA TWA 2 ppm (5 mg/m^3); STEL 5 ppm (10 mg/m^3).

4.4.3 Dusts and Fibers

Dusts are formed by mechanical processes, e.g., grinding, blasting, and drilling, that are common among many of the industries profiled. Particles greater than 10 microns in diameter primarily affect the membranes in the throat and nose and do not tend to reach the lungs (Frumkin 1988, p. 196). Particles less than 10 microns are called respirable particles, because they can be inhaled into the lungs. In general, the deeper the particle penetration, the more severe the effects. Of particular concern are dusts and fumes of toxic metals such as lead and chromium (see Section 4.4.6), and fibers of crystalline silica and asbestos. These fibers lodge deep in the lungs indefinitely, causing lung disease and cancer.

Exposure limits for dusts and fibers in the following sections may be given in units of millions of particles per cubic foot of air (mppcf).

Asbestos

Asbestos is a generic term applied to hydrated magnesium (with the exception of crocidolite) silicate fibers, which are characterized by flexibility, strength, and resistance to fire and chemicals. Asbestos may be found in acoustic and thermal insulation at many plants; around heating ducts, furnaces, and boilers; and lining cooling towers. Long-term exposure to asbestos may cause asbestosis, a pulmonary fibrosis disease. Asbestos is listed by the EPA as a hazardous air pollutant. The exposure limits for asbestos are:

OSHA TWA .2 fibers per cubic centimeter (f/cc); excursions to 1 f/cc are permitted for 30-minute periods.

Asbestos is a recognized occupational carcinogen and is regulated under different subsections than other airborne contaminants (see 29 CFR 1910.1001 and 1910.1101). Asbestos can cause lung and gastrointestinal cancers and pleural and peritoneal mesothelioma in exposed workers. The EPA lists an inhalation slope factor for asbestos of $2.3E-1/\text{fibers/mL}$.

Cement

The alkalinity of cement may cause skin irritation and the presence of hexavalent chromium (chromium VI) in the finished product may cause "cement eczema." Hexavalent chromium is associated with increased incidence of skin and lung cancer. The exposure limits for Portland cement are (if chromium VI is present see Section 4.4.6):

OSHA TWA 5 mg/m³, respirable fraction (if no chromium VI present)
 10 mg/m³, total dust; no STEL defined; the mineral dust
 limit for Portland cement with less than 1% crystalline
 silica is 50 mppcf.

Fiberglass

There are over 70 varieties of fibrous glass, or fiberglass. Fiberglass may cause skin irritation and acute bronchitis and asthma if inhaled (Stellman and Daum 1973, p. 179). The exposure limits for fibrous glass are:

OSHA TWA (Not defined.)
ACGIH and OR-OSHA limit exposure to fibrous glass dust to
a TLV of 10 mg/m³.

Although no conclusive evidence has yet linked fiberglass fibers to respiratory effects similar to those caused by asbestos exposure, the issue is controversial and has been investigated by the World Health Organization. A summary of one symposium (WHO 1987) lists the following key conclusions regarding cancer risks:

- Researchers have found an increased lung cancer risk in production and maintenance workers employed in the early days of the rock/slag wool and glass wool industry.
- The risk has been greater in the rock/slag wool sector of the industry than in the glass wool sector. No increased risk has been found after full introduction of dust-suppressing agents.
- The increased risk may not have been caused by fibers alone.
- It is not now possible to calculate the lung cancer risks associated with varying degrees of exposure because of the absence of a detailed dose-response relationship.
- It is unlikely that work-place exposure over the last 30 years has resulted in any clinical respiratory damage other than the risk of cancer.

Although this research seems preliminary, the fourth conclusion about the absence of a detailed dose-response relationship means that cancer risks cannot now be calculated, but it does not rule out the possibility that low-level exposure to non-suppressed fibers may increase the risk of cancer.

Nuisance Dusts

The health effects of nuisance dusts depends primarily on the constituents of the dust. However, in large enough concentrations, all dusts may be toxic. Inhalation of nuisance dusts may cause allergic reactions and respiratory irritation. However, by definition, nuisance dusts do not cause irreversible, debilitating lung damage or disease. The exposure limits for inert or nuisance dust are:

OSHA TWA 15 mppcf (5 mg/m³), respirable fraction

OSHA TWA 50 mppcf (15 mg/m³), total dust

The state of Oregon TWA for total inert or nuisance dust is 10 mg/m³ for an 8-hour period. In addition, the Oregon Occupational Safety and Health Code specifically limits the total dust levels for 43 substances not regulated by the Federal OSHA to a TWA of 10 mg/m³ (OAR 437, Division 2, Subdivision Z, Table OR-1).

Silica

Silica is a common hazard in many mining, sandblasting, metals cleaning and polishing, and foundry operations. Silica (and asbestos) can be contaminants in other minerals. Quartz, cristobalite, and tridymite are all types of crystalline silica. Silicates are minerals with less than 1% crystalline silica. Excessive exposure to free silica can cause obstructive lung disease, emphysema, tuberculosis, and silicosis. Silica present in other minerals may present an occupational exposure. The hazard degree depends on the silica content, and concentration and size of the airborne dust, as well as the length of exposure. The exposure limits for crystalline silica are:

OSHA TWA	$\frac{10 \text{ mg/m}^3}{\% \text{SiO}_2 + 2}$	Quartz, respirable
OSHA TWA	$\frac{30 \text{ mg/m}^3}{\% \text{SiO}_2 + 2}$	Quartz, total dust

The limits for cristobalite and tridymite are one-half the TWAs for quartz.

Wood Dusts

Wood dusts are potential hazards in lumber and wood products mills. In general, the respirable portion of wood dust in saw mills is low because most particles are greater than 10 microns in diameter (SJO, Shapiro, and Synergic et al. 1984, p. C.20). In planing mills, the respirable particles are higher. Except for cedar dust, wood dusts are regulated as nuisance dusts. Cedar dust can cause "cedar asthma." Dust from pressure-treated wood can pose additional hazards due to exposure to preservatives such as creosote, pentachlorophenol, and inorganic arsenicals. The exposure limits for wood dusts are:

OSHA TWA	5 mg/m ³ , for soft and hard woods except Western red cedar
STEL	10 mg/m ³ ; ACGIH lists a TLV of 1 mg/m ³ for certain hardwoods, including beech and oak

OSHA TWA 2.5 mg/m³ Western red cedar; no STEL defined.

4.4.4 Hydrocarbons

Hydrocarbons, or organic compounds, are ubiquitous in industry. Volatile organic compounds are carbon-based chemicals that evaporate easily, thus giving off vapors that can cause health effects and environmental pollution. Many VOCs adversely affect the ozone layer and are thus being regulated and/or phased out under the provisions of the 1990 Amendments to the Clean Air Act. The aromatic and certain chlorinated hydrocarbons are the most critical in terms of health effects. Other classes of hydrocarbons represented in this section are aliphatic hydrocarbons, which are the basis for lubricants and cutting oils used in machining operations, and glycol ethers, which are used as solvents in high-solids and UV-cured coating systems (solvents are discussed further in Section 4.6.6). Dioxins and other chlorinated organics, such as furans and chlorinated phenolics, are unwanted byproducts of manufacturing processes involving chlorine and hydrocarbons (usually at high temperatures).

Aromatic hydrocarbons are compounds that incorporate one or more benzene rings. Benzene is a carcinogen and is listed as a hazardous air pollutant by EPA. Benzene can be a contaminant in other solvents such as toluene and is a constituent of coke oven emissions. Toluene and xylene, also aromatic hydrocarbons, have been found to cause severe brain abnormalities in children of mothers exposed to the solvents during the manufacture of plastics (Stenner and Baechler 1990, Vol 1, p. 3.14).

Chlorinated hydrocarbons are used in plastics, pesticides, and other chlorinated organic compounds. Methylene chloride and other common solvents, chloroform, carbon tetrachloride, polychlorinated biphenyls (PCBs), and vinyl chloride are all members of this class of organic compounds. The toxicity of these compounds ranges from relatively low to high and is generally associated with the proportion of chlorine in the compound (Hamilton and Hardy 1974, p. 289). Vinyl chloride is a flammable gas listed by the EPA as a priority toxic pollutant. Other compounds in this class are listed as hazardous air pollutants. The extreme volatility of some of these compounds may pose

hazards because high atmospheric concentrations may be achieved rapidly, even if the compounds themselves have low toxicity.

Benzene

Benzene is used primarily as a building block for industrial and consumer chemicals and as a gasoline additive to improve octane rating. Benzene is a potent narcotic and a respiratory irritant. Chronic exposure can result in loss of appetite, nausea, loss of weight, fatigue, dizziness, and irritability. Gases and vapors of benzene and other petroleum derivatives can cause bone marrow and white blood cell damage, resulting in aplastic anemia and increased risk of leukemia. The exposure limits for benzene are:

OSHA TWA 1 ppm; STEL 5 ppm.

Benzene is recognized as an occupational carcinogen and is regulated under a different subsection than other air contaminants (see 29 CFR 1910.1028). The EPA lists an inhalation slope factor for benzene of $2.9E-2$ /mg/kg/day.

Chlorofluorocarbons (CFCs)

Chlorofluorocarbons are a family of inert, nontoxic, and easily liquified chemicals used in refrigeration, air conditioning, packaging, and insulation, and as solvents and aerosol propellants. In the upper atmosphere CFCs release chlorine, which destroys ozone. Freons (brand-name CFCs) are used as foaming agents in urethane foams and as solvents in the microelectronics industries. Freons are generally of low toxicity. However, high concentrations may cause effects ranging from mild central nervous system depression to asphyxiation. Freons may also be considered a health hazard because of their effect on the ozone layer. The exposure limits for three common CFCs, dichlorodifluoromethane (Freon F-12), fluorotrichloromethane (Freon 11), and 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113), are given below.

Freon 11: OSHA ceiling 1,000 ppm ($5,600 \text{ mg/m}^3$); no TWA defined

Freon F-12: OSHA TWA 1,000 ppm ($4,950 \text{ mg/m}^3$); no STEL defined

Freon 113: OSHA TWA 1,000 ppm ($7,600 \text{ mg/m}^3$); STEL 1,250 ppm ($9,500 \text{ mg/m}^3$).

The chronic oral exposure reference doses (RfDs) are as follows: for dichlorodifluoromethane, $2E-1$ mg/kg/day, with the critical effect being

reduced body weight; for, fluorotrichloromethane, 3E-1 mg.kg.day, with survival and histopathology as the critical effects; and for 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113), 3E+1 mg/kg/day, with psychomotor impairment as the critical effect.

Dioxins

Dioxins, or chlorinated dibenzo-p-dioxins (CDDs), are formed by the chlorine bleaching processes in pulp and paper manufacturing and certain petroleum-refining processes (Callahan 1989). Dioxins can cause chloracne (a long-lasting disfiguring skin disease) and may suppress the body's immune system, making it more susceptible to cancer and other diseases.^(a) The most toxic compound in this family of some 100 compounds is 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD). The dioxin, 2,3,7,8-TCDD is an extremely potent animal carcinogen and a probable human carcinogen that can cause health effects at even low levels of exposure (Callahan 1989, p. 31). OSHA has not set an exposure limits for 2,3,7,8-TCDD. Refer to OSHA IMIS2326 for a sampling method.

Dipropylene glycol methyl ether

Dipropylene glycol methyl ether is used in the UV-developing acrylic-ink process. Health effects include nasal and eye irritation, lightheadedness, and headaches. There is some evidence that it causes bone marrow damage (Food Chemistry Toxicology 1985). The exposure limits for dipropylene glycol methyl ether are:

OSHA TWA	100 ppm (600 mg/m ³) with skin absorption indicated; STEL 150 ppm (900 mg/m ³).
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Lubricating and Mineral Oils

Oils may cause acne lesions, infection of sweat pores, and hair folliculitis. Some oils are sensitizers, others are direct irritants. Lubricating and mineral oils have been suspected of causing skin cancer (Burgess 1981, pp. 87-95). Exposure to oil mists has been associated with excessive risks of scrotal, respiratory, and digestive cancers. Mineral oils

(a) From Oregon Department of Environmental Quality (DEQ) information sheet "Facts About Dioxin and Oregon's Pulp Mills," 1990.

may be contaminated with hydrocarbons, metal and flux particles, abrasives, and additives that may pose additional hazards. Some mineral oils form nitrosamines, which are carcinogenic.

Methylene Chloride

Methylene chloride (dichloromethane) is a highly volatile chlorinated hydrocarbon used as a solvent and extracting agent. A common constituent of paint strippers, methylene chloride is the least toxic of the four chlorinated methane derivatives. In high concentrations, it can cause symptoms of intoxication. The body converts methylene chloride to carbon monoxide, which reduces the oxygen-carrying capacity of the blood. The exposure limits for methylene chloride are:

OSHA TWA	500 ppm; no STEL defined
Ceiling	1,000 ppm, the acceptable peak above the ceiling is 2,000 ppm for 5 minutes in any two hours; ACGIH lists a TLV of 50 ppm (175 mg/m ³).

The EPA lists an oral exposure reference dose (RfDo) of 0.06 mg/kg/day with liver toxicity as the critical effect. ACGIH lists methylene chloride as a suspected human carcinogen. The EPA lists it as a potential carcinogen with an inhalation slope factor of 0.014 (mg/kg/d)⁻¹ and an ingestion slope factor of 0.0075 (mg/kg/d)⁻¹.

Phenol

Phenol is a benzene derivative used in the production of insulating materials and resins. Chronic exposure to phenol can cause headaches, cough, fatigue and weakness, lack of appetite, nausea, vomiting, insomnia, and nervousness. Acute exposure can damage the eyes and skin and cause nausea, vomiting, jaundice, difficult breathing, cough, cyanosis, and pulmonary edema. The exposure limits for phenol are:

OSHA TWA	5 ppm (19 mg/m ³) with skin absorption designated; no STEL defined.
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Polychlorinated Biphenyls

Prior to their ban in 1976, polychlorinated biphenyls (PCBs) were used as dielectric materials in electronics components, in surface coatings and fire retardants, and as cutting fluid additives. PCBs may be found in

transformers, capacitors, and heat transfer systems in many industrial settings. Exposure to PCBs can cause chloracne (a long-lasting disfiguring skin disease), pigmentation of skin and nails, swelling of the eyelids, visual disturbances, liver damage and cancer. The exposure limits for chlorodiphenyl, a common PCB, are:

OSHA TWA 1 ppm (42% chlorine), with skin absorption indicated.

OSHA TWA .5 mg/m³ (54% chlorine), with skin absorption indicated.

The EPA classifies PCBs as probable human carcinogens with an oral slope factor of 7.7/mg/kg/day.

Trichloroethylene

Trichloroethylene is a chlorinated hydrocarbon widely used as a degreaser and drycleaning agent. It is listed by the EPA as a hazardous air pollutant. Exposure to trichloroethylene vapors can cause irritation of the mucous membranes in the eyes and nose. Skin contact causes dermatitis.

Trichloroethylene is a narcotic and can cause dizziness, confusion, drowsiness, and loss of consciousness. It is readily absorbed by the lungs and metabolized by the liver. Exposure to trichloroethylene followed by ingestion of alcohol can result in a condition called "degreasers flush" characterized by dilation of the blood vessels and malaise. The exposure limits for trichloroethylene are:

OSHA TWA 50 ppm (270 mg/m³); STEL 200 ppm (1080 mg/m³).

The U.S. EPA lists trichloroethylene as a probable human carcinogen. According to EPA's preliminary risk assessment of ambient air exposures, public health risks are significant -- on the order of 4.1 cancer cases/year and maximum lifetime individual risks of 9.4E-5 (Stenner and Baechler 1990, Vol. 1, p. 3.14).

4.4.5 Irritant and Toxic Gases

Irritant gases primarily affect the respiratory system. Highly water-soluble gases such as ammonia cause immediate respiratory irritation and, in some cases, skin irritation. The less-water soluble the gas, the deeper and more delayed are its irritant effects. Gases such as ozone and nitrogen dioxide can cause respiratory effects many hours after the exposure. Other

toxic gases do not necessarily cause respiratory irritation. Gases such as nitrogen and hydrogen are simple asphyxiants that displace oxygen. Other gases, such as carbon monoxide, are chemical asphyxiants, which cause chemical changes that block delivery or use of oxygen at the cellular level.

Ammonia

Ammonia is extremely common in many industries; it is a common refrigerant and cleaning agent, is used in petroleum refining, is a byproduct of coke oven operation, and is a major component in the manufacture of nitrogenous fertilizers. Ammonia in high concentrations can burn the eyes, skin, and lungs. According to the EPA, in 1987 ammonia emissions were larger than the emissions of any other air toxic (Durenberger 1991, p. 30).

Ammonia gas is also irritating to the eyes and to moist skin. Mild to moderate exposure may result in headaches, burning of the throat, nausea, and vomiting. Intense exposure may cause severe respiratory damage. Inhalation may cause urticaria, an allergic reaction, in rare cases. The exposure limits for ammonia are:

OSHA STEL 35 ppm (27 mg/m³); no TWA defined; ACGIH lists a TLV of 25 ppm (17 mg/m³) and an STEL of 35 ppm (24 mg/m³).

Chlorine

Chlorine is used in paper pulp bleaching, water disinfection, and chemical manufacturing. Chlorine is an eye and respiratory irritant. Exposure to high concentrations can cause stomach pain, nausea, vomiting, weakness, cyanosis, and pulmonary edema. Chlorine combines with body moisture to form acids that are irritating to a variety of tissues. The exposure limits for chlorine are:

OSHA TWA .5 ppm (1.5 mg/m³); STEL 1 ppm (3mg/m³).

Hydrogen Sulfide

Hydrogen sulfide is a byproduct of pulping, oil refining, wastewater treatment, and combustion processes. It is an eye and respiratory irritant that can cause lung disease and nerve damage. Section 4.4.2 (combustion products) lists specific health effects and exposure limits for hydrogen sulfide.

Isocyanates

Isocyanates are used in making polyurethane foam, paints, and insulating materials. Isocyanates are directly irritating to the respiratory tract and are sensitizers. Once sensitized, an individual cannot tolerate additional exposures (SJO, Shapiro, and Synergic 1984, p. C.16). Toluene diisocyanate (TDI), Hexamethylene diisocyanate (HDI), and methylene bisphenyl isocyanate (MDI), also called diphenylmethane diisocyanate, can cause asthma-like attacks, tightness in the chest, difficult breathing, reduced lung capacity over a period of time, jaundice, and possibly chronic liver disease. Burning isocyanates may produce phosgene gas, which is a respiratory irritant and can cause delayed pulmonary edema. The exposure limits for HDI, MDI, and TDI are listed below.

HDI: OSHA TWA not defined; the Oregon limit for 1,6, HDI-based adducts, including isocyanurates, is a TWA of .5 mg/m³ and an STEL of 1 mg/m³

MDI: OSHA ceiling .02 ppm (.2 mg/m³); no TWA defined; the OR-OSHA limit for MDI is a TWA of .005 ppm (.05 mg/m³)

TDI: OSHA TWA .005 ppm (.04 mg/m³); STEL .02 ppm (.15 mg/m³).

Nitrogen Oxides

Nitrogen oxides (NO_x) are used in pickling and etching metals and are byproducts of the manufacturing of acids, nitrogenous fertilizers, and combustion processes. All nitrogen oxides decompose into nitric acid which can cause human tissue damage. Oxides of nitrogen form potentially carcinogenic nitrosamines in the respiratory tract and stomach. Section 4.4.2 (combustion products) lists specific health effects and exposure limits for nitrogen dioxide.

Ozone

Ozone is a product of inert gas-shielded arc welding; food, water and air purification; and food and textile bleaching; and is emitted around high-voltage electrical equipment. Ozone is a strong respiratory irritant and may cause delayed pulmonary edema up to 8 hours following exposure. Ozone has produced chromosome aberrations in experiments and may be a potential carcinogen. The exposure limits for ozone are:

OSHA TWA .1 ppm (.2 mg/m³); STEL .3 ppm (.6 mg/m³); ACGIH lists a ceiling limit of .1 ppm (.2 mg/m³).

4.4.6 Metals and Metallic Compounds

Metals and metallic compounds are used in the manufacture of metal products, as pigments in paints and inks, and catalysts in numerous chemicals manufacturing processes. Certain metals and metallic compounds, including arsenic, chromium, and lead are extremely toxic. Lead is an EPA criteria pollutant; arsenic is listed by EPA as a hazardous air pollutant. Chromium and chromate compounds are found in many metal finishing operations in the electronics and aircraft manufacturing industries.

Even relatively benign metals can be health hazards. For example, metal fumes of all kinds can cause "metal fume fever," a type of allergic reaction. The state of Oregon specifically limits the levels of total dust for metals such as aluminum, molybdenum, and zinc oxide to a TWA of 10 mg/m³ for an 8-hour work day.

Arsenic

Arsenic is used in metal alloys, in the manufacture of pigments, and in semiconductor manufacture. Arsenic may be present as an impurity in many other metals. Dusts and fumes of arsenic can cause skin and gastrointestinal irritation, neuromuscular disorders, and lung and skin cancer. Arsenic can react with acids to produce arsine, a toxic gas that damages red blood cells, thereby decreasing the oxygen-carrying capacity of the blood (Stellman and Daum 1973, p. 245). Exposure to arsine can result in kidney and liver damage. The exposure limits for arsenic are:

OSHA TWA	10 micrograms/m ³ , inorganic arsenic
OSHA TWA	.3 mg/m ³ , organic compounds; ACGIH lists a TLV of .2 mg/m ³ for arsenic and soluble compounds
OSHA TWA	.05 ppm (.2 m/m ³), arsine gas.

Arsenic is a recognized occupational carcinogen and is regulated under a different subsection than other air contaminants (see 29 CFR 1910.1018). ACGIH lists arsenic trioxide production as a suspected human carcinogen.

Chromium and Chromates

Chromium is used in metal alloys, chemical and pigment manufacturing, and metals finishing processes. Chromium can be absorbed through the skin and through inhalation, causing skin and respiratory irritation, and lung cancer. Exposure to chromate compounds is associated with skin ulceration and lung cancer. Chromic acid and chrome metal fumes from process baths can cause irritation and ulceration of mucous membranes, skin damage, and perforation of the nasal septum. The exposure limits for chromium and chromates are:

OSHA TWA 1 mg/m³, chromium metal

OSHA TWA .5 mg/m³, chromium II and III compounds; ACGIH lists a TLV of .55 mg/m³ for chromium metal and chromium II and III compounds; the ACGIH limit for chromite ore and chromium VI compounds is .05 mg/m³

OSHA Ceiling .1 mg/m³, chromic acid and chromates; TWA not defined.

Hexavalent chromium (chromium VI) is considered to be a human carcinogen causing skin and lung cancer (SJO, Shapiro, and Synergic 1984, p. C-13). ACGIH lists chromate ore and certain water insoluble chromium VI compounds as confirmed human carcinogens.

Lead

Lead is used in the manufacture of paints, enamels, and inks, and in the chemicals industry. Ingestion of lead dusts and inhalation of dusts and fumes can cause kidney, gastrointestinal, blood marrow, neuromuscular, and central nervous system damage and reproductive effects. Lead accumulates in bone marrow. With some exceptions, lead toxicity is believed to be reversible (Frumkin and Melius 1988, p. 573). The exposure limits for lead are:

OSHA TWA 50 micrograms/m³.

Because of its extreme toxicity, lead is regulated under a different standard than other air contaminants (see 29 CFR 1910.1025).

Zinc Oxide

Zinc oxide (white pigment) is used in the manufacture of paints and photocopying chemicals. Zinc oxide can pose an inhalation hazard in the work

place. Skin contact can also result in a condition called "oxide pox." The exposure limits for zinc oxide are:

OSHA TWA 5 mg/m³, respirable dust; no STEL defined; the limits are the same for zinc oxide fumes.

OSHA TWA 10 mg/m³, total dust.

4.4.7 Plastics

Plastics are polymers, single molecules hooked together chemically to form a long-chain molecule. The single-molecule building blocks used in plastics manufacture are called monomers. Plastics are either thermoplastics, which can be molded and reshaped repeatedly, or thermosets, which cannot be reformed or melted after initial curing (Hamilton and Hardy 1974, p. 331; Stellman and Daum 1973, p. 225). Acrylics, cellulose, polyvinyl chloride, and polystyrene are thermoplastics. Common thermosets include urea, epoxies, phenolics, polyesters, and polyurethanes.

Health hazards from plastics are generally associated with their manufacture which may expose workers to a variety of toxic compounds in solvents, resins, catalysts, hardeners, stabilizers, plasticizers, dyes, fillers, and curing and foaming agents. The monomers, solvents, stabilizers, and plasticizers are usually the most hazardous substances (Stellman and Daub 1973, p. 225). For example, vinyl chloride, the monomer used to produce polyvinyl chloride, is a recognized occupational carcinogen. Vinyl chloride is a flammable gas listed by the EPA as a priority toxic pollutant. Styrene, a toxic aromatic hydrocarbon, is the monomer in polystyrene and is used as a solvent to dissolve polyesters in producing reinforced plastics. Formaldehyde is used in the production of resins and may be present in incompletely cured products.

Acrylic Acid

Acrylic acid is a monomer used in the production of acrylic resins. Hazards include nasal, skin, and eye irritation, with severe cases resulting in skin burns and blindness. The exposure limits for acrylic acid are:

OSHA TWA 10 ppm (30 mg/m³) with skin absorption indicated; no STEL defined; ACGIH lists a TLV of 2 ppm (6 mg/m³).

Polystyrene

The major hazard associated with polystyrene manufacture is exposure to styrene (see below) and byproducts such as methyl chloride. Polystyrene production workers have been found to suffer from sinusitis, weakness, and irregularities in menstruation, and ovulation (Stellman and Daum 1973, p. 231). When polystyrenes decompose, they form formaldehyde, benzaldehyde, methanol, hydrogen cyanide, ammonia, acrylonitrile, carbon monoxide, nitrogen dioxide, dusts, and styrene, all toxic chemicals.

Styrene

Styrene (vinyl benzene) is an aromatic hydrocarbon used in making plastics and insulating materials. It is the polymer used in polystyrene manufacture. Styrene is strongly irritating to the eyes and upper respiratory tract, and may cause headaches, nausea, and skin irritation. Chronic exposures to styrene may cause damage to the central nervous system and blood-forming elements. There is some evidence that styrene may cause reproductive effects and cancer (Stenner and Baechler 1990, Vol 1, p. 3.17). The exposure limits for styrene are:

OSHA TWA	50 ppm (215 mg/m ³), ACGIH indicates skin absorption; STEL 100 ppm (425 mg/m ³).
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The EPA lists a oral exposure reference dose (RfDo) for styrene of 2E-1 mg/kg/day. with the critical effects being red blood cell and liver toxicity.

Vinyl Chloride

Vinyl chloride is the polymer used in the production of polyvinyl chloride. Occupational exposure to vinyl chloride occurs primarily through inhalation and less frequently through skin absorption. Vinyl chloride is a skin irritant, and contact with the liquid may cause frostbite upon evaporation. Vinyl chloride depresses the central nervous system causing symptoms that resemble mild alcohol intoxication. Lightheadedness, some nausea, and dulling of visual and auditory responses may develop in acute exposures.

OSHA TWA	1 ppm (5 mg/m ³); no STEL defined.
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Vinyl chloride is a recognized occupational carcinogen and is regulated under a different subsection than other air contaminants (see 29 CFR 1910.1017). ACGIH lists vinyl chloride as a confirmed human carcinogen. Vinyl chloride is regarded as a cause of angiosarcoma of the liver. Excess cancers of the lung and lymphatic and nervous system have also been reported.

4.5 PHYSICAL AGENTS

Physical agents are environmental work-place hazards that, like contaminants, may cause health effects in exposed workers. The physical agents discussed here are common in many industrial settings. Noise is specifically regulated by OSHA; nonionizing radiation is regulated in states such as Oregon. The ACGIH specifies exposure limits for all these agents. Non-federal OSHA states such as Oregon may enforce these exposure limits under the so-called "general duty" clause of their occupational safety and health codes.

4.5.1 Noise

There are two types of noise, continuous and impulse, found in occupational settings (Hamernik and Davis 1988, pp. 247-261). Although the definitions are somewhat imprecise, continuous noise is generally considered to last for the entire eight-hour workday, impulse noise typically has high intensity and short duration, and may occur at regular intervals during the work day or only sporadically. In many industrial environments, impulse noise is superimposed on background continuous noise. In addition to hearing effects, excessive exposure to noise may contribute to occupational stress and is suspected of causing damage to the cardiovascular system by raising blood pressure levels (Theriault 1988, p. 435).

Acute exposure may cause tinnitus, vertigo, hearing loss, ear drum perforation, and fractures in the bones in the ear. These effects may occur in one or both ears. The higher the noise level, the more likely it is that effects such as tinnitus and hearing loss will be permanent. Impulse noises are generally more hazardous than continuous noise because their transient nature causes people to subjectively experience them as quieter than they

really are (Hamernik and Davis 1988, p. 248). Thus, their damage potential tends to be underestimated.

Exposure to continuous noise at levels greater than 90 decibels (dB) can cause progressive hearing loss (OTA 1985, pp. 154-158). Noise levels above 80 dB may cause hearing loss. OSHA requires employers to implement a hearing conservation program if noise exposure equals or exceeds a time weighted average (TWA) of 85 dB(A) over 8-hour period.^(a) Reduced noise exposures can be accomplished by redesigning, muffling or enclosing machinery, providing workers with soundproof areas, reducing the time that workers spend in noise areas, and using of hearing protectors. Where noise reduction cannot be achieved by engineering and administrative controls, employers must provide hearing protection devices. Workers exposed to an 8-hour TWA of 90 dB(A) must wear hearing protection devices; if hearing loss has already occurred, hearing devices must be worn with an 8-hour TWA of 85 dB(A).

4.5.2 Vibration

Whole-body exposure to vibration from the operation of equipment, machinery, and vehicles has been suspected of causing health effects ranging from changes in bone structure and nerve conduction velocity to gastrointestinal disturbances and prostatitis (Hu 1988, pp. 267-269). Health hazards are generally associated with vibration at frequencies of 2 to 1,000 hertz. Vibration at the resonant frequency of the eyeballs (60 to 90 hertz) has been associated with vision disorders.

Segmental vibration through a single body part has been associated with lesions in the shoulders and elbows, carpal tunnel syndrome, Raynaud's syndrome, bone cysts and hearing loss. The use of hand tools such as chain saws, grinders, and pneumatic drills can cause Raynaud's syndrome, a painful condition of the fingers caused by constriction of the capillaries. Control of vibration-related health problems requires properly designed hand tools that reduce hand-arm vibration, regular maintenance because unmaintained tools

(a) Higher sound levels are permitted for shorter time periods. See Oregon Occupational Safety and Health Code (OAR 437, Division 121) and ACGIH (1990, pp. 106-107). ACGIH also has established TLVs for impulsive or impact noise with no exposures in excess of 140 decibels permitted (ACGIH 1990, p. 107).

show higher vibration levels, and process redesign to reduce the use of vibratory hand tools. Gloves can reduce vibration and protect the hands against cold, which increases the predisposition to Raynaud's syndrome. ACGIH has established TLVs for hand-arm segmental vibration designed to prevent advanced stages of Raynaud's syndrome (ACGIH 1990, pp. 91-95). The Physical Agents TLV Committee of ACGIH is studying the biological effects literature to determine if a TLV for whole body vibration is warranted.

4.5.3 Temperature Extremes

Exposure to excessive heat and cold can cause health effects and safety hazards. Exposure to heat and cold at levels that exceed the body's capacity to compensate for thermal stress can lead to impaired performance, heat or cold stress, and death (Hu 1988, pp. 269-273). Symptoms of heat stress include discomfort, rash, cramps, heat exhaustion, and heat stroke. The effects of cold stress may include frostbite, trench foot, general hypothermia, local freezing, and metal-to-skin adhesions. ACGIH has established TLVs to prevent both heat and cold stress that account for environmental conditions, work load, clothing, and, in the case of heat stress, hydration (ACGIH 1990, pp. 74-91).

4.5.4 Infrared (IR) Radiation

In industry, infrared radiation is produced directly by lamp sources and indirectly by heat sources such as furnaces and ovens. The primary biological effect of over-exposure is skin burns, although the sensation of heat should alert those being affected (Hu 1988, pp. 265-266). However, the lens of the eye is especially vulnerable because damage may occur before heat is detected. Chronic IR exposure may produce cataracts at levels well below those causing skin burns. Cataracts caused by heat waves or IR radiation are known as heat cataracts. Glass blowers and furnace workers have an increased incidence of all types of cataracts (Hu 1988). Other workers at risk include those in the vicinity of baking and drying lamps, and movie projectionists. Control of IR radiation includes the shielding of sources, filtered eye protection, and increased worker distance from sources to reduce intensity.

ACGIH has established TLVs for exposure to visible and near-infrared radiation in the wavelength range of 400 nanometers to 1,400 nanometers to

protect the eyes.^(a) These guidelines specify formulas that calculate the TLVs for various types of light based on wavelength and luminance (ACGIH 1990 pp. 119-123).

4.5.5 Lasers

Intense laser beams can cause eye and skin damage and burns (Hu 1988). The most common type of laser-related eye damage is caused by diffuse, reflected light. It is uncommon for a laser to hit the eye directly (Tanner 1990). Operators should wear safety glasses and the work cutting area should be enclosed to prevent accidental exposure. Precautions must be taken to minimize diffuse reflected radiation. According to the voluntary American National Standard Code, Z136.1, all protective eyewear for use with lasers should be clearly marked with the optical density and wavelength for which protection is afforded (Tanner 1990). Optical density refers to the ability of the eyewear to absorb specific wavelengths.

The federal government classifies eye hazards from laser radiation according to the following five categories (CFR 1040.10):

- Class I levels of laser radiation are not considered to be hazardous.
- Class IIa levels of laser radiation are not considered to be hazardous if viewed for any period of time less than or equal to 1×10^5 seconds but are considered to be a chronic viewing hazard for any period of time greater than 1×10^5 seconds.
- Class II levels of laser radiation are considered to be a chronic viewing hazard.
- Class III levels of laser radiation are considered to be a chronic viewing hazard.
- Class IIIa levels of laser radiation are considered to be, depending upon the irradiance, either an acute intrabeam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments.
- Class IIIb levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.

(a) Light is generally designated by wavelength rather than frequency. One nanometer is one billionth of a meter (10^{-9} meters).

Diffuse reflections from high-powered lasers may also present fire and burn hazards. Laser installations should be isolated wherever possible, and the laser beam should terminate in a material that is nonreflective and fireproof (Hu 1988). When cutting toxic materials such as plastics and lead, fumes must be controlled and properly exhausted (BDC and RCD 1988).

The ACGIH has established TLVs for exposure to laser light for wavelengths between 700 and 1400 nanometers designed to protect the eyes and skin (ACGIH 1990, pp. 96-105). The TLVs take into account wavelength, irradiance levels, aperture size, and whether the laser is scanned or repetitively pulsed.

4.5.6 Radiofrequency/Microwaves

Heating human tissue requires relatively high power densities, above 10 milliwatts per square centimeter (10 mW/cm^2). Documented adverse human health effects from RF/microwaves at high power levels include cataract formation, testicular degeneration, and at extremely high intensities, death from hyperthermia (Hu 1988). There is considerable controversy over potential health effects caused by long-term exposure to RF/microwave radiation at low levels. Laboratory animal studies have demonstrated neurologic and immunologic effects at levels too low to cause thermal effects (Hu 1988). Some studies link low-level exposure in humans to headaches, depression, cataracts, and cancer. Of particular concern are the magnetic fields (see the Section 4.5.9 on electromagnetic fields).

The Oregon Occupational Safety and Health code specifies an exposure limit for frequencies between 10 MHz and 100 GHz to a power density of 10 mW/cm^2 for periods of six minutes (0.1 hours) or more, and an energy density of 1 mW-hr/cm^2 during any six-minute period (OAR 439 Division 139). This limit applies to both whole body and partial body irradiation.

The ACGIH has developed TLVs for RF and microwave radiation in the frequency range from 30 kHz to 300 gigahertz (GHz). These TLVs are given in Table 4.3. The values are dependent on frequency and were developed to limit the average whole body specific absorption rate (SAR) to 0.4 watts per kilogram of body weight (W/kg) in any six-minute period. The limit is a whole body average and the power density for both pulsed and continuous fields is

TABLE 4.3. Radiofrequency/ Microwave Threshold Limit Values

Frequency			Power Density (mW/cm ²)	Electric Field Strength Squared (V ² /m ²)	Magnetic Field Strength Squared (A ² /m ²)
10	KHz to	3 MHz	100	377,000	2.65
3	MHz to	30 MHz	900/f ²	3,770 x 900/f ²	900/(37.7 x f ²)
30	MHz to	100 MHz	1	3,770	0.027
100	MHz to	1000 MHz	f/100	3,770 x f/100	f/(37.7 x 100)
1	GHz to	300 GHz	10	37,700	0.265

f = frequency in MHz
Source: ACGIH (1990).

averaged over the six-minute period. A ceiling limit is set at 100 mW/cm² to protect against shock and burn hazards. ACGIH recommends the following:

"Needless exposure to all radiofrequency radiation (RFR) exposures should be avoided given the current state of knowledge on human effects, particularly nonthermal effects" (ACGIH 1990, p. 110).

4.5.7 Ultraviolet (UV) Radiation

Ultraviolet radiation is an invisible form of radiant energy produced naturally by the sun in a low-intensity form (Hu 1988, pp. 263-265). The skin and eyes absorb UV radiation and are vulnerable to injury, primarily due to UV-B radiation. The common sunburn is a well known result of acute over exposure to solar UV radiation. Certain chemicals found in drugs and plants increase sensitivity to UV, exacerbating its effects. Chronic overexposure to UV radiation can cause skin cancer. In industrial settings, high-intensity UV exposure occurs primarily from arc welding, but it can also occur through exposure to direct or reflected radiation from UV lamps. Prevention requires the isolation of high-intensity sources and the use of goggles and other shields with proper filters.

Ultraviolet radiation can convert oxygen and nitrogen to ozone and nitrogen oxides, both respiratory irritants. It can also decompose certain solvent vapors, such as chlorinated hydrocarbons commonly used as degreasers, into toxic gases (e.g., perchloroethylene and trichlorethylene into hydrogen

chloride and phosgene). Proper exhaust ventilation and isolation of UV sources from solvent processes are required to control these hazards.

The ACGIH has established TLVs for exposure in the spectral range between 180 and 400 nanometers designed to protect the eyes and skin (ACGIH 1990, pp. 116-119). These values apply to UV radiation from arcs, gas and vapor discharges, fluorescent and incandescent sources, and solar radiation, but not to UV lasers. As for infrared exposure limits, these TLVs depend on wavelength, total irradiance, and aperture of the source.

4.5.8 Visible Light

Different types of lighting may have effects on the eyes (Hu 1988, p. 265). Improper lighting can pose a safety hazard, cause eye strain, and contribute to occupational stress. ACGIH has established TLVs for exposure to visible and near-infrared light and for lasers, an intense form of visible light that can cause eye and skin damage (see Sections 4.5.4 and 4.5.5). The Illuminating Engineering Society (IES) has established illumination level guidelines for various industrial settings (Kaufman and Christensen 1987, Ch. 2).

4.5.9 Electromagnetic Fields

Electric and magnetic fields accompany electric power wherever it is used or transported. Electric fields arise from electric charges in power lines and from the use of electricity in appliances. Magnetic fields accompany electric fields and result from the motion of the electric charge in the form of an electric current. Electromagnetic fields (EMF) refers to the interplay of these fields in combination. In the United States, alternating electric power has a frequency of 60 hertz (Hz), meaning it changes direction 60 times each second.

Electromagnetic fields are pervasive. In addition to power lines, appliances and equipment also produce EMF, although at different frequencies. Nair, Morgan, and Fitzgerald (1990, p. 21) list the following sources and frequencies: stereo headphones (about 1 kHz), television sets (about 20 kHz), AM radio transmitters (about 1 MHz), CB radios (about 30 MHz), FM radio and

television transmitters (about 100 MHz), and microwave ovens (about 2 GHz).^(a) Other sources range from heating and ventilation controls to personal computers and electric razors (Moore 1990).

Workers potentially exposed to EMF at high power densities include those working in proximity to telephone lines and high-voltage electrical lines, as well as electricians, movie projectionists, and welders (Hu 1988, p. 276). Until the mid-1970s most experts felt that electric or magnetic fields of the strengths commonly found in most applications resulted in insignificant biological effects (Nair, Morgan, and Florig 1989, p. 1). This reasoning was based on the fact that, unlike ionizing radiation such as X-rays, these fields transfer very little energy to the cell and do not disrupt chemical bonds. Furthermore, there is not enough energy in most applications to heat the cell to a substantial extent, as does microwave energy.

However, there has been increasing concern over health effects associated with chronic exposures and low level fields. For example, studies have raised concerns about increases in the risk of leukemia in groups exposed to high-level EMF. Additional research is needed to determine if residential and occupational exposure to low-level EMF results in health effects (Hu 1988). There has been considerable controversy over the effects of exposure to EMF at power-frequencies (60 hertz). These fields are also known as extremely low frequency (ELF) fields.^(b) Because of their low frequency, ELF fields interact differently than higher frequency RF fields.

In the ELF range, electric and magnetic fields are considered separately in terms of biological effects. In higher frequency ranges, a fixed relationship exists between the electric and magnetic fields and field exposures of concern are the combined electromagnetic fields. Nair and others (Nair, Morgan, and Florig 1989, p.65; Nair, Morgan, and Fitzgerald 1990) conclude that some epidemiological and cellular level studies support the notion that ELF exposure may act as a cancer promoter (see Health Effects of

(a) One kHz is 1 thousand cycles per second, 1 MHz is 1 million cycles per second, and 1 GHz is 1 billion cycles per second.

(b) The ELF range is that portion of the spectrum from 3 hertz to 3 kilohertz.

ELF below). However, the overall evidence now available is too weak to allow firm conclusions.

Magnetic fields have been of particular concern with respect to health effects and they are harder to shield against than are electric fields. However, field strength falls off rapidly within short distances of an electrical source. In certain work settings, such as VDT operations, workers may need to be moved farther away from the EMF source. For example, it is recommended that VDT operators sit at arm's length (28 inches) away from the front and 4 feet from the sides of the VDT (OR-OSHA 1990, p.9).

As for other frequencies, it is not certain whether they are either more or less biologically effective than power-frequency fields (Nair, Morgan, and Florig 1990, p. 21). There is evidence that the effects of high frequency fields modulated by very low frequency (VLF) carriers can be similar to those of ELF fields.^(a) Furthermore, many high frequency fields induce stronger currents in the body than do ELF sources.

A recent review of major scientific committee reports led the Institute of Electrical and Electronics Engineers (IEEE) to conclude that there is not enough relevant scientific data to establish whether common exposure to power-frequency fields should be considered a health hazard (IEEE 1990). All sources agree that additional research is needed and that it will be several years before definitive conclusions are available.

Scientists do not yet understand a dose-response relationship for EMF and health effects, nor do they understand the mechanics of how cancer or other diseases may result. Still, EMF is being taken seriously as a potential threat to human health. In 1990, the Environmental Protection Agency characterized EMF as a possible, but not yet proven human carcinogen (Moore 1990). Further-more, the IEEE and other organizations are struggling to form standards to EMF exposure for power frequencies.

ACGIH has established TLVs for ELF electric fields up to 30 kilohertz, designed primarily to protect against shock and burn hazards, and is

(a) The VLF range is that portion of the spectrum from 3 to 30 kilohertz.

considering the evidence in support of limits for low-frequency magnetic fields (ACGIH 1990, pp. 123-125).

Health Effects of Extremely Low Frequency

The following summary of potential relationships between ELF fields and health effects is taken from Nair, Morgan, and Florig 1989; Nair, Morgan, and Fitzgerald 1990; and other sources. It is important to bear in mind that the evidence supporting these effects is still inconclusive. However, the following discussion does provide an explanation of possible mechanisms that may precipitate health effects.

A significant number of experiments on individual cells have shown adverse impacts from ELF fields. However, these results do not indicate a clear response at the level of the whole animal. The experiments do demonstrate that fields affect cell membranes, which may influence immune response and cell-to-cell communication; fields may interfere with DNA and RNA processes; and effects may be highly dependent on the intensity, frequency, and time period of the field.

The central nervous system relies on low-frequency electrical impulses to communicate between cells. Thus, this system may be particularly susceptible to ELF. Interactions between fields and the central nervous system may be dependent on specific frequencies and intensities, which may vary with background static fields present, and the time period and duration of the exposure. Developing nervous systems may be especially vulnerable and effects may be latent, manifested only in specific situations or later in time. Extremely low fields are very specific with respect to the regions of the brain tissue affected and the point in the circadian rhythm (biological clock) that the field is administered. Animal studies have demonstrated that 60-hertz fields affect circadian rhythm. It is not clear if these effects are damaging or long-lasting. Potential effects may include altered sensitivity to drugs and toxins, impaired sleep, depression, and reduced alertness.

Several studies have suggested a link between ELF fields and cancer. The following is a summary of major findings.

- Extremely low frequency fields are not known to cause chromosomal damage, thus are not likely to initiate cancer. However, fields may promote cancer by giving transformed cells a growth advantage.
- Some cellular-level experiments show that the cell membrane is an important site for interaction between cells and fields. These sites have also been shown to be a receptor for chemicals that promote cancer.
- Fields may stimulate compounds that all known cancer promoters stimulate, but not all agents that cause stimulation promote cancer.
- Circadian shifts may contribute to the progress of initiated cancer; thus, fields may retard or contribute to tumor growth.
- Fields may contribute to the suppression of the hormone pineal melatonin; this action may contribute to cancer growth.
- Epidemiological studies show a weak association between exposure and nervous system cancer and leukemia.

4.6 HAZARDS ASSOCIATED WITH ENERGY CONSERVATION MEASURE MATERIALS

This section discusses hazards associated with some materials used in the manufacture or operation of energy conservation measures discussed in Chapter 2. These include building materials, coatings, electrochemical solutions, membrane materials, refrigerants, and solvents.

4.6.1 Building Insulation

The primary health hazards associated with building insulation are dusts and fibers, chemicals emissions, and toxic emissions produced by burning insulation. Dust and fiber hazards are associated primarily with asbestos and possibly fiberglass insulation (see Section 4.4.3). Air emissions associated with insulation and other building materials, such as caulking, glues, and solvents, are discussed in Baechler, Hadley, and Marseille (1990). Table 4.4 is taken from this report and summarizes measured emissions from energy-efficient building materials. A companion document discusses health effects from the emitted chemicals (Stenner and Baechler 1990). The health effects associated with some toxic substances, for example monomers, solvents, and blowing agents used in the manufacture of plastics and resins, are described in Section 4.4.

TABLE 4.4. Summary of Emissions from Energy-Efficient Building Materials

Technique	Source	Emissions	Emission rate
Large scale test chamber	R-30 bonded	Formaldehyde--this was the only compound measured--reported values are chamber concentrations.	0.065 ppm @ 77°F ^a
	Fiberglass insulation Kraft-faced		0.072 ppm @ 77°F
	R-19 Kraft-faced		0.072 ppm @ 77°F
	R-11 Kraft-faced		0.072 ppm @ 77°F
	R-11 unfaced		0.085 ppm @ 77°F
	R-13 unfaced		0.085 ppm @ 77°F
	Duct Line--non-woven fabric facing		0.015 ppm @ 77°F ^b
	Duct Line--non-woven fabric facing		0.020 ppm @ 110°F ^b
	Duct Board--1" foil scrim Kraft facing		0.028 ppm @ 77°F ^b
	Duct Board--1" foil scrim Kraft facing		0.051 ppm @ 110°F
Test chamber	Duct Board--1" foil scrim Kraft facing		0.070 ppm @ 110°F
	Silicone caulk	Total organics--major compounds identified include: methyl ethyl ketone, butyl propionate, 2-butoxyethanol, butanol, benzene, and toluene.	
		Sample age: 0.5 hr.	
		Sample age: 1.0 hr.	50.0 mg/m ² -h
Review of test chamber data	Caulking compound	Sample age: 5.0 hr.	30.0 mg/m ² -h
			2.0 mg/m ² -h
		C-10 alkene	1.23 mg/m ² -h
		C 4-alcohol	<0.01 mg/m ² -h
		N-decane	6.82 mg/m ² -h
		N-undecane	<0.01 mg/m ² -h
		Toluene	0.02 mg/m ² -h
	Insulation foam	Ethylbenzene	7.32 mg/m ² -h
		2-xylene	1.02 mg/m ² -h
		3-xylene	2.77 mg/m ² -h
		4-xylene	24.20 mg/m ² -h
		VOC	2.3 mg/m ² -h

TABLE 4.4. (contd)

Technique	Source	Emissions	Emission rate
Test chamber	Rock wool and glass fibers. The following compounds were found in at least one sample of either insulation type taken from a home, school, or office.	18 aldehydes and ketones	Not quantified--concentration greatest when samples were wet.
Test chamber	Fiberglass insulation	Aromatic hydrocarbons	0.00008 mg/m ² -h
	Polystyrene foam & insulation	Aromatic hydrocarbons	0.020 mg/m ² -h
		Halogenated organics	0.00134 mg/m ² -h
		Volatile aromatic compounds	0.02017 mg/m ² -h
		Aliphatic & oxygenated aliphatic compounds	0.00019 mg/m ² -h
		Z-butene-1-01, Dantane, 1,2-dimethyl-cyclopropane, benzonitrile, benzaldehyde	Not quantified
	Duct insulation	Aromatic hydrocarbons	0.00015 mg/m ² -h
		Aliphatic & oxygenated aliphatic organics	0.00013 mg/m ² -h
		Trimethylhexene	Not quantified
	Latex caulk	Halogenated organics	0.005 ^c mg/m ² -h
		Volatile aromatic compounds	0.3809 ^c mg/m ² -h
		Aliphatic & oxygenated aliphatic organics	0.251 ^c mg/m ² -h
		Aliphatic hydrocarbons, aromatic hydrocarbons	Not quantified
Test chamber	Silicone caulk	23 compounds	26.0 mg/m ² -h
	Mineral wool	13 compounds	0.012 mg/m ² -h
	Polystyrene foam insulation	15 compounds	1.4 mg/m ² -h
Test chamber	Polyurethane foam insulation	5 compounds	0.12 mg/m ² -h
	Phenoseal Brand caulk ^d	Butylacetate, 2-ethanol	Not quantified
	Vinyl acrylic latex caulk ^d	Ethylene glycol	Not quantified
	Butyl caulk ^d	Octane, octene, nonane, aliphatic hydrocarbons, alkylbenzenes	Not quantified

a) Chamber background formaldehyde levels ranged from 0.024 ppm to 0.028 ppm.

b) Formaldehyde concentration after test was less than background level, suggesting test material was a sink.

c) Minimum value, compound saturated the detector during analysis.

d) Sample aged 24 hours before vapor collected.

Source: Baechler, Hadley, and Marseilles 1990.

Rigid foam insulation materials, including extruded polystyrene, polyisocyanurates, and phenolics, are used in masonry cavity walls, prefabricated panel walls, low slope roofs, and building HVAC and refrigeration systems.^(a) The use of CFCs as blowing agents for these insulations has raised concerns about its effects on the ozone layer. The blowing agent gas is not released into the atmosphere at the time of use, but gradually over a period of years.

Plastic foams burn differently than typical building materials such as plaster board and lumber. For example, rather than burning in place under test conditions, polystyrene melts (Rose 1987). Depending on how polystyrene fire test results are interpreted, the smoke produced by the melted plastic may exceed code requirements (Rose 1987). Although the fumes released by burning plastic foams have been raised as an important health issue, J. R. Mehaffey of the National Research Council of Canada states that "there seems to be no definite proof that under fire conditions, polyurethane foam insulation augments toxic hazards beyond the levels that already exist in building fires" (Rose 1987). This statement is consistent with the reasoning expressed in Bonneville's EIS prepared for the New Homes programs (BPA 1988, p. 4.35).

4.6.2 Coatings

Coatings, including paints, inks, and resins, can expose workers to a variety of health hazards. These include toxic fumes, gases, vapors, and mists of materials such as acids, caustics, and organic solvents. Paints, resins, inks, and glues use solvents as carriers and diluents for the active ingredients. Increasing environmental and safety regulations regarding solvents containing VOCs has lead to the development of high-performance coatings, including high-solids, water-based, powder, and UV-curable systems (Pollock 1990, p. 68). The health effects associated with specific contaminants such as isocyanates, metals, and plastic resins are discussed in Section 4.4. Solvents are discussed below.

(a) K. R. Taylor. 1987. Issue Paper: The Use of Fluorocarbons in Rigid Foam Insulations. Pacific Northwest Laboratory, Richland, Washington.

Paints

Painting operations may expose workers to pigments, solvents, and thinners. Spray painting can expose workers to pigments and solvent vapors; brushing and dipping exposes workers to solvent vapors, whereas sanding exposes workers to the pigments. Of particular concern are lead and chromate compounds used in pigments--chromates are used as pigments in brightly colored paints--and isocyanates, which are used in polyurethane paints.

Printing Inks

The printing trade uses inks and paints that contain hazardous chemicals including volatile solvents (e.g., dichloromethane), radiation-curable coatings (polyesters with acrylate or methacrylate groups, and others), and pigment chemicals. Oils, used as solvents for some printing inks, may pose additional health hazards. Several studies of occupational exposure to UV inks have found a correlation with contact dermatitis and other skin reactions. There is some evidence that UV-cured inks containing dipropylene glycol methyl ether may be related to bone marrow damage (Food Chemistry Toxicology 1985).

Resins

Resins are used in coating and patching operations in metals finishing and in veneer and airplane manufacture. Resin coatings, including epoxies and phenolics, may expose workers to toxic curing agents, hardeners, catalysts, and solvents. Of particular concern are isocyanates used in manufacturing polyurethane resins and formaldehyde. Exposure to resins such as urea-formaldehyde and phenol-formaldehyde can cause indirect or direct sensitization and skin irritation (SJO, Shapiro, and Synergic 1984, p. C.24). Once sensitized, continued exposure can result in severe skin and respiratory response.

4.6.3 Electrochemical Solutions

Electrochemical processes associated with ECMs include electrochemical machining and electrochemical reduction used in wastewater treatment. Electrochemical processes such as etching and plating employ corrosive solutions of inorganic acids, inorganic bases, and oxidative salts. Some

chemicals that may be contained in these baths are hydrochloric and sulfuric acids, sodium and potassium hydroxide bases, and sodium nitrate and chlorate salts. In general, acids, bases, and salt solutions are irritating by skin contact or through inhalation of vapors.

Electrolytic refining may release arsine gas.

4.6.4 Membrane Materials

Membrane filters are used in separation and concentration processes in food processing, chemicals manufacturing, and wastewater treatment. Materials used to produce membrane filters are primarily plastics, including cellulose esters, PVC, cellulose acetate, and amide, sulfone, and olefin polymers. The primary hazard related to membrane filters occurs during their manufacture when monomers are present. Once polymerized, the materials are bound making them less volatile and, thus less likely to cause health problems. However, noxious chemicals could be released from the membranes if they are involved in a fire. Of particular concern is vinyl chloride, which is used in the manufacture of PVC (see Section 4.4.7 on plastics).

4.6.5 Refrigerants

Ammonia and freons are common refrigerants. The major health hazards associated with refrigerants are due to leaks. Liquid or aqueous ammonia can cause intense irritation of the mucous membranes, eyes, and skin. Freons are generally of low toxicity. However, high concentrations may cause effects ranging from mild central nervous system depression to asphyxiation. Freons may also be considered a health hazard because of their effect on the ozone layer. The health effects of ammonia and freons are discussed in Section 4.4 under irritant gases and hydrocarbons.

4.6.6 Solvents

Organic solvents are widely used in industry as cleaning and degreasing agents, and paint thinners, and are found in glues. Natural solvents are petroleum and coal tar derivatives. Synthetic solvents (halogenated hydrocarbons) substitute chlorine and fluorine for the hydrogen atoms in petroleum and coal-derived solvents. In many cases, these synthetic solvents are noncombustible.

Classes of organic solvents include aliphatic hydrocarbons (glues and cold cleaning); aromatic hydrocarbons (glues and paints); chlorinated hydrocarbons (degreasing and cold cleaning); and polar organics (paint solvents). Of particular concern are the aromatic hydrocarbons, which include benzene and compounds, such as toluene and xylene, made from benzene. The health effects of specific chemicals are discussed in Section 4.4 under hydrocarbons.

All organic solvents can dry and irritate the skin, eyes, and mucous membranes, and affect the central nervous system. Chronic exposure may cause skin disease. Acute exposure may cause headaches, nausea, dizziness, sleepiness, drunkenness, unconsciousness, and death. Some solvents cause permanent nervous system, kidney, and liver damage, and cancer. Studies have shown a decrease in reaction time, dexterity, speed, and memory in workers exposed to solvents for prolonged periods of time (Baker 1988b, p. 411). Thus, in addition to causing health effects, these substances may constitute safety hazards.

There has been considerable concern about the environmental effects of various VOCs. Many VOC solvents are listed by the EPA as hazardous air pollutants. Reduced air emissions of common solvents such as trichloroethane are mandated by the 1990 Amendments to the Clean Air Act. This has led to an increased use of less-volatile alcohols, esters, ketones, and glycol ethers in the coatings industry. Similarly, mandated reductions of CFCs have led the microelectronics industry, which uses large quantities of freons in degreasing operations, to look for substitutes or ways of reducing freon-based processes. Two current alternatives are soap and water and an orange peel-based cleanser (Savage 1990).

5.0 REGULATORY FRAMEWORK

Several federal and state agencies are involved in regulating industries for the purpose of protecting both the environment and the health and safety of workers and the public. This chapter describes these regulatory agencies and their areas of jurisdiction in relation to the major industry groups described in Chapter 3.0. It also describes the major federal legislation governing environmental and occupational impacts discussed in the previous chapters.

5.1 ENVIRONMENTAL REGULATION

Federal and state environmental regulatory agencies are described below, as is important environmental legislation. Table 5.1 indicates, by state, which federal and state agencies have jurisdiction over environmental, health, and safety concerns in Idaho, Montana, Oregon, and Washington. Table 5.2 shows which areas of environmental, health, and safety regulation each of the major industry groups is likely to deal with. Table 5.3 shows where these regulations are discussed in the U.S. Code of Federal Regulations (CFR). Appendix B includes representative air emission and water discharge permits for plants in the Bonneville service area to illustrate how these regulations are applied in practice.

5.1.1 Federal Agencies and Laws

The U.S. Environmental Protection Agency (EPA), created in 1970, is the major federal agency with oversight for environmental regulation. Its mission is to control and abate pollution in the areas of air, water, solid waste, pesticides, radiation, and toxic substances. The EPA seeks to abate and control pollution systematically, by proper integration of a variety of research, monitoring, standard setting, and enforcement activities. Part of EPA's mandate is to protect the public from health hazards posed by industry.

TABLE 5.1. Jurisdiction of Regulatory Agencies

State	Air Emissions	Agency with Jurisdiction							
		Discharges to Surface Water	Discharges to Groundwater	Discharges to Public Treatment Plants	Hazardous Waste Management	Mine Safety and Health	Occupational Health and Safety	Food Processing	Radio Signal Interference
Idaho	IDHW, EPA 10	EPA 10	IDHW	EPA 10	IDHW	MSHA	OSHA, NIOSH	FDA	FCC
Montana	MDHES	MDHES	EPA 8	EPA 8	MDHES	MSHA	OSHA, NIOSH	FDA	FCC
Oregon	ODEQ	ODEQ	ODEQ	ODEQ	ODEQ	MSHA	OR-OSHA, NIOSH	FDA	FCC
Washington	WDOE	WDOE	WDOE	WDOE	WDOE	MSHA	WDLI, NIOSH	FDA	FCC

EPA = U.S. Environmental Protection Agency
 EPA 8 = Region 8 Office of EPA
 EPA 10 = Region 10 Office of EPA
 FCC = Federal Communications Commission
 FDA = Food and Drug Administration
 IDHW = Idaho Department of Health and Welfare
 MDHES = Montana Department of Health and Environmental Sciences
 MSHA = Mine Safety and Health Administration
 NIOSH = National Institute for Occupational Safety and Health
 ODEQ = Oregon Department of Environmental Quality
 OR-OSHA = Oregon Occupational Safety and Health Administration
 OSHA = Occupational Safety and Health Administration
 SIC = Standard Industrial Classification
 WDLI = Washington Department of Labor and Industries
 WDOE = Washington Department of Ecology

TABLE 5.2. Areas of Regulation for Major Industries

SIC Major Group No.	Area of Regulation							
	Air Emissions	Discharges to Surface Water	Discharges to Groundwater	Discharges to Public Treatment Plants	Hazardous Waste Management	Mine Safety and Health	Occupational Health and Safety	Food Processing
10	P	Y	P	N	Y	Y	Y	N
20	Y	P	P	P	P	N	Y	Y
24	P	P	P	P	P	N	Y	N
26	Y	Y	P	P	Y	N	Y	N
28	Y	P	P	P	Y	N	Y	N
29	Y	P	P	P	Y	N	Y	N
32	Y	P	P	P	P	N	Y	N
33	Y	P	P	P	Y	N	Y	N
34, 36, 37	P	P	P	P	Y	N	Y	N

Key: Y = Probably yes (Firms in this group are likely to be involved in activities subjecting them to regulation under this area)
 N = Probably not (Firms in this group are unlikely to be involved in activities subjecting them to regulation under this area)
 P = Possibly (Firms in this group may be involved in activities subjecting them to regulation under this area)

10 = Metal mining
 20 = Food and kindred products
 24 = Lumber and wood products, except furniture
 26 = Paper and allied products
 28 = Chemicals and allied products
 29 = Petroleum refining and related industries
 32 = Stone, clay, glass, and concrete products
 33 = Primary metal industries
 34,36,37 = Metals fabrication, electronics, and transportation equipment

TABLE 5.3. CFRs Pertaining to Environmental, Safety, and Health Concerns

<u>Area of Regulation</u>	<u>CFR^(a)</u>
Air Emissions	40 CFR Subchapter C
Discharges to Surface Water	40 CFR Subchapter D
Discharges to Groundwater	40 CFR Parts 144-149
Discharges to Public Treatment Plants	40 CFR Part 403
Hazardous Waste Management	40 CFR Parts 260-281
Mine Safety and Health	30 CFR Parts 1-100
Occupational Health and Safety	29 CFR Parts 1911-1990
Food Processing	21 CFR Part 110
Radiological Health Performance	21 CFR Parts 1010-1050
Radio Emissions	FCC device certification

(a) CFR = Code of Federal Regulations

The United States is divided into 10 regions for the purposes of EPA's enforcement activities.^(a) The EPA sets national standards and the states and/or regional EPA offices are responsible for seeing that these standards are met. For laws such as the Clean Water Act, the Resource Conservation and Recovery Act (RCRA), and the Safe Drinking Water Act, EPA administers the regulatory program required by the statute unless it finds that a state has a comprehensive alternative program that would be at least as protective. The major federal laws regulating industries discussed in this report are described below.

5.1.2 Air Quality

The federal Clean Air Act of 1970, which was amended in 1977 and 1990, is the basic law regulating air quality in the United States. The Clean Air Act establishes National Ambient Air Quality Standards (NAAQS) for conventional pollutants, sets emission levels for the prevention of significant deterioration (PSD), and regulates emissions of air toxics. The EPA regulates

(a) The headquarters for EPA Region 8, which includes Montana, are in Denver, Colorado. The headquarters for Region 10, which includes Idaho, Oregon, and Washington, are in Seattle, Washington.

two categories of air toxics: criteria pollutants and other air toxics. The six criteria pollutants are ozone, particulate matter, carbon dioxide, sulfur dioxide, lead, and nitrogen dioxide. The Clean Air Act Amendments of 1990 list 189 toxic pollutants that pose health and environmental hazards. The new law requires EPA to set emission standards for all major sources of these pollutants over a 10-year period and requires major sources to install best available control technology even if EPA fails to issue the standards.

There are four types of Clean Air Act-related permits: 1) state emission permits, 2) nonattainment permits, 3) prevention of significant deterioration (PSD) permits, and 4) construction approval permits under the National Emission Standards for Hazardous Air Pollutants (NESHAPS) program. With one exception, all four categories of permits are issued by state or local agencies in Idaho, Montana, Oregon, and Washington. Construction approval for sources of radionuclide emissions is issued by the EPA Region 10 office for Idaho, Oregon, and Washington, and by the Region 8 office for Montana.

5.1.3 Water Quality

The Federal Water Pollution Control Act of 1972, commonly called the Clean Water Act, authorizes federal and state control of pollutant discharges into waters of the United States and into municipal sewer systems. The law, which was amended in 1977 and 1987, includes general pretreatment regulations for new and existing sources of water pollutants. EPA has issued effluent guidelines and standards for approximately 50 categories of sources. Wastewater dischargers must obtain and comply with permits issued under the National Pollution Discharge Elimination System (NPDES). Montana, Oregon, and Washington have been delegated authority by EPA to issue NPDES permits. Permits for Idaho are issued by the EPA Region 10 office in Seattle.

The Safe Drinking Water Act of 1986 governs discharges of wastewater in surface waters, municipal sewers, and wells. The law protects public drinking water supplies and establishes the Underground Injection Control (UIC) Program, which is the principal federal program regulating intentional discharges to groundwater. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund program, governs unintentional releases of hazardous substances to groundwater.

5.1.4 Solid Wastes

The federal Solid Waste Disposal Act of 1965 was amended by the Resource Conservation and Recovery Act (RCRA) of 1976. RCRA concentrated on municipal waste landfills and the treatment and disposal of hazardous wastes, leaving regulation of nonhazardous landfills to the states.^(a) RCRA was reauthorized by the Hazardous and Solids Waste Amendments (HSWA) of 1984, which improved the law's hazardous waste provisions. These amendments were aimed at preventing the types of waste disposal problems that led to the need for the Superfund (CERCLA) program. In general, CERCLA applies to historical wastes whereas RCRA applies to new wastes.

RCRA applies to all industries that generate, transport, store, treat, or dispose of hazardous wastes. Certain wastes listed as hazardous (see 40 CFR Part 261) must be treated and rendered nonhazardous before disposal. In addition to listed wastes, EPA classifies materials as hazardous wastes if designated tests show them to be toxic, reactive, ignitable, or corrosive.

5.1.5 Toxic Substances

Under the Toxic Substances Control Act (TSCA) of 1976, EPA is authorized to require testing of new and existing chemicals that are potentially toxic, and to prohibit or place restrictions on the manufacture, distribution, and use of such chemicals. The definition of "toxic" varies from regulation to regulation. However, the criterion established by the Toxic Substances Control Act is that a substance must pose a "significant" or "unreasonable risk" of hazard, a determination EPA must make using modern risk analysis techniques (Novick, Stever, and Mellon 1991, pp. 2.26-2.30).

5.1.6 Disclosure of Hazards

The 1986 CERCLA Amendments, also known as the Superfund Amendments and Reauthorization Act (SARA), establish a program requiring disclosure to workers and the general public about the dangers of hazardous chemicals, as well as development of emergency response plans for chemical emergencies. SARA Title III, the Emergency Planning and Community Right-to-Know Act of

(a) EPA is considering developing guidelines for regulation of nonhazardous landfills as well.

1986, requires major manufacturing facilities in certain industrial sectors to report their emissions of 359 toxic substances to EPA. These air, water, and land emissions are compiled in EPA's Toxic Chemical Release Inventory (TRI) database. The EPA publishes a national TRI report and regional EPA offices publish inventory data for each region. The TRI database can also provide information on individual facilities.

5.1.7 State Environmental Agencies

The Idaho Department of Health and Welfare (IDHW), the Montana Department of Health and Environmental Sciences (MDHES), the Oregon Department of Environmental Quality (ODEQ), and the Washington Department of Ecology (WDOE) are the principal environmental agencies in Idaho, Montana, Oregon, and Washington respectively. Each agency implements and enforces state environmental laws and certain federal environmental laws that have been delegated to the state for implementation and enforcement. While the activities of the four agencies differ depending on state law, each agency does have programs and requirements for control of air and water pollution and regulation of solid and hazardous waste disposal.

Montana, Oregon, and Washington issue state permits for air emissions and wastewater discharges and administer federal discharge permits. Washington is divided into four regions for the purposes of environmental oversight. Idaho issues state permits for air quality but not for water discharges. Federal permits for air emissions and water discharges in Idaho are issued by the EPA Region 10 office in Seattle. Appendix D lists contact information for these agencies.

5.2 OCCUPATIONAL SAFETY AND HEALTH REGULATION

The major federal regulatory agencies with jurisdiction over the industries profiled in this report are the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA). Both agencies, described below, are part of the U.S. Department of Labor. In addition, individual states may have agencies that regulate occupational health and safety. Table 5.1 indicates, by state, which agencies have jurisdiction over health and safety concerns in Idaho, Montana, Oregon, and

Washington. Table 5.2 shows which areas of health or safety regulation each of the major industry groups is likely to deal with. Table 5.3 shows where these areas of health or safety concern are discussed in the U.S. Code of Federal Regulations (CFR). Federal and state occupational safety and health data reported by Montana, Oregon, and Washington is discussed in Appendix C.

5.2.1 Federal Agencies and Legislation

The Occupational Safety and Health (OSH) Act of 1970 prescribes minimum safety and health standards for most industries and authorizes inspections, citations, and mandatory civil penalties to enforce its standards. Most U.S. workers are covered under the federal OSH Act, with the exception of federal, state, and local government employees, self-employed workers, agricultural workers, and workers in states with approved OSHA programs. Workers covered by other laws and agencies, such as the Nuclear Regulatory Commission, the Mine Safety and Health Act, and the Department of Transportation, are also exempted.

The OSH Act created the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH). The functions performed by OSHA include 1) developing and promulgating occupational safety and health standards, 2) conducting investigations and inspections to determine the status of compliance with safety and health standards and regulations, and 3) issuing citations and proposing penalties for noncompliance with safety and health standards and regulations.

The National Institute of Occupational Safety and Health (NIOSH) is in the Department of Health and Human Services and is part of the Centers for Disease Control of the U.S. Public Health Service. NIOSH's major responsibilities are to 1) conduct laboratory and epidemiological research into the causes of occupational illness and accidents; 2) conduct research and develop criteria documents that recommend exposure limits and other control techniques for work-place hazards; 3) certify the efficacy of personal protective equipment; 4) strengthen the training of occupational health and safety professionals; and 5) develop sampling and measurement methods to evaluate work-place hazards. Although NIOSH develops guidelines and recommends standards, it does not have any enforcement authority.

The federal Coal Mine Health and Safety Act of 1969 created the Mining Enforcement Safety Administration (MESA). The law was amended to cover all mines in 1977 and the agency's name was changed at that time to the Mine Safety and Health Administration (MSHA). MSHA's functions include

- 1) developing and promulgating mandatory safety and health standards applicable to the mining industry,
- 2) ensuring compliance with the standards,
- 3) assessing civil penalties for violations of the standards, and
- 4) investigating accidents.

In addition to these agencies, EPA has some jurisdiction regarding workplace health under the provisions of the Toxic Substances Control Act (TSCA) of 1976. The law requires EPA to regulate "unreasonable risks" to the public and workers. Thus, EPA can regulate substances not already regulated by OSHA and can extend OSHA exposure limits to workers not covered by OSHA. Federal (SARA Title III), state, and local "Right-to-Know" regulations mandate worker and public access to information regarding hazards, as well as reporting of intentional and unintentional releases of toxics into the environment.

5.2.2 State Occupational Safety and Health Agencies

States may assume responsibility for the development and enforcement of occupational safety and health standards under the Occupational Safety and Health Act if the state's plan is approved by the U.S. Secretary of Labor. Such plans have been submitted and approved for Oregon and Washington. The administering state agencies are the Oregon Occupational Safety (OR-OSHA) and Health Administration and the Washington Department of Labor and Industries (WDLI). These plans must at least match federal standards. Some states, such as Oregon, have stricter safety and health standards and better enforcement capabilities than does federal OSHA.

5.3 OTHER FEDERAL AGENCIES

Two other agencies, the Federal Communications Commission (FCC) and the Food and Drug Administration (FDA), promulgate regulations that might affect the energy conservation measures and/or the industries profiled. The FCC regulates interstate and foreign communications by radio, television, wire, and cable. The scope of its regulation includes radio and television

broadcasting; telephone, telegraph, and cable television operation; and satellite communication. The FCC also regulates radio emissions from common industrial equipment such as computers and telecommunications devices.

The FDA is a component of the U.S. Department of Health and Human Services. The FDA is a regulatory agency whose mission is to see that 1) food is safe and wholesome, 2) cosmetics are safe, 3) medicines and medical devices are safe and effective, and 4) radiation-emitting products such as microwave ovens are manufactured to meet performance standards that protect human health and safety. Feed and drugs for pets and farm animals also come under the FDA's regulatory authority.

The FDA's "Current Good Manufacturing Practice in Manufacturing, Packing, or Holding Human Food" (21 CFR Part 110) may be applicable to energy conservation projects. These practices provide direction for food processors and cover such areas as the cleanliness and maintenance of buildings, facilities, and grounds; the construction and maintenance of equipment and utensils; production and process controls; and warehousing and distribution. The Part 110 regulations are taken into consideration in determining whether a food is adulterated within the meaning of the federal Food, Drug, and Cosmetic Act.

The FDA issues performance standards for various products under the Radiation Control for Health and Safety Act of 1968. Manufacturers certify that covered products are in compliance with the standards. Standards have been issued for products that emit ionizing radiation, microwave and radio frequency-emitting products, and light-emitting products such as lasers.

6.0 IMPLICATIONS AND RECOMMENDATIONS

Energy conservation measures designed for industrial use may result in direct or indirect environmental impacts. Effects may result from many stages of measure production, operation, or disposal. This report focuses on impacts in the operation stage. Actual effects from any given measure would depend on the precise technology employed to conserve energy and the process technology where the application is being made. Many different factors, including industry type, work-place conditions, worker training, and existing environmental conditions, may affect environmental outcomes. To address these issues this report has three objectives:

- Describe potential conservation measures that Bonneville may employ in industrial programs and discuss potential primary impacts.
- Characterize industrial systems and processes where the measure may be employed and describe general environmental issues associated with each industry type.
- Review environmental permitting, licensing, and other regulatory actions required for industry and summarize the type of information available from these sources for further analysis.

6.1 CONSERVATION MEASURES

Producing energy-efficient equipment, rather than standard or typical equipment, may involve the use of additional materials or the use of new processes. But the negative impacts from manufacturing a conservation measure can be offset by gains made in its operation. An energy-efficient motor requires a greater quantity of copper and silicon steel than a standard variety. However, these requirements are offset by potentially increased motor life, which may reduce motor rewinding, thus reducing solvent and combustion pollutants.

In addition, conservation measures may reduce the capacity requirements for electrical cables and transformers serving industrial processes. Thus, material savings can be made in the electrical distribution system. Though these savings are real, this report makes no attempt to discuss or quantify them. Reductions in the demand for electricity generation are also not

considered in this analysis, although positive environmental effects are a likely result.

For some conservation measures, entirely new technologies are employed rather than a more efficient version of the same technology. For example, electronic controls can replace manual or mechanical controls. In these instances, the relative environmental effects are dependent on the specific technologies being compared. The new technology may require retraining workers or redefining worker responsibilities.

Some new technologies will directly alter process waste streams. For example, some filtering techniques, such as electrolytic separation, are capable of recovering metals for resale. Some fabrication and drying techniques, such as lasers and infrared radiation, may replace existing combustion processes and thus reduce combustion pollutants. Infrared dryers also reduce solvent emissions from inks that require volatilization in order to set up. Some controls, such as arc furnace controls, energy management systems, and computer-controlled machining, may reduce waste streams by improving manufacturing tolerances and maintaining greater equipment operating efficiencies.

Where electrical equipment replaces equipment that burns natural gas or other fuels, the issue of fuel-switching must be addressed. In these instances, electrical equipment may improve energy efficiency in terms of Btus or dollars required to produce a unit of product. However, an environmental assessment should account for impacts that will result from meeting the increased load from the electrical equipment. The combustion of natural gas at the plant must be weighed against the environmental impacts resulting from burning natural gas or other fossil fuels to generate and transport the electricity.

Potential impacts from electronic equipment may include worker exposure to EMFs. Researchers suspect that such exposure may result in health effects. However, there is a great deal of uncertainty surrounding this issue, and regulatory agencies have been able to provide little guidance for occupational settings.

Table 6.1 lists the conservation measures discussed in Chapter 2 and summarizes potential environmental effects.

6.2 INDUSTRIAL SETTING

Potential environmental effects that may result from industrial conservation measures will be largely dependent on the processes to which the measures are applied. Bonneville has identified 101 plants in the Pacific Northwest that account for 80% of industrial electricity consumption. These plants offer a precise target for a conservation program. (In comparison to the residential program, which involves over 100,000 homes.) The processes involved in these industries are identified in Table 6.2. Applications of conservation measures are identified in Table 6.3

Bonneville's analysis of industrial electricity consumers could be combined in a decision analysis framework with information about environmental effects and the market for conservation measures. This analysis could take into account potential environmental costs and benefits, market potential, and feasibility issues to help design an effective program and focus environmental documentation. An analysis of this type was beyond the scope of this report.

6.3 REGULATORY IMPLICATIONS

The agencies regulating industrial pollution and occupational safety and health form a complex and extensive regulatory framework. Agencies responsible for protecting the environment and occupational safety and health can be expected to take the lead in setting standards for potentially hazardous measures. However, under NEPA, Bonneville is accountable for impacts that may result from its programs.

These impacts may include those from emerging technologies that have not yet been regulated. Past issues of this sort include indoor air quality in residential buildings. Bonneville was among the first federal agencies to take a leading role in investigating its programs that may affect indoor air quality and has been active in researching and mitigating indoor air hazards, although other agencies ultimately took the lead in setting national health guidelines. Thus, where uncertainty surrounds the potential impacts that may

result from conservation measures, Bonneville may take a role in research, policy formation, and mitigation. EMF is a potential example of this type of issue.

In addition to its analytical role, Bonneville has lead other agencies in the formation of information programs. An information program offered by Bonneville to explain the potential health and environmental effects of conservation measures could help industries on probation or operating near environmental safety thresholds to choose measures that would bring needed pollution or hazard reductions.

TABLE 6.1. Summary of Potential Environmental Effects Resulting from Industrial Conservation Measures^(a)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS^(b)	ELECTRIC LOAD INCREASE^(c)	WORKPLACE CONCERNS	EMF^(d)
Adjustable speed drives (ASDs)	(+) Replacing throttling valves may reduce risk of accidental releases of toxics and hazardous materials		(-) May increase noise and vibration (-) May need ventilation upgrades and larger motors to control heat generated (-) Electrical interference with other equipment may require harmonic filtering	Maybe
Arc furnace controls	(+) Proper control may decrease ozone production and reduce ash production			
Energy management systems (EMS)	(+) Proper temperature control may lead to less waste/rejection of thermally labile materials		(-) May effect lighting and ventilation systems (-) Shutoff of refrigeration systems during condensation may contribute to indoor air pollution by promoting microbial growth	
Power factor controllers				Maybe
Computer-controlled machining			(-) Stress may result from line speedup and loss of job control (-) Increased repetitive motion disorders, eye strain, and fatigue may be associated with VDT use	Maybe

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS ^(b)	ELECTRIC LOAD INCREASE ^(c)	WORKPLACE CONCERNS	EMF ^(d)
Robotics		Maybe, if machine drive replaces human energy	(+) May reduce hazardous work and repetitive motion disorders (-) Hazards associated with unguarded mechanical parts (-) Stress and alienation associated with automation	
High-efficiency motors	(-) Upgrades use more raw materials, e.g., copper and silicon steel (-) Solvent processes used to remove old windings and insulation may generate hazardous wastes (-) Old motor capacitors may contain PCBs		(+) Quieter and less vibration (-) May increase ventilation requirements	Maybe ^(e)
Pumps	(+) Use of sealless pumps in hazardous fluid pumping may reduce risk of accidental releases of toxics and hazardous wastes (+) Replacing throttling valves with ASDs may reduce accidental releases		(+) Use of sealless pumps in hazardous fluid pumping may reduce risk of accidental releases of toxics and hazardous wastes (+) Replacing throttling valves with ASDs may reduce accidental releases	
Conveyor systems	(+) Belt conveyors in hog fuel boilers generate less dust than do pneumatics, reducing particulate emissions (+) Conveyors can replace diesel-equipment in mining, reducing exhausts	Yes, if replaces fossil-fueled equipment	(-) May increase ambient noise levels (-) High-speed and mechanical safety hazards (-) Suction and pressure environment hazards (+) Conveyors may reduce diesel exhaust hazards in underground mining	
Convection heating	(-) Use of natural gas as fuel generates air pollutants; drilling and extraction may generate air and water pollutants		(-) Health and safety hazards associated with high temperatures and combustion byproducts	

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS^(b)	ELECTRIC LOAD INCREASE^(c)	WORKPLACE CONCERNS	EMF^(d)
Induction heating and drying	(+) Eliminates combustion byproducts	May replace fossil fuels		Maybe
Infrared radiation (IR) heating and drying	(+) Eliminates combustion byproducts (+) Solvents in coating systems, but may be more efficient than conventional coatings which also use solvents	May replace fossil fuels		
Microwave radiation heating and drying	(+) Eliminates combustion byproducts	May replace fossil fuels	(-) High power densities produce thermal effects and burn hazards (-) May interfere with medical equipment, e.g., pacemakers	Maybe
Radio frequency radiation (RFR) heating and drying	(+) Eliminates combustion byproducts	May replace fossil fuels	(-) High power densities produce thermal effects and burn hazards (-) May interfere with medical equipment, e.g., pacemakers	Maybe
Ultraviolet (UV) radiation heating and drying	(+) Eliminates combustion byproducts (+) Eliminates solvents and may reduce volatile emissions	May replace fossil fuels	(+) May reduce use of solvents (-) Skin and eye hazards (-) Photochemical effects include ozone formation, e.g., in arc welding (-) May decompose some solvents into toxic gases (-) Some UV cured inks may cause bone marrow damage	

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS ^(b)	ELECTRIC LOAD INCREASE ^(c)	WORKPLACE CONCERNS	EMF ^(a)
Desiccant dehumidifiers	(+) May replace refrigeration systems using chlorofluorocarbons (CFCs)		(+) Replacing condensation systems may reduce indoor air pollution by reducing microbial growth (-) Excessive dehumidification is uncomfortable (-) Contact with eutectic salts used in some systems may cause skin irritation	
Heat pump dehumidifiers	(+) Reduces combustion byproducts if replaces fuel-burning equipment, e.g., lumber dryers	Yes, if replaces fossil fuels		
Cooling towers and chillers	(-) Polyvinyl chloride (PVC) fill used in some cooling towers is made from vinyl chloride, an EPA criteria pollutant. Use and disposal of these materials may be a problem. (-) Burning PVC fill may release toxic gases		(-) Provide good environment for microorganisms which may contribute to indoor air pollution (-) Hazards associated with replacing old asbestos filler (-) Hazards associated with PVC production	
Thermal storage			(-) Contact with eutectic salts use in some systems may cause skin irritation (-) Provide good environment for microorganisms which may contribute to indoor air pollution	
Refrigeration upgrades	(-) Rely on CFCs which are linked with ozone depletion (-) Use ammonia, a toxic air pollutant		(-) Hazards associated with exposure to ammonia (-) ASDs that shutoff refrigeration systems during condensation may contribute to indoor air pollution by promoting microbial growth	

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS ^(b)	ELECTRIC LOAD INCREASE ^(c)	WORKPLACE CONCERNS	EMF ^(d)
Heat recovery	(+) Recovering heat from process waters could reduce waste heat (-) Heat recovery from flue gases may interfere with pollution control equipment and increase emission levels		(-) Hazards associated with high temperatures (-) Problem of cross-pollution contamination in air-to-air systems	
Heat pumps	(+) Reduces combustion byproducts if fuel-burning equipment replaced (-) Closed-cycle systems may use CFCs as refrigerants	Yes, if replaces fuel-burning equipment		
PINCH technology	(+) May reduce fuel combustion and reduce combustion byproducts			
Electrochemical machining (ECM)	(-) Likely to produce more problematic wastes than conventional techniques	Maybe	(-) Releases hydrogen which is highly flammable (-) Exposure to acids and salt solutions may be hazardous	Maybe
Induction heating (hardening, welding)				Maybe
Lasers (cutting, hardening, welding)	(+) Less distortion and scrap due to precision (+) Eliminates solvents used in alternative technologies		(-) Skin and eye hazards (-) Cutting materials such as lead and plastics may release toxic gases	
Water-jet cutting			(-) Hazards associated with high-pressure systems (-) Increased noise (-) Airborne abrasive particles may be hazardous	

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS^(a)	ELECTRIC LOAD INCREASE^(a)	WORKPLACE CONCERNS	EMF^(a)
Electrolytic separation	(+) Used to recover process materials (+) Used as a waste reduction technique (-) Spent process chemicals may have to be disposed of as hazardous wastes	Yes, if replaces fuel-burning techniques	(-) Process chemicals and fumes may be hazardous	
Freeze concentration	(+) Do not require heat (+) Used to recover process materials (+) Used in wastewater treatment (+) Reduce combustion byproducts if replace fuel-burning equipment	Yes, if replaces fuel-burning techniques		
Membranes	(+) Used to recover process materials (+) Used as a waste reduction technique (+) Do not require heat (+) Reduce combustion byproducts if replace fuel-burning equipment (-) May have to be disposed of as hazardous materials if contaminated (-) Vinyl chloride, an EPA criteria pollutant, used in production of some membrane materials (-) May release toxic chemicals if burned		(-) Hazards associated with PVC production (-) Membrane materials may release toxics if burned	
Insulation	(-) CFCs used as foaming agents in rigid foam insulation (-) Off-gassing of volatile organics (VOCs)		(-) Hazards may be associated with natural and synthetic respirable fibers (-) Upgrades may expose workers to asbestos (-) Plastic foam and cellulose insulation may present fire hazards (-) Off-gassing of VOCs may contribute to indoor air pollution	

TABLE 6.1. (contd)

ENERGY EFFICIENCY IMPROVEMENTS	MATERIAL AND WASTE STREAM EFFECTS ^(a)	ELECTRIC LOAD INCREASE ^(c)	WORKPLACE CONCERNS	EMF ^(d)
Compressed air systems			(+) Efficiency reduces noise	
Lighting upgrades	(-) Old light ballasts may contain PCBs		(+) Improved lighting (-) Some types of lighting not appropriate for indoor settings	
Water conservation and wastewater recycling	(+) Reduced water use (+) Recover process materials			

- (a) Many of the potential effects identified in this table can be mitigated. However, mitigation and control techniques are not covered in this document.
- (b) More efficient operation in general reduces material and energy inputs and thus may reduce waste streams.
- (c) Electricity generation may have impacts that are not considered here. However, more energy efficient technologies may result in reduced electricity transmission systems (i.e., downsizing of capacity).
- (d) Electromagnetic fields (EMF) may be generated by these energy efficiency improvements. There was no information in the literature surveyed on the magnitude of these fields. Furthermore, there is considerable controversy about whether these fields pose health threats and if so, at what power density levels.
- (e) Motor windings may generate EMF. However, efficient motors may reduce overall EMF.

TABLE 6.3. Industrial Process Energy Measure Applications

ECMs	Industrial Processes												
	Cool- ing	Curing	Cutting	Drying	Heat Treat- ing	Join- ing	Melt- ing	Mixing	Other Process Heating	Sep./ Conc	Moving	Light.	Comp Air
Controls													
ASDs	•							•			•		•
Arc Furnace Controls							•						
Computer-Controlled Machinery		•	•			•					•		
Energy Management Systems	•			•					•			•	
Power Factor Controllers	•	•	•	•	•	•	•	•	•	•	•	•	
Robotics			•		•	•	•				•		
Motor-Drive													
Conveyors									•		•		•
Motors											•		
Pumps	•										•		•
Heating/Drying Technologies													

TABLE 6.3. (contd)

ECMs	Industrial Processes												
	Cool- ing	Curing	Cutting	Drying	Heat Treat- ing	Join- ing	Melt- ing	Mixing	Other Process Heating	Sep./ Conc	Moving	Light.	Comp Air
Convection		•			•				•				
Infrared				•					•				
Microwave		•							•				
RFR		•		•					•				
Ultraviolet				•					•				
Dehumidifiers													
Desiccant				•									
Heat Pump		•		•					•				
Refrigeration Technologies													
Cooling Tower Upgrade	•												
Refrigeration Upgrade	•												
Thermal Storage	•								•				
Heat Recovery Technologies													

TABLE 6.3. (contd)

ECMs	Industrial Processes												
	Cool- ing	Curing	Cutting	Drying	Heat Treat- ing	Join- ing	Melt- ing	Mixing	Other Process Heating	Sep./ Conc	Moving	Light.	Comp Air
Heat Recovery	•	•							•				
Heat Pumps	•	•		•					•				
Pinch	•	•		•					•				
Fabrication and Finishing													
Electrochemical Machining					•								
Induction Heating					•								
Lasers			•		•		•						
Water Jets			•										
Separation and Concentration													
Electrolytic										•			
Freeze Concentration										•			
Membranes										•			
Energy Systems													

TABLE 6.3. (contd)

ECMe	Industrial Processes												
	Cool- ing	Curing	Cutting	Drying	Heat Treat- ing	Join- ing	Melt- ing	Mixing	Other Process Heating	Sep./ Conc	Moving	Light.	Comp Air
Insulation	•								•				
Compressed Air	•												•
Lighting	•											•	
Renewables			•				•		•				
Wastewater									•				

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APPENDIX A

INDUSTRIAL ELECTRICITY USERS BY SIC CODE

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INDUSTRIAL ELECTRICITY USERS BY SIC CODE

This appendix provides background information on the industry classification process used in Chapter 3, which profiles the major electricity-consuming industries in the Pacific Northwest. Section A.1 discusses how these industries were identified. Section A.2 explains how the Standard Industrial Classification (SIC) code system works, defines the major industry groups represented, and gives examples of industries within each SIC code grouping.

A.1 INDUSTRY SELECTION

The starting point for the industry profiles in Chapter 3 was Bonneville's list of the 101 largest industrial electricity users served by public utilities in the Pacific Northwest (see Table A.1). The list ranks plants according to energy consumption. On the list are representatives of 11 major industry groups as designated by two-digit SIC code (Section A.2 describes how the codes work). Four-digit SIC codes for plants on the list were identified by reference to the manufacturers' directory for the appropriate state (e.g., ODC 1989; WDC 1990). Bonneville estimates that the listed plants consume about 80% of the electricity used for industrial purposes in the Pacific Northwest.

Several plants had changed ownership, a few were no longer in operation, or could not be located. In some cases, Bonneville's SIC code for the facility was based on the parent company's industrial classification but the plant itself engaged in activities that place it under another SIC code, sometimes in another major industry. For example, the major industry group for Tektronix Inc. is "Measuring, Analyzing, and Controlling Instruments" (SIC 38). However, the Forest Grove, Oregon, Tektronix plant on the Bonneville list manufactures printed circuit boards, which are classified in the "Electronic and Electrical Equipment" (SIC 36) major group.

TABLE A.1. Bonneville List of Top 101 Electricity Users in the Northwest

Company	City	Electric Utility	2 digit SIC	USE (aMW)	Area Offi
=====	=====	=====	=====	=====	=====
1 Weyerhaeuser Paper Co.	Longview, Wa	Cowlitz County PUD	26	225.0	LCA
2 Northern Pacific	Longview, Wa	Cowlitz County PUD	26	88.0	LCA
3 James River Corp	Clatskanie, Or	Clatskanie PUD	26	76.0	LCA
4 Longview Fibre	Longview, Wa	Cowlitz County PUD	26	74.0	LCA
5 Weyerhaeuser Paper Co.	Springfield, Or	Eugene Water& Elec	26	71.0	LCA
6 Occidental Chem	Tacoma, Wa	City of Tacoma	28	62.0	PSA
7 Ponderay Newsprint Co.	Usk, Wa	Pend Oreille PUD	26	60.0	UCA
8 Georgia Pacific	Toledo, Or	Central Lincoln PUD	26	58.0	LCA
9 Boise Cascade		City of Tacoma	26	49.8	PSA
10 Boeing Company		Seattle City Light	37	49.7	PSA
11 Pennwalt Corp	Tacoma, Wa	City of Tacoma	28	38.0	PSA
12 NW Glass Simpson Tacoma		Seattle City Light	32	35.0	PSA
13 Kraft	Tacoma, Wa	City of Tacoma	26	32.0	PSA
14 Weyerhaeuser		Snohomish County PUD	24	32.0	PSA
15 Kemnord Inc. International	Moses Lake, Wa	Grant County PUD	28	30.0	UCA
16 Paper	Gardiner, Or	Central Lincoln PUD	26	30.0	LCA
17 Scott Paper Co.	Everett, Wa	Snohomish County PUD	26	30.0	PSA
18 Silicon Metaltech		Douglas County PUD	33	30.0	UCA
19 Boeing Company		Snohomish County PUD	37	29.5	PSA
20 Daishowa America	Pt. Angeles	City of Pt. Angeles	26	28.0	PSA
21 Newmont Gold Co.		Wells Rural Elec	10	25.0	SRA
22 Cyprus Thompson Creek		Salmon River Elec	10	23.0	SRA
23 Cascade Steel	McMinnville, Or	City of McMinnville	33	20.4	LCA
24 Weyerhaeuser Paper Co.	Grays Harbor, Wa	Grays Harbor PUD	26	20.0	PSA
25 Seattle Steel Inc	Seattle, Wa	Seattle City Light	33	20.0	PSA
26 British Petroleum Refining		Whatcom County PUD	29	16.8	PSA
27 ITT Rayonier	Pt. Angeles, Wa	City of Pt. Angeles	26	16.0	PSA
28 Kalama Chemical	Kalama, Wa	Cowlitz County PUD	28	14.0	LCA
29 Salmon Day Steel		Seattle City Light	33	13.7	PSA
30 Boise Cascade Co		Clark County PUD	26	13.0	LCA
31 Weyerhaeuser Paper Co.		Snohomish County PUD	26	13.0	PSA
32 Simpson Timber Co.	Shelton, Wa	Mason County PUD #3	24	11.7	PSA
33 Dow Corning	Springfield, Or	Springfield PUD	33	9.5	LCA
34 Chevron Inc.		Columbia R. PUD	29	9.5	LCA
35 Chevron Chemical	Kennewick, Wa	Benton County PUD	28	9.0	SRA
36 Grays Harbor Paper	Hoquiam, Wa	Grays Harbor PUD	26	8.0	PSA
37 Ideal Basic Ind.		Seattle City Light	32	7.5	PSA
38 Asamera Mineral	Wenatchee, Wa	Chelan County PUD	10	7.0	UCA
39 Asarco Troy Mine		Northern Lights Inc	10	7.0	UCA
40 Heinz H. J. Co.		Burley Municipal	20	7.0	SRA
41 ITT Rayonier		Grays Harbor PUD	26	7.0	PSA
42 Union Carbide	Tacoma, Wa	City of Tacoma	28	7.0	PSA
43 Westinghouse Electric		Idaho Falls Elec	34	6.6	SRA
44 Boise Cascade Co.	Lagrande, OR	Oregon Trail Elec	24	6.0	SRA
45 Weyerhaeuser		City of Seattle	24	6.0	PSA
46 Weyerhaeuser		Lewis County PUD	24	5.8	PSA
47 Gourmet Brands		Columbia Basin Elec	20	5.3	SRA
48 J.R. Simplot		Keyburn Electric	20	5.0	SRA
49 I. B. P. Inc		Benton Rural Elec	20	4.8	SRA
50 Lamb Weston Inc.		Umatilla Electric	20	4.8	SRA

TABLE A.1. (Contd)

51	Morton Thiokol		Grays Harbor PUD	26	4.8	PSA
52	Weyerhaeuser		Emerald PUD	24	4.6	LCA
53	Siltec Alumina		Salem Electric	36	3.9	LCA
54	Lamb Weston Inc.		Benton Rural Elec	20	3.7	SRA
55	Lehigh Portland Cements		Pend Oreille County	32	3.6	UCA
56	Simpson Timber Co		City of McCleary	24	3.5	PSA
57	Cascade Hardwood		Lewis County PUD	24	3.5	PSA
58	Weyerhaeuser		Pacific County PUD	24	3.5	PSA
59	Sound Refining Co		City of Tacoma	29	3.4	PSA
60	Multnomah Plywood	St. Helens	Columbia River PUD	24	2.9	LCA
61	Tillamook Creamery		Tillamook PUD	20	3.4	LCA
62	Bohemia Drain		City of Drain	24	2.5	LCA
63	Bohemia Dorena		Lane Electric Coop	24	2.5	LCA
64	South Coast Lumber	Gold Beach	Coos-Curry Elec Co-op	24	2.1	LCA
65	Co-Plywood	N. Bonneville	Skamania County PUD	24	2.0	LCA
66	Pope & Talbot	Oakridge	Lane Electric Coop	24	2.0	LCA
67	Agripac	Salem	Salem Electric	20	1.5	LCA
68	Seneca Lumber	Parker	Blachly-Lane Cooperative	24	1.7	LCA
69	States Veneer	Parker	Blachly-Lane Cooperative	24	1.5	LCA
70	Gold Beach Plywood		Coos-Curry Elec Co-op	24	2.0	LCA
71	SanPoil Lumber		Ferry County PUD	24	1.7	UCA
72	Pope & Talbot	Oakridge	Lane Electric Co-op	24	2.0	LCA
73	Boise Cascade Lumber	Lagrande	Oregon Trail Elec.	24	1.7	SRA
74	Tektronix	Filbert	Forest Grove City	38	1.7	LCA
75	Green Veneer	Tumble Creek	Consumer Power	24	0.7	LCA
76	Leading Plywood	Wren	Consumer Power	24	0.9	LCA
77	Willamette Industries	Lebanon	Consumer Power	24	1.1	LCA
78	Dee Forest Products	Central	Hood River Elec	24	0.9	LCA
79	Hanel Lumber	Neal Creek	Hood River Elec	24	0.5	LCA
80	Boise Cascade	Goldendale	Klickitat County PUD	24	0.5	SRA
81	Champion International	Goldendale	Klickitat County PUD	24	1.0	SRA
82	SDS Lumber	Bingen	Klickitat County PUD	24	0.7	SRA
83	Pacific Crown	Plummer	Kootenai Electric Coop	24	0.5	UCA
84	Plum Creek Lumber		Mission Valley Power	24	1.4	SRA
85	John Day Lumber		Oregon Trail Electric	24	1.0	SRA
86	Melhuic Lumber Co.		Oregon Trail Electric	24	1.0	SRA
87	Prairie Wood Products		Oregon Trail Electric	24	1.0	SRA
88	Twin City Foods	Ellensburg	City of Ellensburg	20	1.4	UCA
89	Georgia Pacific	Parker	Blachly-Lane Cooperative	24	1.2	LCA
90	Bennett Lumber	Potlatch	Clearwater Power	24	1.3	UCA
91	Brookings Plywood	Gold Beach	Coos-Curry Elec Co-op	24	1.4	LCA
92	Hanel Lumber	Main	Hood River Electric	24	1.1	LCA
93	Tillamook Lumber	Tillamook	Tillamook PUD	24	1.4	LCA
94	Flavor Land Food	Forest Grove	Forest Grove	20	0.7	LCA
95	Hazelwood Bakery	McMinnville	McMinnville	20	0.7	LCA
96	Oregon Turkey	Salem	Salem Electric	20	0.7	LCA
97	Triangle Veneer	Parker	Blachly-Lane Coop	24	0.5	LCA
98	Croman Corp	Oakknoll	Ashland	24	1.3	LCA
99	Bonniers Ferry Mill	Bonniers	Bonniers Ferry	24	0.5	UCA
100	Louisiana Pacific	Moyie	Bonniers Ferry	24	1.1	UCA
101	W.D.O Mill	Carson	Skamania County PUD	24	0.9	LCA

Within each major group, only some sectors or subindustries as designated by four-digit SIC code are represented by plants on the Bonneville list. In many cases only a single plant appeared for a major industry group. In other cases, most plants within a major industry group fell within a single four-digit industry classification. For example, most plants in the "Paper and Allied Products Industry Group (SIC 26) were pulp and paper mills (SIC 2621). Thus, representative industries within each major group were selected for the purposes of Chapter 3. Whenever possible, subindustries not already described in other Bonneville reports (see Battelle 1984; Bechtel 1984; and SJO, Shapiro, and Synergic 1984) were selected to be profiled.

A.2 MAJOR INDUSTRY GROUPS

The Standard Industrial Classification (SIC) system divides the mining sector of the economy into four major industry groups (SICs 10-14) and the manufacturing sector into 20 major industry groups (SICs 20-39) as defined by two-digit SIC codes (see OMB 1987). Major groups are divided into three-digit and four-digit SIC-code subcategories. Each commercial establishment in the United States is assigned a four-digit industry code based on the manufacturer's primary product or group of products, regardless of their type of ownership.

The major industry groups profiled in Chapter 3 are, in order by Standard Industrial Classification (SIC) code: metal mining, food processing, wood products, pulp and paper, chemicals, petroleum refining, cement, primary metals, metals fabrication, electronics, and transportation equipment. Sections A.2.1 through A.2.11 define these industry groups and list three-digit SIC-code subcategories.

A.2.1 Metal Mining Industry (SIC 10)

This major group includes establishments primarily engaged in mining, developing mines, or exploring for metallic minerals (ores). These ores are valued chiefly for the metals they contain. The metals are recovered for use individually or as constituents of alloys, chemicals, pigments, or other products. This major group also includes all ore dressing and beneficiating operations, whether performed at mills operated in conjunction with the mines

or at mills, such as custom mills, operated separately. This group includes mills that crush, grind, wash, dry, sinter, calcine, or leach ore, or perform gravity separation or flotation operations.

<u>SIC Code</u>	<u>Description</u>
101	Iron Ores
102	Copper Ores
103	Lead and Zinc Ores
104	Gold and Silver Ores
106	Ferroalloy Ores, except Vanadium
108	Metal Mining Services.

A.2.2. Food and Kindred Products (SIC 20)

This major group includes establishments that manufacture or process foods and beverages for human consumption, and certain related products, such as manufactured ice, chewing gum, vegetable and animal fats and oils, and prepared feeds for animals and fowl.

<u>SIC Code</u>	<u>Description</u>
201	Meat Products
202	Dairy Products
203	Preserved Fruits and Vegetables
204	Grain Mill Products
205	Bakery Products
206	Sugar and Confectionary
207	Fats and Oils
208	Beverages
209	Miscellaneous Foods.

A.2.3. Lumber and Wood Products, except Furniture (SIC 24)

This major group includes establishments engaged in cutting timber and pulpwood; as well as merchant sawmills, lathe mills, shingle mills, cooperage stock mills, planing mills, and plywood mills and veneer mills engaged in manufacturing finished articles made entirely or mainly of wood or related materials.

<u>SIC Code</u>	<u>Description</u>
241	Logging
242	Sawmills and Planing Mills
243	Millwork, Veneer, Plywood, and Structural Wood Members
244	Wood Containers
245	Wood Buildings and Mobile Homes
249	Miscellaneous Wood Products.

A.2.4. Paper and Allied Products Industry (SIC 26)

This major group includes establishments primarily engaged in the manufacture of pulps from wood and other cellulose fibers, and from rags; the manufacture of paper and paperboard; and the manufacture of paper and paperboard into converted products, such as paper coated off the paper machine, paper bags, paper boxes, and envelopes. Also included are establishments primarily engaged in manufacturing bags of plastic film and sheet.

<u>SIC Code</u>	<u>Description</u>
261	Pulp Mills
262	Paper Mills, excluding Building Paper
263	Paperboard Mills
264	Miscellaneous Converted Paper Products, etc.
265	Paperboard Containers and Boxes
266	Building Paper and Board Mills.

A.2.5. Chemicals and Allied Products (SIC 28)

This major group includes establishments producing basic chemicals, and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: 1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; 2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and 3) finished chemical products to be used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

<u>SIC Code</u>	<u>Description</u>
281	Industrial Organic Chemicals
282	Plastics materials and Synthetics
283	Drugs
284	Soap, Cleaners, Toilet Goods
285	Paints and Allied Products
286	Industrial Allied Products
287	Agricultural Chemicals
289	Miscellaneous Chemical Products.

A.2.6. Petroleum Refining and Related Industries (SIC 29)

This major group includes establishments primarily engaged in refining petroleum, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials.

<u>SIC Code</u>	<u>Description</u>
291	Petroleum Refining
295	Asphalt Paving and Roofing Materials
299	Miscellaneous Petroleum and Coal Products.

A.2.7. Stone, Clay, and Glass Products (SIC 32)

This major group includes establishments engaged in manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, cut stone, abrasive and asbestos products, and other products for materials taken principally from the earth in the form of stone, clay, and sand.

<u>SIC Code</u>	<u>Description</u>
321	Flat Glass
322	Glass, Pressed or Blown
323	Products of Purchased Glass
324	Cement, Hydraulic
325	Structural Clay Products
326	Pottery and Related Products

- 327 Concrete, Gypsum, Plaster Products
- 328 Cut Stone and Stone Products
- 329 Miscellaneous Nonmetallic Mineral Products.

A.2.8. Primary Metal Industries (SIC 33)

This major group includes establishments engaged in smelting and refining ferrous and nonferrous metals from ore, pig, or scrap; in rolling, drawing and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable. This major group includes the production of coke.

SIC Code Description

- 331 Blast Furnace and Basic Steel Products
- 332 Iron and Steel Foundries
- 333 Primary Nonferrous Metals
- 334 Secondary Nonferrous Metals
- 335 Nonferrous Rolling and Drawing
- 336 Nonferrous Foundries
- 339 Miscellaneous Primary Metal Products.

A.2.9. Fabricated Metal Products, except Machinery and Transportation Equipment (SIC 34)

This major group includes establishments engaged in fabricating ferrous and nonferrous metal products, such as metal cans, tinware, hand tools, cutlery, general hardware, nonelectric heating apparatus, fabricated structural metal products, metal forgings, metal stampings, ordnance (except vehicles and guided missiles), and a variety of metal and wire products, not elsewhere classified.

SIC Code Description

- 341 Metal Cans and Shipping Containers
- 342 Cutlery, Hand Tools, and General Hardware
- 343 Plumbing and Heating, except Electric
- 344 Fabricated Structural Metal Products
- 345 Screw Machine Products, Bolts, etc.
- 346 Metal Forgings, Stampings

- 347 Metal Services not elsewhere classified
- 348 Ordnance and Accessories, Products
- 349 Miscellaneous Fabricated Metal Products.

A.2.10. Electronic and Other Electrical Equipment and Components, except Computer Equipment (SIC 36)

This major group includes establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and utilization of electrical energy. Included are the manufacturing of electricity distribution equipment, electrical industrial apparatus, household appliances, electrical lighting and wiring equipment, radio and television receiving equipment, communications equipment, electronic components and accessories, and other electrical equipment and supplies.

SIC Code Description

- 361 Electrical Distributing Equipment
- 362 Electrical Industrial Apparatus
- 363 Household Appliances
- 364 Electric Lighting and Wiring Equipment
- 365 Radio and Television Receiving Equipment
- 366 Communication Equipment
- 367 Electronic Components and Accessories
- 369 Miscellaneous Electrical Equipment and Supplies.

A.2.11. Transportation Equipment (SIC 37)

This major group includes establishments engaged in manufacturing equipment for the transportation of passengers and cargo by land, air, and water. Important products produced by establishments classified in this major group include motor vehicles, aircraft, guided missiles and space vehicles, ships, boats, railroad equipment, and miscellaneous transportation equipment, such as motorcycles, bicycles, and snowmobiles.

SIC Code Description

- 371 Motor Vehicles and Equipment
- 372 Aircraft and Parts
- 373 Ship and Boat Building and Repairing

- 374 Railroad Equipment
- 375 Motorcycles, Bicycles, Parts
- 376 Guided Missiles, Space Vehicles
- 379 Miscellaneous Transportation Equipment.

APPENDIX B

REGIONAL PUBLIC AIR AND WATER POLLUTION DATA

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REGIONAL PUBLIC AIR AND WATER POLLUTION DATA

This appendix looks at some public sources of data on air and water pollution generated by manufacturing facilities in the Bonneville service area. Air and water quality reports published by state regulatory agencies provide extensive information on pollution control and monitoring programs for each state. States also maintain various computer databases on air and water pollution. For example, Oregon and Washington maintain source and emission inventories for major air pollution sources.

Permits issued under the federal Clean Air and Clean Water Acts provide a variety of information on individual plants, including operating parameters, pollution sources, emission limits, control techniques, and monitoring and reporting requirements. Permit files in state air and water quality bureaus may also include engineering and land-use studies; site, process, and equipment information; and monitoring data for specific manufacturing facilities.

B.1 AIR QUALITY

Air quality in Idaho, Montana, Oregon, and Washington is regulated by state and local agencies.^(a) These agencies conduct monitoring and enforcement programs aimed at reducing pollution in areas that currently exceed applicable air quality standards (nonattainment areas) and preventing deterioration of air quality in areas currently meeting the standards. The agencies also monitor visibility in designated national parks and wilderness areas.

In Idaho, air pollution control is the responsibility of the U.S. Environmental Protection Agency (EPA)-Idaho Operations Office and the Idaho

(a) See the BPA Environmental Manual for more information on state and local environmental regulations, permitting procedures, and pollution control activities.

Department of Health and Welfare.^(a) The Montana Department of Health and Environmental Sciences administers that state's air pollution control program, although local health officials may be delegated review authority in some cases. Oregon has one local air pollution agency, the Lane Regional Air Pollution Authority. Air pollution control in the rest of the state is the responsibility of the Oregon Department of Environmental Quality.

In Washington, primary enforcement of air quality regulations is left to local agencies, which set specific controls on the emission of gaseous and solid contaminants for all sources in their areas. The Washington Department of Ecology sets state minimum source emission standards and maintains jurisdiction over pulp mills, aluminum reduction plants, motor vehicle emissions, and counties in eastern Washington with no local agency. The State Department of Ecology operates four regional air quality bureaus.

B.1.1 Statewide Air Quality Data

The federal Clean Air Act gives the EPA authority to establish National Air Quality Standards (NAAQS) for six criteria pollutants: ozone, particulate matter, carbon dioxide, sulfur dioxide, lead, and nitrogen dioxide.^(b) Each state may regulate additional pollutants (see MDHES 1989, Appendix B; ODEQ 1989, p. 19; and WSDE 1989, p. 21, for state air quality standards). For example, Montana regulates nine classes of pollutants as well as visibility. Oregon regulates volatile organics (VOCs), noise, and asbestos. State air quality agencies publish annual reports describing air quality program activities that contain extensive monitoring data.

Emission factors used in estimating total emissions are generated by business associations, EPA, and special studies.^(c) Other emissions

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- (a) Contact information for the agencies mentioned in this appendix can be found in Appendix D.
 - (b) The NAAQS currently regulate fine particulate matter (PM₁₀) consisting of particulates less than 10 microns in diameter. The federal standard for total particulates (TSP) was dropped in 1987. However, Montana, Oregon, and Washington continue to regulate this class of pollutant.
 - (c) Personal communication from Washington State Department of Ecology to Michael Baechler dated Feb. 14, 1991.

estimation methods commonly used are actual source testing and material balances. Air pollution sources are generally divided into point sources, area sources, and mobile sources. Point sources emit relatively large volumes of air pollutants from a single location. Examples include rock quarries, lumber and paper mills, and other manufacturing plants and processes. Area sources include wood stoves, slash and field burning, forest fires, backyard burning, and dust emissions from roads.

The Oregon DEQ maintains a detailed statewide inventory of air pollution emissions from over 1,350 point sources and 936 area sources.^(a) This database can provide different types of information. Figure B.1 is a printout from the inventory showing the four major point sources of total particulate pollutants. These sources are paper and wood products mills. The inventory can provide additional information on individual sources. Figure B.2 is a printout from the Source Registration Listing (REG) File, which shows major sources in order by SIC code and their total annual emission rates of criteria pollutants.^(b)

Figure B.3 is a printout from the Basic Equipment Listing File showing operating parameters, fuel usage, emissions, and emission control equipment for listed equipment at a pulp and paper mill. The stacks at this mill are coded SV0 which designates a vertical discharge from a round stack. The Basic Equipment Code Manual is over 20 pages of equipment differentiated by industry, fuel type, and pollutants generated.

The Washington Emission Data System, an inventory of major sources of criteria pollutants and other toxics, contains data on some 1,000 sources.^(c) This inventory can provide different types of data. For example, Figure B.4 is a printout of inventory data showing annual point source emissions of criteria pollutants by industry type. The industrial boiler category is made

(a) Maintained by the Technical Services Section of Oregon DEQ's air quality division.

(b) Figures B.2 and B.3 are based on 1987 data.

(c) Maintained by the Washington State Department of Ecology's air program office in Olympia.

up of boilers from all point sources, so the other categories do not include boiler operations.

Figure B.5 is a printout showing annual criteria pollutant emissions from selected point sources by source type. These particular sources were chosen from the Bonneville list of the region's major electricity consuming plants (see Appendix A). The source classification code (SCC Code) is based on industry, type of equipment or process, fuel used, and pollutants generated.

B.1.2 Permit Data

As was explained in Chapter 5 of this document, there are several types of Clean Air Act-related permits, all of which are issued by state or local agencies in Idaho, Montana, Oregon, and Washington. Construction approval may be required for new and modified point sources. Existing point sources above a certain size require air contaminant discharge permits. In general, area sources do not operate under any emission permit system. Oregon DEQ does require permits for road and highway construction, parking facilities, and airports.

In order to receive a permit, sources must demonstrate that they can operate with emissions at or below prescribed rates. Allowed emissions may vary by issuing agency and geographic region depending on concentrations of emission sources, population, economic conditions, or land-use patterns. Furthermore, emission limits may be more stringent in nonattainment areas. In the case of industrial sources, EPA has set federal emission standards for various categories of manufacturing. However, states and local authorities may have adopted different limits.

Air permits usually list actual operation time (hours per year), annual throughput (tons of material processed per year), visible and particulate emission sources, baseline emission data, and emission limits. These permits may apply only to a single piece of equipment, such as a boiler, or may cover multiple processes and pieces of equipment at a plant. Figure B.6 gives the performance standards and emission limits taken from an Oregon steel mill permit. Permits for modifications specify baseline emissions and proposed site emissions. These plant site emission detail sheets may run to many

pages. For example, Figure B.7, taken from the Oregon permit for a large pulp and paper mill, is the first of eight pages detailing criteria pollutant emissions.

In addition to the actual permits, permit files maintained by the EPA state and local regulatory agencies can provide a wealth of information about a particular plant or facility. These records are public information and may be obtained by contacting the appropriate regulatory agency (see Appendix D). Permit files may include construction permits, modification and renewal applications, agency staff review reports and fact sheets, self-monitoring data, and engineering studies.

For example, fact sheets and application reviews may contain detailed evaluations of plant operations and emission control systems. Supporting materials for applications may include detailed site plot plans and process flow diagrams with material inputs and outputs. Agency and self-monitoring data of various sources and pollutants, required to show compliance with permit limits, may also be included in these files.

B.2 WATER QUALITY

The National Clean Air Act regulates emissions into surface and ground waters of the United States.^(a) Water quality regulations are aimed at promoting beneficial use of waters, including domestic water supplies, agricultural water supplies, wildlife habitat, and recreation on or in the water (IDHW 1988b). Water discharges by point sources are regulated under the National Pollutant Discharge Elimination System (NPDES).

The Idaho Department of Health and Welfare (IDHW) administers water quality programs in Idaho, although NPDES permits are issued by EPA Region 10.^(b) The Water Quality Bureau of IDHW is also the permitting agency for mining operations using cyanidation for recovery of precious metals (IDHW 1988b, p. 11). The Safe Drinking Water Act regulates the quality of

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- (a) The Safe Drinking Water Act regulates injection or underground disposal of fluids.
 - (b) Contact information for the agencies mentioned in this appendix can be found in Appendix D.

groundwater, which is the main source of drinking water in Idaho (IDHW 1988, p. 135).

Montana's Department of Health and Environmental Sciences, Oregon's Department of Environmental Quality, and Washington's State Department of Ecology administer statewide water quality programs, issue NPDES permits, and monitor compliance. Washington's programs operate through four regional water quality offices.

B.2.1 Statewide Data

The federal Clean Water Act requires each state to report every two years to EPA on water quality in the state. These reports (referred to as "305(b) reports") provide information on the status of the state's surface waters, groundwater, and wetlands; describe water quality programs; and present monitoring data.^(a) Monitoring activities may include ambient monitoring, investigative monitoring, and source-related compliance monitoring.

Point source pollutants are discharged from a specific point or stationary location. Common point sources are industrial and municipal sewage treatment plants. Storm sewers and combined sewer overflows are point sources of water pollutants. In the case of nonpoint sources, there is no identifiable point of release or specific point of entrance into a waterway or aquifer. Nonpoint source pollution includes runoff from agricultural lands, mining operations, logging activities, construction sites, and city streets, as well as land application and treatment of wastes, municipal landfills, and domestic septic systems.

In Idaho and Montana, point sources are not major contributors to surface water pollution. For example, the Montana water quality bureau estimates that point sources are responsible for less than 10% of the state's impaired surface waters (MOHES 1990, p. iii). There is little urban

(a) Section 305(b) of the federal Clean Water Act requires each state to submit a biennial report to the U.S. Environmental Protection describing the quality of its waters. EPA has developed a computerized information management system called the Section 305(b) Waterbody System to assist states in compiling and reporting this information (WSDE 1990, p. 5).

development, manufacturing, or heavy industry in the state (MDHES 1990, p. 4). For both states, agriculture, mining, forest practices, and construction are major sources of water pollution. The Idaho water quality bureau identifies the top four surface water contaminants as heavy metals from historic and current mining; heavy metals and pesticides from agriculture; chlorinated hydrocarbons and untreated toxics from municipal wastewater discharges; and heavy metals drainage from natural mineralization of water courses (IDHW 1988a, p.11).

Examples of groundwater pollution sources are surface spills, leaking underground tanks, and landfills. Groundwater impacts from point sources, such as leaking storage tanks, are generally localized. The Idaho DEQ estimates that the area of impact from a point source is on the order of acres or tenths of a square mile (IDHW 1988a, p. 101). The role of nonpoint sources in groundwater contamination is not well-understood. Few states have comprehensive groundwater monitoring programs and so must rely on contamination estimates and expert opinion.

Idaho DEQ maintains a computerized Groundwater Contamination Log. In 1987, there were 43 incidents of groundwater contamination recorded in the log (IDHW 1988a, p. 99). In Montana, the top three groundwater contamination sources are underground storage tanks, injection wells, and septic tanks (MDHES 1990, p. 17). In Oregon, groundwater contamination from industrial activities has been identified at approximately 75 sites (ODEQ 1990, p. 4.1). These activities include chemical manufacturing, metals plating, wood treatment, oil/gas storage and refueling areas, electronics, food processing, aluminum plants, and pulp and paper mills. The state of Washington is in the process of establishing an Ecology Wastewater Inventory System database that will summarize compliance and monitoring data (WSDE 1990, p. 157).

B.2.2 Permit Data

All point discharges require an NPDES permit -- issued by state water quality agencies in Montana, Oregon, and Washington. NPDES permits for Idaho are the purview of the EPA Region 10 office. Industrial point sources are classified as "major" or "minor" sources depending on a point system used by the EPA, which considers the volume of wastewater discharged, the volume and

flow characteristics of the receiving water body, and the composition of the wastewater being discharged. The Clean Water Act allows states to issue state permits as well as NPDES permits.

NPDES permits are issued for five-year periods, after which they must be renewed. Permits specify wastewater sources, receiving waters, discharge locations, effluent limits, required waste treatment or control techniques, and self-monitoring and reporting requirements. As mentioned above, there are not many point sources in Idaho and Montana so there are few NPDES permittees in these states.

There are 1,450 industrial and agricultural sources in Oregon with either NPDES permits or state Water Pollution Control Facility Permits to treat and/or dispose of wastewater (ODEQ 1990, p. 1.6). Of these, less than 250 have individual permits, and only 24 NPDES permittees are considered major dischargers.^(a) Oregon DEQ reports that during the 12 months preceding the publication of its most recent 305(b) report, 17 of the 24 major permittees exceeded permit limits or were otherwise in violation of a permit condition at least once, although most violations were deemed minor and temporary in nature.

In Washington, 464 industrial sources are operating under NPDES permits and 295 sources are operating under state permits (WSDE 1990, p. 70). Washington issues state waste discharge permits (SWDP) for discharges to groundwater and indirect (pretreated) discharges. For example, low-chloride water from a chemical plant is pretreated then discharged into a municipal wastewater treatment plant. This discharge is regulated by SWDP conditions, which are listed as a special condition in the chemical plant's NPDES permit.

Effluent limits and monitoring requirements are specified in Schedules A and B of Oregon's NPDES permits and in Special Conditions S.1 through S.3 of Washington's NPDES permits. Other special conditions may include state discharge conditions or govern solid/hazardous waste disposal. Regulated discharges include storm water and noncontact cooling water as well as process wastewater. Some permits will only specify a single source, others may

(a) General permits are issued for minor industrial and agricultural sources.

specify discharge limits and monitoring requirements for multiple outfalls. Figure B.8 is taken from an NPDES permit issued by EPA Region 10 for a molybdenum mine and concentration mill in Idaho. This permit regulates mill process wastewater, mine drainage, and storm water runoff.

Effluent limits may be specified for a variety of pollutants, including suspended solids, acidity (pH), temperature, toxic metals, nitrogen and phosphorous compounds, bacteria, and hydrologic modifications. Some of these pollutants, such as bacteria and dioxin, present a public health risk; others impact aquatic ecosystems. Effluent limits may be both technology-based and water-quality based. Washington state requires major industrial dischargers to provide effluent toxicity data, which must be determined by chemical-specific monitoring and bioassays.

Figure B.9 gives the effluent limitations and monitoring requirements taken from a Washington NPDES permit for one of two permitted outfalls at an organic chemical manufacturing plant that discharges wastewater into the Columbia River. There are four pages of limitations for this outfall in the permit.

There has been considerable concern in Oregon and Washington about dioxin in the Columbia River from kraft pulp mills that use chlorine in their bleaching processes. In response to EPA studies of the region's pulp and paper mills, Oregon DEQ developed individual control strategies for the state's three bleached kraft pulp mills and proposed modifications to their NPDES permits (ODEQ 1990, p. 5.6). These modifications included a time schedule for reducing the discharge of dioxin and discharge limitations for dioxin and other chlorinated organic compounds, such as absorbable organic halides (AOX). Oregon DEQ also recommended a change in chlorine bleaching processes to minimize the use of elemental chlorine.

In addition to the actual permits, permit files maintained by EPA, state, and local regulatory agencies can provide a wealth of information about a particular plant or facility. These records are public information and may be obtained by contacting the appropriate regulatory agency (see Appendix D). Permit files may include construction permits, modification and renewal

applications, agency staff review reports and fact sheets, self-monitoring data, and engineering studies.

B.3 TOXICS RELEASES

Air, water, and land emissions of over 300 toxic substances are compiled in EPA's Toxic Chemical Release Inventory (TRI) database. Releases and transfers off-site of these chemicals are reported on a national and regional basis. In 1988, EPA Region 10 recorded 597 facilities reporting 2,028 cases of releases or off-site transfers of listed toxics in Alaska, Idaho, Oregon, and Washington. The 10 chemicals with the highest total releases and transfers were ammonia, methanol, ammonium sulfate, sulfuric acid, acetone, toluene, zinc compounds, phosphorous, methyl ethyl ketone, and chloroform (Hall and Steyer 1990, p. 55).

Figure B.10 gives 1988 regional totals by industry category for air, direct water, water via publicly owned treatment works (POTW), and on-site land releases, and other off-site transfers. The paper and chemical industries accounted for over 60% of all toxic transfers and releases (Hall and Steyer 1990, p. 59).

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EI NUMBER	SOURCE NAME	ADDRESS	ZIP	CITY CODE	MAJOR SIC	UTM ZONE	UTM X COORD.	UTM Y COORD.	TOTAL PARTICULATE
40004	JAMES RIVER II INC	WAUNA MILL CLATSKANIE	97016	07	2621	W	468900	5111100	1313.33
208866	WEYCO - SPRINGFIELD	785 N. 42ND STREET	97477	33	2421	W	503720	4877550	1526.90
180013	WEYERHAEUSER COMPANY	PO BOX 9 KLAMATH FALLS	97601	10	2421	W	597100	4669200	1803.32
210005	GEORGIA PACIFIC CORP	PO BOX 580 TOLEDO	97391	18	2631	W	425500	4940600	2048.46

SOURCE: Oregon DEQ Emission Inventory System.

FIGURE B.1. Oregon Emission Inventory System -- Major Total Particulate Sources
(Total Particulate >= 999 tons/year)

S.I.C.	EI NO.	DATE	NAME & LOCATION	UTM COORDINATES (METERS)	STATE PLANE COORDINATES (FEET)	GROUND				
2631	210005	10/73	GEORGIA PACIFIC CORP PO BOX 580 TOLEDO CITY CODE 18 ZIP 97391	WEST X = 425,500 ZONE Y = 4,940,600	NORTH X = 1,104,781 ZONE Y = 365,440	ELEVATION 64 FEET				
OWNERSHIP: AGENCY (OFFICE) / INSP				TOTAL SOURCE ESTIMATED ANNUAL RATES OF EMISSIONS IN TONS PER YEAR						
PRIVATE DEQ (BQ) / 02										
OTHER SIC NUMBER(S):										
ACD PERMIT IS REQUIRED										
				! FINE	TOTAL	SULFUR	NITROGEN	CARBON	TOTAL	OTHER !
				! PARTIC	PARTIC	OXIDES	OXIDES	MONOXIDE	ORGANIC	INORGS !
				! 1,940.5	2,005.2	1,559.2	967.9	10,827.1	124.8	120.7 !

SOURCE: Oregon DEQ Emission Inventory System.

FIGURE B.2. Registration Listing for Pulp and Paper Mill

EI NO: 210005 S.I.C. 2631 SOURCE NAME: GEORGIA PACIFIC CORP SOURCE LOCATION: PO BOX 580 TOLEDO

STACK DATA

BEC	ID	DATE	HEIGHT (FT)	CROSS-SECT. AREA (SQ FT)	TEMP (F)	VELOCITY (FT/MIN)	VOLUME (SCFM)
SV0	12	9/74	31	0.7	169	UNKNOWN	UNKNOWN
SV0	13	9/74	121	19.6	700	UNKNOWN	UNKNOWN
SV0	15	9/74	113	19.6	600	UNKNOWN	UNKNOWN
SV0	17	9/74	300	209.5	163	UNKNOWN	UNKNOWN
SV0	19	9/74	85	56.2	450	UNKNOWN	UNKNOWN
SV0	20	9/75	95	56.2	450	UNKNOWN	UNKNOWN

ESTIMATED ANNUAL RATES OF EMISSIONS IN TONS PER YEAR

			AGY STACK		OP SCHED		FUEL EST		EMISSION		ANNUAL		FINE		TOTAL		SULFUR NITROGEN		CARBON		TOTAL		OTHER	
SEC	ID	DATE	INS	ID NO	HR	DA	WK	USE	CODE	UN	CONTROLS	THRUPUT	PARTIC	PARTIC	OXIDES	OXIDES	MONOXIDE	ORGANIC	INORGANICS					
000	3&4	7/88	ADO		24	7	51	P	2	2	35 42 00	140203.0	192.77	256.57	0.00	196.28	701.01	119.17						
021	123	7/88	ADO		24	7	51	P	2	3		1672.3	2.09	2.09	0.50	83.61	16.72	4.43						
025	123	7/88	ADO		24	7	51	P	2	3		2056.0	17.57	18.50	245.17	56.53	5.13	1.16						
K46	1	7/88	ADO	017	24	7	51	P	4	3	77 00 00	505209.6	138.93	138.93	50.52	252.60	2526.05	0.00					4.96	TRS
K47	1	7/88	ADO	012	24	7	51	P	4	1		505209.6	0.00	0.00	0.00	0.00	0.00	0.00					6.32	TRS
K51	1	7/88	ADO		24	7	51	P	4	3		505209.6	0.00	0.00	0.00	0.00	0.00	0.00					7.88	TRS
K52	1	7/88	ADO	017	24	7	50	P	4	3	83 72 94	505209.6	1523.30	1523.30	1263.02	378.91	7578.14	0.00					99.24	TRS
K54	1	7/88	ADO		24	7	51	P	4	3	70 92 64	505209.6	65.82	65.82	0.00	0.00	0.00	0.00					2.32	TRS

SUMMED ANNUAL EMISSION RATES FOR THIS SOURCE: 1940.48 2005.21 1559.21 967.93 10827.05 124.76 120.72

SOURCE: Oregon DEQ Emission Inventory System.

FIGURE B.3. Basic Equipment Listing for Pulp and Paper Mill

CATEGORY	TSP	% TSP	PM10	% PM10	SO2	NOx	% NOx	VOC	% VOC	CO	% CO
Livestock - Beef	7,646	16	1,560	8	9	0	31	0	0	0	0
Forest Products - Wood	4,875	10	1,501	7	9	0	122	0	1,352	3	2,542
Forest Products - Paper	4,561	9	2,326	11	8,133	6	3,196	5	4,207	11	18,679
Chemical Production	328	1	70	0	119	0	945	1	756	2	9
Petroleum Prod - Refining	1,453	3	396	2	10,794	8	5,448	8	13,518	34	3,736
Petroleum Prod - Asphalt	1,660	3	423	2	112	0	78	0	45	0	53
Mineral Prod - Cement	436	1	222	1	559	0	768	1	0	0	82
Mineral Prod - Other	3,028	6	846	4	341	0	595	1	15	0	115
Metals - Iron & Steel	820	2	552	3	1,697	1	684	1	629	2	5,855
Metals - Aluminum	8,350	17	3,943	19	21,729	17	253	0	1,252	3	202,729
Transp Equip - Aircraft	0	0	0	0	0	0	0	0	2,719	7	0
Transp Equip - Other	24	0	2	0	0	0	0	0	1,468	4	8
Air Transportation	76	0	50	0	110	0	1,012	2	2,553	6	5,798
Electric Services	3,276	7	3,158	16	67,998	52	33,182	51	859	2	2,800
Grain & Field Beans	1,880	4	675	3	0	0	0	0	1	0	0
Petroleum Bulk Terminals	17	0	13	0	244	0	44	0	2,792	7	5
National Security	295	1	180	1	571	0	759	1	2,932	7	3,590
Industrial Boilers	6,664	14	3,659	18	18,722	14	17,536	27	2,995	7	17,398
Other	2,995	6	732	4	100	0	1,008	2	1,881	5	500
TOTALS	48,384	100	20,308	100	131,247	100	65,661	100	39,974	100	263,899

SOURCE: Washington Department of Ecology Emission Data System.

FIGURE B.4. Washington Annual Point Sources of Criteria Pollutants (tons/year)

1988 Emissions Inventory - Selected Sources

cntry	srce	Plant Name	Plant Address	City Name	Zip	TSP T/yr	PM10 T/yr	SO2 T/yr	NOx T/yr	VOC T/yr	CO T/yr	SCC Code
1560	0037	ATOCHEN NORTH AMERI	2901 TAYLOR WAY	TACOMA	98421	0	0	0	3	0	0	10200401
1560	0037	(was Penmont)			9							10200602
0980	0053	BOEING ADVANCED SYS	9725 E MARGINAL W	SEATTLE	98108	1	1	18	26	235	7	10200501
0980	0053				9							10200602
0980	0053				9							40100252
0980	0053				9							40100257
0980	0053				9							40202402
0980	0061	BOEING AEROSPACE (K	20403 68TH AV S	KENT	98032	0	0	0	21	90	5	10200501
0980	0061				9							10200602
0980	0061				9							40100252
0980	0061				9							40100255
0980	0061				9							40202401
0980	0061				9							40202402
0980	0061				9							40202406
0980	0156	BOEING AEROSPACE (P	7755 E MARGINAL W	SEATTLE	98108	3	3	28	55	656	13	10200401
0980	0156				9							10200501
0980	0156				9							10200602
0980	0156				9							40100255
0980	0156				9							40202401
0980	0156				9							40202402
0980	0156				9							40202406
0980	0015	BOEING COMMERCIAL A	700 15TH AVE SW	ALBURN	98002	0	0	0	0	314	0	40100252
0980	0015				9							40202402
0980	0052		800 LOGAN AVE N	RENTON	98055	0	0	0	0	739	0	10200401
0980	0052				9							10200602
0980	0052				9							40100255
0980	0052				9							40202401
0980	0052				9							40202402
0980	0052				9							40202406
0980	0146		7370/8701 E MARGI	SEATTLE	98108	0	0	0	0	200	0	40200901
2000	0039		3003 W CASINO RD	EVERETT	98201	22	21	66	343	1250	15	10200601
2000	0039				9							40100252
2000	0039				9							40100257
2000	0039				9							40202401
2000	0039				9							40202402
2000	0039				9							40202406
0980	0193	BOEING ELECTRONICS	600 SW 41ST ST	RENTON	98055	0	0	0	0	18	0	40100252
0980	0193				9							40100257
0980	0193				9							40202402
2400	0005	BP OIL COMPANY	PO BOX 8	FERNDALE	98248	374	105	3431	605	2141	177	10200401
2400	0005				9							10200601
2400	0005				9							10200701
2400	0005				9							10200802
2400	0005				9							30188803
2400	0005				9							30600103
2400	0005				9							30600104
2400	0005				9							30600401
2400	0005				9							30600503
2400	0005				9							30600701
2400	0005				9							30600805
2400	0005				9							40301098
2400	0005				9							40301099
2400	0005				9							40301104
2400	0005				9							40301108
2400	0005				9							40301110
2400	0005				9							40301117
2400	0005				9							40600141
2400	0005				9							40600160
2400	0005				9							40600161
2400	0005				9							40600250
2400	0005				9							40600251
2400	0005				9							40600253
0160	0002	CHEVRON CHEMICAL	P.O. BOX 6148	KENNEWICK	99336	133	18	0	469	0	1	10200602
0160	0002				9							30101302
0160	0002				9							30102705
0160	0002				9							30102709

FIGURE B.5. Washington Emission Inventory -- Annual Emissions of Criteria Pollutants (tons/year)

1988 Emissions Inventory - Selected Sources

nty srce	Plant Name	Plant Address	City Name	Zip	TSP T/yr	PM10 T/yr	SO2 T/yr	NOx T/yr	VOC T/yr	CO T/yr	SCC Code
1160 0002	CHEVRON CHEMICAL	P.O. BOX 6148	KENNEWICK	99336	133	18	0	469	0	1	30102711
1160 0002				9							30102713
1160 0002				9							30102718
1160 0002				9							30188801
4480 0009	KALAMA CHEMICAL	1296 NW 3RD	KALAMA	98625	43	19	59	65	348	13	10200401
4480 0009				9							10200602
4480 0009				9							10200603
4480 0009				9							10201201
4480 0009				9							30125801
4480 0009				9							30188801
4480 0009				9							30188803
4480 0009				9							30188804
4480 0009				9							30199999
4480 0009				9							40200922
4480 0009				9							49099999
4480 0009				9							50300202
1540 0001	LAFARGE CORP	BOX 85	METALINE FALLS	99153	187	72	240	229	0	16	30188801
1540 0001	(Plant Closed 6/90)			9							30500606
1540 0001				9							30500612
1540 0001				9							30500617
1540 0001				9							39000201
1560 0002	OCCIDENTAL CHEMICAL	605 ALEXANDER AVE	TACOMA	98421	1	1	0	69	1	17	10200401
1560 0002				9							10200602
1560 0021	SOUND REFINING INC.	2628 MARINE VIEW	TACOMA	98422	5	5	56	15	300	1	10200602
1560 0021				9							30500207
1560 0021				9							30600103
1560 0021				9							30600504
1560 0021				9							30600702
1560 0021				9							30600801
1560 0021				9							30600802
1560 0021				9							30600803
1560 0021				9							30600804
1560 0021				9							40301001
1560 0021				9							40301007
1560 0021				9							40301013
1560 0021				9							40301015
1560 0021				9							40301101
1560 0021				9							40301107
1560 0021				9							40600134
1560 0021				9							40600235
4480 0003	MEYERMAEUSER CO	PO BOX 188	LONGVIEW	98632	261	202	1704	2600	1187	3559	10200205
4480 0003				9							10200401
4480 0003				9							10200601
4480 0003				9							10200902
4480 0003				9							10201301
4480 0003				9							10300799
4480 0003				9							30700105
4480 0003				9							30700106
4480 0003				9							30700110
4480 0003				9							39000499
4480 0003				9							39000599
4480 0003				9							39000699
4480 0003				9							39000999
4480 0003				9							40201301

10200205 - Boiler (Bituminous Coal)
 10200401 - Boiler (Residual Oil)
 10200501 - Boiler (Distillate Oil)
 10200601 - Boiler (Natural Gas)
 30102711 - Chemical Manufacturing (Ammonium Nitrate Production)
 30188801 - Fugitive Emissions
 40100252 - Degreasing Unit (organic solvents)

SOURCE: Washington Department of Ecology Emission Data System.

FIGURE B.5. (contd)

<u>Sources</u>	<u>Opacity</u> (1)	<u>Grain Loading</u> (2)	<u>Pounds/Hour</u>	<u>Tons/Year</u>
Electric Arc Furnace	3%	0.0052	20.5	19.8
Melt Shop Fugitive Emissions and Alloy Feeding	6%	--	3.2	9.8
Melt Shop Dust Handling Equipment Fugitive Emissions	10%	--	3.1	1.0
Slag Handling & Storage Fugitive Emissions	20%	--	1.3	4.3
Reheat Furnace (Natural Gas)	10%	--	0.4	0.9
Slag Crusher	15%	--	0.6	0.7

Notes: (1) Opacity which shall not be equalled or exceed for a period aggregating more than three (3) minutes in any one hour, except that the EAF baghouse is determined by EPA Method 9.
(2) Grain loading means grains/dry standard cubic foot determined in accordance with the Department Source Test Manual

SOURCE: Oregon DEQ Air Contaminant Discharge Permit.

FIGURE B.6. Performance Standards and Emissions Limits for a Steel Mill (Oregon)

Emission Point	Operating Parameters ⁽¹⁾	Emission Factor		Emissions	
		Rate ⁽¹⁾	Reference	lbs/day	tons/yr
Recovery furnace	804 ADMT/day 361 days/yr operating	0.705 kg/ADMT ⁽¹⁸⁾	Research-Cottrell Proposal		225.6
Natural gas	1,063.6 ADMT/day (max)	3,260 lbs/day	Regulatory limit	3,260.0	
	1.166 x 10 ⁶ therms/yr ⁽¹⁹⁾	2.5 lbs/10 ⁶ ft ³	AP-42		incl.
	4.27 x 10 ³ therms/day ⁽³⁾			incl.	
Lime kiln	804 ADMT/day 350 days/yr operating	0.38 lb/ADMT	1978 monitoring data		117.9
#6 Residual Oil	1,063.6 ADMT/day (max)	800 lbs/day	Regulatory limit	800.0	
	51,810 bbls/yr ⁽²⁾	17 lbs/10 ³ gal	AP-42		incl.
	8.225 gal/day ⁽³⁾			incl.	
Natural gas	1.06 x 10 ⁶ therms/yr ⁽²⁾	3.0 lbs/10 ⁶ ft ³	AP-42		incl.
	4,006 therms/day ⁽³⁾			incl.	
Smelt dissolving tank vent	804 ADMT/day 361 days/yr operating	0.195 kg/ADMT	1978 monitoring data		62.4
Lime slaker stack	1,063.6 ADMT/day (max)	400 lbs/day	Regulatory limit	400.0	
	750 dscfm	0.1 gr/dscf	DEQ factor ⁽⁴⁾		2.7
	350 days/yr operating	0.132 gr/dscf	DEQ factor ⁽⁴⁾	20.4	
Pulp dryer					
Pulp loss	361 days/yr operating	800 lbs/day	C-2 data ⁽⁵⁾		144.4
	144,000 dscfm	0.05 gr/dscf	DEQ estimate	1,480.9	
			AP-42		incl.
Natural gas	586.2 x 10 ⁴ therms/yr ⁽¹⁹⁾	2.5 lbs/10 ⁶ ft ³			
	361 days/yr operating			incl.	
	2.147 x 10 ⁴ therms/day ⁽³⁾				
Propane	8,868 therms/yr ⁽¹⁹⁾	2.5 lbs/10 ⁶ ft ³	AP-42		incl.
	361 days/yr operating				
	32.5 therms/day ⁽³⁾			incl.	
Paper machine & winder	74,000 dscfm	0.05 gr/dscf	DEQ estimate		123.2
Natural gas	804 TADP/day (ave.)				
	350 days/yr operating				
	1,063.6 TADP/day (max.)			1,006.7	
	2.9 x 10 ⁶ therms/yr ⁽²⁾	2.5 lbs/10 ⁶ ft ³	AP-42		0.4
	8,286 therms/day			2.1	

NOTES: (19) Fuel usage adjusted for a 3.2% production increase over baseline.

AEDS (9/84) PD4000.4T

SOURCE: Oregon DEQ Air Contaminant Discharge Permit.

FIGURE B.7. Plant Site Emissions Detail Sheet for Particulates for a Pulp and Paper Mill (Oregon)

Effluent Parameter	Effluent Limitation		Alternate Effluent Limitations ^{1/} Maximum Daily, (mg/l)	Monitoring Requirements	
	Avg. Monthly (mg/l)	Max. Daily (mg/l)		Frequency	Sample Type
Flow	---	---		Daily	----
Total Suspended Solids (TSS)	20.0	30.0		Weekly	Grab
Arsenic	---	0.490		Monthly	Grab
Cadmium	---	0.0053	background or 0.10 whichever is more stringent	Monthly	Grab
Lead	---	0.0589	background or 0.6 whichever is more stringent	Monthly	Grab
Mercury	---	0.0002	background or 0.002 whichever is more stringent	Monthly	Grab
Copper	---	0.0245	background or 0.30 whichever is more stringent	Monthly	Grab
Zinc	---	0.165	background or 1.5 whichever is more stringent	Monthly	Grab

^{1/} The selection of alternate limits are at the option of the permittee. If alternative limits are selected, background concentrations shall be based on pollutant levels in Thompson Creek upstream of the confluence of Buckskin Creek, at a point where the samples will not be affected by the discharge. Samples of Thompson Creek water at this site shall be collected on the same day as the effluent sample.

SOURCE: NPDES Permit Issued by EPA Region 10.

FIGURE B.8. Effluent Limitations and Monitoring Requirements for a Molybdenum Mine Concentration Mill (Idaho)

Parameter	EFFLUENT LIMITATIONS		MONITORING REQUIREMENTS	
	Daily Average	Daily Maximum	Minimum Frequency	Sample Type
Flow	N/A ¹	0.225 mgd	continuous	recording
BOD ₅	37 lb/day 30 mg/l	99 lb/day 77 mg/l	daily	24-hr composite (refrigerated)
TSS	52 lb/day 41 mg/l	169 lb/day 132 mg/l	daily	24-hr composite
Oil & Grease	10 mg/l	15 mg/l	1/week	grab
pH	shall be within the range of 6.0 to 9.0		daily	24-hr composite
Copper	0.348 lb/day 0.165 mg/l	0.812 lb/day 0.384 mg/l	1/week	24-hr composite
Nickel	0.205 lb/day	0.483 lb/day	1/week	24-hr composite
Zinc	0.252 lb/day	0.627 lb/day	1/week	24-hr composite
Total Phosphorous	5 mg/l	8 mg/l	1/week	24-hr composite
Ammonia (as N)	15 mg/l	30 mg/l	1/week	grab
Total Phenols ²	NA	NA	1/week	grab
Cyanide	NA	NA	1/month	grab
Magnesium	NA	NA	1/quarter	24-hr composite
Cobalt	NA	NA	1/quarter	24-hr composite
Arsenic	NA	NA	1/quarter	24-hr composite

¹The Permittee shall monitor the flow and report both the daily average and daily maximum values.

²According to Method 420.1 (colormetric, 4 AAP), published in "Methods for Chemical Analysis of Water and Wastes," EPA, 1979, or latest revision.

SOURCE: NPDES Issued by Washington State Department of Ecology.

FIGURE B.9. Effluent Limitations and Monitoring Requirements for an Organic Chemical Manufacturing Plant (Washington)

SIC Code Major Group		Total Air	Direct Water	On-Site Land	Water via POTW	Other Off-Site	Total Env Releases	Total Rel/Trans	
None/Not 20-39	0	15,177	1,000	0	26,000	1,540	16,177	43,717	0.0%
Food	20	626,335	413,403	632,963	828,090	293,750	1,672,701	2,794,541	2.2%
Tobacco	21	510	0	0	23,697	0	510	24,207	0.0%
Textiles	22	0	0	0	12,000	0	0	12,000	0.0%
Apparel	23	16,821	0	0	0	540	16,821	17,361	0.0%
Lumber	24	5,671,478	44,416	92,864	1,203	162,775	5,808,758	5,972,736	4.8%
Furniture	25	118,863	0	0	0	7,400	118,863	126,263	0.1%
Paper	26	13,970,590	17,392,519	607,373	6,367,418	1,599,241	31,970,482	39,937,141	31.8%
Printing	27	22,136	0	0	0	1,101	22,136	23,237	0.0%
Chemicals	28	27,386,587	188,901	8,996,933	32,767	672,882	36,573,822	37,279,471	29.7%
Petroleum	29	1,194,910	252,746	82,990	2,000	62,731	1,531,664	1,596,395	1.3%
Plastics	30	2,778,057	10,054	0	1	40,051	2,788,111	2,828,163	2.3%
Leather	31	1,250	0	0	119,100	17,500	1,250	137,850	0.1%
Stone/Clay	32	46,087	18	8,736	268	31,550	54,841	86,659	0.1%
Primary Metals	33	3,807,024	79,789	180,825	371,951	3,851,157	4,067,638	8,290,746	6.6%
Fabr. Metals	34	2,956,613	1,022	500	129,197	1,091,950	2,958,135	4,179,282	3.3%
Machinery	35	936,229	500	4,612	16,930	113,241	941,341	1,071,512	0.9%
Electrical	36	1,029,988	643	853,000	461,393	655,957	1,883,631	3,000,981	2.4%
Transportation	37	8,667,926	750	5,400	18,687	4,157,318	8,674,076	12,850,081	10.2%
Instruments	38	3,681,952	0	0	151,076	192,781	3,681,952	4,025,809	3.2%
Misc. Manufac	39	540,684	0	0	0	17,679	540,684	558,363	0.4%
DOE Hanford	99	822	0	655,033	66	12,106	655,855	668,027	0.5%
Total		73,470,039	18,385,761	12,121,229	8,561,844	12,983,250	103,979,448	125,524,542	100.0%

SOURCE: EPA 1990, p.59.

FIGURE B.10. Region 10 1988 Releases and Transfers by Industry Category (SIC Code Major Group), Excluding Aluminum Oxide and Sodium Hydroxide, in pounds.

APPENDIX C

OCCUPATIONAL INJURY AND ILLNESS STATISTICS

APPENDIX C

OCCUPATIONAL INJURY AND ILLNESS STATISTICS

The two primary sources of nationwide data on occupational injuries and illness are the Survey of Occupational Injuries and Illnesses and individual state's statistics on workers' compensation claims. This appendix explains how these data are reported and summarizes national and state data for 1988, the most recent year for which data are publicly available. This information is intended as background information for evaluating the occupational hazards associated with various industry sectors and energy conservation measures discussed in this document.

Each of these data sources has its limitations and, because of the different methods used in collecting the data, they are not easily compared. The survey calculates injury and illness incidence rates which can be used to judge the relative hazardousness of a particular industry. It also gives detailed information on the occurrence of types of occupational illnesses. Workers' compensation records are extremely detailed on the nature and extent of workplace injuries. These data can be used to get a sense of the type of accidents that cause injuries, the tools and working conditions that contributed to the accidents, and the types of occupations and industries with the highest number of injuries and illnesses.

C.1 SURVEY OF OCCUPATIONAL INJURIES AND ILLNESSES

The Survey of Occupational Injuries and Illnesses is a federal-state cooperative program, coordinated by the U.S. Department of Labor, Bureau of Labor Statistics (BLS). The program compiles data on injuries and illnesses gathered by an annual survey of employers on a state-by-state basis. Because the survey is based on a sample of business establishments, in some cases the data is incomplete or uncertain. However, it can be used to judge the relative hazardousness of various industry segments. The survey includes detailed information on occupational illnesses, which is not true of most

workers' compensation reports, because occupational illnesses make up only a small percentage of all claims.

C.1.1 Survey Methodology

Each participating state collects data from the Occupational Safety and Health Administration (OSHA) records of a scientifically selected sample of establishments across the state and generates estimated for industry groups according to the nature and size of business. Data were available for 1988 for three of the four states in the Bonneville service area: Montana, Oregon, and Washington.^(a)

The scope and method of the national survey is described in Appendix A of the Occupational Injuries and Illness report (BLS 1990) and in each state's annual report (MDLI 1988, ODIF 1988a, and WDLI 1988a). Only firms with more than 11 employees are included in the sample and certain industries are exempt from OSHA record-keeping requirements. Employers maintain a log and summary of recordable occupational injuries and illnesses. Injuries are recorded if they result in death, lost worktime, medical treatment other than first aid, loss of consciousness, restriction of work or motion, or transfer to another job.

An occupational injury is defined by the Department of Labor as any injury that results from a work-related accident or from exposure involving a sudden event in the work environment (BLS 1990, p. 1). An occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment (BLS 1990, p. 3). Included are acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact.

Estimates for injuries are only published if they meet employment and response rate criteria (WDLI 1988a, p. 65). Aside from illnesses, which are reported by type of disease, most of the data in the survey consists of incidence rates, which indicate the number of injuries and illnesses per 100 full-time workers. These rates are reported by two- and three-digit SIC code

^(a) Data for Idaho were not available.

industries. Incidence rates are calculated using a formula such as the following formula:

$$IR = \frac{N \times 200,000}{EH}$$

where IR = Incidence rate
 N = Number of Injuries or Illnesses
 EH = Total hours worked by all employees during the year
 200,000 = Base for 100 full-time equivalent workers, working 40
 hours per week, 50 weeks per year

Incidence rates for total cases of reported injuries and/or illnesses are broken down into lost workday cases, nonfatal cases without lost workdays, and fatalities. The survey also reports the number of lost workdays, which are broken down into days away from work and days of restricted work activity.

Lost workday figures give some indication of the severity of the injuries and illnesses occurring in an industry. Incidence rates give some indication of the relative hazardousness of the industry. For example, in Oregon the data are used to develop schedules for OSHA inspections. However, incidence rates depend in part on the number of workers employed in an industry. Thus, two industries or states may have the same absolute number of injuries and illnesses but report different incidence rates if their employment base is different.

Each survey report gives standard errors for incidence rates and total cases by industry, by type of illness, and broken down between injuries and illnesses. These standard errors range from small to quite large. For example, in Washington for an industry group to be included in the survey, the relative standard error must be 25% or less for nonmanufacturing industry groups, and 30% or less for manufacturing groups.

C.1.2 Hazardous Industries

The most recent year for which national survey data are available is 1988 (BLS 1990). During that year, there were nearly 6.2 million job-related injuries and 240,900 occupation illness cases reported in the private sector.^(a) Mining (SIC 10) accounted for 1% of injuries (62,500 cases) and 0.8% of all illnesses (1,900).^(b) The manufacturing sector (SICs 20-30) accounted for nearly 2.3 million injuries (37%) in 1988 and about 176,600 (73%) of illness cases reported by the private sector.

In 1988, there were 3,300 work-related fatalities in private sector establishments with 11 or more employees (BLS 1990, p. 6). Deaths due to occupational diseases are included in the "All Other" column. Manufacturing and mining rank second and fifth among all industry groups in terms of total fatalities, as shown in Table C.1. The BLS notes that fatalities are difficult to measure in a sample survey so the number of fatalities may be significantly understated.

The highest national incidence rates of injuries and illnesses in 1988 were in construction (SICs 15-17), transportation and public utilities (SICs 40-49), and manufacturing (SICs 20-39). Locally, manufacturing industries, construction, and agriculture, and forestry and fishing (SICs 01-09) ranked highest in all three states as shown in Table C.2. In Oregon and Montana manufacturing had the highest incidence rate, followed by construction and agriculture (see Table 1 in MDLI 1988, ODIF 1990a, and WDLI 1988b). In Washington, construction had the highest rate, followed by agriculture and manufacturing. Mining ranked fourth in Montana, eighth in Oregon, and ninth in Washington.

In Montana, lumber and wood products (SIC 24) had the highest total cases incidence rate in the manufacturing sector, followed by food (SIC 20), mining (SIC 10), and printing and publishing (SIC 27). These incidence rates are shown in Figure C.1. The other industry groups in SICs 20 to 39 were not

^(a) Total cases are composed of lost workday cases, nonfatal cases without lost workdays, and fatalities.

^(b) Data for the mining industry is provided to the BLS by the Mine Safety and Health Administration.

reported. The incidence rate per 100 full-time workers of all injuries and illness for all manufacturing industries was 21 (see Table C.2).

Figure C.2 shows the 1988 incidence rates for manufacturing industries in Oregon (taken from the Oregon Occupational Injury and Illness Survey: Calendar Year 1988, ODIF 1990a). The incidence rate for all manufacturing industries was 15.9 per 100 full-time workers (see Table C.2). SICs 22, 29, and 39 were not reported. Of the industries profiled in Chapter 3 of this document, primary metals (SIC 33), transportation equipment (SIC 37), lumber and wood products (SIC 24), fabricated metal products (SIC 34), food products (SIC 20), and stone, clay, and glass (SIC 32) all had incidence rates higher than the rate for all manufacturing. Eight of the 10 most hazardous industries at the three-digit SIC level were engaged in some type of manufacturing activity.^(a) Of these, primary nonferrous metals (SIC 333), meat products (SIC 201), iron and steel foundries (SIC 332), and sawmills and planing mills (SIC 242) ranked second, fourth, eighth, and ninth in terms of lost workday rates.

In Washington, the two major industry groups with the highest incidence rates of lost workday cases were lumber and wood products (SIC 24) and primary metals (SIC 33). Figure C.3 shows the 1988 incidence rates for manufacturing industries in Washington. Of the other manufacturing major industry groups covered in this report, stone, clay, glass and concrete products (SIC 32), food and kindred products (SIC 20), and fabricated metal products (SIC 34) ranked eighth, ninth, and tenth in terms of incidence of illness and injury. Paper, transportation, and electronic equipment had incidence rates below the total manufacturing average (WDLI 1988a, p. 19).

C.1.3 Occupational Illnesses

The most commonly reported diseases in 1988 were disorders associated with repeated trauma, which accounted for 48% of illnesses reported nationwide, followed by skin diseases and conditions, which accounted for 24% of total illnesses (BLS 1990, pp. 3-5 and Table 7). These proportions are reflected in state statistics, as shown in Table C.3.

^(a) Manufacturing industries are usually analyzed at the three- or four-digit SIC level.

Repeated trauma disorders include conditions caused by repeated exposure to motion, vibration, or pressure; noise-induced hearing loss; bursitis; and carpal tunnel syndrome. Of all industries nationwide, meat packing plants (SIC 2011) had the highest incidence rate of disorders associated with repeated trauma.

Skin diseases and disorders, the second most common category of illness, includes dermatitis, eczema or rash, and chemical burns. Respiratory conditions due to toxic agents, were third and included pneumonitis and acute congestion due to chemicals, dust, gases, or fumes. All other occupational illnesses includes anthrax, infectious hepatitis, malignant and benign tumors, and food poisoning.

In Montana, an estimated 415 occupational illnesses were recorded in 1988 in Montana (MDLI 1988, p.3). Over a quarter of all illnesses were disorders associated with repeated trauma. In Oregon, an estimated 3,140 occupational illnesses were recorded in the private sector (ODIF 1990a, p. 5). Repeated trauma and skin disease accounted for 69.3% of all occupational illnesses. In Washington, the manufacturing sector accounted for the highest number of reported illness cases: 2,575 or 56% of all illnesses (WDLI 1988a, pp. 11-12). Mining accounted for less than 0.2%.

Because employers and physicians don't always recognize illnesses as being work related, work-related illness may be underestimated in the rates of occurrence of illness in the private sector (BLS 1990, p. 3). Nevertheless, the data on illnesses is more detailed than what is found in workers' compensation data.

C.2 Workers' COMPENSATION DATA

In addition to the annual survey data, states compile statistics on claims filed for occupational injuries and illnesses. The reporting system created by OSHA and BLS requires employers to report data in a standardized format. Injuries and illnesses are coded by nature, source, type of accident, and body part affected. However, caution must be used when making comparisons between data from different states since reporting requirements, coverage, and benefits vary from state to state. Furthermore, the data may or may not

include claims covered by self-insured and third-party insurers as well as by state workers' compensation funds.

C.2.1 Accident Classification

The so-called Z16.2 system developed by the American National Standards Institute (ANSI), classifies the cause of workplace injuries by accident type.^(a) This system has been adopted by workers' compensation boards in many states. The entire list of accident types is given in Figure C.4. According to Keyserling (1988), the categories accounting for the majority of occupational injuries are "struck by," "caught in, under or between (CIUB)," "fall from elevation," "fall on same level," "overexertion," and "motor vehicle accidents." Historically these categories account for almost three-quarters of industrial accidents, with overexertion and struck by accidents leading the list.

- "Struck by" covers a wide variety of situations in which the worker is hit by a moving object or particle. Approximately one-third of these accidents are caused by falling objects, including objects dropped during materials-handling tasks such as lifting and carrying. This category also covers accidents caused by flying objects such as small airborne particles released during grinding, chipping, and machining.
- "Fall from elevation" accidents include falls from ladders, elevated scaffolds, walkways, and work platforms. Over 40% of accidents in this category occur in the construction industry. "Fall on the same level" includes accidents caused by slipping, tripping, and missteps.
- Overexertion results from the use of excessive physical effort to lift, pull, push, wield, or throw the source of injury, which in many cases is a box, barrel, or container. Overexertion and repetitive trauma injuries frequently occur on jobs that require manual materials handling or highly repetitive hand motions such as assembly work.
- Overexertion is responsible for the majority of sprains and strains (which primarily affect backs). Struck-by and struck-against accidents account for most of the cuts, lacerations, punctures, cuts, and bruises.
- A large number of striking accidents involve finger injuries. Common sources of injury are body motion, working surfaces (e.g., floors and steps), boxes and other containers, tools, machines, metal items (e.g., structural metal and fasteners) and vehicles.

^(a) The correct name for the system is the American National Standard Method of Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries (ANSI Z16.2).

- Motor vehicle accidents, striking accidents, and falls account for most work-related fatalities.

C.2.2 Regional Workers' Compensation Data

In Montana, there were 29,699 claims for the private sector, including 34 fatalities (MDLI 1989). Services (SICs 70-86) accounted for the largest number of injury and illness claims (28.7%), followed by retail trade (SICs 52-59), and manufacturing. Table C.4 gives the total number of claims in Montana, Oregon, and Washington for selected industry divisions.^(a) Montana does not calculate claims rates but does report incidence rates, which are identical to the survey rates mentioned in Section C.1.2.

Sprains and strains were the most frequent disabling injury (42.6%), followed by open wounds (27%), and bruises and crushing injuries (13.5%). The most common part of body affected was back and spine (21%), hands and fingers (20.6%), and legs and ankles (13.5%). Working surfaces were the leading source of injury (13.6%), followed by hand tools (10%), and boxes and barrels (8.9%).

In 1988 in Oregon, there were 43,660 accepted disabling claims, including 81 fatalities (ODIF 1990b). Of all industry divisions, manufacturing had the highest number of total claims, followed by retail trade and services. However, construction had the highest claims rate with 8 claims per 100 workers, followed by mining and manufacturing. Within the manufacturing division, lumber and wood products (SIC 34) was responsible for 47.8% of all claims. Manufacturing was responsible for 36% of illness claims, 65.1% of which were for inflammation and carpal tunnel syndrome (see Table C.5 and C.6).

One-half of all claims were from sprains and strains. The back and trunk areas were the body parts affected in 41% of all claims, with back strains being the most frequent disabling injury (11,417 claims). Overexertion was the type of accident in 36.9% of all claims, and bodily motion was the most frequently cited source of injury, followed by working surfaces (14.0%), and boxes, barrels, containers, and packages (12.4%) (see Table C.7). Work-

^(a) Oregon's worker's compensation data represent compensable (accepted) claims. Washington often excludes self-insured medical.

related illnesses accounted for 3,779 claims, or 8.7% of total claims. Table C.8 gives the total number of illness claims by nature of illness.

The Washington Department of Labor and Industries received a total of 239,248 claims for the private sector during 1988, including 83 fatalities, of which 217,326 were accepted. Manufacturing accounted for slightly less than half of all claims (23.5%) (see Table C.9). Washington does not calculate claims rates. Instead it calculates injury frequency by occupational risk classifications (WDLI 1988b, pp. 62-69, Text Table M). Precision, production, craft, and repair workers as an occupational group were at the greatest risk of injury, accounting for 42,992 (24.6%) of all injuries (WDLI 1988b, p. 38). Construction industries employed 41.3% of these injured workers; manufacturing industries employed 20.7%.

Sprains and strains were the leading type of injury, accounting for 36.9% of all injuries and illnesses. Working surfaces were cited as the source of injury in 11.6% of all claims, and exertion was the most common type of accident, accounting for 25.8% of all claims (see Table C.10). According to WDLI (1988b, p. 3), there are 30,000 possible source type combinations using their coding system. Of these, 13,442 claims were for strains and sprains to the back due to overexertion while lifting boxes; 8,197 abrasions to the eyes were caused by particles rubbing or abrading; and 5,673 cuts/lacerations to the fingers were caused by knives striking.

Work-related illnesses accounted for 7,729 claims, or 4.2% of total claims. Table C.5 gives the total number of illness claims by nature of illness. The three most frequently reported illnesses were systemic poisoning, dermatitis, and conditions of the nervous system.

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Source: MDLI 1988

FIGURE C.1. Montana Injury and Illness Incidence Rates for Manufacturing Industries in 1988 (SICs 20-29)

Source: ODIF 1988a

FIGURE C.2. Oregon Injury and Illness Incidence Rates for Manufacturing Industries in 1988 (SICs 20-29)

Source: MDLI 1988

FIGURE C.3. Washington Injury and Illness Incidence Rates for Manufacturing Industries in 1988 (SICs 20-29)

Struck by

Caught in, under, or between (CIUB)

Fall from elevation

Fall on the same level

Overexertion

Motor vehicle accident

Contact with electric current

Struck against

Contact with temperature extremes

Rubbed or abraded

Bodily reaction

Contact with radiation, caustics, toxic
and noxious substances

Public transportation accident

Other

Unknown

Figure C.4. Accident Types Listed in ANSI Z16.2 Classification System

TABLE C.1. U.S. Fatalities by Cause and Industry Division, 1987-88 Average^(a)

Cause	Total Private Sector ^(c)	Agriculture, Forestry, & Fishing	Mining-Oil & Gas Only	Construction	Manufacturing	Transportation & Public Utilities ^(d)	Wholesale & Retail Trades	Finance, Insurance, & Real Estate	Services
Total, all causes	100	3	2	27	24	17	15	3	8
Highway vehicles	100	3	2	17	16	26	14	6	15
Falls	100	1	1	47	18	3	24	0	7
Electrocutions	100	2	1	44	13	27	9	0	4
Industrial vehicles or equipment	100	7	4	30	26	11	17	(e)	3
Heart attacks	100	2	2	28	27	16	6	7	11
Struck by objects other than vehicles or equipment	100	4	9	23	40	8	14	0	3
Assaults	100	4	0	1	35	49	89	5	14
Aircraft crashes	100	3	0	5	25	59	2	1	5
Caught in, under, or between objects other than vehicles or equipment	100	2	0	66	25	4	2	0	1
Explosions	100	0	3	31	41	5	16	0	4
Gas inhalation	100	8	3	21	40	18	8	2	1
Fires	100	0	1	34	45	8	6	0	6
Plant machinery operations	100	1	1	6	85	0	7	1	0
All other ^(f)	100	4	1	24	31	23	6	0	10

^(a) Results are average of 2 years because sampling errors for cause of fatality data are too large to provide reliable annual estimates at the industry division level.

^(b) Cause is defined as the object or event associated with the fatality.

^(c) Excludes coal, metal, and nonmetal mining and railroads, for which data are not available.

^(d) Excludes railroads.

^(e) Between 0.1 and 0.5 percent.

^(f) The "All other" category includes, for example, contact with carcinogenic or toxic substances, drowning, train accidents, and various occupational illnesses.

NOTE: Because of rounding, components may not add to totals.

SOURCE: BLS 1990, p.50

TABLE C.2. 1988 Injury and Illness Incidence Rates by Industry Sector
(number of cases per 100 full-time employees)

State	Agriculture (SIC 01-09)	Mining (SIC 10-14)	Construction (SIC 15-17)	Manufacturing (SIC 20-39)	Total Private
Montana					
Employment ^(a)	1,900	6,200	8,500	20,800	209,000
Total Cases ^(b)	14.3	10.2	20.3	21	9.3
Lost Workday Cases ^(b)	5.6	5.7	7.2	8.5	3.6
Lost Workdays ^(c)	110.2	126.5	112.6	172.5	74.6
Oregon					
Employment ^(a)	26,200	1,600	40,000	216,300	955,400
Total Cases ^(b)	12.7	5.8	15.6	17.5	11.1
Lost Workday Cases ^(b)	7.6	3.1	7.2	8.9	5.6
Lost Workdays ^(c)	191.4	95.9	165.4	181.1	101.7
Washington					
Employment ^(a)	46,300	3,300	96,000	338,600	1,615,000
Total Cases ^(b)	14.3	7.6	22.0	15.6	11.0
Lost Workday Cases ^(b)	6.6	3.4	10.6	7.3	5.2
Lost Workdays ^(c)	113.2	110.2	195.3	121.2	85.7
United States					
Employment ^(a)	1,114,100	721,000	5,125,000	19,403,000	88,698,800
Total Cases ^(b)	10.9	8.8	14.6	13.1	8.6
Lost Workday Cases ^(b)	5.6	5.1	6.8	5.7	4.0
Lost Workdays ^(c)	101.8	152.1	142.2	107.4	76.1

^(a) Average Annual Employment for 1988.

^(b) Total cases includes lost workday cases and nonfatal cases without lost workdays. Lost workday cases includes fatalities.

^(c) Lost workdays includes days away from work and days of restricted work activity.

SOURCE: National and State Occupational Injury and Illness Surveys, Table 1 (BLS 1990, MDLI 1988, ODIF 1990a, WOLI 1988a).

TABLE C.3. 1988 Estimated Occupational Illnesses by Category of Illness

Type of Illness	Oregon		Montana		Washington		United States	
	No. Cases	% Total	No. Cases	% Total	No. Cases	% Total	No. Cases	% Total
Skin diseases or disorders	615	19.6%	28	6.8%	1,114	24%	57,900	24%
Dust diseases of the lungs	28	0.9%	4	1.0%	113	2%	2,900	1%
Respiratory conditions due to toxic agents	191	6.1%	25	6.1%	577	13%	16,100	7%
Poisoning	122	3.9%	12	2.9%	248	13%	5,500	2%
Disorders due to physical agents	182	5.8%	10	2.4%	306	7%	17,300	7%
Disorders associated with repeated trauma	1560	49.7%	118	28.6%	1,606	35%	115,400	48%
All other occupational illnesses	436	13.9%	216	52.3%	651	14%	25,600	11%
Total	413	100%	3,140	100%	4,615	100%	240,700	100%
Total Incidence Rate ^(a)	9.3		0.4		0.3		0.3	

^(a) Number of illnesses in per 100 full-time workers.

SOURCE: Federal and State Occupational Injury and Illness Surveys (BLS 1990, MDLI 1988, ODIF 1990a, WDLI 1988a).

TABLE C.4. 1988 Worker's Compensation Claims by Industry Division

	Agriculture (SIC 01-09)	Mining (SIC 10-14)	Construction (SIC 15-17)	Manufacturing (SIC 20-39)	Total Private
Montana:					
Employment ^(a)	31,400	6,300	9,000	21,400	--
Total Claims ^(b)	1,708	1,041	2,937	4,752	29,699
Incidence Rate ^(c) (per 100 workers)	14.3	7.9	14.8	20.2	--
Oregon:					
Employment ^(a)	48,200	1,400	39,000	214,300	977,500
Total Claims ^(b)	2,143	86	3,126	12,883	39,450
Claims Rate ^(c) (per 100 workers)	4.4	6.1	8.0	6.0	4.5
Washington:					
Employment ^(a)	--	--	--	--	--
Total Claims ^(b)	10,242	570	28,972	42,931	182,946
Claims Rate ^(c)	--	--	--	--	--

(a) The sources of employment figures vary by state and by industry division. The most common sources are state employment departments or U.S. Department of Commerce data.

(b) Oregon data is for accepted claims. Washington excludes self-insured medical.

(c) Only Oregon reports claims rates. Montana reports injury and illness incidence rates from the Occupational Injury and Illness Survey.

SOURCE: Annual Worker's Compensation Summaries (MDLI 1988, ODIF 1990b, WDLI 1988b).

Table C.5. Number of Disabling Claims by Industry and Source of Injury or Illness, Oregon, 1988

Industry ^(a)	Source of Injury or Illness											
	SIC Code ^(b)	Total	Boxes, Containers, etc.	Chemicals	Hand Tools	Hoists, Conveyors	Machines	Metal Items	Vehicles	Plants, Trees, Wood	Working Surfaces	All Others
Mining		86	4	--	4	1	7	12	10	5	14	29
Metal Mining	10	1	--	--	--	--	1	--	--	--	--	--
Oil and Gas Extraction	13	34	3	--	1	--	2	4	3	2	7	12
Nonmetallic Minerals	14	51	1	--	3	1	4	8	7	3	7	17
Manufacturing		12883	1084	142	825	203	1069	1122	649	2279	1301	4209
Food and Kindred Products	20	1729	368	28	69	21	117	60	107	55	199	705
Meat Products	201	207	30	1	15	--	17	5	12	3	9	115
Fruits and Vegetables	203	671	121	13	22	11	50	27	38	33	92	264
Bakery Products	205	158	29	2	2	1	17	6	12	2	25	62
Beverages	208	147	61	3	2	2	3	2	18	6	12	38
Misc. Food Products	209	323	66	5	19	2	16	2	11	5	36	161
Lumber and Wood Products	24	6160	133	17	434	133	429	260	321	2078	693	1662
Logging	241	1820	7	--	250	6	23	37	127	583	297	490
Sawmills, Planing Mills	242	1909	42	5	73	78	170	90	78	749	168	456

Table C.5. Number of Disabling Claims by Industry and Source of Injury or Illness, Oregon, 1988 (contd)

Industry ^(a)	Source of Injury or Illness											
	SIC Code ^(b)	Total	Boxes, Containers, etc.	Chemicals	Hand Tools	Hoists, Conveyors	Machines	Metal Items	Vehicles	Plants, Trees, Wood	Working Surfaces	All Others
Veneer, Plywood, Millwork	243	1776	58	9	79	37	180	76	89	582	146	520
Mobile Homes, Wood Buildings	245	251	7	--	17	--	11	32	10	18	43	113
Misc. Wood Products	249	384	17	3	15	11	41	24	17	139	37	80
Paper and Allied Products	26	399	46	3	22	10	49	35	17	29	33	155
Paper Mills	262	206	21	2	13	6	32	17	10	7	16	82
Paperboard Mills	263	61	5	--	1	3	3	6	1	8	4	30
Converted Paper Products	264	63	10	--	3	1	6	6	3	5	8	21
Chemicals and Allied Products	28	101	21	5	5	--	14	6	5	--	12	33
Petroleum and Coal Production	29	22	6	--	--	--	1	--	1	1	3	10
Stone, Clay and Glass Production	32	206	23	1	14	2	13	24	17	6	22	84
Concrete, Gypsum, and Plaster	327	107	10	1	7	2	5	14	12	5	7	44
Primary Metal Industries	33	613	47	7	51	12	31	168	19	9	43	226
Blast Furnaces, Steel	331	81	8	1	8	1	4	28	--	1	5	25

Table C.5. Number of Disabling Claims by Industry and Source of Injury or Illness, Oregon, 1988 (contd)

Industry ^(a)	Source of Injury or Illness											
	SIC Code ^(b)	Total	Boxes, Containers, etc.	Chemicals	Hand Tools	Hoists, Conveyors	Machines	Metal Items	Vehicles	Plants, Trees, Wood	Working Surfaces	All Others
Iron and Steel Foundries	332	222	6	3	18	6	9	71	8	2	9	90
Primary Nonferrous Metals	333	196	20	3	20	4	7	35	6	3	24	74
Fabricated Metal Production	34	731	90	18	40	8	86	162	25	15	59	228
Cutlery, Hand Tools, etc.	342	58	8	2	5	1	4	7	1	2	4	24
Fabricated Struct. Metal Products	344	330	24	4	20	4	28	81	6	10	35	118
Electronic Equipment	36	314	36	14	16	1	29	30	18	7	23	140
Transportation Equipment	37	441	28	11	46	1	27	85	35	4	33	171
Motor Vehicles and Equipment	371	257	20	2	25	1	14	55	19	1	13	107

(a) Includes all industries covered by Oregon Worker's Compensation Laws.

(b) Standard Industrial Classification Manual, 1972 Edition, 1977 Supplement.

— Dashes indicate no claims were received.

Source: ODIF 1990b.

TABLE C.6. Number of Disabling Claims by Industry and Type of Accident or Exposure, Oregon, 1988

Industry ^(a)	SIC Code ^(b)	Total	Type of Accident or Exposure										
			Struck By or Against	Falls	Caught In or Between	Rubbed or Abraded	Bodily Reaction	Over-exertion	Contact Temp. Extreme	Caustic, Toxic, Noxious,	Motor Vehicle Accident	Industrial Vehicle Accident	All Others
Mining		86	13	17	12	1	8	25	2	1	5	1	1
Metal Mining	10	1	--	--	1	--	--	--	--	--	--	--	--
Oil and Gas Extraction	13	34	4	9	3	--	3	12	1	--	1	--	1
Nonmetallic Minerals	14	51	9	8	8	1	5	13	1	1	4	1	--
Manufacturing		12883	2610	1694	1049	133	1985	4481	123	220	119	77	392
Food and Kindred Products	20	1729	245	235	132	10	329	629	21	59	11	6	52
Meat Products	201	207	35	9	14	--	53	85	2	3	1	1	4
Fruits and Vegetables	203	671	99	108	61	6	140	208	6	21	2	2	22
Bakery Products	205	158	15	30	15	1	26	64	2	1	1	--	3
Beverages	208	147	17	14	9	--	17	78	--	3	3	--	6
Misc. Food Products	209	323	40	41	19	1	60	114	5	26	2	3	12
Lumber and Wood Products	24	6160	1545	976	539	52	842	1851	34	43	69	58	151
Logging	241	1820	705	451	122	13	186	209	8	9	54	24	39
Sawmills, Planing Mills	242	1909	356	230	204	16	278	727	14	10	6	14	54
Veneer, Plywood, Millwork	243	1776	334	196	167	15	295	676	8	20	8	14	43

TABLE C.6. Number of Disabling Claims by Industry and Type of Accident or Exposure, Oregon, 1988 (contd)

Industry ^(a)	SIC Code ^(b)	Total	Type of Accident or Exposure										
			Struck By or Against	Falls	Caught In or Between	Rubbed or Abraded	Bodily Reaction	Over-exertion	Contact Temp. Extreme	Caustic, Toxic, Noxious,	Motor Vehicle Accident	Industrial Vehicle Accident	All Others
Mobile Homes, Wood Buildings	245	251	59	52	13	5	41	71	1	2	--	--	7
Misc. Wood Products	249	384	86	45	32	3	40	159	3	2	1	6	7
Paper and Allied Products	26	399	66	42	35	1	67	138	7	6	1	6	30
Paper Mills	262	208	36	21	24	--	38	56	2	3	--	5	21
Paperboard Mills	263	61	12	7	2	1	13	18	3	1	--	1	3
Converted Paper Products	264	63	5	9	3	--	11	29	1	1	1	--	3
Chemicals and Allied Products	28	101	15	14	4	1	16	42	1	5	2	--	1
Petroleum and Coal Production	29	22	1	3	--	--	4	10	1	--	--	1	2
Stone, Clay and Glass Production	32	206	28	25	16	3	25	94	2	2	6	--	5
Concrete, Gypsum, and Plaster	327	107	17	8	9	1	17	44	1	2	4	--	4
Primary Metal Industries	33	613	105	47	35	11	119	235	23	11	3	2	22
Blast Furnaces, Steel	331	81	19	6	4	2	17	28	2	1	--	--	2
Iron and Steel Foundries	332	222	41	12	12	2	43	87	10	5	1	--	9
Primary nonferrous metals	333	196	28	24	11	5	43	68	4	4	--	2	7

TABLE C.6. Number of Disabling Claims by Industry and Type of Accident or Exposure, Oregon, 1988 (contd)

Industry ^(a)	SIC Code ^(b)	Total	Type of Accident or Exposure										
			Struck By or Against	Falls	Caught In or Between	Rubbed or Abraided	Bodily Reaction	Over- exertion	Contact Temp. Extreme	Caustic, Toxic, Noxious,	Motor Vehicle Accident	Industrial Vehicle Accident	All Others
Fabricated Metal production	34	731	154	75	64	9	90	291	7	19	3	--	19
Cutlery, Hand Tools, etc.	342	58	7	5	--	3	12	27	--	2	--	--	2
Fabricated Struct. Metal Products	344	330	85	43	21	3	40	120	3	3	2	--	10
Electronic Equipment	36	314	37	33	15	2	59	138	2	15	2	1	10
Transportation Equipment	37	441	75	39	28	9	90	169	3	14	--	1	13
Motor Vehicles and Equipment	371	257	45	14	16	7	61	102	--	3	--	1	8

(a) Includes all industries covered by Oregon Worker's Compensation laws.

(b) Standard Industrial Classification Manual, 1972 Edition, 1977 Supplement.

-- Dashes indicated no claims were received.

Source: ODIF 1990b.

TABLE C.7. Number of Disabling Claims by Source and Nature of Injury or Illness, Oregon, 1988

Source of Injury or Illness	Total	Nature of Injury or Illness									
		Amputation	Burns	Bruises, Minor Crush.	Bursitis, Synovitis, etc.	Cut, Puncture	Dislocation	Fracture, Major Crush.	Hernia	Sprains, Strains	All Others
Conveyors	235	9	--	48	--	39	5	53	--	53	28
Electric Apparatus	215	1	16	9	5	10	3	6	5	128	32
Heat, Atmospheric	8	--	--	--	--	--	--	--	--	--	8
Heating Equipment, NEC	125	1	26	5	--	10	3	8	3	67	2
Noise	180	--	--	--	--	--	--	--	--	--	180

-- Dashes indicate no claims were received.

NEC = Not elsewhere classified.

Source: ODIF 1990b.

Table C.8. 1988 Occupational Illness Claims by Nature of Illness for Oregon and Washington^(a)

Nature of Illness	Oregon		Washington	
	Total Claims	% Illness Total	Total Claims	% Illness Total
Carpal Tunnel Syndrome	1,212	32.1%	--	--
Circulatory System Conditions	33	0.9%	23	0.3%
Cold Effects, Environmental	10	0.3%	--	--
Dermatitis	203	5.4%	1,415	18.3%
Hearing Loss	184	4.9%	543	7%
Heart Conditions	31	0.8%	8	0.1%
Heat Effects, Environmental	8	0.2%	56	0.7%
Infectious or Parasitic Disease	55	1.5%	101	1.3%
Inflammation of Joints, Tendons, etc.	1171	31%	411	5.3%
Mental Stress, Mental Conditions	176	4.7%	39	0.5%
Nervous System Conditions	115	3.0%	1553	20.1%
Pneumoconiosis	1	--	85	1.1%
Poisoning, Systemic	257	6.8%	1,713	22.2%
Radiation Effects	19	0.5%	852	11%
Respiratory System Conditions	26	0.7%	137	1.8%
All Other Illnesses	278	7.4%	793	10.3%
Total Illness Claims^(c)	3,779	100%	7,729	100%

(a) Idaho does not breakdown illness claims by type of illness.

(b) Oregon cases are accepted claims only. Washington cases may exclude self-insured medical.

(c) Percentages may not add up to 100% because of round-off error.

SOURCE: State Worker's Compensation Annual Reports (ODIF 1990b, WDLI 1988b).

TABLE C.9. Nature of Injury or Illness: Number of Cases by Industry, Washington, 1988 (Source: WDLI 1988b)

	INDUSTRY OF INJURED	TOTAL	AMPUTA- TIONS	BURNS HEAT	BURNS CHEM	CONTU- SIONS	LACER- ATIONS	FRAC- TURES	ABRA- SIONS	SPRAIN STRAIN	OCCUP. DISEASE	OTHER NATURE	UN- KNOWN
103	Lead and Zinc Ores	1	0	0	0	0	1	0	0	0	0	0	0
104	Gold and Silver Ores	17	0	0	0	0	1	1	1	4	7	3	0
108	Metal Mining Services	29	0	0	2	3	8	4	2	5	1	4	0
109	Misc. Metal Ores	1	0	0	0	0	0	0	1	0	0	0	0
10	Metal Mining	48	0	0	2	3	10	5	4	9	8	7	0
201	Meat Products	1010	3	12	5	103	275	41	27	396	107	37	4
202	Dairy Products	287	0	7	3	41	30	17	7	117	39	24	2
203	Canned Fruits and Vegetables	1,370	2	38	49	170	203	63	54	564	160	61	6
204	Grain Mill Products	279	0	4	8	37	46	17	19	104	27	17	0
205	Bakery Products	265	2	9	5	36	31	16	4	119	24	16	3
206	Sugar and Confectionery Prod.	160	1	10	3	19	26	9	4	80	6	2	0
207	Fats and Oils	56	0	4	2	8	7	2	5	24	2	2	0
208	Beverages	429	2	2	4	36	48	15	13	231	51	20	7
209	Misc. Food Preparation	1,462	5	16	9	216	377	54	59	542	113	71	0
20	Food and Kindred Products	5,318	15	102	88	666	1,043	234	192	2,177	529	250	22
241	Logging Camps and Contractors	4,550	12	22	6	725	794	368	276	1,580	351	399	17
242	Sawmills and Planing Mills	3,342	21	18	4	502	668	205	263	1,256	246	149	10
243	Veneer, Plywood Mills	2,765	16	22	18	314	850	117	232	921	168	99	8
244	Wood Containers	302	1	0	1	43	91	15	37	86	22	5	1
245	Wood Builders	210	0	1	0	30	67	8	15	65	10	14	0
249	Misc. Wood Products	906	4	5	9	132	238	46	69	309	52	42	0
24	Lumber and Wood Products	12,075	54	68	38	1,746	2,708	759	892	4,217	849	708	36
261	Pulp Mills	216	1	1	0	16	15	8	3	119	42	9	2
262	Paper Mills	204	1	2	1	24	28	20	2	79	41	5	1
264	Converted Paper Products	364	1	2	4	60	98	20	13	130	17	18	1
265	Paperboard Containers	209	0	3	2	29	66	7	12	71	10	9	0
266	Building Paper and Board Mills	1	0	0	0	0	0	0	0	1	0	0	0
26	Paper and Allied Products	994	3	8	7	129	207	55	30	400	110	41	4

TABLE C.9. Nature of Injury or Illness: Number of Cases by Industry, Washington, 1988 (Source: WDLI 1988b) (contd)

	INDUSTRY OF INJURED	TOTAL	AMPUTA- TIONS	BURNS HEAT	BURNS CHEM	CONTU- SIONS	LACER- ATIONS	PRAC- TURES	ABRA- SIONS	SPRAIN STRAIN	OCCUP. DISEASE	OTHER NATURE	UN- KNOWN
281	Industrial Inorganic Chem.	312	0	4	6	38	100	5	11	111	19	17	1
282	Plastics, Synthetic Resins	114	0	3	4	18	34	9	8	31	5	2	0
283	Drugs	47	0	2	4	4	11	1	2	16	6	1	0
284	Soaps, Detergents	47	0	0	8	7	7	4	1	17	1	2	0
285	Paints and Varnishes	95	1	1	6	9	20	2	6	38	6	6	0
286	Industrial Organic Chem.	62	0	3	5	11	11	1	4	22	4	1	0
287	Agricultural Chemicals	103	0	2	3	10	18	3	6	39	14	8	0
289	Misc. Chemical Products	61	0	3	0	6	20	5	6	19	1	1	0
28	Chemical, Allied Products	841	1	18	36	103	221	30	44	293	56	38	1
291	Petroleum Refining	108	0	8	5	11	9	9	7	45	9	5	0
295	Paving, Roofing Materials	44	0	0	2	6	4	5	2	18	4	3	0
299	Misc. Petroleum Products	3	0	0	0	2	1	0	0	0	0	0	0
29	Petroleum Refining	155	0	8	7	19	14	14	9	63	13	8	0
322	Glass, Glassware	28	0	0	0	1	11	3	4	7	2	0	0
323	Glass Products	114	1	2	0	11	31	12	2	47	5	3	0
324	Cement, Hydraulic	20	0	2	0	1	3	0	2	9	3	0	0
325	Structural Clay Products	40	0	0	0	5	10	3	4	15	2	0	1
326	Pottery, etc.	15	0	0	0	3	2	0	1	6	1	2	0
327	Concrete, Plaster Products	825	1	14	17	107	152	58	86	295	55	39	1
328	Cut Stone Products	16	0	0	2	4	2	0	1	3	4	0	0
329	Abrasive, Asbestos Products	85	0	1	2	14	18	2	8	29	7	4	0
32	Stone, Clay, Glass Products	1,207	2	21	21	151	263	78	111	424	82	50	4
331	Steel Works	254	2	8	2	22	58	22	33	74	27	6	0
332	Iron, Steel Foundries	1,111	1	63	10	155	137	64	344	236	65	33	3
333	Primary Smelting, Refining	159	3	8	0	9	15	14	4	72	22	11	1
335	Rolling, Drawing, Extruding	1,029	1	83	6	129	50	63	38	354	257	43	5
336	Nonferrous Foundries	452	0	47	5	57	73	20	53	154	26	15	2
339	Misc. Primary Metal Prod.	35	0	2	0	5	8	3	8	7	2	0	0
33	Primary Metal Industries	3,040	7	211	23	377	341	186	480	897	399	108	11

TABLE C.9. Nature of Injury or Illness: Number of Cases by Industry, Washington, 1988 (Source: WDLI 1988b) (contd)

	INDUSTRY OF INJURED	TOTAL	AMPUTA- TIONS	BURNS HEAT	BURNS CHEM	CONTU- SIONS	LACER- ATIONS	PRAC- TURES	ABRA- SIONS	SPRAIN STRAIN	OCCLIP DISEASE	OTHER NATURE	UN- KNOWN
341	Metal Cans	65	1	2	1	5	8	6	13	13	13	3	0
342	Cutlery, Hand Tools	94	0	3	2	12	15	3	27	24	4	4	0
343	Heating, Plumbing Fixtures	31	0	1	0	2	9	3	6	7	2	1	0
344	Fabricated Structural Metal	2,601	8	58	20	260	793	112	484	566	222	73	5
345	Screw Machine Products	72	0	2	1	5	28	2	10	20	3	1	0
346	Metal Forging, Stamping	411	1	7	3	40	81	15	101	57	98	7	1
347	Coating, Engraving	377	0	7	22	37	68	15	58	123	29	18	0
348	Ordinance and Accessories	3	0	0	0	1	0	0	2	0	0	0	0
349	Misc. Fabricated Metal Prod.	314	0	7	2	39	96	17	50	73	17	13	0
34	Fabricated Metal Products	3,968	10	87	51	401	1,098	173	751	883	388	120	6
361	Electric Transmission	83	0	0	8	7	24	4	16	18	3	3	0
362	Electric Apparatus	56	0	4	1	4	13	3	15	14	2	0	0
363	Household Appliances	82	1	2	0	7	27	3	11	25	4	2	0
364	Electric Lighting	31	1	0	0	4	10	2	4	7	1	2	0
365	Radio, TV Receiving Equipment	67	2	0	2	13	15	0	3	28	3	1	0
366	Communication Equipment	84	0	2	0	9	30	2	9	18	12	1	1
367	Electronic Components	481	0	11	41	50	124	11	47	134	51	12	0
369	Misc. Electrical Equipment	40	0	1	1	5	14	2	3	12	2	0	0
36	Electrical Equipment	924	4	20	53	99	257	27	106	256	78	21	1
371	Motor Vehicles and Parts	542	1	9	10	71	108	40	107	134	42	19	1
372	Aircraft and Parts	2,256	10	8	15	168	449	137	118	804	376	139	32
373	Ship, Boat Building	1,183	0	6	23	137	265	53	135	389	126	45	4
374	Railroad Equipment	100	0	1	0	16	13	3	7	36	15	8	1
375	Motorcycles, Bicycles, Parts	41	0	5	0	3	18	1	5	6	3	0	0
376	Missiles, Space Vehicles	29	0	0	0	3	11	0	1	10	3	1	0
379	Misc. Transportation Equip.	191	0	0	1	27	71	3	23	45	13	5	3
37	Transportation Equipment	4,342	11	29	49	425	935	237	396	1,424	578	217	41

TABLE C.10. Number of Claims by Two-Digit Source of Injury or Illness, Washington, 1988

Source of Injury	SIC Code	Total	Ampu- tations	Burns, Heat	Burns, Chemical	Contu- sions	Lacer- ations	Frac- tures	Abra- sions	Sprain, Strain	Occu- pational Disease	Other Nature	Unknown
Conveyors	013	614	11	0	0	197	149	70	11	127	19	25	5
Electrical Apparatus	015	1128	2	103	0	94	219	20	43	421	47	178	1
Heat (Environ- mental)	024	61	0	0	0	0	0	0	0	0	60	1	0
Heating Equipment	025	787	0	292	0	92	111	15	5	225	13	34	0
Noise	044	527	0	0	0	0	0	0	0	0	524	3	0

Source: WOLI 1988b.

APPENDIX D

INFORMATION SOURCES

APPENDIX D

INFORMATION SOURCES

Electric Power Research Institute (EPRI) reports by Resource Dynamics Corporation (RDC and BCD 1988) and Battelle-Columbus (1986a) are useful sources for information on the entire manufacturing sector. Several Bonneville reports give process and environmental impact information for selected industry groups in the Pacific Northwest (Battelle 1984; Bechtel 1984; and SJO, Shapiro, and Synergic 1984). Although old, several EPA reports are useful for confirming process and pollutant information (EPA 1976; EPA 1980). Industrial hygiene books, particularly Cralley and Cralley (1982) and Burgess (1981), are good sources for industry-specific process descriptions as are waste management books and articles (see MacGregor 1980; series of articles appearing in JAPCA in 1988). Manufacturing and industrial handbooks (Amstead, Ostwald, and Begeman 1987; Bolz 1977; and DeGarmo 1979) provide non-industry-specific process information.

Other individual sources of information on specific topics are listed below.

OCCUPATIONAL INJURIES AND ILLNESS DATA

Idaho

Stewart Johnson
Public Information Officer
Idaho Industrial Commission
317 Main Street
Boise, ID 83720
(208) 334-6013
(208) 334-2321 fax

Kevin Zuha, data processing

Montana

Sven Taffs
Montana Dept. of Labor and Industry
Research and Analysis Bureau
PO Box 1728
Helena, MT 59624
(406) 444-2430

Oregon

Department of Insurance and Finance
Research and Statistics Section
21 Labor and Industries Building
Salem, OR 97310

Kathy Thomas
(503) 378-8254

Washington

State of Washington
Department of Labor and Industries
Division of Industrial Safety and Health
805 Plum Street, SE
Building 6, 3rd Floor
Olympia, WA 98504

Bridget Flory - Compensation Claims
Data Analysis
Department of Labor and Industries
HC-217-1
905 Plum Street
Olympia, WA 98504
(206) 753-6458

Kitty Lovett - Occupational Illness
and Injury Summary
Research and Data Development
PO Box 2589
Olympia, WA 98504
(206) 753-8254

AIR EMISSIONS DATA

Idaho

Orville Green, Manager
Policy and Permitting
Air Quality Bureau
Boise, ID
(208) 334-5898

Patricia Rayne
Public Records
1410 N. Hilton
Boise, ID 83706
(208) 334-0417 fax

Don Gibbons
U.S. EPA Idaho Office
(208) 334-1450

Montana

Harry Keltz - Statewide and permits
Montana Air Quality Bureau
Dept. of Health and Environmental
Sciences
Coggeswell Building
Helena, MT 59620
(406) 444-3454

Oregon

Air Quality Division
Oregon DEQ
522 SW Fifth
Portland, OR 97207

Wes Risher - Air Emission Inventory
(503) 229-5540

John MacKeller, Public Affairs
(503) 229-6488

Washington

Sally Otterson - Statewide
State of Washington
Department of Ecology
Air Program
MS PV-11
Olympia, WA 98504-8711
(206) 459-6248
(206) 438-7484 fax

WATER DISCHARGE DATA

Idaho

Water Quality Bureau
Dallas -
(208) 334-0412

Kali Buchendorf, Secretary
6(208) 334-0412

J.J. Brown
Water Division
US EPA, Region X
1200 6th Avenue
M/S WD-134
Seattle, WA 98101
(206) 553-1214

Mary Nielson, FOIA Officer
M/S MD-103

Sally Hanft, FOIA Water Division
(206) 553-0165 fax

Montana

Water Quality Bureau
Dept. of Health and Environmental
Sciences
Helena, MT 59620

Loren Bahls - Water Quality
(503) 444-2406

Fred Shewman - Head of Permitting
Section

Mike Pasichnyk - Works with permit
data

Oregon

Water Quality Division
OR DEQ

Shirley Kangla - Public Affairs
(503) 229-5766

Kent Ashbaker, Manager
Industrial Waste Section
(503) 229-5325

Washington

Water Program
Department of Ecology

Bev Poston - Waste Water Discharge
(206) 438-7039

Arlene Army - Industrial Division,
Pulp & Aluminum Mills, Oil
Refineries
(206) 586-1074

Regional Offices:

1. John Glen
NW Regional Office
(206) 867-7033

Judith Fisher - Files and Records
(206) 867-7239
(206) 867-7098 fax

2. Daryl Anderson, Manager
SW Regional Office
Tumwater, WA
(206) 753-2892

David - Files and Records
(206) 586-0368

3. Rick Frye
Central Regional Office
(509) 575-2821

Also:

John Purdente
Dave Huffman

4. Carl Nuechterlein, Director
Eastern Regional Office
Spokane, WA
(509) 456-6198

Roger Ray - Permitting
(509) 456-6174

HAZARDOUS WASTE AND WASTE REDUCTION

Oregon

Maryanne Fitzgerald
Hazardous Waste Reduction Program
OR DEQ
(503) 229-5913

Joyce Thomas, Library
(503) 229-5826
Wed thru Fri only

Dennis Walthall - State Toxic
Release Inventory Report
State Fire Marshall's Office
Salem, OR
(503) 378-2885

Washington

Department of Ecology

Denise Christianson -
Resource Center
(206) 438-7585

Waste Reduction Hotline, Mark Bendut
1-800-822-9933

Northwest

Phil Wong - Toxic Release
Inventory Report
US EPA, Region 10
(206) 553-4016

US ENVIRONMENTAL PROTECTION AGENCY, REGION 10

EPA Permit Compliance System
(206) 553-1223
Vaughn Blethen
US EPA Region 10

ELECTRIC POWER RESEARCH INSTITUTE

Process Industries Coordination
Office
1-800-4320 AMP
Vienna, VA
703-749-7900

- EPRI Chemicals and Petroleum
Office
Mr. Edward Mergens, Manager
3162 Lake Crescent
Kingwood, TX 77339
713-358-2557

- Food Processing Industry
Mr. Richard J. Schadelbauer
Resource Dynamics Corporation
8605 Westwood Center Drive
Vienna, VA 22182
(703) 356-1300

Center for Materials Fabrication
Columbus, OH
614-424-7737
Tammy Moynihan - Communications

- EPRI Pulp and Paper Office
Dr. Robert Hart, Manager
Institute for Paper Science and
Technology
575 14th Street, NW
Atlanta, GA 30318
404-853-9511

Center for Metals Production
Carnegie Mellon University
Pittsburgh, PA
412-268-3496
John Kollar

INDUSTRIES

Aerospace

Boeing
General Information - (206) 655-1131

Office of Environmental Affairs
Renton, WA
(206) 393-4780
Dave Smukowski, Environmental
Operations Officer
Kirk Thomson, Director

Judy Mork
(206) 585-7042
(206) 393-4781
Environmental/Safety/Health
Communications Manager
The Boeing Company
PO Box 3707, MS 6U-02
Seattle, WA 98124-2207

John Hendricks, Energy Manager
(206) 393-2784

Pulp and Paper

American Paper Institute
New York, NY 212-340-0600

Institute of Paper Science and
Technology
Atlanta, GA
404-853-9500

Technical Assistance to the Pulp and
Paper Industry (TAPPI)
Atlanta, GA
Jennifer - Research Librarian
404-446-1400 ext. 274

The TAPPI Journal
Backorders 1-800-332-8686

CONSULTANTS

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Seattle, WA
(206) 447-1805
Anne Devries
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R. Scott Butner
Pacific Northwest Laboratory
509-375-2675

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Bonneville Library
(503) 230-4171
Portland, OR

EPA Library
(206) 442-1289
Seattle, WA

Hanford Technical Library
FTS 8-444-5451
(509) 376-5451
Richland, WA

Multnomah County Library
(503) 223-7201
Portland, OR

NIOSH Library
(513) 533-8321
Cincinnati, OH

NIOSH Publications
1-800-356-4674

National Technical Information
Service (NTIS) Orders
1-800-336-4700

Portland State University Library
(503) 725-4617
-government documents
(503) 725-4126