Section **18**

The Engineering Environment

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18.1 ENVIRONMENTAL CONTROL

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REFERENCES: ''McGraw-Hill Encyclopedia of Environmental Science.'' Beckmann, ''Health Hazards of Not Going Nuclear,'' Golem Press, Boulder, CO. Edinger et al., ''Heat Exchange and Transport in the Environment,'' P.B. 240757 NTIS, USDA, Nov. 1974. Corbitt, ''Standard Handbook of Environmental Engineering,'' McGraw-Hill.

PRINCIPLE OF ENVIRONMENTAL CONTROL

Nature has provided two almost inexhaustible sumps for maintaining a steady state environment on earth. The first of these is the 2.7 K background temperature of absolute space, which nature uses for heat rejection to close its heat balances. The second is the oceans, which serve to close the material balances of its cyclic processes by accepting the combined runoffs of the continents. The greatest engineering progress comes when people control their environmental activities so as to take maximum advantage at minimum cost of these sumps and of nature's cyclic processes. This is the **basic principle** upon which the science of **environmental control** is founded. With it, any environmental problem can be modeled on a conveniently small scale and then solved precisely by LeChatelier's controlled equilibria principle for any large-scale operation. When the principle is applied to obtain optimum yield of a desired end product or result, it will help predict the necessary input compositions, pressure, temperature, and concentration. This same principle is applied in other diverse fields of study such as genetics.

NATIONAL POLICY

The National Environmental Policy Act of 1969, Public Law 91-190 (NEPA), concerns air, water, and land quality and conservation of natural resources. Section 2 of NEPA declares a national policy which will encourage productive and enjoyable harmony between people and their environment and which will enrich their understanding of ecological systems and natural resources.

Section 101(b) (2) provides for the ''widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable consequences.''

Section 101(b) (5) provides for achieving ''a balance between population and resource use which will permit high standards of living'' (e.g., cost/benefit balancing).

Section 101(b) (6) provides for enhancing the quality of renewable resources and the maximum attainable recycling of depletable resources (e.g., developing breeder reactors to extend nuclear fuel reserves).

Section 102(c) requires that all agencies of the federal government shall file environmental impact statements. These detail in a published document for each case: (*a*) its adverse environmental effects, (*b*) its alternatives, (*c*) its enhancement of long-term environmental productivity, and (*c*) its irreversible and irretrievable commitments of natural resources.

Legislation most responsive to the NEPA objectives so far is the Magnetic Fusion Energy Act of 1980. Aiming for a working magnetic fusion system by the year 2000, this act set as a goal a controlled nuclear fusion economy by the middle to late twenty-first century. (See Considine, ''Energy Technology Handbook,'' McGraw-Hill.)

AN OVERVIEW OF ECOLOGY

(See also Sec. 9.1)

Ecology is the study of the **biosphere,** a hypothetical system comprising the surface of the earth and all the subsystems necessary to maintain a steady-state life-support system. The **thermal cycle** is open, isenthalpic, and irreversible. Solar energy is utilized, becomes degraded, and is finally rejected into outer space by means of long-wave radiation through the optical window of the earth's atmosphere. Major quasicyclic processes in the biosphere, necessary for life support, are the **hydrological cycle,** the **carbon cycle,** the **nitrogen cycle,** the **potassium cycle,** the **phosphorous cycle,** and the **sulfur cycle.** These are almost closed cycles, which are occasionally interrupted and renewed by techtonic geological upheavals.

In these cycles, vegetation and animal wastes decay, thereby furnishing nutrients to land, air, and water. New green plants grow, animals eat them, and the recycling continues. Ecologically, the bacteria which decompose all these wastes are called *destroyers,* the green plants which employ photosynthesis are called *producers,* and animals which eat the plants are called *consumers.* A hypothetically bounded small portion of the biosphere is called an **ecosystem.** All ecosystems are **open,** as their essential cycles extend into the biosphere.

An ecologically idealized community would be one in which the ecosystem, including the surrounding agricultural area, would operate steady-state, almost closed cycle. Tucson, Arizona, approaches this state, its crops being irrigated by tertiary sewage treatment so that water and all the plant nutrients, are recycled. Minerals entering the ecosystem through the Santa Cruz River and imported fuels are almost counterbalanced by exports of crops from the area and by irrigation runoff into the normally dry Gila River bed. These activities conform to nature's naturally occurring cycles, and maintain the fertility of the soil.

In larger, heavily overpopulated communities, however, people's activities are counter to nature's, and so humanity suffers. The earth is denuded of local vegetation, and crops are imported. All the nitrogen, potassium, sulfur, and phosphorus contained in the agricultural commodities and fuels, instead of being recycled to the farmlands, are burned or handled by the waste disposal systems of the communities and dumped into rivers and harbors, thereby reaching the oceans and being lost to the continents, despite the recycling and soil fixation methods intended by nature to prevent such losses. Severe pollution problems result, mainly from nonpoint sources and storm run-offs which are not amenable to control, no matter how much money is spent. But the major damage done is depletion of wetlands, forests, and farmlands and buildup of atmospheric CO_2 from fossil-fuel use. It is irreversible and irretrievable and will continue until our society finally faces the fact that the changes required to help stem these events must be made on a local as well as planetwide level.

Environmental control seeks to subdue and to utilize nature's ecological cycles in order to serve people's needs, thereby conserving natural energy and mineral resources, and to replenish desirable local flora and fauna populations by agriculture and cultivation to provide adequate food, clothing, and shelter. Environmental control seeks to extend depletable fuel supplies with clean, abundant forms of gravitational, solar, and nuclear energy (fission and fusion). Also, replenishable substitutes for other depletable resources are sought, as well as recovery and recycling means for scarce and irretrievable substances. Environmental control seeks to conserve land and water quality by diversion into adequately controlled drainage canals of concentrated runoffs, e.g., from irrigation, municipalities, industries and mining, so that these nonrecyclable, unsalvageable mixtures are ultimately discharged into the oceans, where they blend inconsequentially with the vastly larger amounts of runoff from the continents, occurring naturally as part of the hydrological cycle. The public standard of living is highest when all these things are done voluntarily by a responsible, cost-conscious citizenry.

The following subsections describe typical, cost-effective, and productive practices among the free nations. These should be considered to the extent permitted by local regulations.

COST/BENEFIT BALANCING AND ISO 9000 REGISTRATION

REFERENCES: Summary of UWAG-EEI Comments on EPA's Proposed Regulations under 304, 306, and 316(a) of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, June 1974. Effluent Limitations Guidelines for Steam Electric Power Generating Point Source Category 40 CFR, Chapter I, Subchapter N, Part 423. Craig, ''The No Nonsense Guide to Achieving ISO 9000 Registration,'' ASME.

Cost/Benefit Calculations

In order to assess the feasibility [under Section 304b (1B) of the FWPCA Amendments of 1972] of any environmental control technology or augment, both the public cost and benefit of its operation must be considered. For demonstrating feasibility, this dimensionless cost/benefit ratio has the limits

$$0 \leq C/B \leq 1$$

The upper limit of unity means that \$1 spent in the incremental public operational costs of the augment will yield \$1 of return in public benefits. If an augment is required for which the cost/benefit ratio is greater than unity, it is unfeasible. (It is more feasible to accept the pollution.) If an augment is required for which the cost/benefit ratio is negative, the public benefit is negative and constitutes a public detriment. The more that is spent on such an augment, the worse the environmental degradation becomes.

EXAMPLE. Once-through vs recirculating cooling systems: A 1,000-MW(e) steam/electric generating plant is operating with once-through cooling on a river. The heat rate is 10,300 Btu/kWh (0.33 thermal efficiency), with about one-half of the heat, or 5,150 Btu/kWh, being discharged into the river. The public benefit of this thermal enrichment is a stable and abundant fish population, which is estimated to offset all public detriments except occasional fish kills caused by emergency shut-downs. These average each year not more than 8-h duration and \$45,000 public detriment.

Proper environmental management to provide emergency heating of the water during unexpected outages will avoid the fish kills with an estimated 90 percent confidence factor. A cooling tower retrofit will reduce the thermal discharge by 90 percent but will substitute some undesirable atmospheric, noise, and stream pollution conditions. Neglect these problems, but otherwise compare the feasibility of an open-recirculation cooling tower retrofit with that of proper environmental management.

First alternative: Environmental management of existing plant. The annual public detriment for the fish kills is \$0.045/kW(e) of installed capacity. For avoiding these by emergency heating of the river water, let the estimated operating cost to the consumer be \$1 per million Btu. The annual environmental management cost for an 8-h outage per year becomes:

$$8 \text{ h} \times \$.00515/\text{kWh} = \$0.0412/\text{kW(e)}$$

The cost/benefit ratio becomes \$0.412/\$.045 or 0.916, so that 91.6¢ spent will yield \$1 return in public benefits. This is a wise investment. For the existing plant the possibility of a fish kill is reduced to one-tenth its original value, and the remaining annual public detriment becomes \$0.0045 per kW(e) of installed capacity.

Second alternative: Retrofit of an open recirculating cooling tower. The viability of a cooling tower retrofit must be assessed on the basis of this reduced public detriment for the existing plant. The estimated annual operating cost to the public for a cooling tower augment, based on public operational overhead, a 1970 overall plant investment, and a 3 percent incremental capacity loss, due to the retrofit, is \$20/kW(e) of installed capacity. Dividing this by the \$0.0045 expected public benefit yield a cost/benefit ratio of 4,444. This means that \$4,444 must be spent (and the cost passed on to consumer) for every dollar of public benefit. As this is clearly not in the public interest, it is unfeasible. It is cheaper to replenish the fish supply. Moreover, the 3 percent capacity loss of power generation due to the augment results in a 3 percent wastage of fuel and a 3 percent increase in the total thermal discharge to the environment. Energy, in contrast to the fish population, is a nonreplenishable natural resource. It must be conserved, and it must be considered when assessing the public detriment. Valued at 3 percent of the heat rate, \$1 per million Btu and 0.9 load factor, this waste of natural resources will cost \$2.435 per kW(e) annually.

Loss of cooling water by evaporation in the cooling tower is also a public detriment that can be conservatively valued at 25¢ per 1,000 gal. At 5,150 Btu/kWh thermal discharge rate and 0.9 evaporative load factor, this depletion of a natural resource will cost:

$$0.9 \times 5{,}150 \times \$0.25 \times 24 \times 365 \div 8.33 \times 10^6 = \$1.219/\text{kW(e)}$$

Subtracting these two detriments, amounting to \$3.654, from the annual public benefit of \$0.0045 for conserving the fish population yields a negative public benefit due to the augment of −\$3.65. The overall cost/benefit of this installation therefore becomes

$$\$20/(-\$3.65) = -5.48$$

The negative sign indicates that money spent to improve the environment by this means simply makes matters worse. The expected public benefit is not possible, and therefore the technology is not economically achievable.

Achieving and Practicing ISO 9000 Registration

Both capital and operating costs of a new or reorganized operation or venture can be minimized through the mechanism of ISO 9000 registration. In this way parts, machinery, construction, management, and operating and servicing techniques are standardized locally, and ultimately internationally. The favorable economics that ensue are of immeasurable consequence in a competitive marketplace and contribute to the optimum utilization of labor, facilities, and raw materials. A large portion of the benefits which accrue are related to personnel involved in the business entity.

Direct Water Cooling

For large-scale power generation, natural surface cooling in open water bodies is most cost-effective. The intake and outfall should be so oriented as to minimize possibility of heat recirculation and short-circuiting, which can usually be done by locating the outfall sufficiently down current of the intake.

Surface discharge of the condenser water as a hot, buoyant plume requires the least area of water surface for heat dissipation, yields the largest value for the overall surface heat transfer coefficient K, and hence minimizes both the cost and environmental impact of the facility.

The surface heat-transfer coefficient K combines the heat loss contributions due to longwave radiation, evaporation, and convection into a function which can be reliably estimated by two independent equations (J. E. Edinger, 1974):

$$K = H_s(T_s - T_{dp})^{-1} \tag{18.1.1}$$

$$K = \frac{T_s - 183.16}{20} + (0.47 + B)f(W) \tag{18.1.2}$$

where K = overall surface heat-transfer coefficient, W/(m²·K); H_s = gross 24-h average sunshine factor, W/m²; T_s = water surface temperature, ambient, K; T_{dp} = dew point temperature, K; W = wind speed, m/s; $f(W)$ = wind speed function, $9.2 + 0.46W^2$ (Brady, 1969), W/(m²·mmHg); B = slope of vapor pressure curve at $T_m = ½ (T_s - T_{dp})$, mmHg/K.

The derivative of the 1967 ASME steam table saturation line B is given accurately over the temperature range 0 to 50°C by the Rapier log-hyperbolic curve fit

$$B = \frac{5{,}301.734}{T_m^2} \exp\left(20.94673 - \frac{5{,}301.734}{T_m}\right)$$

The overall heat transfer coefficient K can be most accurately obtained from Eq. (18.1.1), since all the variables can be directly measured; then the wind speed function $f(W)$ can be determined for the particular site by substitution of K into Eq. (18.1.2). On the other hand, if T_s is not known, both T_s and K can be approximated by iteration between the two equations, after adopting a reasonable wind speed function, such as the Brady parabola, given above.

Once the value of K has been determined and the temperature rise through the condensers has been decided upon, the initial temperature difference or excess above ambient lake surface temperature at the discharge point, and the final temperature difference or excess above ambient at the plant intake, can be readily calculated, since the effective area A_e in square metres from the discharge point up to the intake determines the log-mean temperature difference, as given by the equation

$$\text{LMTD, °C} = \frac{\text{thermal discharge rate, W}}{KA_e}$$

At locations where limited quantities of water are available, some heat recirculation occurs and, particularly during summer months, can cause temperatures in excess of 32°C at the inlet of the plant. When considering such a location, tradeoffs should be made to determine whether it is more economical to accept a higher temperature at the inlet or to install auxiliary cooling means such as towers or spray ponds.

EXAMPLE. During July, a proposed inland lake site has a gross sunshine factor of 387.3, a dew point of 13.9°C, and a wind speed of 4.07 m/s. Iteration yields 26.1°C for the water surface temperature and 31.8 W/($m^2 \cdot K$) for the heat-transfer coefficient. If thermally loading the lake will cause a temperature excess of more than 8° at the intake, tradeoffs should be considered here.

CONTROL OF THERMAL DISCHARGES

(See also Sec. 9.5.)

REFERENCES: ''Water Resources and Waste Heat,'' *Power Eng.*, pp. 26–33, June 1973.

The total solar flux reaching the earth is 182 trillion kW; 32.4 trillion kW is utilized in the hydrological cycle, whereby freshwater distilled from the oceans is utilized on the continents by the plant and animal kingdoms and finally drains back into the ocean to complete the cycle. The entire thermal demand estimated for the United States in 1980 was 5 billion kW, very small compared with the solar flux in the earth's biosphere. The temperature of the earth's biosphere is stabilized by reradiating the solar flux as long wave radiation back into absolute space through the ''optical window'' (7- to 13-μm wavelength) of the earth's atmosphere. For example, if once-through cooling for 25,000 MW(e) power generation were added to Lake Michigan, the average surface temperature rise would be limited to ¼°F by longwave radiation from the surface of the lake.

The Joint Committee on Atomic Energy, 93d Congress (1973), anticipated that by 1980 the total heat dissipated into the environment by the generation and use of energy in the United States will be equivalent to 43.2 million bbl of oil per day. The combined heat loss caused by electric and industrial power generation will be 11.5 million bbl per day, or 26.6 percent, which includes all the point sources. Distributed and diffuse sources, such as automotive, residential, commercial, and industrial heating and cooling systems, which constitute the balance, account for 73.4 percent of the heat dissipation, and create ''heat islands'' around every major metropolis. About half the heat loss from power generation is presently discharged into bodies of water via nonconsumptive once-through cooling systems and does not contribute to the ''heat island.'' The use of consumptive evaporative cooling for this would add to the atmospheric discharges in the ''heat island'' and raise the ambient temperatures. By 1978, increased urbanization in the Los Angeles Basin will raise the ambient temperature an estimated 5°F. The surface temperatures of water bodies in the Basin would be raised over 5°F, which exceeds guideline limitations for thermal discharges. By the year 2000, if evaporative cooling towers are required for all the incremental power generating capacity, the New York–Philadelphia ''heat island'' will suffer a mean ambient temperature increase of about 15°F, and the cooling towers will consume twice the flow of the entire Colorado River Basin, 31,000 ft^3/s, or 3,000 times their 1970 consumption of water. Not included is the ''greenhouse'' effect of excess CO_2 in the atmosphere from the burning of fossil fuels. An estimated trillion tons of CO_2 will have accumulated, and trapped solar radiation will have raised the earth's mean temperature 3.6°F (2 K). (See Plass, Carbon Dioxide and Climate, *Sci. Amer.*, 41–47, July 1959, pp. 41–47. Also pp. 173–175, Sept. 1983.)

For the year 2000, the percentages of total heat discharged to the environment from various human activities have been estimated as shown in Table 18.1.1.

Table 18.1.1 Heat Discharged into Environment; Year 2000 (Estimate)

Thermal discharge source	Coolant	Total heat, %
Residential and commercial	Atmospheric and water	31.75
Industrial	Atmospheric and water	27.00
Transportation (all forms)	Atmospheric	22.20
Electric power generation	Atmospheric and water	14.30
Electric power consumption	Atmosphere	4.75
Total heat into environment		100.00

The data and projections cited above are dated, and certainly the current situation is different from all projections, but only in degree. The data in Table 18.1.1 are useful in that they address a global problem. Increased use of nuclear fuel to power central-station electric generating plants reduces the heat discharged into the atmosphere from exhaust stacks, but there is almost the same amount of rejected heat dissipated to condenser cooling water or to the atmosphere in cooling towers. Likewise, there is much controversy among the polity in the matter of the greenhouse effect, ozone holes, mandated use of electric-driven vehicles, and so on. The solutions offered to ameliorate those problems are not universally acceptable, but recognition of the existence of problems in this regard is not usually contested. In certain quarters the solution prated is for so-called renewable sources of energy which are ''benign'' (i.e., solar energy), but the technology is not refined yet to make the extraction of solar energy competitive. Much intellectual effort and well-intentioned persuasion must be brought to bear on this and associated type problems as the population grows and the consumption of fossil fuels continues apace.

The largest thermal discharge, 31.75 percent, is primarily attributable to residential and commercial heating and ventilating systems, with air conditioning units making the most undesirable contributions to the environmental ''heat island'' effect. Cogenerative district heating, better thermal insulation, and reduction of electrical loads (such as by replacing electrical heating units with steam or gas-fired units and atmospheric air conditioners with once-through, water-cooled units) could substantially reduce the undesirable side effects.

The second largest thermal discharge is from industry. Because of keen marketplace competition, thermal processes have been selected to provide the most favorable cost/benefit ratio for the consumer. Regulatory control here, except to prevent malpractices, can do more public harm than good. Industrial/nuclear power complexes, where practicable, will produce the maximum public benefit.

Transportation is the third largest contributor to the ''heat island'' effect and the one with the worst side effects. Thermal discharge to city streets could be reduced to one-third its present value and petroleum stocks conserved if all-electric transportation could be substituted economically for the internal combustion engine. This would be particularly advantageous in the summertime.

The smallest contributor to the ''heat island'' effect is electric power generation, which accounts for 7.15 percent of the total atmospheric discharge, with another 7.15 percent thermal discharge to water. Irrigation canals, navigation canals, and artificial waterway complexes designed to include treated municipal effluents could, if implemented in the future, provide sufficient water for a significant number of thermal power generating units, save energy, and reduce the atmospheric discharge near cities by as much as 7.15 percent.

In short, the environmental impact of heat discharged by human activities can be minimized and fuel conserved by cascading processes to get the highest practicable thermodynamic efficiencies and the lowest practicable heat-sink temperatures. Greater efforts must be brought to bear in the matter of curtailment of CO_2 emissions from all sources, inasmuch as they are recognized to have a deleterious effect in polluting the global environment as well as bringing about higher ambient temperatures. Reforestation and/or the maintenance of green spaces and the increased utilization of nonfossil fuels are looked upon with favor in these regards.

Use of Cooling Towers

(See Sec. 9.5.)

REFERENCES: Nomographs for Thermal Pollution Control Systems, EPA 660/2-73-004, Sept. 1973.

In locales where water supplies are inadequate to provide nonconsumptive once-through cooling, evaporative open-recirculating cooling towers become necessary. These consume water at about 2 percent of the recirculation rate, but reduce circulation into rivers or streams by over 95 percent even when employing low concentrating cycles. Nomographs are available from EPA which provide cost comparisons of the cooling systems sampled by Table 18.1.2. Selection of the most feasible cooling system depends on specific site conditions. Economics dictate once-through cooling where possible, wet cooling towers or ponds where water supplies are limited, and dry cooling towers where water is unavailable. All of these will contribute significantly to the ''heat island'' effect unless specifically designed to provide buoyant plumes that will puncture inversion layers.

Table 18.1.2 Cooling System Augments

Cooling systems	Relative capital cost	Power consumption
Natural draft wet towers	3.2	Low
Mechanical draft wet towers	1	High
Spray ponds	2.3	High
Cooling ponds	1.4	Low
Natural/mechanical draft dry towers	7.3/6.7	Medium/high

Wet cooling towers substitute water pollution for thermal pollution by concentrating blowdown, require chemical treatment, and release heavy-metal corrosion products into the blowdown stream. Their operation requires an optimized water chemistry which balances the acid treatment and cycles of concentration to provide nonaggressive water with a slightly positive Langlier index, and to retard the buildup of scale. The Langlier (saturation) index is the difference between the actual measured pH and the calculated pH_s at saturation with $CaCO_3$. A zero Langlier index balances pH, alkalinity, and calcium hardness, and establishes the threshold for alkaline scale formation. (For further information on this and other water treatments, see Betz, ''Handbook of Industrial Water Conditioning,'' Betz Laboratories.) For environmental reasons, pretreatments based upon zinc, chromate, and phosphate inhibitors should generally be avoided, while posttreatments to remove pollutants and corrosion products from the blowdown may have to be employed. With all constraints considered, the most economical design results from a series of tradeoffs. Dry cooling towers are justified only where water shortages preclude the use of evaporative coolers, as their cost, inefficiency, and environmental impact from abnormal heating of the air are otherwise excessive.

Cooling towers may be required by environmental regulations, and ''zero discharge'' of blowdown may also be required, with high concentrating cycles and ''perpetual storage'' of the resultant salty wastes. The salty plume will cause additional difficulties. Blowdown volume can be reduced by concentrating to 10 percent solids using vapor compression. The power requirement for this is 90 kWh/kgal evaporated. Further concentration requires open kettles. (For further information, see Kolflat, Cooling Tower Practices, *Power Eng.*, pp. 32–39, Jan. 1974, and Boles and Levin, Treating Cooling Tower Blowdown, *Power*, pp. 68–76, Aug. 1974.)

WASTEWATER CONTROL

REFERENCES: The Clean Water Act of 1972, as amended through 1981, PL 97-117. Sittig, ''Resource Recovery and Recycling Handbook of Industrial Wastes,'' Noyes Data Corp., Park Ridge, NJ. Lund, ''Industrial Pollution Control Handbook,'' McGraw-Hill. ''Pollution Control Technology,'' Research and Education Association, New York.

Industrial Categorization by the 1972 FWPCA Amendments (Clean Water Act)

The Federal Water Pollution Control Act (FWPCA) Amendments of 1972, Public Law 92-500, preempt all existing federal regulations by authorizing guidelines for ''effluent discharges,'' rather than by controlling ''receiving water quality.''

Title III, Section 306(b) (1) (A) categorizes sources. ''Source'' means any building, structure, facility, or installation from which there is or may be the discharge of pollutants for which effluent limitations guidelines and revisions will be developed. These are published periodically in the Federal Register, under the 40 CFR part numbers shown by Table 18.1.3. The limitations were to be achieved by July 1, 1977, for ''best practicable control technology currently available'' (BPCTCA) and by July 1, 1983, for ''best available technology economically achievable'' (BATEA).

Both BPCTCA and BATEA guidelines must meet feasibility and achievability criteria under cost/benefit testing and will be modified periodically to reflect current needs and technology.

Pretreatment guidelines have been established by EPA under Section 307(b) to control industries with effluent discharges into municipal systems. Industrial wastes not so regulated become part of the municipal wastewater flow and thus a municipal responsibility.

Permit and Application for Industrial Discharges

The Permit Program for Industrial Discharges under the provisions of the ''Refuse Act of 1899'' was previously administered by the Army Corps of Engineers. The Clean Water Act of 1972 incorporated this program and transferred control from the Army Corps of Engineers to the EPA.

A Permit Program Application plus an environmental report [see NEPA-102(c) for criteria] is filed by the discharger with the state, which then refers it to the Regional EPA permit section for review. The state draws a permit that includes limitations, compliance schedules, and state monitoring requirements, making the permit forms available to the public 30 days prior to issuing the permit. Hearings on the permit may cause much delay. After this procedure is completed, the permit may be issued for a maximum of 5 years.

Environmental Considerations for Construction Projects

Introduction The environmental considerations which follow should be taken into account by industry when preparing an environmental report for construction projects, and before an effluent discharge permit can be granted. Cost/benefit factors for applicable environmental control technologies and regulations limiting effluent discharges should be obtained and included in the record of public hearings and should lead to rational decision-making based on a total short- and long-term project cost to the public consumer in relation to the worth of anticipated public benefits. (*Note:* Cost/benefit ratios for meeting effluent discharge regulations can be obtained from the comments submitted to EPA by the categories of industries listed by Table 18.1.3. Public costs generally range from 100 to 1,000 times greater than social or environmental benefits. The engineer will also find these reports a valuable source of design information for environmental projects.)

It should be recognized that the considerations identified should be individually tailored to respond to the unique guidelines for effluent discharge encountered on a particular project and in a particular state.

General Construction Projects

1. What site selection criteria will be used? Will they include cost/benefit balancing of all environmental worth factors such as the conservation of land and fuel reserves, air and water quality, noise, impacts on residents of the area, fish, wildlife, and vegetation? Will alternative sites and alternative orientations of the plant on the selected site be considered?

Table 18.1.3 Industries Categorized under 40 CFR, Chapter I, Subchapter N

Industrial groups	Part nos.	Stds. of performance
1. Food and grain processing	405–409	In general, BPCTCA 1977 guidelines limit pH* between 6 and 9, BOD,* TSS,* and COD,* to the ppm range, toxic substances, e.g., Ba, Pb, Hg, Ag, As, Cr^{+6}, F, to nontoxic concentration. BATEA 1983 guidelines limit these further on nonprocess streams, and seek ''zero discharge'' of process streams.
2. Textiles	410	
3. Feed lots; meat products	412; 432	
4. Chemical; petroleum metallurgy	410–424	
5. Power generation	423	
6. Leather, glass, and rubber products	425–427	
7. Wood products, paper, and pulp	428–431	
8. Oil, gas, coal, minerals and biochemicals	434–440	
9. Tars, asphalt, paint inks, and gums	443–458	
10. Pesticides, chems. and explosives	455–457	
11. Photographic, hospts.	459–460	

* BOD (biochemical oxygen demand); TSS (total suspended solids); COD (chemical oxygen demand); pH (log of the reciprocal hydrogen ion concentration).

2. What disposition will be made of solid and liquid residues (ashes and chemical and industrial wastes)? Does the disposal method include adequate cassetting or neutralization to minimize the danger of soil or water pollution? What steps are planned to contain and reclaim ash dumps and chemical and oil spills to avoid pollution of surface and groundwater by runoff? What provision has been made for the disposal of waste-concentrated brines? If waste disposal into water bodies is planned, what will be the dollar value of its detriment to aquatic life? To what degree will tidal action and currents dilute plant effluents? What disposition will be made of potentially harmful and toxic corrosion products occurring in the plant effluent? Can they be injected into underground aquifers? What provision will be made for controlling the release of waste material into water bodies? If additional units are constructed, what will be the total load of waste materials? What downstream environmental effects can be anticipated with respect to humans, crops, forests, and wildlife? With what cost-effectiveness can any harmful effects be minimized by dilution and toxic materials be discharged below toxic concentrations to merge into the normal background of compositions?

3. What public benefits and detriments will thermal effluents have on the receiving waters? What temperature increase can be anticipated? Is there sufficient water motion in the receiving bodies to dissipate heat effectively? Has the use of cooling towers been explored? What is the probable cost of their public detriment, incurred by the cooling towers' consumptive use of water and energy, by producing fog and undesirable weather conditions through the dissipation of waste heat, and by producing blowdown which may require treatment?

4. What impact will the impoundment for a water supply have in terms of the destruction of agricultural, forest lands, and habitats for fish and wildlife? What measures are planned to mitigate the loss of natural habitats for fish and wildlife? To what degree will archaeological and scenic values be affected? How will the reservoir and downstream flow affect water quality parameters, i.e., temperature, dissolved oxygen, nutrients, nitrogen concentration, hydrogen sulfide, and color?

5. How vulnerable is the facility to surface subsidence, earthquakes, hurricanes, war, insurrection, and other catastrophes? What is the probable annual cost (e.g., liability insurance cost) of the environmental degradation which could be expected from such catastrophes? What preventive and remedial safeguards for downstream inhabitants will be incorporated in plant design and construction? What provisions are made for training plant operators in environmental protection?

6. Have the environmental consequences of transportation, pipeline, and power transmission been considered in site selection? What steps are planned to avoid soil erosion and the silting of streams as pipelines, transmission facilities, and access roads are constructed?

7. What provision has been made for recycling and for industrial by-product development associated with the facility? (See also Sec. 6.10.) What impact will that activity have on the environment?

Process Selection, Recycling, and Ultimate Disposal of Residual Wastes

(See also Sec. 6.10.)

In the design of an industrial installation, segregation of process and nonprocess streams, together with good housekeeping practices and diversion of storm waters will generally result in minimum volumes of water requiring special treatments before being discharged. Wastewater treatment processes involved are: chemical and physical treatments for removal of undesirable waste products; suspended and dissolved solids from process waste streams; removal of corrosion products and carbonaceous wastes (biological treatment) from nonprocess streams; oil-water separations; suspended-solids removal from storm runoffs; good housekeeping and protected stockpiling to prevent contamination of runoffs; and blending of treated effluents and impoundment to meet local end-of-pipe regulations (see Table 18.1.4).

Recycling of consumer and commercial wastes back to their sources (e.g., crankcase oil, glycol, fat, photographic and plating wastes, paper, rags, rubber, metals, and irrigational and fertilizer values of municipal wastes), following the good housekeeping practices of industry, is a very cost-effective method for reducing municipal stream pollution. However, within most industries recycling of salvageable material is almost always practiced to the point of optimum return, so that proposed benefits from further recycling in an effort to obtain ''zero discharge'' are usually minimal. Recycling, or ''closed-cycle'' water reuse schemes consume water and produce blow-down streams of concentrated pollutants in contrast to ''open-cycle'' schemes, whereby solids have traditionally been discharged at normal and below toxic levels, within the assimilative capacity of the receiving bodies of water. The latter, and not the former, conserves water and enhances the naturally occurring ecological cycles—provided, of course, that abnormal toxic substances are not discharged, but are removed by a posttreatment for ultimate disposal.

Descriptions, flow sheets, and costs for a variety of industrial water-

Table 18.1.4 Removal Process Guide for Selected Contaminants

Treatment processes	pH, acidic, alkaline	Suspended and precipitated solids	Bacteria, odor, organic, color	Nutrients (N, P)	Herbicides, pesticides, CN^-	TDS	Oils, solvents	Heavy metals Cr^{6+}
Chemical*	C	B	A	A	A	A, B	B	A, B
Clarification† and settling		G, D, I	D, E, H	H, D		D	F, H, D	D, I
Selected‡ biological			J, K	J, K	K		J	
Desalting§			O, M	L, N		L	O, M	L, N
Sludge¶ dewatering		P	P				P	P

* A, selected chemical treatment; B, coagulation; C, neutralization.
† D, selected clarification; E, aeration, oxidation; F, flotation, decantation; G, filtration; H, lagooning; I, sedimentation.
‡ J, secondary (e.g., aerobic, anaerobic); K, tertiary (e.g., carbon adsorption; extended aeration); anaerobic dentrification.
§ L, selected desalting and brine blowdown; M, membranes; N, ion exchange; O, distillation.
¶ P, dewatering (e.g., gravity, centrifugal, vacuum filtration; drying).

use and recovery schemes are found in ''Water Reuse, Industry's Opportunity'' (1973), published by the AIChE.

Water reuse by consumptive processes always results in a stream of concentrated residual wastes for which an ultimate disposal site must be found. Thus, for brine from saline-water conversion processes, there are four major avenues: (1) ocean discharge; (2) underground discharge into saline aquifers; (3) dry lake beds, liner protected; and (4) solidification and use for landfill. Reference to current regulatory and trade publications should be made to determine which of these is permitted for a given situation.

ATMOSPHERIC POLLUTION

REFERENCES: Laws: Current Legislation, *Chem. Eng.*, June 21, 1971. Victor Sussman, New Priorities in Air Pollution Control, *Jour. Air Poll. Control Assoc.*, **21**, no. 4, April 1971, p. 201. Corbitt, ''Standard Handbook of Environmental Engineering,'' McGraw-Hill.

Abstract of Federal Air Pollution Control Legislation

Clean Air Amendments, 1965 Authorized federal control of new motor vehicle emissions. Extended federal control to cover international pollution originating in the United States.

Clean Air Act of November 21, 1967 Under Public Law 90-148 the states are held responsible for establishing local air quality standards consistent with federal criteria.

Clean Air Act Amendments of 1977 Under Public Law 95-95, the EPA can require offending sources to be shut down immediately. Unsatisfactory state enforcement programs can be taken over and run by the EPA. New plants and new additions to old ones must have the best available pollution control technology, and meet emission standards, including zero levels for hazardous substances. A 90 percent reduction from baseline in automotive emissions is required.

The deadline set forth in the act requiring cities to comply with federal standards by 1987 was not possible to meet universally, although some cities did meet the criteria for SO_2 and ozone.

Clean Air Act of 1990 This was the first new air pollution legislation since the 1977 amendments. Briefly, its major requirements are to reduce SO_2 emission by 50 percent and to set emission standards for a number of chemicals which had not been addressed in previous legislation, as amended. The gradual phaseout of use of CFCs is set forth, with complete elimination set for 1996. Airborne pollution respects no national boundaries; accordingly, there has been much cooperation among sovereign nations to solve, among others, the serious problem of acid rain resulting from some forms of pollution.

Some Existing Federal Standards The EPA publishes in the Federal Register national ambient air quality standards covering six pollutants (see Table 18.1.5).

Effect of Energy Crisis on Legislation The energy crisis of the 1970s led Congress in 1974 to consider legislation to postpone the NEPA and to modify the Clean Air Act in order to provide relief from the shortage of petroleum and natural gas. Currently, there are abundant supplies of all types of fossil fuels available in the global market, and at competitive prices. There was no actual postponement of then-extant legislation, but concerted efforts to abate CO_2 pollution resulting from a fossil-fuel-based economy continue. (See discussion above under ''Control of Thermal Discharges.'') Electric power generation increases worldwide. Most of it is represented by fossil fuel plants as dictated by local resources available and the state of those local economies. Few unexploited very large water power sites exist, and of those, only a handful are economically viable in the current market. Nuclear-powered plants are being emplaced in many parts of the world, although no new plants have been ordered in the United States for almost 20 years. In some quarters it appears inevitable that the conflicting requirements of pollution abatement, reduction of CO_2 in the atmosphere, and reluctance to exploit nuclear power will ultimately result in the reemergence of nuclear power. The timing is not clear, and it will be a function, among other things, of the successful and timely resolution of the problems attendant disposal of high-level radioactive wastes, depletion of fossil fuel reserves, and possible development of advanced-type nuclear reactors which may prove economically and environmentally viable sometime in the twenty-first century.

It would be prudent to conserve irreplaceable natural resources by utilizing them in the most productive energy, materials, and ecological cycles. Often, alternative methods are at cross purposes with those objectives and result in inadvertent squandering of those resources.

Table 18.1.5 Ambient Air Quality Standards

Pollutant	Primary	Secondary, if not same as primary
Particulates, $\mu g/m^3$		
Annual geometric mean	75	60
Max. 24-h conc.*	260	150
Sulfur dioxide, $\mu g/m^3$		
Annual arith. aver.	80 (0.03 ppm)	
Max. 24-h conc.*	365 (0.14 ppm)	
Max. 3-h conc.*		1,300 (0.5 ppm)
Carbon monoxide, mg/m^3		
Max. 8-h conc.*	10 (9 ppm)	
Max. 1-h conc.*	40 (35 ppm)	
Ozone, μ/m^3		
1-h max.*	160 (0.08 ppm)	
Lead particulates, $\mu g/m^3$		
Calendar qtr., aver.	160 (0.24 ppm)	
Nitrogen dioxide, $\mu g/m^3$		
Annual arith. aver.	100 (0.05 ppm)	

* Not to be exceeded more than once a year.
NOTE: All values subject to periodic revision.

SOURCES AND CONTROL OF AIR POLLUTION

REFERENCES: Magil, Holden, and Ackley, ''Air Pollution Handbook,'' McGraw-Hill. Gibbs, ''Clouds and Smoke,'' Churchill. White, ''Industrial Electrostatic Precipitation,'' Addison-Wesley. Morgensen, ''Fan Engineering,'' Buffalo Forge. Dallavalle, ''Micrometrics,'' Pitman. Stern, ''Air Pollution,'' Academic Press. ''Air Pollution Engineering Manual,'' J. A. Danielson, EPA-Research Triangle Park, NC, May 1973.

Table 18.1.6 Principal Air Pollutants

		Particulate matter			
Gases	Vapors	Dusts	Fumes	Smokes	Mists
Acid gases	Alcohols	Alumina	Metallic halogens	Ash	Acid
Carbon monoxide	Esters	Calcium fluoride	Metallic oxides	Cinders	Chromic
Hydrogen chloride	Hydrocarbons	Cement	Silicon tetrafluoride	Organic compounds	Phosphoric
Hydrogen fluoride	Ketones	Coal		Soot	Sulfuric
Hydrogen sulphide	Mercaptans	Grain		Tobacco	Organic chemicals
Nitrogen oxides		Limestone			Oils
Sulfur dioxide		Metal			Salt spray
Alkaline gases		Ore			
Ammonia		Rock			
		Wood			

Table 18.1.7 Pounds of Contaminants Discharged Daily from Domestic Sources in a Metropolitan Area of 100,000 Persons

	Pounds per day per 100,000 persons using each category of heating and refuse disposal					
	Fuel—domestic heating			Domestic incineration		
Principal contaminants	Coal	Oil	Gas	Backyard burning	Household* incinerator	Apartment incinerator
SO_x	42,000	17,000	0.4	180	1	12
NO_x	8,000	6,000	6	90	1,150	30
H_2S	1,000	500	0.1			24
NH_3	2,000	800	0.3	345		24
HCl	2,000	500	0.3			
Aldehydes	2,000	800	1	600	8,400	72
Organics	20,000	4,000	1	42,000	12,000	1,800
Organic acids	30,000	12,000	1	225	1,900	4,800
Solids	200,000	800	0.1	3,400	16,500	4,000
Total of above categories, lb	307,000	42,400	10	46,800	40,000	10,700
Total of above categories, kg	139,100	19,210	4.5	21,200	18,120	4,850

* Add 17 percent for cigarette smoking (1984 estimate).
NOTES: Each column shows estimates of the pollutants released to the atmosphere if the entire population used the noted fuel or method of incineration.
SO_x—oxides of sulfur—SO_2 and SO_3.
NO_x—oxides of nitrogen.
Aldehydes measured as formaldehyde.
Organic acids measured as acetic acid.
Total includes only above categories and does not imply total contamination in the ambient atmosphere.
SOURCES: Eliassen, Domestic and Municipal Sources of Air Pollution, *Proc. National Conference on Air Pollution,* 1958.

Domestic and Municipal Sources of Air Pollution

(See Tables 18.1.7 and 18.1.8.)

All **pollutants** are usually classified as gases, vapors, and **particulate matter** (see Table 18.1.6 and Fig. 18.1.1). Particulate matter includes: **Dusts**—a loose term applied to solid particles predominantly larger than colloidal and capable of temporary gas suspension. Dusts do not tend to flocculate except under electrostatic forces; they do not diffuse but settle under the influence of gravity. Dusts result from such operations as crushing, grinding, drilling, screening, and blasting. **Fumes**—the solid particles generated by condensation from the gaseous state, generally after volatilization from melted substances, and often accompanied by a chemical reaction such as oxidation. For example, zinc vapor will evaporate from the surface of heated liquid metal and will then condense upon contact with ambient air to form small, fluffy particles of zinc oxide. Fumes are usually less than 1 μm, although they may coalesce or flocculate to form larger particles. **Smokes**—gas-borne particles (usually less than 0.5 μm) resulting from incomplete combustion of materials such as wood, tobacco, coal, and oil. **Mists** and **plumes**—loose terms applied to dispersions of liquid particles (0.1 to 2.5 μm), the dispersion being of low concentration and the particles **large.**

Low-Emission Automotive Propulsion Systems

(See Secs. 9.6 and 11.1.)

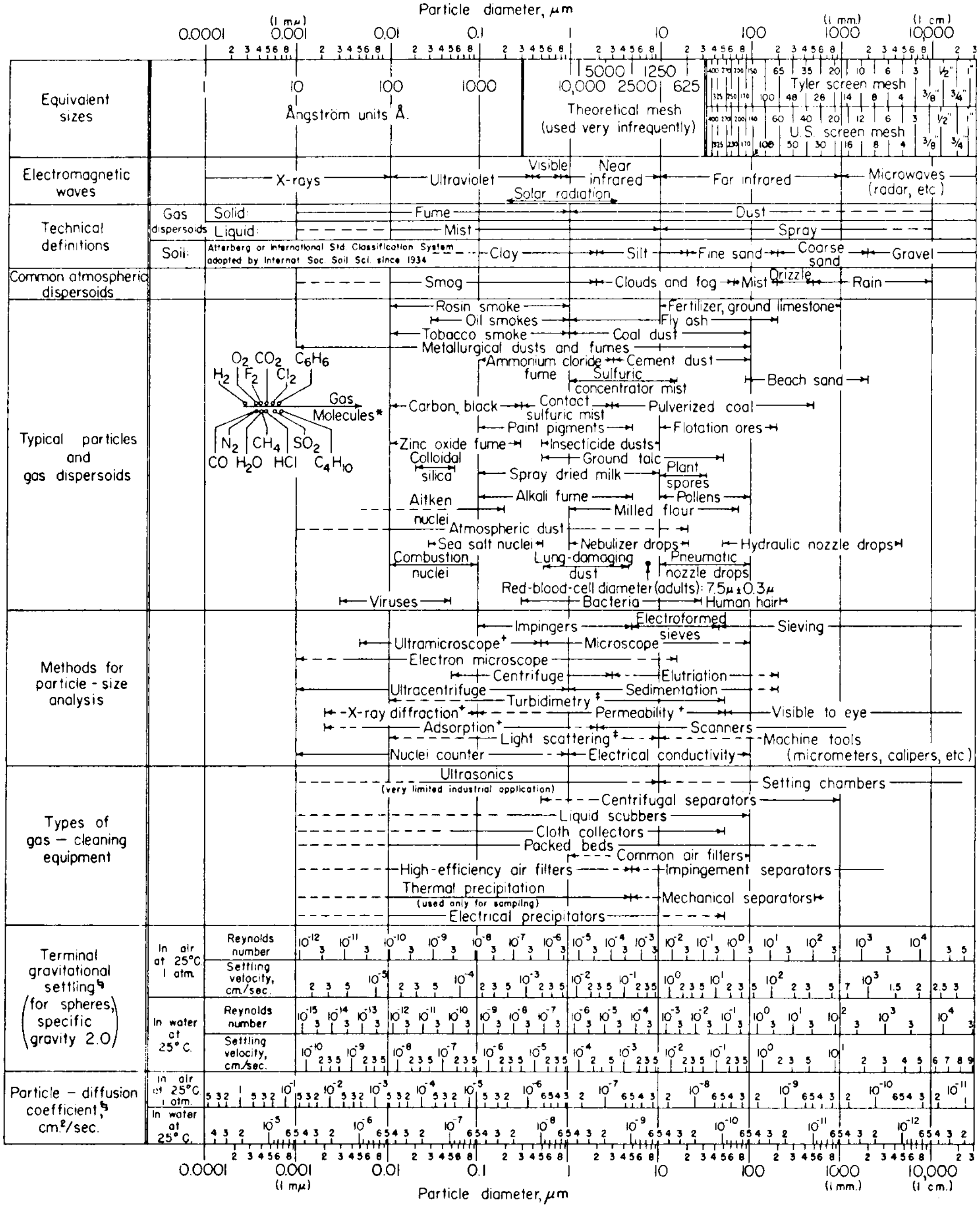
The automobile is a major source of air pollution and a significant contributor to photochemical smog (caused by the products of photoreactions in the atmosphere—organic peroxides, peracids, hydroxy peracids, peroxyacyl nitrate, and other compounds). For every 1,000 gal of gasoline consumed by an automobile engine, there are discharged the following air pollutants, in pounds: carbon monoxide, 3,000; hydrocarbons, 200 to 400; nitrogen oxides, 50 to 150; aldehydes, 5; sulphur compounds, 5 to 10; organic acids, 2; ammonia, 2; solids, 0.3.

Conventional Gasoline Engines A major thrust aimed at the reduction of air pollution from automotive exhausts resulted in enactment of legislation to increase the fuel economy obtained by passenger cars. Commonly known as the **corporate average fuel economy (CAFE)** program, the legislation sought to increase average fuel economy from 18 mi/gal (1978) to 27.5 mi/gal (1985). Current average fuel economy for passenger cars is slightly above 28 mi/gal (1995).

In the quest to reduce pollutants entrained in automotive exhaust gases, it was also recognized that the alarmingly high levels of lead in the local atmosphere, especially in large urban areas and their surrounds, had to be eliminated. This led to a dual approach: introduction of nonleaded gasoline (with the concommitant phaseout of leaded fuel) and incorporation of catalytic converters as original equipment by passenger car manufacturers. The two matters went hand in hand, for it was known that a practical catalytic converter would be rendered ineffective if it were contaminated by lead (or phosphorus). At this time, all passenger cars (with a few exceptions, e.g., some off-road vehicles on farms) are equipped with catalytic converters. The converter functions to reduce the levels of emission of carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x). Chemical reactions take place when the exhaust gases pass through the converter, resulting in conversion of the offending pollutants to CO_2, water vapor, and nitrogen. The

Table 18.1.8 Sources of Air and Typical Loss Rates

Class	Aerosols	Gases and vapors	Typical loss rates
Combustion processes	Dust, fume	NO_2, SO_2, CO, organics, acids	0.05–1.5% by weight of fuel
Stationary engines	Fume	NO_2, CO, acids, organics	4–7% by weight of fuel (hydrocarbons)
Petroleum operations	Dust, mist	SO_2, H_2S, NH_3, CO, hydrocarbons, mercaptans	0.25–1.5% by weight of material processed
Chemical processes	Dust, mist, fume, spray	Process-dependent (SO_2, CO, NH_3, acids, organics, solvents, odors, sulfides)	0.5–2% by weight of material processed
Pyro- and electro-metallurgical processes	Dust, fume	SO_2, CO, fluorides, organics	0.5–2% by weight of material processed
Mineral processing	Dust, fume	Process-dependent (SO_2, CO, fluorides, organics)	1–3% by weight of material processed
Food and feed operations	Dust, mist	Odorous materials	0.25–1% by weight of material processed



* Molecular diameters calculated from viscosity data at 0°C.

\+ Furnishes average particle diameter but no size distribution.

‡ Size distribution may be obtained by special calibration.

§ Stokes-Cunningham factor included in values given for air but not included for water

Fig. 18.1.1 Sizes and characteristics of airborne particles. *(From C. E. Lapple, Stanford Res. Inst. Jour., vol. 5, p. 94, Third Quarter 1961. Reproduced by permission.)*

catalytic converter will function properly only if free of contaminants (lead and phosphorus, cited above) and if maintained properly to prevent operation at extremely high temperatures. Continued improvements in design and construction have proved effective in reducing pollutants ascribable to automotive exhaust gases, and have done so at no appreciable loss in fuel economy.

Fuel Injection Gasoline Engines A typical fuel injection engine of about 1,700-cm^3 displacement and burning 91 octane fuel, when compared with a conventional two-carburetor engine of the same displacement and using the same gasoline, will demonstrate an improved gasoline economy and substantially lower emissions because of improved combustion.

Stratified-Charge Gasoline Engines In the stratified-charge engine, a rich mixture is ignited in a precombustion chamber by a spark plug and is then fed into the main combustion chamber, where it ignites a much leaner mixture of gas and air. By this means, relatively low peak combustion temperatures, a slow rate of combustion, and an overabundance of free air are obtained. The respective results are low emissions of NO_x, hydrocarbons, and CO, without misfiring.

Methanol, Ethanol, and Propane Engines These are basically modified gasoline engines. Pure methanol and ethanol burn almost pollution-free, even without a converter. They have heating values slightly over one-half those for gasoline, but their combustion efficiency is higher. Methanol and ethanol can be synthesized from coal gas; ethanol is also produced from vegetable matter (primarily grains). Combined fuel consisting of gasoline and ethanol (gasahol) has been introduced in some parts of the country, but has yet to become a definitive widespread fuel, primarily because of the current abundance of petroleum feedstocks. (See Considine, ''Energy Technology Handbook,'' McGraw-Hill.)

Two-Stroke Diesel Engines (See Sec. 9.6) With its high compression ratio (up to 21) and complete combustion, the two-stroke diesel engine is an excellent performer. Emissions are quite low and it is highly efficient. Its apparent disadvantages, such as high weight, high initial cost, noise, slow acceleration, and difficult cold-weather starting, have been worked on and overcome, so that the passenger car diesel engine is now available from several manufacturers.

Philips (Stirling Cycle) Engines (See Secs. 4.1 and 9.1) These are external combustion engines, using helium or freon as a working fluid. Consequently, they require no pollution control devices, since combustion occurs in a highly efficient burner system. In the Stirling cycle, the engine, too, is highly efficient and has a low specific fuel consumption. With its heat exchangers, the system is somewhat bulky and requires expensive construction techniques. Nevertheless, the engine holds considerable promise because it can utilize almost any kind of fuel.

Gas Turbines Much effort has been invested to develop gas turbine driven vehicles. Numerous problems and high cost have all but ruled these highly efficient devices out of consideration.

Hydrogen Fuel Cells (See Sec. 9.1) In 1974 a compact fuel system was developed that reacts gasoline with other liquids to produce hydrogen. In addition, a packaged industrial power plant was developed which re-forms fossil fuel into hydrogen and, using fuel cells, delivers 26 MW of net power at a 9,000 Btu/kWh heat rate. Thus, it is now within the range of practicality to power electrically driven automobiles with compact, lightweight fuel cell generating systems that operate at high overall thermal efficiency, and are pollution-free. Considerable developmental effort will have to be made, however, to design the automobile. This system, if successfully developed, could outperform the huge, heavy, and underpowered electric storage battery systems currently proposed for electric vehicles.

Classification of Solid Pollutants

The **micrometer** (10^{-6} m), abbreviated μm, is customarily used to measure fine particles. Particles over 10 μm (10^{-5} m) are classified by Gibbs as **dusts;** between 0.1 and 10 μm, **clouds;** between 0.001 and 0.1 μm, **smokes;** below 0.001 μm, molecular dimensions. The law governing the **terminal velocity of the settling of particles** under the influence of gravity varies with the size of the particle. In the turbulent region (above 2,000 μm)

$$V_t = Ks^{1/2}p^{1/2}D^{1/2} = k_1\sqrt{SD}$$

In the intermediate region (between 1,000 and 100 μm), the law is $V_n = K's^{2/3}\rho^{-1/3}\eta^{-1/3}D = k_2 s^{2/3}D$. In the streamline region (2 to 50 μm), Stokes' law holds: $V_s = K''sD^2\eta^{-1} = k_3 sD^2$. From 0.1 to 1.0 μm, Cunningham's correction must be applied to Stokes' law:

$$V_c = V_s(1 + 1.72\lambda/D) = V_s(1 + 0.172/D)$$

Below 0.1 μm, the movement due to molecular shock (brownian motion) exceeds that due to velocity. In these equations, V is the terminal velocity, ft/min; D, particle diameter, μm; p, gas pressure, atm; s, specific gravity; ρ, gas density, g/cm^3; η, gas viscosity, P; λ, mean free path of the gas molecules, μm. The equations for falling in standard air are given below, where values of the constants give velocities in m/s. For irregular shapes, $k_1 = 0.142$, $k_2 = 0.00259$, and $k_3 = 1.98\ (10)^{-5}$. For spheres, $k_1 = 0.243$, $k_2 = 4.11\ (10)^{-3}$, and $k_3 = 3.0\ (10)^{-5}$.

The **Tyler standard screen scale** is related to particle size as below:

Meshes per in	10	20	35	48	64	100	150	200	325
Micrometer scale	1,650	830	420	300	220	150	110	74	44

Diameters of the more common gas molecules range from about 0.0003 to 0.00045 μm; their mean free path is from 0.06 to 0.2 μm at atmospheric pressure.

The size ranges of **particles** in typical **aerosols** and **industrial dusts** are, in micrometers: raindrops, 500 to 5,000; mist, 40 to 500; fog, 1 to 40; tobacco smoke, 0.01 to 0.15; oil smoke, 0.03 to 1.0; pigments, 1 to 7; fly ash, 3 to 70; carbon black, 0.04 to 0.2; pulverized coal, 10 to 400; foundry dusts, 1 to 200; cement, 10 to 150; metallurgical fumes, 0.1 to 100; sprayed zinc dust (condensed), 2 to 15; normal impurities in quiet outdoor air, less than 1; dust particles causing silicosis, below 10; pollens, 20 to 60; plant spores, 10 to 30; and bacteria, 1 to 15.

Normal **city air** carries around 0.0006 g of suspended matter per cubic foot (1.37 mg/m^3), which is a practical limit for most industrial gas cleaning; the amount of dust in normal air in manufacturing plants frequently is as high as 0.002 gr/ft^3 (4.58 mg/m^3). The amount of dust in **blast-furnace gas** after passing the first dust catcher is of the order of 10 gr/ft^3 (22.9 g/m^3), the same as raw hot producer gas. All dust content figures are based on air volumes at 60°F and 1 atm (15.6°C and 101,000 N/m^2).

Cleaning Apparatus

The removal of suspended matter is accomplished by the following methods. Each particle case must be studied to find the most desirable method. Economic considerations require that cleaning should not be any more thorough than necessary.

Gravity Separation This method is applicable only to the larger-sized suspended particles (100 μm and over). A long horizontal chamber is built, in which the gases are slowed down to a velocity which will allow the particles to settle to the bottom of the chamber. Even gas flow should be maintained throughout the chamber. Hoppers or a drag scraper are used to collect the settled-out material. The settling rate can be calculated by Stokes' equation above, and the size of the settling chamber for a given particle size determined.

Inertia Separation An effort is made in inertia separators to magnify the settling tendency of solid or liquid particles in gases by increasing the velocity of the gas and by providing for rapid changes in direction which, by inertia, cause the particles to leave the gas stream. Baffle chambers are used for this purpose with a zigzag movement of the gas.

Of all inertia separators, the **cyclone** type constitutes the most widely used industrial dust collector. The gas is passed tangentially into a vertical cylinder with a conical bottom. The gas follows a spiral path, with most of the separation taking place in the smaller sections of the cyclone. Cyclones can be used when particles of over 5 μm diam are involved. **Multiclones** have a large number of parallel, small cyclone units. The gas pressure drop is about 4 times the entrance velocity head (1 to 4 in w. g.). The dust content of the cleaned gas is seldom less than 1 gr/ft^3 (2.29 g/m^3).

In the **Rotoclone** apparatus, the impeller is a concave disk with curved blades along which the dust slips and is discharged over the edge of the disk into a ring-shaped dust chamber. The main air stream leaves in a wide scroll on the side of this chamber. The apparatus is usually preceded by a cyclone for removal of coarse dust. By spraying water in the entering air, the precipitation efficiency of dust removal can be materially raised. Particles of minimum size 8 μm are claimed to be removed by the dry apparatus, 1 μm by the wet apparatus. The power for dust separation cannot readily be separated from that for compressing the gases. The power requirement is 3 bhp per 1,000 ft^3/min for an outlet

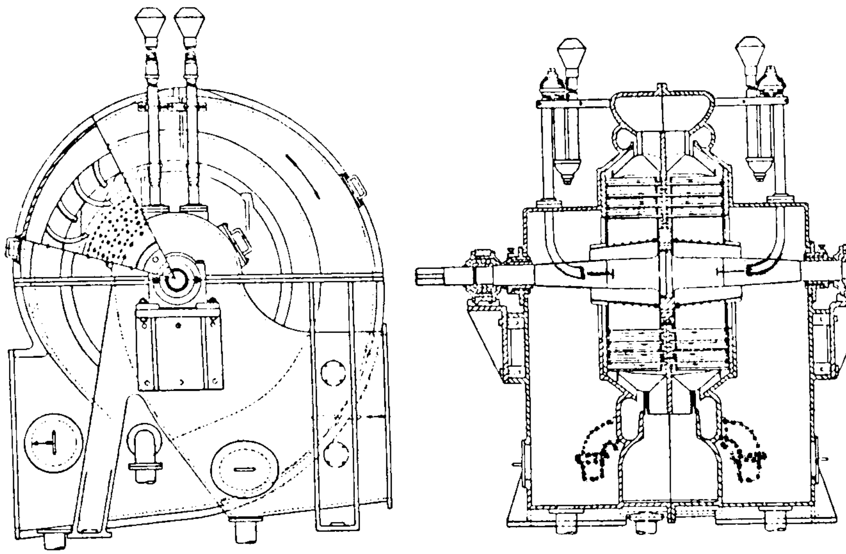


Fig. 18.1.2 Theisen disintegrator air washer.

pressure of 10 in w. g.; in the water-sprayed machine, the required power is at least 25 percent more.

Static spray scrubbers are usually of the tower type, the gas passing upward countercurrently to the descending liquid. Sets of sprays are placed in the top zone, with various materials used in layers to channel and mix the gas and water. Hurdles, cylindrical tiles, and random-packed ceramic tiles or metal spirals are common packing materials. With a gas flow-rate of about 350 ft^3/min per ft^2 of cross-sectional area and a water rate of 25 gal/Mft^3 of gas, a cleanliness of 0.1 to 0.3 gr/ft^3 can be obtained with blast furnace, coke oven, and producer gas. The pressure drop through a tower scrubber is in the range of 4 to 10 in w. g. The scrubber process is used as the primary cleaning and cooling stages before the cleaning of gases.

Dynamic Spray Scrubbers Contact between water droplets and suspended matter in gas is improved by mechanical agitation of gas and water. The *Thiesen* disintegrator (Fig. 18.1.2) is an example of a modern type of dynamic spray scrubber. It consists of a substantial cast-iron casing enclosing two stationary and one motor-driven rotor basket. The water is injected by gravity to the center of the perforated cones. Centrifugal force distributes the water over the bar system. The rotation atomizes the water which agglomerates with the dust, wetting it to effect its removal. The disintegrator is always followed by a moisture eliminator which removes the wetted particles from the gas. The range of cleanliness is between 0.02 and 0.005 grains of dust per cubic foot. In addition, any desired pressure increase up to 16 in w. g. can be obtained. The disintegrator is not sensitive to the quality of the incoming gas. It will clean just as well with 0.30 gr/ft^3 in the entering gas as with 0.10 gr. It has been installed mostly on blast-furnace gas cleaning systems. In recent years, it has been successful on waste-gas cleaning for the oxygen steelmaking process and electric-furnace waste-gas cleaning systems. A similar dynamic scrubbing effect can be obtained by spraying water into the ''eye'' of the final exhaust fan and dewatering with a wet cyclone. Water requirements range from 4 to 8 gal per 1,000 ft^3/min of gas, and a power demand of from 4 to 10 kW per 1,000 ft^3/min of gas.

The other example of dynamic spray scrubbers is the **Pease-Anthony Venturi.** In this system, the gas is forced through a Venturi throat in which the gas is mixed with high-pressure water sprays. A tank after the Venturi is needed to cool and eliminate the moisture. Cleanliness in the range of 0.1 to 0.3 gr/ft^3 has been reported.

Filtration is comparatively little used for cleaning fuel gases; it is in extensive use in cleaning air and waste gases. Materials used for gas filtration are ordinarily thickly woven cotton or wool cloth for temperatures up to 250°F; for higher temperatures, metal cloth or woven glass cloth is advisable. The gases filtered should be well above their dew point, as condensation on the filter cloth plugs the pores. If necessary, saturated gas should be reheated. The cloth is frequently made into ''bags,'' tubes of 6 to 12 in in diameter and up to 40 ft long, suspended from a steel framework (baghouse). The gas inlet is at the lower end through a header to which the bags are connected in parallel; the outlet is through a housing surrounding all the bags. At frequent intervals, the operation of all or part of each unit is interrupted while the bags are pulsed, shaken, or reverse-air-cleaned to dislodge the accumulated dust, which drops back into the gas-inlet header and is removed by a conveyor screw. The dust content can be reduced to 0.01 gr/ft^3 or less at reasonable cost. The apparatus also is used for the recovery of valuable solids from gases.

Electrical Precipitation This principle, although involving highly technical physioelectrical phenomena, is generally familiar to all. If suspended particles are placed in a high-voltage electric field, they receive an electric charge and move toward one or the other of the electrodes between which the electric field is established. If one electrode is a pipe or flat plate and the other electrode is a wire axially suspended in the center of the pipe or between two plates, the field is strongest around the wire and weakest near the surface of the pipe or plate. The charged dust particles move from the strong part of the field toward the weak part of the field.

Two types of precipitators are manufactured. **The vertical-round type** is usually built in a cylindrical tank having a header sheet near the inside top. In this header sheet are nested pipes which act as the collecting electrodes. The high-voltage ionizing electrodes are twisted square steel rods, about ¼ in in size, supported from above the header sheet and hung axially in the collecting electrode pipes. Water is introduced above the header sheet and flows over weir rings at the tops of the pipes to form a water film on the inside of the pipes. **The horizontal-plate type** has vertical parallel plates as collecting electrodes. The discharge electrodes are a series of wires suspended equidistantly between the plates, and can be operated as either a ''wet'' or ''dry'' unit. When used as a wet precipitator, weir boxes are built on the top of each plate to produce a wetting of both sides of the plate, washing the collected particles down the plate. As a dry precipitator, a rapping device operated on a time cycle shakes the plates, causing the collected particles to fall into a hopper under the plates. Dry collection requires injection of a conductive gas such as SO_3 to work efficiently. (See Marchello, ''Control of Air Pollution Sources,'' Marcel Dekker, p. 182.)

The electrical apparatus provided with a precipitator to produce a dc potential of 30,000 to 90,000 V can be mechanical, vacuum tube, or solid state. Power packs are self-contained cabinet-type units, built in sizes from 2½ to 50 kVA. Rectifiers are mounted in a substation building close to the precipitator or can be mounted in weatherproof enclosures on the roof of the precipitator. Controls can be at a distance because the wiring is of low potential.

The efficiency of dust removal by precipitators is expressed as $\log (1 - E) = t \log K$, where E = the efficiency as fraction removal; t = the time the gas is in the electric field, s; and K = an apparatus constant varying from 0.05 to 0.80 (''Cottrell Electrical Precipitators,'' Western Precipitator Corp.; see also Schmidt and Anderson, *Elec. Eng.*, 1938). The above function implies that small variations of t cause considerable variations of $(1 - E)$, the fraction of dust left in the gas. This indicates a sensitivity of the precipitators to overload. (See Table 18.1.12 for common applications).

Precipitators working on coke oven gas for tar removal, under favorable temperature and moisture conditions, show outlet figures of 0.005 gr of dry tar per ft^3 of gas with inlet of 0.25 gr/ft^3. The outlet tar content increases rapidly upon overloading the apparatus.

Precipitators for blast furnace gas reduce the dust to about 0.01 gr/ft^3. Electric precipitators are used for removal of suspended matter from gases and air from boiler gases, metallurgical fumes, cement and lime dusts, etc. Precipitators can be built for dust in practically all particle sizes, as well as mist. They cannot collect material in the gaseous or vapor state. Precipitators are not applicable where explosive gas or dust is involved in the presence of air or oxygen in explosive proportions because of the hazard of ignition by an electric spark.

Blast-Furnace Gas Cleaning Modern equipment for this service represents a field in which gas cleaning has been developed to a high degree of efficiency. The method described here is used on most modern blast-furnace gas-cleaning plants.

The **dust catcher** is a large cylindrical steel tank, brick-lined, about 30 to 40 ft in diameter. The dust catcher is fundamentally a settling chamber. Dust is dropped out of the gas by reducing the velocity of the flow. Gas enters at 400°F approx and with 10 to 20 gr of dust per cubic foot. A good dust catcher will clean the gas to 3 gr of dust per cubic foot.

The **primary washer** is a cylindrical steel shell 16 to 21 ft in diameter, with a conical bottom section. Four to five banks of ceramic, round, or cross-partition tile are arranged in the tower. At the top, sprays cover the top bank of tile with an even distribution of water at the rate of 7 to 9 gal/($ft^2 \cdot$ min). Size of the tower is determined with a gas rate of 350 ft^3/min per ft^2 of cross-sectional area. The gas enters the washer at an angle of 45° downward, passes up through the tile and out a main at the top of the washer. The water passes down through the tile banks and collects the dust removed from the gas. The water collects in the bottom section and overflows through a pipe arranged with a gas seal. The water then is sent to a thickener for removal of the iron-ore dust. The gas enters the washer at 400°F approx and is cooled to 100°F approx. The dust content of the gas is reduced to about 0.15 to 0.30 gr/ft^3, which is satisfactory for entrance into a precipitator or Theisen disintegrator.

Electrostatic precipitators reduce the dust content of the gas to the cleanliness required by its final use. The following are common requirements for blast furnace gas in grains per cubic foot at standard conditions (1 atm, 70°F): hot blast stoves, 0.01; boilers, 0.01; soaking pits, 0.10; coke ovens, 0.005.

Effect of Sulfur Gases and Particulates on Vegetation

REFERENCES: Kamprath, E. J., ''Possible Benefits from Sulfur in the Atmosphere.'' *Combustion,* **44,** no. 4, 1972, pp. 16, 17; Grennard and Ross, Progress Report on Sulfur Dioxide, *Combustion,* **45,** no. 7, 1974, pp. 4–9; Wagner, TVA's Proposed Clean Air Strategy, *Public Utilities Fortnightly*, pp. 34–37, June 6, 1974.

Damage from Sulfur Fumigation Vegetation is damaged by abnormal concentrations (above 0.3 ppm) of sulfur gases at ground level. Users of sulfur-bearing fuels may become involved with damage claims where ground-level concentrations are of consequent increasing importance. The contaminants causing damage to vegetation are sulfur trioxide (SO_3), sulfates, sulfur dioxide (SO_2), and particulate materials.

Particulate materials on leaf surfaces have no harmful effect other than to exclude sunlight, and to that extent, retard growth.

Sulfur trioxide is hygroscopic and occurs at ground level as sulfuric acid mist. Plant damage has been observed in the field. Sulfur trioxide is deleterious to plants, animals, and humans.

Impure sulfur dioxide (SO_2) has the greatest effect on plants. Concentrations greater than 0.3 ppm will damage the leaves of sensitive vegetation if maintained for over 5 h. Animals and humans are more resistant than plants. Concentrations above 0.5 to 2.0 ppm are recognizable by smell and taste. The concentration and the duration of the fumigation determine the degree of injury. (See Table 18.1.9). Environmental con-

Table 18.1.9 Susceptibility of Vegetation to Injury by Sulfur Dioxide (from Field Observations)

Maximum susceptibility	Moderate susceptibility	Resistant
	Weeds	
Plantain	Bracken fern	Goldenrod
Ragweed	Wild carrot	Small-leaved milkweed
Smartweed	Wild grape	Knotweed
Dewberry	Sweet clover	Milkweed
Greenbriar		
Dandelion		
Galinsoga		
Pigweed (redroot)		
	Wildflowers	
Greenbriar	Blackberry	Goldenrod
Galinsoga	Witch hazel	Small-leaved milkweed
Dandelion	Huckleberry	Elderberry
	Blueberry	Mountain laurel
	Bracken fern	Yarrow
	Viburnum	Knotweed
	Wild carrot	Joe-Pye weed
	Sweet clover	Milkweed
	Farm crops	
Alfalfa	Alsike clover	Potato
Oats	Corn	
Buckwheat	Cabbage	
Barley		
	Garden vegetables	
Beet	Huckleberry	Onion
Endive	Blueberry	Cucumber
Bean	Tomato	Corn
Peas	Parsley	Potato
Brussels sprouts	Cauliflower	
	Landscape materials	
Hawthorn	Huckleberry	Hazelnut
Sunflower	Blueberry	Mountain laurel
Cosmos	Nasturtium	
Sweet William	Dahlia	
	Gladiolus	
	Willow	
	Trees	
White pine	Larch	Red pine
Hemlock	Scotch pine	Blue spruce
Hawthorn	Norway spruce	Black locust
Black birch	Sumac	Black oak
Yellow birch	Ash	Red oak
	Wild cherry	White oak
	Domestic apple	Sugar maple
	Willow	Swamp red maple
		Norway maple

Table 18.1.10 Emission of Sulfur-Bearing Gases and Solids from a 1,000,000-kW (1,000-MW) Fossil Fuel Fired Power Station

Fuel:	Mid-western bit coal	Eastern bit coal	Central Ill. bit coal	High-sulfur fuel oil	Low-sulfur fuel oil
Firing method:	Pulv.-coal round burners	Pulv.-coal round burners	Cyclone burners	Round burners	Round burners
Sulfur content of fuel, %	4.14	1.15	4.65	2.41	0.40
Ash content of fuel, %	18.16	7.59	15.00	0.10	0.10
Sulfur-bearing gases leaving boiler:					
Sulfur dioxide, lb/h	69,000	15,100	97,500	23,200	3,620
Sulfur trioxide, lb/h	3,450	755	4,875	1,160	180
Total sulfur-bearing gases, lb/h	72,450	15,855	102,375	24,360	3,800
Solids in flue gas leaving boiler:					
Sulfur compounds, lb/h	4,600	920	920	2,520	420
Carbon, lb/h	8,280	2,760	1,190	4,200	4,200
Fly ash, lb/h	118,680	38,640	20,250	420	420
Total solids, lb/h	131,560	42,320	22,360	7,140	5,040
Collection efficiency,* %	99 +‡	99 +‡	99 +‡	†	†
Solids in flue gas leaving stack, lb/h	360	360	15	†	†

* Based on clear stack.
† See text. Firebox temperatures are kept below 1,900°F to control NO_2 emissions.
‡ Total efficiency whether combination mechanical and electrostatic units or electrostatic alone, with SO_3 injection.
NOTE: 1 lb/h = $7.55(10)^{-3}$ kg/s.

ditions of temperature, humidity, soil moisture, soil fertility, nutrient supply, light intensity, age of plants, and moist-leaf conditions have a marked influence on the effect of sulfur dioxide on vegetation.

Benefits from Sulfur in the Atmosphere In normal atmospheric concentrations below 0.3 ppm, as occurs in metropolitan areas 95 percent of the time, sulfur dioxide is an essential plant nutrient. Vegetation utilizes it for growth by absorption from the atmosphere through leaves, and from rain-saturated earth through the roots. Fossil fuels, by virtue of their origin as former vegetation, contain from 0.4 to over 4 percent sulfur (Table 18.1.10). To maintain the natural ecological sulfur cycle for sustaining plant growth, this organic sulfur should be recycled back into the soil. As sulfur in stack gases is brought down by rainfall largely over a radius of about 15 mi from steam-electric plants in rural areas, averaging about 5 lb/(acre · year) (0.55 g/m^2), anywhere from 20 to 50 percent of the annual sulfur requirement for crops can be furnished by stack emissions, while the balance must be supplied by fertilizers. Agriculture requires annually 10 to 40 lb/acre (1.11 to 4.44 g/m^2) of sulfur, which, in the absence of stack emissions, must be furnished by direct sulfur application for optimum yields of crops.

The sulfur dioxide problem, therefore, is mainly one of preventing excessive ground-level concentrations, whereby a normal plant nutrient can become a menace. Two methods of control are possible when burning fossil fuels: sulfur oxide removal by wet scrubbing, or dispersion by tall stacks with subsequent precipitation by normal rainfall.

Sulfur Oxide Removal Processes Stack-gas scrubbing processes remove sulfur from the flue gas but also increase the buildup of atmospheric CO_2. In 1973 the seven most promising stack-gas scrubbing processes selected for further study by the Sulfur Oxide Control Technology Assessment Panel were

1. Catalytic oxidation of SO_2 to SO_3, to recover sulfuric acid as a saleable by-product
2. Wet lime/limestone scrubbing, which produces calcium sulfite sludge for disposal
3. Alkali scrubbing without regeneration, which produces 18 percent sodium sulfite brine for disposal
4. Alkali scrubbing with lime regeneration, which produces calcium sulfite sludge for disposal
5. Alkali scrubbing with thermal regeneration, which recovers SO_2 gas by-product, and a sodium sulfite/sulfate brine for disposal
6. Magnesium oxide scrubbing, with off-site sulfuric acid manufacture and regeneration of magnesium oxide by others
7. Alkali scrubbing, plus electrodialytic regeneration to recover SO_2 gas and a purge stream of impure brine

A comparison of these systems is given by Table 18.1.11. The sulfur

Table 18.1.11 Comparison of SO_2 Control Systems

Process	Requirements	Throwaway or recovery	Additional cost of power generation, %	SO_2 control efficiency, %	Additional plant capacity investment, %
SDEL*	Fuel-switching and tall stacks		1–2.35	99 +	1–2.8
Low-sulfur fuel (coal or oil)			28–85	Varies	—
Dry fluidized-bed combustors	Limestone (200% of stoichiometric)	Throwaway $CaSO_3/CaSO_4$	25–38	50–90	25–90
Wet lime/limestone scrubbing	Lime (100–120% stoich.); limestone (120–150% stoich.)	Throwaway $CaSO_3/CaSO_4$	19–37	60–85	17–30
MgO scrubbing	MgO carbon and fuel (for regeneration and drying)	Recover conc. H_2SO_4	25–50	90	20–35
Catalytic oxidation (add-on)	V_2O_5 catalyst heat	Recover dilute H_2SO_4	25–45	85–90	25–40
Na_2SO_3 scrubbing	Sodium makeup heat	Recover conc. H_2SO_4 or sulfur	25–50	90	25–40
Double alkali	Sodium makeup plus lime (100–130% stoich.)	Throwaway $CaSO_3/CaSO_4$	17–35	90	15–30

BASIS: 80 percent plant load factor. Yearly fixed charges are 18 percent of capital investment. Cost ranges are for 200- to 1,000-MW plant sizes. Costs of sludge disposal ponds not included.
SOURCES: Burns and Roe data, TVA's Clean Air Strategy. *Public Utilities Fortnightly*, 34: June 6, 1974.

dioxide emissions limitations (SDEL) case, with its low-cost and negligible environmental impact, is technically justifiable with a cost/benefit ratio of 0.19. The other designs are bulky, costly, noisy, and experimental. They consume energy, water, fuel, and chemicals, and require direct sulfur application to surrounding agricultural areas, plus waste sludge disposal. These adverse environmental impacts usually result in negative total public benefits, unjustifiable except under unusually favorable circumstances.

By far the most difficult and costly environmental hazard produced by sulfur removal is the volume of high chemical-oxygen-demand (COD) liquid and solid wastes produced. This contaminated thixotropic sludge is environmentally unacceptable for landfill or for any other conceivable use. Reduction to elemental sulfur for permanent underground storage by an inverse Frasch process would reduce the volume of wastes, but the cost is exorbitant. Moreover, even if sulfur is removed, the buildup of acid gases (mainly CO_2) in the global atmosphere will continue unabated, along with increasing acid rains, as the CO_2 content of the air increases. Substitution of nuclear fuels for fossil fuels will correct the situation.

Sulfur Dioxide Emission Limitation (SDEL) Programs

To avoid the water pollution difficulties and the wet sludge disposal difficulties introduced by wet scrubbing, Tennessee Valley Authority and others have developed various SDEL programs.

SDEL methods employ combinations of five or more sensing, dispersing, and limitation approaches simultaneously.

1. Very tall stacks (1,000 ft) for dispersing SO_2 gases high in the atmosphere, thereby minimizing unacceptable ground-level concentrations and occurrences. (See the Holland equation for stack height, below.)
2. Atmospheric (AFBC) and pressurized (PFBC) fluidized bed combustor units utilizing pulverized coal with limestone or dolomite added to the bed to absorb sulfur dioxide. The bed is cooled internally by steam coils. Ninety percent sulfur removal along with low NO_x is possible. Stack gases are cleaned mechanically and electrostatically. (See Energy Technology Conference VIII, Government Institutes, Rockville, MD, pp. 893–919.)
3. Computers, which quickly correlate meteorological and plant operational data, so as to anticipate and prevent unacceptable ground-level concentrations.
4. Sensors and monitors, which sense and record automatically the local ambient SO_2 concentrations, and pH's, thereby ensuring the effectiveness of the control operations. (Limestone application is made directly to lakes in the area to raise pH.)
5. Emission limitations, accomplished by fuel switching between high- and low-sulfur fuels during normal power plant operations, and by local power generation curtailment during emergency situations, when even switching to low-sulfur fuels might not provide acceptable ground-level concentrations.
6. Daily local plant weather observations and meteorological measurements by means of light aircraft and balloons. These approaches allow high sulfur fuels to be burned most of the time, thereby conserving scarce low sulfur fuels for domestic and other ground level uses not employing SDEL methods.

As opposed to wet scrubbers for SO_2 control, SDEL methods are estimated to require less than one-tenth the total investment cost and one-thirteenth the annual operating cost, exclusive of wet sludge disposal costs.

Atmospheric Dispersion of Pollutants from Stacks

Stacks can provide effective atmospheric dispersion of gaseous and particulate pollutants with acceptable ground-level concentrations. Theoretical and empirical formulas are available to estimate the dispersion of air borne pollutants continuously emitted from stacks. Effective stack height of a plume is given by $H = h_s + h_r$. (See notation below.)

Notation

Symbol	Definition	System of consistent units
b	Atmospheric-dispersal parameter	Dimensionless
d	Stack-exit diameter	m
H	Effective stack height	m
h_r	Rise of plume	m
h_s	Stack height	m
p	Atmospheric-dispersal parameter	Dimensionless
Q	Emission rate of pollutant	m^3/s
Q_h	Heat emission rate	cal/s
q	Atmospheric-dispersal parameter	Dimensionless
u	Mean wind speed	m/s
v	Stack-exit velocity	m/s
X_g	Ground-level concentration of pollutant at a distance x from base of stack	ppm by vol
X_{mg}	Maximum ground-level concentration of pollutant at a distance x_m from base of stack	ppm by vol
x	Downwind distance from emission source in direction of mean wind	m
x_m	Distance from base of stack to maximum ground-level concentration	m
σ_A	Basic diffusion parameter related to azimuth plume angle in radians	m^{1-q}
σ_E	Basic diffusion parameter related to elevation plume angle in radians	m^{1-p}

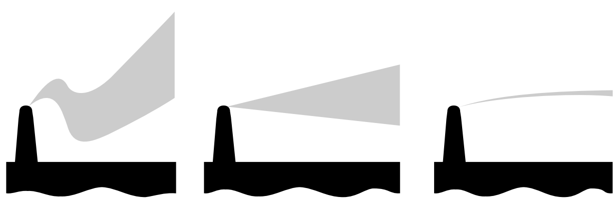
The Holland formula, recommended for calculating h_r, is $h_r = (1.5vd + 4.09 \times 10^{-5} Q_h)/u$. A ratio of stack height h_s to building height of 2½ to 1 or more is commonly used to avoid entrapment of the plume in the vortex of adjacent buildings and the associated high values of ground-level concentration X_g. Stack-exit velocity v should be 14 to 28 m/s (45 to 90 ft/s) to minimize plume entrapment in stack vortices. The lower the ratio of stack inside to outside diameter at its top, the higher the necessary v.

The **Cramer equation,** recommended for calculating X_g, is $X_g = 10^6\, Q/(\pi u x^b \sigma_A \sigma_E) \exp\,[H^2/(2\sigma_E^2 x^{2p})]$. The equation is for sampling intervals of approximately 20 min, with X_g varying approximately inversely as the one-fifth power of the interval.

Simplified approximate formulas for X_{mg} and x_m are

$$X_{mg} = 2Q\,10^6 \sigma_E/(\pi e^{uH^{1.9}} \sigma_A) \text{ and } x_m = H/(1.35\,\sigma_E)$$

Atmospheric dispersal characteristics and hence the values of X_g, X_{mg}, and x_m are influenced by thermal stratification and atmospheric turbulence. A superadiabatic (adiabatic) (subadiabatic) lapse rate, i.e., a drop in temperature with altitude greater than (equal to) (less than) 5.4°F per 1,000 ft (9.84 K/km) results in an unstable (neutral) (stable) atmosphere with much (moderate) (very little) vertical mixing. (See Fig. 18.1.3.)



(a) (b) (c)

Fig. 18.1.3 Height and plume behavior for (*a*) unstable, (*b*) neutral, and (*c*) stable conditions.

The recommended parameters for use in the Cramer equations under the above conditions of thermal stratification are:

Thermal stratification	σ_A, rad	σ_E, rad	b	p	q
Unstable	0.39	0.13	2	1.1	0.9
Neutral	0.21	0.07	1.85	1.0	0.85
Stable	0.12	0.04	1.6	0.8	0.8

The above formulas deal only with steady-state conditions. There are transient meteorological conditions which can result in significant ground-level concentrations of pollutants and which cannot readily be analyzed by computations. These conditions include the breakup of a temperature inversion and the slow, steady buildup of pollutants during stagnations accompanied by deep ground fogs in a valley. For large power plants, high stacks (400 ft and more) (122 m), high stack-exit velocities [45 to 90 ft/s (13.7 to 27.4 m/s)], and adequate exit temperatures [250 to 300°F (394 to 422 K)] are usually effective in avoiding such fumigations.

Stack Emissions

Emission of sulfur-bearing gases and solids from a 1,000-MW fossil-fuel fired power station is shown in Table 18.1.10. (See also Tables 18.1.12 and 18.1.13 for more data.) Reducing the remaining solids in stack emissions from bituminous coal fired (excluding stoker firing) power boilers to 0.02 gr/standard ft^3 (45.8 mg/m^3) and less results in a clear stack discharge. This requires collection efficiencies of 99+ percent, attainable with commercial equipment. These high collection-efficiency requirements demonstrate the need for optical instruments which will readily determine stack-emission quality. The **Ringelman chart** is frequently used to evaluate stack emission, but it is a crude and inaccurate method. A good indicator is a stack emission invisible to the naked human eye. With oil firing, present practice is to control stack emissions by furnace design, combustion control, use of additives, and multiple cyclone-type collectors located in the low- or high-temperature zones of the flue-gas system. For future plants of 1,000 MW and larger, use of high-temperature electrostatic precipitators located ahead of the air preheater may be considered.

Air Pollution Control in Various Industries

(See Tables 18.1.12 and 18.1.13.)

Industrial sources of air pollution and typical loss rates are given in Table 18.1.8.

Nonferrous metal smelting (e.g., copper, zinc, lead) and thermal operations (e.g., blast furnace, sintering, converters) are sources of air pollution and of potentially recoverable metallic materials. A large variety of collection equipment has been tried. Experience has proved that precipitators, cloth filters, and gas washers are best.

Paper industry sources of air pollution are (1) recovery furnace gases and (2) lime kiln exhaust gases. Noxious gases require scrubbing. **Recovery-furnace gases** in the sulfate and soda processes of manufacture emit solids [2 to 6 gr/standard ft^3 (4.6 to 13.7 g/m^3)] which are mainly sodium salts. The small particle size is particularly bothersome because of the large, obscuring plume in the stack tail. Chemically, the solids are destructive to painted and finished surfaces (e.g., automobiles, structures). Valuable constituents are recovered for return to the cycle. Electrostatic precipitators with 95 to 99 percent efficiency are favored for collection and return of solids. Corrosion-resistant materials (glazed tile, special cements) must be used to reduce maintenance. **Lime kilns** are used to calcine calcium carbonate and recover it as CaO for use in the process. The consequent air pollutant is recovered by gas washers and mechanical collectors.

Cement industry sources of air pollutants are (1) clinker kilns and (2) bagging and other mechanical operations. The **kilns** are the major source of air pollution, with large, unattractive exhaust plumes depositing cement-making solids on the landscape and on painted surfaces. Damage

Table 18.1.12 Common Applications of Industrial Precipitators

Industry	Application	Gas-flow range, ft^3/min*	Temp. range, °F	Percent weight of dust (below 10)	Usual efficiencies, %	Dust conc. range in ppm† by wt in air	Temp. range, K
Electric power	Fly ash from pulverized-coal-fired boilers	50,000–750,000	270–600	25–75	95–99+	760–9,500	405–589
Portland cement	Dust from kilns	50,000–1,000,000	300–750	35–75	85–99+	950–29,000	422–672
	Dust from dryers	30,000–100,000	125–350	10–60	95–99	1,905–29,000	325–450
	Mill ventilation	2,000–10,000	50–125	35–75	95–99	9,500–98,000	283–325
Steel	Cleaning blast-furnace gas for fuel	20,000–100,000	90–110	100	95–99	38–950	306–317
	Collecting tars from coke-oven gases	50,000–200,000	80–120	100	95–99	190–1,905	300–322
	Collecting fume from open-hearth and electric furnaces	30,000–400,000	300–700	95	90–99	95–5,700	422–644
Nonferrous metals	Fume from kilns, roasters, sintering machines, aluminum potlines, etc.	5,000–1,000,000	150–1100	10–100	90–98	5,700–95,000	339–867
Pulp and paper	Soda-fume recovery in kraft pulp mills	50,000–200,000	275–350	99	90–95	950–7,600	408–450
Chemical	Acid mist	2,500–20,000	100–200	100	95–99	38–1,905	311–367
	Cleaning hydrogen, CO_2, SO_2, etc.	5,000–20,000	70–200	100	90–99	19–1,905	295–367
	Separate dust from vaporized phosphorus	2,500–7,500	500–600	30–85	99+	19–1,905	533–589
Petroleum	Powdered catalyst recovery	50,000–150,000	350–550	50–75	90–99.9	190–4,800	450–561
Rock products	Roofing, magnesite, dolomite, etc.	5,000–200,000	100–700	30–45	90–98	950–4,800	311–644
Gas	Tar from gas	2,000–50,000	50–150	100	90–98	19–3,800	283–339
Carbon black	Collecting and agglomerating carbon black	20,000–150,000	300–700	100	10–35	57–9,500	422–644
Gypsum	Dust from kettles, conveyors, etc.	5,000–20,000	250–350	95	90–98	2,850–9,500	394–450

* ft^3/min = 4.72(10)$^{-4}$ m^3/s.
† 1 ppm = 0.525 gr/1,000 ft^3 = 2 mg/m^3, in air.
SOURCE: Holden and Ackley, "Air Pollution Handbook," McGraw-Hill.

Table 18.1.13 Characteristics of Air- and Gas-Cleaning Devices

Name of device: General class	Name of device: Specific type	Device most suitable for	Removable contaminants	Optimum size particle, μm	Limits of gas temperature, °F	Opt. conc., ppm by wt	Lim. gas temp., K
Odor adsorbers	Shallow bed	Atmospheric air cleaning	Malodors, gases	(Molecular)	0–100	< 1.9	256–311
Air washers	Spray chamber		Lints, dusts, pollens, tobacco smoke	> 20	40–700		
	Wet cell			> 5	40–700	< 9.5	278–644
Electro. precip., low-voltage	Two-stage, plate			< 1	0–250		
	Two-stage, filter			< 1	0–180	< 1.9	256–394
Air filters, viscous-coated	Throwaway			> 5	0–180	< 3.81	256–356
	Washable			> 5	0–250	< 3.81	256–394
Air filters, dry-fiber	5–10 μm			> 3	0–180	< 1.9	256–356
	2–5 μm			> 0.5	0–180	< 1.9	256–356
Absolute filters	Paper	Stack gas cleaning	Special†	< 1	0–1,800	< 1.9	256–1,256
Industrial filters	Cloth bag		Dusts, fumes, smokes, mists	> 0.3	0–180‡	> 190	256–356
	Cloth envelope			> 0.3	0–180‡	> 190	256–356
Electro, precip., high-voltage	Single-stage, plate			< 2	0–700	> 190	256–644
	Single-stage, pipe			< 2	0–700	> 190	256–644
Dry inertial collectors	Settling chamber			> 50	0–700	> 9,520	256–644
	Baffled chamber			> 50	0–700	> 9,520	256–644
	Skimming chamber			> 20	0–700	> 1,905	256–644
	Cyclone			> 10	0–700	> 1,905	256–644
	Multiple-cyclone			> 5	0–700	> 1,905	256–644
	Impingement			> 10	0–700	> 1,905	256–644
	Dynamic			> 10	0–700	> 1,905	256–644
Scrubbers§	Cyclone		Gases, vapors, malodors	> 10	40–700	> 1,905	256–644
	Impingement			> 5	40–700	> 1,905	256–644
	Dynamic			> 10	40–700	> 1,905	256–644
	Fog			< 2	40–700	> 190	256–644
	Pebble bed			> 5	40–700	> 190	256–644
	Multidynamic			< 1	40–700	> 190	256–644
	Venturi			< 2	40–700	> 190	256–644
	Submerged nozzle			> 2	40–700	> 190	256–644
	Jet			< 5	40–700	> 190	256–644
Incinerators	Direct			Any	2,000	Combustible	1,367
Afterburners	Catalytic			(Molecular)	1,000	any	811
Gas absorbers	Spray tower			(Molecular)	40–100	> 1.9	278–311
	Packed column			(Molecular)	40–100	> 1.9	278–311
	Fiber cell			(Molecular)	40–100	> 1.9	278–311
Gas adsorbers	Deep bed			(Molecular)	0–100	> 1.9	256–311

* Based on std. air @ 0.075 lb/ft^3 (1.2 kg/m^3).
† Bacteria, radioactive, or highly toxic fumes.
‡ 500°F for glass (553 K), 450°F for Teflon (505 K), 275°F for dacron (408 K), and 240°F for orion (389 K).
§ Reheating of scrubbed stack is necessary to avoid plumes.
SOURCE: Jorgensen, ''Fan Engineering,'' Buffalo Forge Co. Used by permission.

is reduced by the use of electrostatic precipitators with the wet process and cyclones plus cloth filters with the dry process. **Bagging and other mechanical losses** are reduced by use of cloth filters following cyclone separators.

Carbon-black production utilizes electrostatic precipitators, cloth filters, and scrubbers to collect the black from the gas stream and to control air pollution.

Iron-and-steel-industry sources of air pollution are cupolas, oxygen-furnaces, electric-furnaces, and sintering operations. The dispersoids in these operations are mostly oxides of iron in particle sizes below 10 μm and with loadings ranging to 15 gr/standard ft^3 (34.3 g/m^3). Dust emittance is acceptably controlled generally by use of precipitators and scrubbers for open-hearth and basic oxygen processes, use of cloth filters and scrubbers for electric furnaces, and use of precipitators, scrubbers, and filters for sintering.

Petroleum-refining sources of air pollution are mainly gaseous in nature. Mercaptans are removed by scrubbing. Solid dispersoids from the fluid-cracking processes are removed by electrostatic precipitators and/or cyclone-type collectors.

Miscellaneous Dusts Four industrial dusts have been classified as causing severe respiratory ailments: asbestos, causing asbestosis; crystalline silica, causing silicosis; cotton and cottonseed dust, a powerful allergen causing bronchial asthma and byssonosis; and lead, causing plumbism.

In mining operations and foundries, cyclonic collectors, followed by baghouses, have been found most effective. Likewise, in textiles and in cottonseed-oil pressing, baghouses following the lint-collecting cyclones can remove almost 100 percent of the hazardous pollutant.

Large central incineration plants can produce odors, noxious gases, and particulates (see Sec. 7.4). Odors and noxious gases can be minimized by carefully controlled combustion, using modern traveling-grate continuous systems. Furnace temperatures between 1,600 and 1,900°F (1,150 to 1,300 K) are recommended. Particulates can be minimized by well-managed covered conveying of dust-bearing refuse, incinerator residues and fly ash, and the use of electrostatic precipitators and wet scrubbers to comply with increasingly stringent air quality standards. (See Table 18.1.13.) Gaseous emissions of SO_x, CO, and NO_x do not cause problems with continuous incineration, as their concentrations are small, but HCl and HF from plastics are hazardous. Stack height should be sufficient to minimize ground effects of any residual pollution. Municipal refuse can also be fired into waste heat utility boilers, a fuel conservation measure which will be increasingly important in electric power cogeneration.

RADIOACTIVE WASTE MANAGEMENT

REFERENCES: Cochran and Tsoulfanidis, ''The Nuclear Fuel Cycle: Analysis and Management,'' American Nuclear Society. ''Radiological Health Handbook.'' Nuclear Waste Policy Act of 1982 and its 1987 amendments. Low Level Radioactive Waste Policy Act of 1980 and its 1985 amendments, 10CFR 50 Appendix 1, and 10 CFR 20.

General Considerations

Under existing legislation and authorization the Nuclear Regulatory Commission (NRC) has the primary responsibility for developing and regulating waste management methods and practices, sites of operation, and enforcement of all applicable standards, including those developed adjunctively with EPA. Radioactive wastes are generally divided into five general categories by the Nuclear Waste Policy Act: (1) **high-level waste (HLW);** (2) **transuranic (TRU) waste;** (3) **low-level waste (LLW);** (4) **uranium mill tailings;** and (5) **naturally occurring and accelerator-produced radioactive material (NARM).** HLW is ''the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains fission products in sufficient concentrations, and other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation.'' TRU wastes are wastes that contain alpha-particle-emitting radioisotopes with atomic numbers greater than 92 and half-lives longer than 5 years. LLW is defined as material which is ''not HLW, spent nuclear fuel, TRU or by-product material, and material which the NRC, consistent with existing law, classifies as LLW.'' LLW is generated by the nuclear power industry, hospitals, and other medical facilities, universities, and research laboratories. Examples of LLW include contaminated clothing, tools, syringes, cotton wipes, paper, rags, and other trash. Uranium mill tailings also are treated as radioactive wastes and are not transported from their generation point. NARM is not regulated by the NRC, but is regulated by the individual states. Usually, most NARM qualifies as LLW and most often is treated as such.

HLW and TRU wastes are covered under the **Nuclear Waste Policy Act (NWPA),** which spells out the step-by-step procedures for all tasks related to their disposal. The NWPA details the process to be followed in the selection of repositories for the disposal of HLW, TRU waste, and spent nuclear fuel; the development of interim storage and monitored retrievable storage for HLW and spent fuel; and the responsibilities and obligations of the Department of Energy and the nuclear utilities.

LLW is governed by the **Low Level Radioactive Waste Policy Act (LLRWPA).** The LLRWPA dictates that every state is responsible for the disposal of all LLW generated within its borders, and assumes that the LLW can be stored safely on a regional basis. To carry out the disposal of LLW, many states have entered into ''compacts'' with other states to site and operate regional disposal facilities. Other states have chosen to develop their own disposal sites. The LLW generated by nuclear power plants usually consists of three types: gases, liquids, and solids.

Gases From the buildings which contain the fuel-handling system, auxiliary equipment, and waste systems, ventilating air, filtered if necessary, is released through a vent which is monitored for radioactive gases, iodine, and airborne particulates. Automatic controls will shut down the ventilating system, thereby stopping any release of airborne activity if the monitor set points.

Ventilating air for the containment vessel, which holds the reactor, primary pumps, and steam generators, is drawn when it is necessary for inspections or for other reasons to purge the vessel. **Purge air** is filtered through high-efficiency particulate air (HEPA) and through charcoal filters before release. In case monitor set points are exceeded, purging is automatically curtailed.

The third source of gases is the nitrogen cover gas of the volume control system in the PWR, and the steam jet ejector system in the BWR. Krypton, xenon, and iodine are produced within the reactor and mix with the cover gas. To release them, the principle employed is to ''delay and decay'' by compressing them into decay tanks of about 45 days' storage capacity in the PWR case, and into decay pipes of 20- to 60-min storage capacity in the BWR case. All releases are carefully monitored to be within established limits.

Liquids Liquid radwaste streams from boiling water reactors may be classified into two major systems. In one of these, relatively high-radioactivity, low-conductivity water is reclaimed by filtration and deionization, and is stored for recycling into plant makeup systems. In the other, relatively low-radioactivity, high-conductivity water from floor and laboratory drains, laundry drains, makeup demineralizer regeneration, and equipment decontamination is treated by various means, such as filtration, waste concentration, and deionization, is monitored and recycled for in-plant use. Pressurized water reactors can be characterized by three major liquid streams. The first of these consists of borated, relatively high-radioactivity demineralized water from the primary cooling loop. During the feed-and-bleed operating mode, borated water is removed and replaced with freshwater, which slowly reduces the amount of chemical shim (boric acid) present. A boric acid evaporator makes it possible to recover boric acid and to recycle a large portion of the distillate. The second major stream consists of floor and equipment drains from the containment vessel and the auxiliary building and from the radiochemistry laboratory, which go to a large **waste holdup tank.** These are subsequently transferred to an evaporator, and the distillate therefrom is deionized, passed through a radiation monitor, and then recycled. With both types of reactor, the heavy ends, crud, and dirt concentrate in the evaporator feed tank. This waste is pumped to the radwaste **drumming station,** where it is solidified with Portland cement or chemical grout. The third of the major streams is soapy water from laundry and showers. Because of foaming difficulties, this stream is not always processed through an evaporator, but instead is filtered or put through a reverse osmosis unit, monitored for radioactivity, and if satisfactory, released.

Solids Solid wastes for BWRs and PWRs are handled similarly. Evaporator and filter sludges are pumped to the radwaste drumming station and solidified with Portland cement or chemical grout in 55-gal (or larger) drums. Spent ion-exchange resins that are not regenerated are sent to an accumulation tank for decay and are then flushed into a shipping cask and dewatered for removal to a burial ground. They may also be solidified. Balable wastes are drummed but, if highly radioactive, are set in concrete. Large, heavy, junk equipment items can sometimes be stored on-site more economically than cutting them up and packaging them for off-site shipment.

Reference to current federal regulations and trade publications must be made to keep abreast of the latest developments.

SOLID AND HAZARDOUS WASTE MANAGEMENT

REFERENCES: ''Pollution Control Technology, Solid Waste Disposal,'' Research & Educational Assn., New York. Sittig, ''Handbook of Toxic and Hazardous Chemicals''; also Sittig, ''Resource Recovery and Recycling Handbook of Industrial Wastes,'' Noyes Data Corp., Park Ridge, NJ. Exner, ''Detoxication of Hazardous Waste,'' Ann Arbor Science Publishers. The Resource Conservation and Recovery Act of 1976 (RCRA) (as amended in 1980), PL 96-482 and CERCLA, PL 96-510 (SW-171). Metry, ''The Handbook of Hazardous Waste Management,'' Technomic Publishing, Westport, CT. Peirce and Vesilind, ''Hazardous Waste Management,'' Ann Arbor Science Publishers, Ann Arbor, MI. Current EPA regulations.

Solid waste includes solids discarded permanently, or temporarily, and materials suspended in air or water. Also forming part of this group are wet solids with insufficient liquid content to be free-flowing. Total solid wastes (excluding sewage) produced currently in the United States

Table 18.1.14 Cost/Benefit Evaluation of Recycled Sewage Sludge as Fertilizer (Denver)*

	Total cost delivery and application, $/dry ton	Current worth of nutrients, $/dry ton	Disposal cost savings, $/dry ton	Total benefit (worth and savings), $/dry ton	Cost/benefit
Air-dried (trucked)	$ 4.00	$ 8.37	$11.34	$19.71	0.20
Liquid (5% solids) (trucked)	14.00	12.20	11.34	23.54	0.595
Liquid (5% solids) (pipelined)	9.00	12.20	11.34	23.54	0.382

* 1975 data.

amount to about 250 million tons/year, or about 1 ton/(person · year), and include all industrial, domestic, commercial, and agricultural wastes. Between 4 and 5 percent of that total constitutes **hazardous wastes** subject to special handling and/or disposal. It is projected that the total solid waste stream will increase to 300 to 350 million tons by early in the twenty-first century. The increasing accumulation of dry waste which results from the high standard of living of modern society will deplete existing economically exploited natural resources and further aggravate the already costly waste disposal problem. Product and energy recovery, therefore, constitutes the preferable direction to follow rather than elaborate means of disposal. There is, however, a growth factor for solid residuals which is caused by environmental control legislation: unpredictable amounts of waste generated by air and water pollution control. Environmental regulations in effect simply transfer the pollution from those media to the solid state, and vice versa.

Federal Environmental Legislation See RCRA and CERCLA following.

Solid Waste Disposal

Solid waste handling involves two main steps: collection and disposal. **Solid waste conditioning** involves recovering those materials of value already present while conditioning the rest for conversion, recycling, or ultimate disposal. **Solid waste segregation** prior to collection into refuse, combustible wastes, noncombustible wastes, and hazardous waste is always a beneficial preconditioning step.

The principal solid disposal methods used are **incineration, landfill,** and **ocean disposal.** Many mining and processing operations leave a process residue on the premises since disposal cost elsewhere is prohibitive. Examples are red mud from refining bauxite and sulfite sludge from SO_2 stack gas scrubbing processes.

Landfilling requires spreading and compacting the waste and covering it with soil. This system is applicable both to biodegradable and nondegradable types of wastes. Leaching contamination of ground water must be prevented by installing liners. Careful attention must be given to possible subsidence and gas formation in landfilling. Topsoil disposal is limited to biodegradable organic materials.

Ocean dumping takes advantage of the ocean bottom trench configuration and the dispersing effects of ocean currents. Until recently, ocean dumping was the ultimate form of ocean disposal, but the practice has effectively ceased. The cost/benefit of ocean disposal was very favorable compared to alternate methods, but is now highly regulated and, with rare exceptions, the practice is proscribed and illegal. Ecological considerations effectively rule out this form of waste disposal for the foreseeable future.

Incineration is a volume reduction process rather than solid waste disposal, resulting in a residue which still must ultimately be disposed of. Heating values of solid wastes range from 5,000 to 15,000 Btu/lb for ordinary trash and industrial wastes. The growth of incineration is affected by higher fuel costs, construction costs, and added expense for air pollution and hazardous waste control.

Another means of solid waste reduction is **composting,** not widely used because of the limited market for its products, but ultimately may become more widely spread to maintain a rural-urban ecological balance.

Product Recovery

The average solid waste (per 100 lb) produced daily in the United States is roughly 6 lb industrial (from process), 5 lb municipal, and 89 lb mine tailings, smelter slags, dredging spoil, and agricultural wastes. Materials salvaged from solid waste recycled back to their sources not only reduce disposal costs but also conserve farmland values and natural resources. Recovery of metal, paper, glass, plastics, and hazardous substances is an outstanding example of materials recycling.

Materials separation from solid waste may be performed by physical or chemical means. The most common types of equipment used are material separators (varies with application: magnetic, thermal, flotation, size reduction—shredders, crushers, grinders, and pulverizers), materials flow (conveyors, lifters), mixers, and blenders. (See Sec. 10.)

Basic chemical conversion processes for industrial waste are hydrogenation, oxidation, acetylation, cross-linking cellulosic materials. For more detail, see Engdahl, ''Solid Waste Processing—A State of the Art Report on Unit Operations and Processes,'' Public Health Service Publication No. 1856, Supt. of Documents, Washington, DC.

Biochemical processing of wastes from the food and chemical industries is common practice. An example is recovery of B-complex vitamins and animal feed from solid brewery wastes.

Pyrolysis of organic wastes can economically utilize them as supplementary fuels depending upon waste types and waste energy conversion processes. New efforts are being made in that direction to process municipal refuse as well as industrial and hazardous wastes.

Dry sludge production from municipal sewage has been achieved with the development of activated sludge processes using high purity oxygen. These processes reduce the volume of activated sludge by two-thirds and improve its dewatering characteristics.

Table 18.1.14 itemizes the 1975 cost factors at Denver from which cost benefit ratios have been developed. (See Cost/Benefit Balancing.) The cost benefit for air-dried sludge is particularly favorable, inasmuch as for every 20¢ invested, the public consumer receives $1.00 in benefits (1990 data).

RCRA AND CERCLA

The Resource Conservation and Recovery Act of 1976 (RCRA), as amended in 1980, regulates current and future waste disposal practices, including both municipal and hazardous waste, while the **Comprehensive Environmental Response Compensation and Liability Act (CERCLA),** or ''Superfund,'' cleans up old, hazardous waste sites. Also, see 39 CFR 158, parts 240 and 241. ''Thermal Processing and Land Disposal of Solid Waste.''

Hazardous Waste Management RCRA defines *hazardous waste* as a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may:

> cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The act requires EPA to promulgate regulations establishing criteria and standards for all aspects of hazardous waste management. The regulations developed by the EPA designate a large number of substances as hazardous and also provide specific characteristics to determine whether a particular waste is hazardous. The characteristics include ignitability, corrositivity, reactivity, and EP toxicity.

The EPA also promulgated regulations establishing standards for hazardous waste treatment, storage, and disposal facilities. Provisions include groundwater protection, development and implementation of contingency plans, closure and postclosure activities, and specific facility performance standards. The standards cover facilities such as tanks, surface impoundments, land treatment, landfills, incineration, underground injection, and physical, chemical, and biological treatment. Other regulations cover ''cradle-to-grave'' control of the collection, source separation, storage, transportation, processing, treatment, recovery, and disposal of such wastes. Generators of these wastes bear the ultimate legal responsibility and are required to keep specific records for the disposition of their hazardous wastes by means of a manifest system.

18.2 OCCUPATIONAL SAFETY AND HEALTH

by Pascal M. Rapier and Andrew C. Klein

REFERENCES: ''General Industry Guide for Applying Safety and Health Standards,'' 29CFR 1910 OSHA, U.S. Dept. of Labor, 1973, and Amendments. 29CRF 1910.1–1910.309, *Fed. Reg.,* **37:**202, Oct. 18, 1972, and Amendments.

WORKER'S COMPENSATION LAWS

Worker's compensation laws in this country were introduced in 1911 and have now been enacted in all the states. The principle involved is that the worker injured or disabled in industry should be enabled, through proper medical treatment, to return to wage-earning capacity as promptly as possible and, while incapacitated, should receive compensation in lieu of wages, regardless of fault. The expense of medical treatment and compensation should properly be borne by industry and become a part of the cost of its products. The laws generally provide that workers injured in industry shall be furnished the necessary medical treatment, and, in addition, compensation based on a percentage of their average weekly wages, payable periodically. Dependents of employees killed in industry are likewise compensated.

Many states have supplemented their worker's compensation laws by providing comparable benefits in cases of incapacity or death due to occupational disease. Some states make these provisions applicable only in case of specified occupational diseases; others make them of general application to cases of any disease directly attributable to the employment. At the present time, all states and the District of Columbia provide for compensation benefits in occupational-disease cases either by enlarging the scope of the worker's compensation law, by separate legislative enactment, or by judicial construction.

The enactment of worker's compensation laws has been followed in many jurisdictions by more stringent provisions relating to factory inspections for the prevention of accidents in industry and of occupational disease.

The enactment of worker's compensation and occupational-disease laws has increased materially the cost of insurance to industry. The increased cost and the certainty with which it is applied have put a premium on accident-prevention work. This cost can be materially reduced by the installation of safety devices. Experience has shown that approximately 80 percent of all industrial accidents are preventable.

SAFETY

REFERENCES: ''General Industry Guide for Applying Safety and Health Standards,'' 29CFR 1910 OSHA, U.S. Dept. of Labor, 1973. 29CRF 1910.1–1910.309, *Fed. Reg.,* **37:**202, Oct. 18, 1972. ''Accident Prevention Manual for Industrial Operations.'' National Safety Council. ''Manual of Accident Prevention in Construction,'' Associated General Contractors of America, Inc. American Conference of Governmental Industrial Hygienists, ''Industrial Ventilation—A Manual of Recommended Practice.'' Blake, ''Industrial Safety.'' Prentice-Hall. DeReamer, ''Modern Safety Practices,'' Wiley. Heinrich, ''Industrial Accident Prevention,'' McGraw-Hill. Patty (ed.), ''Industrial Hygiene and Toxicology,'' Interscience. Simonds and Grimaldi, ''Safety Management,'' Irwin. Stubbs (ed.), ''Handbook of Heavy Construction,'' McGraw-Hill. Labor laws applicable in the jurisdiction where the working enterprise is located.

The person(s) responsible for overseeing the safety of all operating personnel must be cognizant of the latest laws and regulations pertaining to worker safety, which are changed and/or updated from time to time.

The logical time to install safety devices is when new machines are being built, while general construction work is being done, or when alterations or repairs are being made; results can be accomplished with a minimum of expense and delay at the time plans and specifications are being prepared.

Checking for Safety To ensure that the question of safety will not be overlooked, it is well to have all plans, specifications, and drawings checked for safety, making special provision for this in each set of specifications and in the title plate of each drawing.

Buildings

(See 29CFR 1910, Subparts D, E, and F, as amended.)

Plant Arrangement A fundamental factor in effective accident prevention is the provision of ample ground space in the plant site to reduce crowding of buildings, congestion of plant traffic, unusual fire hazards, unsafe yard conditions, etc. One-story buildings have definite advantages in regard to fire hazards, building collapse, and natural lighting.

Where a plant is located near a main line of a railroad, consideration for safe access by employees and vehicular traffic should be given serious attention. Safe passageways from one building to another are also important. Blind corners, doorways opening onto yard railway tracks, etc., should be avoided as much as possible, and, where such conditions must necessarily exist, safety railings, gates, signs, or gongs should be installed to warn pedestrians of danger.

Because of their inherent **hazards of fire and explosion,** the storage, handling, and utilization of *flammable liquids* should be carefully controlled. The National Fire Codes, promulgated by the NFPA, are considered authoritative in establishing minimum safeguards necessary to control these hazards. It is necessary in any event to conform to the requirements of any applicable state and local code.

Buildings in which **dusty operations** are carried on should be designed to present a minimum area of projections, ledges, and resting places for dust accumulations.

Floors, Stairways, Aisles, etc. Probably the most important factor to be considered in connection with floors, stairways, etc., concerns **slipperiness.** Floors and stairs should be free from projecting nails, boltheads, etc., as noiseless as possible, wear well, and be strong enough to carry safely any static or moving load. The weight of modern industrial machinery and material handling equipment should be carefully considered in checking floor-load calculations. Floors and stairways should be kept clear of unnecessary obstructions over which workers may trip.

Spilling of oil, water, acid, etc., should be prevented to eliminate slipping hazards. Splash guards, drip collectors, etc., can be designed in many instances to reduce slippage. Excessive spillage of dusty materials onto the floor is sometimes taken care of by installing floor gratings beneath which pits or conveyor systems are located to collect the falling material.

Ample aisle space is very important, especially in foundries where workers carry ladles of molten metal and where there is considerable shop traffic involving power-driven trucks, etc. Aisles should be clearly marked off to assist in keeping them clear. One-way traffic is often advantageous.

Stairways should be provided with **handrails** on both sides, and an intermediate middle handrail should be installed on stairways over 88 in in width. Nonslip treads on stairs are desirable. Stairways should be adequately lighted (see Sec. 12.5).

Exits and Fire Escapes (See Life Safety Code NFPA.) As far as practicable, all doors should open outward or with the natural direction of egress; they must not block passageways from other floors or parts of the building.

For factories, not less than two means of exit should be provided on every floor, including basements, of all buildings or sections; these exits should be separated in such a manner that they are not likely to be cut off by a single local fire. The location of stairways around or adjacent to passenger elevators is undesirable unless there is separation by fire walls.

Outside fire escapes are inferior to stairways as means of egress. Where they are used, they should be located on blank walls or arranged so that persons on them will be protected from flames issuing from windows or openings underneath by use of wired glass in standard metal frames, fire doors, etc. Outside fire escapes, to provide maximum protection for persons using them during fire, should be enclosed in noncombustible towers which will protect against weather, smoke, or fire, with access through or over some intermediate balcony or structure to the building proper.

Lighting (See Sec. 12.5) Adequate lighting has a definite bearing on the prevention of accidents. Workrooms should be well lighted to reduce eye strain and the possibility of permanent eye impairment and also to remove any danger of employees falling over obstructions or being caught in machinery in darkened areas.

Ventilation (See Sec. 12.4) A lack of adequate ventilation in a workroom tends to bring on fatigue and reduces the alertness of workers, thus making them more susceptible to accidents. Where injurious dusts or noxious vapors are encountered, it is necessary to provide for their removal by the installation of adequate local exhaust systems (see Sec. 12.4 and ACGIH ''Industrial Ventilation'' and ASA Standard, ''Fundamentals Governing the Design and Operation of Local Exhaust Systems'').

Identification of Piping (See Sec. 8.7) It is desirable that a plan of identifying the contents of various pipelines be adopted so that in case of an emergency it will be possible to determine quickly the service of all pipelines involved.

Mechanical Guarding in Machine Design

(29CFR 1910, Subpart 0, as Amended.)

The most logical time at which to consider the safeguarding of a machine is during its design. In this stage, features of safe operation can be incorporated so that there will be a minimum of specific guarding required on the finished machine. The following points are fundamental considerations concerning accident prevention which should be taken into account in machine design.

Care should be taken in arranging clearances of moving parts to avoid shearing or crushing points in which hands or other parts of operator's body might be caught or injured.

Arrangements should be made so that adjustments, inspections, and hand lubrications can be done safely.

Machines should be so designed that operators are not required to stand in an uncomfortable position, reach over moving parts, or exert themselves in awkward positions.

Machines should be designed so that there will be little danger of the operator tripping over parts of the frame or striking against projecting parts during normal operation movements.

Careful attention should be given to strength of all parts whose failure might result in injury to operator.

All guards, covers, or enclosures should be designed strong enough to prevent the possibility of their giving way and permitting an accident in case the operator should fall or be thrown against them.

Point-of-Operation Guarding The point of operation on a machine is taken to be that zone where the work of the machine is actually performed and where the operator, by manipulating the material being processed, is exposed to a hazard from moving parts of the machine. Guards for point-of-operation protection are placed on the machines as additional equipment. The first requirement for a successful guard of this type is that it shall be convenient and not interfere with the operator's movement or affect the output of the machine. The following statements describe several basic principles which may be utilized in point-of-operation guarding.

Where possible, the **danger point** should be completely **covered** by a barrier or enclosure before the hazardous operation of the machine begins. This may be accomplished for example on a treadle-controlled machine by having the treadle operate the guard which, when in proper location, will then activate the machine.

Operator's hands may be kept out of dangerous positions by installing **starting devices** so located that, to operate the machines, both hands of the operator must be out of the danger zone.

Feeding devices may be used so that material to be processed is placed in a feeding mechanism at a point where there is no exposure to moving parts. Special holders or feeding tongs can also be used to place work in hazardous positions.

Electronic controls, which operate by the interruption of a light beam or other energy source to protect the danger zone, may be used to start and stop machines.

Electrical interlocks on guarding devices may be utilized in operating circuits so that unless a guard is in proper position the circuit is open and no current will flow until the machine is safely protected by the guard being brought into proper position.

Automation has minimized the hazards associated with the manual handling of stock and has eliminated the need for repetitive exposure at the point of operation, but the urgency of making repairs or adjustments introduces the need for special precautions covering maintenance work, such as locking out the power source.

Electric Equipment

(See 29CFR 1910, Subpart S, as amended.)

In considering electrical equipment for industrial establishments, it should be borne in mind that the **hazard** to human life **increases with increase in voltage**. Thus, economy in transmission wiring and copper parts, which is achieved through the use of high voltage motors, may be offset by increased danger of accident. For small motors, lights, and general service inside industrial plants, installations of 110 or 220 V are recommended.

All **switches, fuse boxes, terminals, starting rheostats, motors,** etc., located within 8 ft of a floor or working platform, should be enclosed or guarded in such a manner as will prevent accidental contact with live parts, irrespective of voltage. **Switches** should be arranged so that they can be locked in the open position, to guard against a switch being activated accidentally while workers are at work on the lines or equipment that the switch controls. **Equipment for operation at 550 V and higher** should be isolated from other operating equipment, in separate rooms or enclosures, with provision to lock these enclosures. **All metallic cases, frames,** and **supports** of such equipment should be permanently grounded; foundation bolts should not be depended upon for this purpose, but substantial ground conductors should be used. It is preferable to have these ground wires accessible for inspection. **All low voltage secondary circuits** of 300 V or less (such as light, motor, and meter circuits) should be permanently grounded whenever a neutral point is available for the purpose. Secondary circuits of 250 V or less should be permanently grounded even though a neutral point is not available. Whenever grounding has to be omitted, the frame or casing of the apparatus should be permanently grounded, and all live parts of the secondary circuit should be shielded to prevent accidental contact therewith. It is also desirable to have floors or platforms adjacent to switchboards built of nonconducting material, or suitably insulated. In the absence of such construction, rubber mats may be used.

Portable electric lamps, tools, and machines are subjected to severe operating conditions. Many electric shock fatalities have occurred on electric portables, even with 110-V lighting circuits. Cable used to service portable equipment should be high-grade insulated cord designed for the service, not ordinary twisted lamp cord. Its mechanical attachment to both the portable and the attachment plug or source of power should be designed to prevent sharp bending or chafing that would break down the insulation. All portable lamps should have nonmetallic sockets (such as rubber, plastic, or porcelain). The heavier portable tools and machines cannot practically have their metallic parts insulated from contact by the operator, and protection from shock due to accidental charge thereon must be provided by means of a special grounding wire. Such protective grounding should be in the form of an additional wire in the cable that feeds the portable device. One end should be permanently connected to the machine frame and the other connected to ground through an additional pole in both the attachment plug and the receptacle to which the device is to be attached.

Occupational-Disease Prevention

(See 29CFR 1910, Subpart G, as amended.)

In any industrial operation where a toxic material is being processed in such a manner that those persons engaged in or working near the operation are exposed to appreciable quantities of dusts, fumes, vapor, or gas, it is important that adequate control measures be adopted. The following statements cover the major considerations involved in the application of effective control to industrial occupational disease.

Contaminants (See 29CFR 1910, 93.) The physical and chemical characteristics of a contaminant should be known. In the case of dusts or fumes, the chemical nature, particle size, solubility, etc., should be determined. For gases or vapors, the composition, vapor pressure, flash point, etc., are important factors. In all atmospheric contamination, the quantity of material in the worker's breathing zone must be known before the degree of hazard can be evaluated. The chemical characteristics are important in the selection of materials to be used in the construction of any control equipment where corrosion, etc., might be factors.

A careful investigation should be made to determine accurately the sources from which the contaminant is being produced or from which it is being dispersed. The most common types of dust-producing operations are crushing, screening, grinding, polishing, etc. Dispersion of dust is encountered in practically all dry handling operations of fine materials. Vapors and fumes are produced by chemical processes and reactions and are most commonly found in connection with the use of solvents.

A number of testing instruments and procedures have been developed for determining quantitatively the concentrations or amounts of various toxic material in the atmosphere of a work room (see ACGIH, ''Air Sampling Instruments'' and reports of U.S. Public Health Service and U.S. Bureau of Mines; see also AIHA Hygienic Guide Series and ACGIH, ''Annual Threshold Limits''). In general, the seriousness of any exposure involving a health hazard is directly proportional to the dosage (concentration and length of time of the exposure). Engineering control should be directed to the reduction of these two factors.

Local Ventilation at the Source of Contaminant Removal by means of exhaust hoods, enclosures, etc., so located as to prevent the escape into occupied areas of any appreciable amount of contaminant at its source is the most effective method of control. For details of hood design, piping, collectors, fan characteristics, and for general principles of exhaust design system, see Sec. 12.4. and ANSI Standard, ''Fundamentals Governing the Design and Operation of Local Exhaust Systems''; AFS, ''Engineering Manual for Control of In-plant Environment in Foundries.''

Natural ventilation has a limited application in industrial occupational disease control. It is important with a natural ventilation system to maintain close supervision of adjustment as required by changes in temperature, wind directions, etc. Regular tests of air content should be made to check on the degree of dilution being obtained. This method of control is not recommended for exposures where severe hazards exist owing to extreme toxicity or high concentrations.

Isolation Under some circumstances, the isolation of a hazardous operation, physically, or in point of time, is required. For example, a hazardous operation may be carried on in a separated room in which all contamination can be confined or it may be carried on outside regular working hours when no one except the persons engaged in the operation will be present. By isolating an operation, the number of persons exposed to any accompanying hazard may be reduced to a minimum.

Process Revision The possibility of substituting a less toxic material should be borne in mind; e.g., high-boiling-point distillates for benzol in rubber cements, thinners, etc.; dolomite lime for quartz in foundry parting compounds. It may be possible to reduce the concentrations of objectionable contaminants and the time of exposure by changing handling operations, by substituting mechanical feeds or conveyors for manual operations, or by installing automatic machinery or controls so as to dispense with the presence of an attendant. An automatic temperature or pressure control device, in connection with a chemical process, may reduce materially the time of an operator's exposure as well as prevent the production of excess or undesirable fumes or gases. An enclosed conveyor system handling dry material and automatically weighing it may be utilized to eliminate a severe exposure that would result from hand shoveling.

Physical Hazards In addition to exposures to toxic gases, vapors, dusts, fumes, etc., there are several physical conditions such as abnormal pressures, temperatures, and humidities as well as radiation (including ultraviolet; infrared; X-ray; α, β, and γ rays from radioactive substances; and radiation from handling radioactive isotopes), all of which may, in case of excessive exposure, prove detrimental to the health of exposed persons. Evaluation depends on physical methods of measurement. Protective measures include shielding from radiation and control of exposure time rather than ventilation, as in the case of atmospheric contaminations.

Ambient Noise Control (See also Sec. 12.6) Outer property noise propagation is regulated by EPA, under provisions of the Noise Control Act of 1972; Section 6 applies to new-product noise emission standards; Section 17 is concerned with noise emission regulations for railroads and Section 18 for motor carriers. EPA is directed to publish noise emission guidelines in the *Federal Register.* The regulation for aircraft-airports are promulgated by the Federal Aviation Administration (FAA) consistent with Section 611 of the Federal Aviation Act of 1958 and guidelines proposed by EPA.

Occupational Noise Exposure Mandatory protection of employees against noise is required by 29CFR 1910.95 as follows:

(*a*) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table 18.2.1 when mea-

Table 18.2.1 Permissible Noise Exposure*

Duration, h/day	Sound level, slow response, dBA
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

* 29CFR 1910.95.

sured on the A scale of a standard sound-level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined from Fig. 18.2.1. Octave band sound-pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound-level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table 18.2.1.

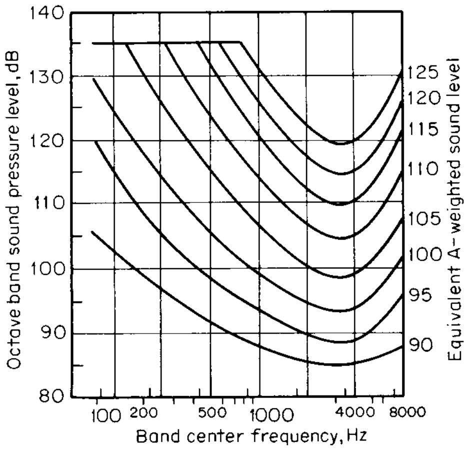


Fig. 18.2.1 Equivalent sound-level contours.

(*b*) (1) When employees are subjected to sound levels exceeding those listed in Table 18.2.1, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table 18.2.1, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table. (2) If the variations in noise level involve maxima at intervals of 1 s or less, it is to be considered continuous. (3) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the fractions $C_1/T_1 + C_2/T_2 + \cdots + C_n/T_n$ exceeds unity, then the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140-dB peak sound-pressure level.

Personal Respiratory Protection (See 29CFR1910, 134, as amended.) Where it is not practicable to control air contamination in the breathing zone of workers by adequate exhaust ventilation, etc., and it is necessary for personnel to be exposed to harmful amounts of dust, smoke, fumes, or gases or to work in an atmosphere with a deficiency of oxygen, personal respiratory equipment must be provided. Such equipment is not, in general, suited for prolonged daily use because of inherent discomfort and inconvenience to the wearer. For emergency or temporary situations or until effective control of contamination can be developed and applied, personal respiratory protection should be given very careful consideration where harmful exposures are encountered (see ''The Respirator Manual,'' prepared jointly by the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists). The U.S. Bureau of Mines (Schedules 19 and 21) has developed certain standards for approval of respiratory protection devices. The equipment may be (1) **supplied-air respirators** (hose type), devices that supply clean, respirable air to the wearer through a hose line extending from a source outside the contaminated zone; (2) **supplied-oxygen respirators** (self-contained type of oxygen-breathing apparatus), devices that supply oxygen to the wearer from a source of supply that he or she carries as part of the respirator; or (3) **filter-type respirators,** which may be chemical filter respirators that remove the harmful constituents from air passing through them by chemical reactions, absorption, and adsorption, including ordinary gas masks and chemical respirators; or which may be mechanical-filter respirators that remove the harmful constituents from air by mechanical filtration, including dust, mist, or fume respirators.

Safety Codes and Published Material. OSHA The American National Standards Institute (ANSI) publishes a series of ANSI Standards. State and local ordinances must be complied with as required.

The National Safety Council publishes a series of Industrial Data Sheets and Safe Practice Pamphlets covering the safeguarding of industrial operations, in addition to literature, posters, films, and other safety educational material. The annual publication ''Accident Facts'' reports current trends in accident experience on an overall basis.

United States government agencies, such as the Bureau of Mines, the Bureau of Labor Statistics, the National Bureau of Standards, and the Division of Labor Standards publish statistical information concerning industrial-accident occurrence and accident prevention. The National Fire Protection Association (NFPA) promulgates fire codes and publishes information of all types relating to fire protection.

The Williams Steiger Act of 1970 created the **Federal Occupational Safety and Health Administration** (OSHA), which has now codified and published blanket standards for national enforcement in all public safety and health areas. Updated revisions will continue to appear in the Federal Register under Title 29 CFR1910 and 1518, and these standards make all preexisting standards obsolete.

Radiation Health Physics (Nuclear Regulatory Commission, Code of Federal Regulations 10CFR 20; International Commission of Radiological Protection, Pub. 30, Radiological Health Handbook) **Radiation,** which accompanies all nuclear reactions, can be advantageous or disadvantageous, depending generally on the manner in which contact is made and on the amount of energy involved. In its application to humans, the common terminology includes **radiation absorbed dose (rad)** and **dose equivalent,** measured in SI units as **gray (Gy)** and **sieverts (Sv),** respectively. In an older, though still common, usage, the respective units are designated **rad** and **rem.** Absorbed dose, measured in grays (or rads), is a measure of the energy absorbed from radiation per unit mass of irradiated material. Absorbed dose is applicable to all types of ionizing radiation and irradiating material. The amount of biological damage to human tissue, however, depends on the type of radiation and its energy. Thus, absorbed dose measurements must be modified in order to relate the amount of energy absorbed to the biological effect. Dose equivalent, as measured in sieverts (or rems), accounts for these effects through the use of **radiation weighting factors** (formerly known as **quality factors), *Q*.** For radiation protection purposes, the **dose equivalent** is defined as the product of the absorbed dose and the radiation weighting factor. The currently accepted weighting factors are 1, for photons and electrons of all energies; 5, for protons with energies greater than 2 meV; 20, for alpha particles, fission fragments, and heavy nuclei; from 5 to 20, for neutrons, depending on the neutron energy.

Exposure to radiation may be divided into two general types: (1) external exposure, which is that resulting from radiation sources external to the body; and (2) internal exposure, which is that resulting from radionuclides within the body. Radiation-protection standards are established for both types of exposure. Limits for external exposure are given in units of sieverts per unit of time. Basic limits currently are based on a control point of 1 year. Local operational rules may specify control limits for shorter exposure times (day, week, month), such limits being based on the basic limits. Radiation-protection standards for controlling internal exposures are based on the same basic limits as those for external exposures. Controls, however, are affected by the use of **annual levels of intake (ALIs)** and **derived air concentration (DAC)** values established for all radionuclides. Many factors (physical, chemical, biological, and physiological) are involved in determining the ALI and DAC of a radionuclide. As such, the ALIs and DACs of the radionuclides have a very wide range of values. All **ALIs** and **DACs** are normally expressed in terms of **bequerels** and **bequerels per cubic metre,** respectively. Generally, ALI and DAC values are based on a 40-h workweek for persons exposed to radiation.

Monitoring is the periodic or continuous determination of the presence and extent of ionizing radiation and radioactive contamination. It provides information for radiation protection and normally is assigned to a health physics group, which establishes schedules, executes or supervises the operation, and evaluates their results. It is divided into these special types: personnel, area, source, surface, air, and water.

Regulations governing exposure to radiation are promulgated in the form of Nuclear Regulation Commission regulations found in 10CFR 20. The current **occupational dose limit** is 0.050 Sv (or 5.0 rem) total effective dose equivalent per year. The total effective dose equivalent includes both external and internal doses. Additional radiation protection limits exist for radiation exposures to individual organs of the body, the lens of eye, and the extremities. Reference to the current full statement of 10CFR 20 is mandatory for a complete understanding of the regulations.

18.3 FIRE PROTECTION

by Pascal M. Rapier and Andrew C. Klein

REFERENCES: ''Fire Protection Handbook,'' ''National Fire Codes,'' ''Fire Inspection Manual,'' National Fire Protection Assn. ''Handbook of Industrial Loss Prevention,'' McGraw-Hill. ''Uniform Building Code 1976,'' International Conference of Building Officials, Building Offic. and Code Admin. International (BOCA). Fire Insurance Assn. (FIA), Factory Mutual (FM), Code of Federal Regulations: 29CFR 1518, July 1976, and 29CFR 1910, July 1976, Jan. 28, 1977, as amended.

IMPORTANCE OF FIRE PROTECTION
(29CFR 1910, Subpart L)

The profitable use or availability for use of facilities is the aim of all business, whether industrial, mercantile, professional, scientific, or educational. Destruction of or damage to the facilities cripples the attainment of that purpose.

Monetary compensation for destroyed property and for resulting lost profits is obtained by the purchase of insurance. Reputation, goodwill, and other intangible factors may be irreparably damaged. Loss of life is not recoverable. Loss by fire is largely an avoidable, nonproductive tax resulting from carelessness, ignorance, apathy, or incompetence. The annual fire loss in the United States (refer to NFPA) has increased steadily since 1964 at about 8 to 12 percent per year, reflecting the population and economic growth and inflation. In recent years, the number of losses has exceeded 2 million. Building fires have made up in excess of 80 percent of the **amount** of loss but only about 40 percent of the **number**.

Fire-Loss Prevention Neither insurance organizations nor legally established regulatory bodies assume the responsibility of industry for conserving its own resources and operating its facilities safely, although they may detect deficiencies or a lack of compliance with regulations and may serve in a consulting capacity. Fire loss prevention is an indispensable element in industry and business. It exists only with top management direction and the support of labor.

The designation **fire protection** usually encompasses the entire field of **prevention of loss by fire,** including both the causes for the occurrence of fires and methods for minimizing their consequences. Included along with fire are other destructive agencies such as explosion, lightning, electric current, wind, earthquake, nuclear excursions, and radioactive contamination. OSHA and building codes mandate minimum standards of protection to prevent injury and loss of life. Higher standards to protect investment are a worthwhile management option.

Fire brigades (29CFR 1910.164) are essential to the development and maintenance of an effective fire protection program at every job site. By prompt, immediate response and notification of the local fire department, every effort should be made to bring the fire quickly under control during the early minutes of an outbreak. The immediate availability of the correct fire protection and suppression equipment is essential.

Fire protection engineering involves the application of sound engineering principles to the reduction of loss by fire and related hazards. The Society of Fire Protection Engineers has established a well-defined scope for fire-protection engineering practice, both in building design and in safe operating practices.

Limitation of Loss With large businesses it is difficult to limit single destructive occurrences to an amount that will not be catastrophic to the owner or to others having a financial interest. Principles and methods for preventing large losses by fire are well known to fire protection engineers.

Sources of Fire Protection Information Much specific, detailed, and technical information is given in the standards, codes, and rules of the NFPA, Factory Mutual Engineering Division, Factory Insurance Assoc., American Insurance Association, ANSI, Underwriters Laboratories Inc., and may also be found in the procedures of many insurance companies and inspection bureaus.

The NFPA ''Handbook of Fire Protection'' and the Factory Mutual ''Handbook of Industrial Loss Prevention'' are especially comprehensive references. The most complete and readily available source of standards is the ''National Fire Codes,'' prepared and published by the NFPA, currently in ten volumes as follows: 1—Flammable Liquids; 2—Gases; 3—Combustible Solids, Dusts, and Explosives; 4—Building Construction and Facilities; 5—Electrical; 6—Sprinklers, Fire Pumps and Water Tanks; 7—Alarms and Special Extinguishing Systems; 8—Portable and Manual Fire-control Equipment; 9—Occupancy Standards and Process Hazards; 10—Transportation. Many of the standards have been adopted by insurance inspection and advisory groups, such as the American Insurance Association, and by Federal, state, and municipal regulatory bodies and have been incorporated into building codes and other regulations. The Occupational Safety and Health Administration (OSHA) U.S. Dept. of Labor, is promulgating blanket national standards for fire protection, which appear in the Federal Register under Title 29, Code of Federal Regulations for the working place, and Part 1518 during construction. Where applicable, these supersede and make obsolete all existing standards.

CONSTRUCTION

Building construction and the protection of buildings and their contents against fire are frequently governed by local building codes and ordinances and by insurance standards. When new construction or changes are planned, the property owner should have the advice of a competent fire protection engineer and should consult local authorities and insurance carriers to avoid delay and the possibility of expensive changes later.

Some construction features which have increasing importance in fire-loss prevention are (1) the trend toward large fire areas which present high values to possible loss and make manual fire fighting difficult; (2) blank wall, air-conditioned, and artificially lighted buildings which interfere with ready access; and (3) mechanization of materials handling, resulting in conveyor systems that interconnect areas, and in larger storage areas with high-piled stock which make fires difficult to extinguish. These cause increased cost of fire protection and emphasize the need for automatic fire control methods, sources of dependable water supplies, and special extinguishing systems. A measure that should be adopted where practical is the use of outdoor, totally enclosed process equipment, with shelters provided only for control rooms, laboratories, and some maintenance functions.

Types of Construction **Fire-resistive** refers to types that withstand considerable fire without serious damage, such as reinforced concrete or protected steel. **Noncombustible** refers to any construction that contains no elements of burnable material built which may be structurally damaged by fire, such as unprotected metal. **Combustible** means structures entirely of combustible materials or having combustible elements of such character and distribution that a fire can spread and contribute fuel so that severe damage results. Combustible types of construction are frequently subdivided into (1) ''heavy timber,'' also called ''plank on timber,'' ''mill'' or ''slow burning'' that has masonry walls with floors and roof of plank on heavy timbers; (2) ''ordinary construction'' that has masonry walls with floors and roof made of boards on joists and is sometimes called ''quick burning''; (3) ''wood frame'' that has all of its elements of wood, except that the exterior may be surfaced with a noncombustible sheathing.

Many types of construction have composite elements that may include combustible materials. Insulation, acoustic materials, and surface treatments may aid the start and contribute to the rapid spread of fire. A roof of interlocking metal sheets, with asphalt on its upper surface as part of a vapor barrier or as an adhesive for insulation or weather surfacing, can, if initially heated by a local interior exposing fire, furnish gaseous fuel through the joints to produce a spreading damaging fire. Owing to the difficulty and cost of protection, enclosed spaces at roofs, ceilings, in walls, and below floors should be avoided. Important steel structural members and steel supports for heavy equipment that may be exposed to severe fire should have heat-insulating protection. Economic tradeoffs, based on the probability of exposure, should be made.

Fire Performance of Building Materials The kind and amount of fire protection needed are governed by the fire performance of materials used in construction and by the combustibility of building contents. Completely noncombustible construction avoids the need for sprinkler protection, provided that contents are also certain to be noncombustible. Knowledge of the fire performance of materials, based upon tests made by qualified laboratories, is essential before they are adopted (see Sec. 6.8). Fire performance is in two categories, fire resistance and fire hazard.

Fire resistance measures the susceptibility of materials to damage by exposure to fire and is usually measured as the time period of exposure, without significant damage, to a standard fire-exposure as specified by standard fire tests, such as ''ASTM E-119 Fire Tests of Building Construction and Materials,'' and expressed as a **fire-resistance classification** in hours as ½ h, 2 h, 6 h, etc.

Fire-hazard indicators are also in two generally recognized categories used by the Underwriters Laboratories. The **listing** of specific appliances and materials indicates that the products comply with the Laboratories' test requirements, with particular reference to fire-preventive and fire protective capabilities when the manufacturer's instructions and limitations of use have been followed. The **fire-hazard classification** of materials and products is related mainly to burning characteristics. It has a numerical basis determined by (1) flame spread, (2) fuel contributed, (3) smoke-developed. A fire hazard classification of 0 indicates a material with a fire performance equivalent to that of cement board composition. A value of 100 corresponds to the behavior of red oak lumber. Building codes and other regulations generally prescribe limiting values for fire hazard classifications.

Protection against Exposure Fires Protection of buildings or other structures against fires in nearby property must sometimes be provided. A practical barrier against a conflagration is the presence of fire-resistive buildings along the exposed side. Usually the most severe exposure is localized, and protection against it may be provided by a blank brick or concrete wall, by wired-glass metal-frame windows, or by open sprinklers alone or in combination. The relative value of various safeguards against exposure fires has been estimated to be roughly blank brick or concrete walls, 100; tin-clad shutters, 60; wired-glass windows, metal frames, glass block (4 in minimum thickness), 40; wired-glass windows, wooden frames, 20; plain glass windows, 5; additional value of open sprinklers with any of the foregoing, except blank fire walls, 30; open windows, 0.

Horizontal Cutoffs Provide effective fire walls between important buildings, and subdivide large building areas in order to limit the probable maximum damage from a single fire.

Vertical Cutoffs Enclose stairs, elevator wells, vertical conveyors, chutes, and other floor openings with adequate fire-resistive walls, having fire doors or their equivalent at openings to prevent the rapid spread of fire and heat upward from floor to floor.

Isolation of Hazards Cut off hazardous occupancies by fire-resistive partitions or fire walls or, if the degree of hazard warrants, isolate them in separate buildings. Make provision for adequate ventilation and for explosion vents where needed.

Floor Leakage Provide drained, watertight floors over large values susceptible to water damage.

Storehouses and Vaults Provide suitable storehouses for large quantities of combustible raw stock, tools, and patterns, and for valuable finished goods. Provide reliable vaults for the storage of business records and valuable drawings.

SAFEGUARDS DURING BUILDING CONSTRUCTION
(20CFR 1518, Subpart F)

A building under construction is more vulnerable to fire than the same building completed and in use with normal fire protection. As construction progresses, concentrations of readily combustible materials appear at new locations from day to day. So do many potential ignition sources—temporary heaters, welders' torches, roofers' tar kettles, and workers' discarded matches or cigarettes. If fire starts, wall and floor openings create draft and help flames to spread rapidly. Many serious construction fires have taken place. Most can be prevented. Guard against cutting and welding hazards by proper supervision of operations. Plan in advance for effective notification of, and coordinated firefighting operations with, any available public fire department. (See 29CFR 1518.24.)

Start installation of the fire-protective equipment—including water supplies, yard mains, and hydrants—as soon as construction of the building starts. Make layouts for sprinklers as soon as building drawings are completed, and let contracts without delay. It is sometimes possible to arrange for limited temporary protection by providing connections for hose from the piping system which furnishes water for construction uses. Have hose and nozzles available as soon as the yard piping, hydrants, and water supplies are ready. Distribute ample hand extinguishing equipment throughout the premises, including contractor's temporary buildings.

Temporary Heating Arrange any needed heat safely. Use coke as fuel for salamanders, rather than wood trash or rubbish. Oil-fired heaters, if well-designed and properly located, are safer. Unit heaters are still better and are recommended if an adequate steam supply is available. Locate salamanders or oil heaters away from woodwork or tarpaulins. Keep the floor clean and free from combustible material. Flameproofed, water-repellent tarpaulins are available, and their use is advised. The tarpaulin salamander wooden-form combination has caused many serious fires, particularly in reinforced concrete construction work during freezing weather. Scaffolding constructed of metal, or of fire-retardant-treated wood, largely avoids a serious fire hazard. Locate construction sheds a safe distance from a building under erection, never inside.

Temporary Storage Keep combustible storage out of buildings under construction, as far as possible and at least 10 ft (3.05 m) from structures when stored outside. Under no conditions erect canvas tents or wooden shelters inside. A safe location and good fire protection are important for valuable equipment or machinery, delivered before the building is ready for its installation.

AUTOMATIC SPRINKLERS (29CFR 1910.195)

Advantages of Automatic Sprinklers Automatic sprinklers are the most dependable and effective means of fire protection. The advantages are (1) automatic sprinklers go into operation soon after a fire starts, and before it has gained dangerous proportions; (2) the automatic sprinklers that open are over, and in the vicinity of, the fire; (3) fires at all locations, including out-of-the-way places, are controlled as effectively as fires easily seen and reached; (4) sprinklers operate where fire fighters could not enter or would be driven out by heat or smoke; (5) sprinklers are always ready; (6) only sprinklers that are needed to control a fire operate, so that water is used to better advantage than from hose streams.

Where Sprinklers are Needed Automatic sprinklers are needed for complete protection where there is an appreciable amount of combustible material in either building construction or in building contents, e.g., (1) throughout buildings having floors or roofs of sufficient combustibility to contribute to a spreading fire, whether or not the contents are combustible; (2) in wholly noncombustible buildings where contents are combustible, including the storage or use of flammable liquids; (3) in concealed spaces, such as attics and under low roofs, if they contain any combustibles, including heat insulation and exposed electric wiring; (4) in vacant spaces beneath a combustible first floor of a building, unless the floor is completely tight, the space sealed against entry, and no possible sources of ignition are present; (5) in dryers, large ducts, closets, and small offices, unless there is no fuel for a fire in either the construction or the contents; (6) under wide storage shelves or work tables over 4 ft in width having any combustible stock, and under canopies over platforms where combustible materials may be present.

Sprinklers over Electric Equipment If the construction is fire-resistive or adequately fireproofed, sprinklers can generally be omitted in electric generator rooms and over switchboards. If voltages exceed 600, it is generally better to replace combustible roofs or ceilings with noncombustible construction or to protect all exposed woodwork with metal lath and cement plaster, rather than to install sprinklers. Metal shields or hoods may be used to protect generators, switchboards, or other important electrical equipment from possible water damage.

Automatic-Sprinkler Equipment The responsibility for the design of automatic sprinkler systems should be given only to experienced and responsible parties. Approval of preliminary layouts and working plans are usually required by municipal or insurance inspection bureaus before installation is started. Sprinkler installation is a well-established trade by itself. Standards for the Installation of Sprinkler Systems are given in complete detail in a publication under that name by the National Fire Protection Assoc.

Dry Pipe Systems The ordinary wet pipe sprinkler system cannot be used where subject to temperatures below freezing. A dry pipe system must be substituted. In the dry pipe system the sprinkler piping contains air under pressure instead of water. When a sprinkler is opened by fire, the air pressure falls and water is admitted automatically by the operation of a dry pipe valve.

Special Sprinkler Systems The deluge system is a special type of sprinkler equipment frequently used in hazardous occupancies, such as airplane hangers and storage areas for flammable liquids or materials, where a flash fire could spread before the regular automatic sprinklers became operative, and where the prompt discharge of a large amount of water over a considerable area is needed. The deluge system has sprinkler heads with the fusible element removed. Water is controlled by a quick-opening valve (deluge valve) operated by heat sensitive elements distributed over the area protected. Piping and heads are arranged as in a standard sprinkler system, with larger pipe sizes.

Precision systems are actuated by heat-sensitive devices, smoke detectors, or ionization detectors, which trip a controlling valve and admit water to the otherwise dry sprinkler piping before the regular closed automatic sprinkler heads operate. The system has the advantage of giving an alarm before sprinklers operate. Accidental opening of automatic sprinklers or mechanical breakage of piping does not result in the discharge of water.

Deluge and other systems actuated by heat-sensitive or other special devices introduce additional mechanical equipment and lose the simplicity of the standard automatic sprinkler system. Some additional skilled maintenance is required. Various arrangements for mechanically supervising the condition of such equipment can be provided.

Nonfreeze sprinkler systems are small and are sometimes used in relatively unimportant locations where it is impracticable to provide heat. They consist of special piping connections to wet-pipe systems, with a nonfreezing solution in the exposed piping. Antifreeze solutions (glycols) are acceptable for this purpose. They should be limited to systems with less than 20 heads. It is better to provide heat, to connect to existing dry pipe systems, or to provide small dry pipe valves. Nonfreeze systems are preferable to shutting off the sprinklers and draining the piping during the winter. No portion of an automatic sprinkler system connected to a public water supply should be filled with a nonfreeze liquid without determining that the arrangement will comply with water department health regulations.

Outside sprinklers are used for protection against fire from outside sources. Windows in outside walls present the most frequent problem. Outside sprinklers may be operated either manually or automatically. The effectiveness of these systems depends on the water supply valve opening in time. They can sometimes be adapted to automatic control by a thermostatically operated deluge valve.

Types of Automatic Sprinkler Heads Approved automatic-sprinkler heads are well standardized as to the rate of water discharge, pattern of discharge, and temperature operating characteristics. The essential elements of an automatic sprinkler are a nozzle, a closing device that is released at a definite temperature, and a deflector that produces the desired distribution pattern. Temperature ratings appropriate for the location must be selected. The ratings for normal atmospheric temperatures, not substantially above 100°F, are 135 to 165°F. Ratings for other ceiling temperature ranges are as follows:

Max ceiling temp		Sprinkler rating	
°F	K	°F	K
101–150	311–338	175–212	352–373
151–225	339–380	250–286	394–414
226–300	381–442	325–360	436–455

Heads of higher rating are obtainable for ambient temperatures up to 500°F. Corrosion-resistant heads, usually wax or plastic coated, are obtainable for use in corrosive atmospheres.

Sprinkler Flow Alarms The flow of water from a sprinkler system may be made to sound an alarm which gives warning of both a fire and accidental leakage from the system. This alarm may be either a hydraulic gong or an electric bell, or both. If the property has no constant attendance, or if added security is desired, central-station supervisory service is available in many industrial centers. This service transmits water flow alarms to public fire departments and can perform numerous other supervisory functions. Preaction alarms give advance notice of hazard.

Location and Spacing of Automatic Sprinklers As the purpose of an automatic sprinkler system is to protect both building and contents, the water distribution pattern and the quantity of water applied must be held within close limits. Sprinklers customarily are installed so that the discharge from one head is allowed for each 60 to 130 ft^2 of floor area. The distance between adjacent heads should not exceed 15 ft. Spacing averages 80 to 120 ft^2 per head with 8 to 12 ft between heads.

Recent developments in sprinkler system design for the more severe hazards produced by high piled combustible goods or flammable liquids are leading to standards including a **discharge density** in terms of gallons per minute per square foot of floor area. In this consideration building contents, rather than building construction, are the determining factor. Densities called for commonly have been in a range of 0.15 to 0.3 gal/min per ft^2 of floor area. High-piled storage of combustible materials, such as rolled paper, imposes a severe hazard which may call for a water density of 0.6 gal/min per ft^2, or more. NFPA standards (1973) call for intermediate levels of sprinkler heads in high rack storage areas. Open and deluge sprinklers require hydraulically designed systems based on friction loss instead of standard pipe schedules (see NFPA No. 13, No. 13a, and No. 231c).

The number of heads, to be supplied through pipes of standard sizes, with ordinary hazards and reasonably uniform water discharge, is as follows:

Size of pipe, in	Max. no. of sprinklers	Size of pipe, in	Max. no. of sprinklers
1	2	3½	65
1¼	3	4	100
1½	5	5	160
2	10	6	275
2½	20	8	400
3	40		

Not more than eight sprinklers should be on one branch line on either side of a cross main. For deluge systems, with which all heads are open and must be supplied simultaneously, and for especially hazardous occupancies where a large proportion of the automatic heads are expected to operate, larger pipe sizes are required as follows:

Size of pipe, in	Max. no. of sprinklers	Size of pipe, in	Max. no. of sprinklers
1	1	3	27
1¼	2	3½	40
1½	5	4	55
2	8	5	90
2½	15	6	150

WATER SUPPLIES FOR FIRE PROTECTION

(See Sec. 3.3 for hydraulics, Sec. 8.7 for piping, Sec. 9.6 for engines, Secs. 14.1 and 14.2 for pumps.)

Insurance companies or their inspection and engineering bureaus should be consulted concerning water supply requirements for fire service. In addition to providing water for automatic sprinklers, the supply should be adequate for hydrants and hose streams. Common water supplies are public water systems, gravity tanks or private reservoirs, and fire pumps taking suction from aboveground suction tanks, rivers, or ponds. Two or more independent supplies are usually needed for larger properties. Strong, dependable public water systems alone are adequate only for small plants, of good construction, having safe occupancies, and not dangerously exposed.

The ''primary'' water supply automatically maintains pressure on the property fire system at all times. The ''secondary'' supply supplements it as needed. The **primary supply** should not be less than 500 gpm available at a pressure that will be effective for automatic sprinklers at the highest plant elevation. A **secondary water supply** serves several purposes. The most important usually is to provide more water, frequently at higher pressure than is available from the constant primary supply. A secondary supply is also of value in maintaining protection at any time the primary supply may be interrupted due to public supply deficiencies or to the necessity of taking tanks or reservoirs out of service for repairs and maintenance.

High water demands for special hazard protection, especially where large areas must have deluge system protection, can seldom be met by connections to public water systems. Fire pumps and suction reservoirs can give the added volume of water at desirably high pressure for the expected duration of the total demand, which is made up of the anticipated sprinkler demand and an allowance for the number of hose streams likely to be used. Large airplane hangars, large building areas containing flammable liquids, or very extensive properties that could have a general fire, approaching conflagration proportions, can have an estimated total demand of 5,000 gal/min or even more.

Gravity Water Tanks The smallest gravity tank on a tower considered advisable for fire protection is 25,000 gal, which may be suitable for the protection of small properties. Water from tanks of such limited size should be reserved for automatic sprinklers only. Tanks of 50,000- to 100,000-gal capacity may provide either the primary or secondary supplies for large properties of moderate hazard. Tanks combining fire service and domestic or industrial supplies in a single structure are allowable, provided that the amount needed for the fire supply cannot be withdrawn into the industrial use system.

Gravity tanks should be at such elevation that the bottom of the tank will be at least 35 ft above the highest sprinkler to be supplied. The bottom of large tanks, intended to provide water for hose streams as well as sprinklers, should be at least 75 ft, and preferably 100 ft, above ground level.

Pressure Tanks Hydropneumatic steel tanks can be used for primary water supplies for demands of short duration, such as needed to bring automatic fire pumps into full operation. Under some conditions they can be used to facilitate the automatic control of the automatic fire pumps by providing a rapid drop in the control pressure. High cost and limited capacity deter the general use of pressure tanks.

Private Fire Pumps Well-located fire pumps with ample suction supplies and capable of maintaining high pressure over a long period provide a very satisfactory secondary supply. Centrifugal fire pumps of approved design are in common use. Practically all new installations use centrifugal pumps driven by electric motors, gasoline or diesel engines, or steam turbines. The electric motor driven centrifugal pump is most desirable because of simplicity of control and operation. Gasoline engine drives are used to a limited extent where other reliable sources of power are not available, or as auxiliary units in connection with other pumps.

Adequate suction and reliable power supply are essential for fire pumps. The suction supply should be sufficient to operate the pump at rated capacity for at least 1½ h at the smaller plants, and an inexhaustible suction supply is desirable for good protection of the largest industrial properties.

An automatically controlled, electrically driven centrifugal fire pump is sometimes used as a booster pump when the public water is of good volume but too low in pressure for direct use in sprinkler systems.

Fire pumps are used in capacities of 500, 750, 1,000, 1,500, and occasionally 2,000 or 2,500 gal/min. The 750 and 1,000 gal/min sizes are most common.

Fire Department Connections For properties where the public water supply is at comparatively low pressure but adequate in quantity, fire department connections to the plant fire-service piping can serve as a valuable auxiliary for pumpers to deliver water into the fire system at high pressures. In city properties, particularly, fire department connections are usually a part of the sprinkler system.

UNDERGROUND WATER PIPING FOR FIRE SERVICE

Complete specifications or standards covering all of the main features of underground piping for fire service are given in NFPA National Fire Codes, vol. 6, ''Sprinklers, Fire Pumps, and Water Tanks,'' and the Factory Mutual ''Handbook of Industrial Loss Prevention.'' The ''Handbook of Cast-Iron Pipe,'' published by the Cast-Iron Research Association, contains much useful information.

Underground Mains Buried underground piping should be located so that hydrants and control valves are at a safe distance from possible falling building walls. A complete loop system around buildings or groups of buildings, with multiple supplies preferably connected at opposite sides and with prudently located division valves, affords the best hydraulic characteristics for heavy flows and for freedom from impairments. Pipe trenches should allow careful laying and uniform support for the pipe. Foreign materials should be kept out of the pipe. Pipe should be anchored at bends, dead ends, and branch connections. The system should be hydraulically tested for 2 h at a minimum pressure of 200 lb/in^2 or at least 50 lb/in^2 in excess of the maximum static pressure if it is to be more than 150 lb/in^2. Leakage at joints must be less than specified amounts. Underground piping should be thoroughly flushed before it is connected to indoor piping. Pipe should be buried well below the deepest frost penetration as shown by weather charts. In the coldest areas a cover of at least 5 ft is necessary. In the southern states 2½ ft may be adequate, except that under roadways a greater cover may be needed for protection against traffic loads. Clearance to prevent breakage by settlement is needed at foundation walls.

Soil Corrosion Rapid external corrosion of cast iron pipe may be expected if the mains pass under coal piles, through cinder fill, or where pickling liquors, acids, alkalies, or salts penetrate the soil. Cast iron pipe covered with heavy coating of asphalt, or other pipe suitably covered should be used to offset soil corrosion in such locations. Backfill should be of clear sand or gravel. (See Secs. 6.8 and 6.9.)

Type of Pipe Pipe for underground use is usually cast iron or steel. Ordinarily the working water pressure rating does not need to exceed 150 lb/in^2. Representative specifications for pipe suitable for fire service are: ''Specifications for Cast-Iron Pit-Cast Pipe'' (ANSI A21.2 or AWWA C102), ''Specifications for Cast-Iron Pipe Centrifugally Cast in Sand-Lined Molds'' (ANSI 21.8 or AWWA C108); asbestos-cement pipe should conform to ''Tentative Standard Specifications for Asbestos-Cement Water Pipe'' (AWWA C400) or ''Commodity Federal Specification SS-P-55/A.''

OUTSIDE HYDRANTS AND HOSE

Location of Hydrants Where space permits, outdoor hydrants and hose provide a supplemental to automatic sprinklers and afford means for fighting fires in combustible yard storage, in railroad cars and vehicles, and small combustible unsprinkled sheds. Recommended space between hydrants varies from 150 to 300 ft, depending upon the type of buildings and the character of outdoor combustibles. Hose for outdoor use, 2½ in in size, is made of woven cotton or modern synthetic fiber and rubber-lined.

STANDPIPES AND INSIDE HOSE
(29CFR 1910.158)

Standpipe systems furnish the best means of obtaining effective fire streams in the upper stories of buildings. They are designed for small hose streams used by the occupants and for large hose streams to be used by public or plant fire departments. Outlets may be designed to supply both. In buildings of unusual height, standpipes are sometimes supplied by a series of fire pumps and tanks at different elevations.

Small hose is of particular value in areas with hazardous occupancies, such as opener, picker, spinning, and woodworking rooms. Hose should be 1½-in cotton, rubber-lined, or unlined linen, with ⅜- or ½-in nozzles. Spray-type nozzles are usually best for the hazards mentioned. The water supply should preferably be taken from a connection independent of the sprinkler piping so that hose streams will be available when the sprinklers are shut off after a fire or during sprinkler repairs or changes. Small hose, for fire service only, in locations of ordinary hazards, may be connected to wet pipe sprinkler systems, but in no case should hose connections be made to sprinkler lines smaller than 2½-in diam. (See Sec. 8.7.)

SPECIAL FORMS OF FIRE PROTECTION

Special types of protection are adapted to the control of unusual hazards, such as flammable liquids. Equipment should be secured from makers specializing in the form of protection required, but such use does not supplant general building protection by automatic sprinklers.

Water Spray A dense strong spray of water from suitably designed nozzles is effective for controlling fires in flammable liquids of moderate hazard, for unusually flammable solid materials, and for surface fires of ordinary combustible materials. Such a system may be most appropriate for the protection of transformers and other oil-filled electric equipment and for systems handling fuel or lubricating oil under pressure. The entire zone to be protected must be within reach of the strong spray. Water pressures of 50 lb/in^2 prevail with properly designed equipment. (See Sec. 3.3.)

Foam Foams for fire control provide a blanketing action to exclude air and in some cases to give useful insulating effect. Foams are commonly designated as ''chemical foam'' and ''air foam,'' depending upon their service or method of production. For flammable-liquid fires, foam is available for manual or automatic applications with a selection of characteristics appropriate for a wide variety of conditions. The amount of foam varies from ½ ft^3 to several cubic feet per square foot of surface protected. Rate of application and means of distribution largely determine its effectiveness. A sprinkler system, designated as ''Foam-water,'' provides an initial discharge of very fluid foam backed up by a sprinkler discharge of water. Special **alcohol type** foam is needed for application to alcohols, alcohol-type liquids, and organic solvents, all of which seriously break down the commonly used foams. **High expansion** foams are available. They are easily produced in a **high expansion foam generator** by blowing air through a screen wet with a continuous spray of water having a bubble producing additive. The foam is very light and fluid and can be applied to fill completely and quickly a room or other enclosed area of considerable size. One gallon of high-expansion foam-producing liquid can form as much as 1,000 gal of foam. Ordinary foam producing liquids yield only about 10 gal of foam per gal of liquid.

Carbon Dioxide (29CFR 1910.161) For (1) flammable liquids; (2) electric equipment, such as large enclosed electric generators; and (3) hazards where a space-filling effect by an inert atmosphere is needed, or where a nonwetting extinguishing agent is desired. Carbon dioxide for fire extinguishing is available in small cylinders for manual use, in banks of large cylinders, or in refrigerated storage tanks for piped extinguishing systems.

Dry chemical (29CFR 1910.160) extinguishers and extinguishing systems are mainly used for flammable liquids and electrical fires. They are effective also on surface fires in combustible fibers. Multipurpose dry chemical extinguishers have special ingredients which make them suitable for fires in ordinary combustibles.

PORTABLE HAND EXTINGUISHERS
(29 CFR 1910.157)

Hand-operated extinguishers and small hose are effective when employees are on hand to attack fires immediately after discovery. They are frequently used to put out the final vestiges of fires brought under control by automatic sprinklers. Grouped by hazards, the hand extinguishers are selected from four classifications, as shown by Table 18.3.1.

Table 18.3.1 Portable Extinguishers by Hazard Classification

Extinguisher type	Class A general purpose	Class B flammable liquids	Class C electrical fires	Class D combustible metal
Foam	x			
Loaded stream	x	x		
Dry chemical		x	x	
CO_2 (plastic horn)		x	x	
Vaporizing liquid		x	x	
Dry powder				x

SOURCE: NFPA Handbook, vol. 17.

18.4 PATENTS, TRADEMARKS, AND COPYRIGHTS

by Paul E. Crawford and R. Eric Hutz

PATENTS

REFERENCES: Chisum, ''Patents,'' Matthew Bender. Rules of Practice of U.S. Patent and Trademark Office, 37 C.F.R. §1, et seq.

United States

(All statutory references are to the Patent Act of 1952, 35 U.S.C., et seq.)

Types of Patents Granted in the United States United States patents are classified as utility, design, and plant patents with the first category comprising the vast majority of patents granted in the United States. A design patent can be obtained for any ''new, original and ornamental design for an article of manufacture'' (35 U.S.C. §171). The emphasis in design patents is on the ornamental, rather than functional, aspects of the article of manufacture. A plant patent may be obtained by ''whoever invents or discovers and asexually reproduces any distinct and new variety of plant'' (35 U.S.C. §161), and gives that person the right to exclude others from asexually reproducing the plant or selling or using the plant so produced (35 U.S.C. §163).

The Patent Grant In return for a full disclosure of an invention to the public in the patent document, the United States will grant an exclusive monopoly to an inventor or her or his assignee for the term of the patent. As a result of U.S. ratification of the GATT treaty, the patent term for utility patents has changed from 17 years from the grant of the patent to 20 years from the initial filing date of the application. This new patent term begins on the date the patent is issued and ends 20 years from the date of initial filing. The new 20-year term from date of filing applies to all patents granted on applications filed on or after June 8, 1995. All patents based on applications filed prior to June 8, 1995, will have a term that is the greater of the 20-year term provided by the new law or 17 years from the grant. The 20-year term can also be extended for a maximum of 5 years for delays in grant of a patent due to interferences, secrecy orders, or successful appeals to the Patent and Trademark Office (PTO) or the courts. However, any extensions are subject to certain limitations. The term for a design patent is 14 years. After the term of the monopoly expires, the public is then free to practice the invention. Alternatively, an inventory may choose not to disclose his or her invention to the public but instead maintain it as a trade secret; but by doing so, an inventor cannot stop others from using his or her invention if someone else independently develops the same invention.

Determining What Is Patentable The basic statutory requirements for patentability are utility of the invention (35 U.S.C. §101), novelty (35 U.S.C. §102), and nonobviousness (35 U.S.C. §103). To meet the utility requirement, an inventor need only disclose in his or her patent an invention which is new, useful, and functional in the field of applied technology as opposed to theoretical or abstract ideas. Also, developments in the nontechnical arts, social sciences, methods of doing business, computer programs per se, and the like are not generally patentable. However, there have been recent developments in the law that have expanded the possibilities for patenting certain types of business systems and some aspects of computer programs. A patent professional should be consulted regarding these developments.

The novelty and nonobviousness requirements of the patent laws are assessed in light of the prior art which generally comprises all written materials antedating the inventor's application for a patent and/or his or her actual date of invention (see section on interferences below for more detail on what constitutes date of invention). Also included in prior art are prior public uses and sales by others of the same or similar processes or products as that of the inventor. A prior public disclosure or offer to sell by the inventor made more than 1 year before the inventor's patent application also constitutes prior art which can prevent the grant of a patent [35 U.S.C. §102(b)]. Thus, it is crucial that patent applications be promptly filed (within a year) after any effort at commercial exploitation of an invention by or on behalf of the inventor. In assessing an invention against the novelty requirement of 35 U.S.C. §102, the courts have held that if the invention is different—without regard to how different—from each item of prior art, it meets that requirement. In other words, if no single piece of prior art discloses the invention, it is considered novel under 35 U.S.C. §102.

Since few inventions—at least not those for which patent protection is sought—are identical to any single item of prior art, the patentability of most patents must be assessed under 35 U.S.C. §103, i.e., whether ''the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.'' Such assessment requires a factual determination at the time of the invention of the prior art, differences between the prior art and the invention, and the level of skill in the art to which the invention pertains, and a further assessment whether those differences would have been obvious in light of the level of skill of the practitioners in the art. To assist in this determination, the Supreme Court has indicated that courts should look to important background facts such as long-felt need for the invention, failure of others to achieve the invention, and ultimately, any commercial success of the invention [*Graham v. John Deere Company of Kansas City*, 383 U.S. 1, 86 S.Ct. 684 (1966)].

Documentation of an Invention In ongoing research, recordation of developments is essential to prove the date of invention. The date of invention may become important in a PTO proceeding to determine priority of invention as between two inventors. Such a proceeding is called an **interference**. In an interference, the priority of invention must usually be established by contemporaneous, witnessed documentation of the work underlying the invention. A notebook used to record, explain, and date research work is invaluable in an interference to prove an early invention date. The notebook should be signed by the researcher and witnessed by one or more persons who have direct knowledge of, and understand, what was being done during the making of the invention.

Prior to the recent ratification of the GATT and NAFTA treaties, inventive activity occurring in foreign countries could not be relied upon to establish a date of invention in the United States. As a result of GATT and NAFTA, 35 U.S.C. §104 has been amended to provide that evidence of inventive activity in the territory of a World Trade Organization (WTO) member country, Canada, or Mexico be treated the same as inventive activity in the United States. This change in law applies to all applications filed on or after January 1, 1996. However, a date of invention may not be established in a WTO member country (other than the United States, Canada, or Mexico) that is earlier than January 1, 1996, except as provided by statute (35 U.S.C. §119 and §365). Thus, companies or individuals engaging in research in foreign countries may rely on that activity in an interference.

Preparing the Patent Application A recommended first step in preparing an application is to evaluate the prior art and its relation to the invention for which patent protection is to be sought, utilizing the obviousness guidelines of the Supreme Court noted above. The most comprehensive source of prior art is the search room at the PTO in Arlington, Virginia, where over 4 million patents and publications are available to the public and are broken down into thousands of classes and subclasses to facilitate a search. Less comprehensive compilations of U.S. patents can also be found in the libraries of many large cities. Copies of U.S. patents can be obtained from these libraries or directly from the PTO. Search results should be evaluated by a competent patent attorney or agent who can advise whether the invention is patentable over the prior art uncovered and who can also focus on the differences between the invention and prior art when preparing a patent application covering the invention.

If the invention, after careful evaluation, is considered to be patentable, the next step is identification of the proper inventors. In the United States, patent applications are filed in the name of the individual(s) who contributed to all or part of the invention rather than the legal owner of the invention or application, e.g., the inventor's employer. Where two or more persons contributed to all or part of the invention (a joint invention), the respective efforts of these persons must have been made in collaboration with each other and the invention must be the product of their aggregate efforts.

The patent application comprises four essential parts: the specification or detailed description of the invention; claims, particularly pointing out the features which the inventor considers to be his or her invention; a drawing illustrating the invention, where applicable; and an oath or declaration of the inventor(s) stating a belief that he or she believes himself or herself to be the original and first inventor of the invention claimed in the application (35 U.S.C. §§111–115).

In addition to the standard patent application, applicants may elect to file a provisional application. A provisional application only requires the filing of a specification complying with 35 U.S.C. §112, paragraph 1, and drawings where necessary for the understanding of the invention. The application must be made in the name of the inventors, include the appropriate filing fee and a suitable cover sheet. A provisional application does not require any claims, nor does it require an oath or declaration. A provisional application is not examined by the PTO, cannot claim priority of an earlier application, and cannot issue as a patent. In addition, provisional applications will automatically become abandoned 12 months after filing and can become abandoned prior to the expiration of that 12-month-period for failure to respond to a PTO requirement or to pay a required fee. A provisional application may be revived, but its pendency cannot extend beyond 12 months from its filing date. The provisional application is a form of domestic priority system which provides a quick and inexpensive method to establish an early effective filing date which establishes a constructive reduction to practice for any invention described in the application. However, this priority is only effective provided a suitable nonprovisional application is filed prior to the expiration of the provisional application.

Proceedings in the U.S. Patent and Trademark Office After the application is filed with the appropriate fee ($365 to $730 basic fee for utility patents; $150 to $300 for design patent; and $245 to $290 for plant patent), an examiner in the PTO reviews the application to ensure compliance with all statutory requirements as to the form of the application and to independently assess the patentability of the claims in the application in light of prior art. If found to be patentably distinct from the prior art, a patent will be granted upon payment of another fee ($605 to $1,210 for a utility patent; $210 to $420 for a design patent; $305 to $610 for a plant patent). If the examiner concludes the invention claimed in the application is not patentable over prior art, all such claims will be rejected. An administrative appeal to the Patent Office Board of Appeals is available to challenge such rejection, and a further appeal to the federal courts is available from an adverse decision of the Board of Appeals (35 U.S.C. §§134, 141, 145).

To maintain a patent, the owner must also make periodic payments to the PTO before the fourth, eighth, and twelfth anniversaries of the patent grant. These maintenance payments increase from $480 to $960 to $1,450 to $2,900 as the patent ages. Since the above-mentioned fees change annually, all fees should be determined in advance to avoid the consequences of fee underpayment.

Rights of a Patent Owner A patent gives the patent owner (either original applicant or her or his assignee) the right to prevent anyone else from infringing upon his or her patent rights by making, using, offering to sell, selling within the United States, or importing the patented invention into the United States. If someone else does infringe a patent, the patent owner can seek an injunction against further infringement and/or damages for such unauthorized use of his or her invention (35 U.S.C. §§281–284). The federal courts have exclusive jurisdiction over suits relating to patents.

A patent owner may commercially exploit his or her patent by selling (assigning) or licensing it to another. Multiple licenses can be granted under a single patent giving each licensee nonexclusive rights under the patent. Geographic and use limitations in a license are also possible as a means of maximizing the patent owner's benefit from his or her patent.

Reissue and Reexamination of Patent If through inadvertence, accident, or mistake, the original patent was defective or claimed too much or too little, the error may be repaired by a reissue proceeding provided the subject matter needed to correct the mistake appeared in the original patent (35 U.S.C. §251). The term of a reissued patent expires the day the original patent would have expired.

Also, if the patentability of a patent is put in question, either the patent owner or a third party may ask the PTO to reexamine and reevaluate the patent vis-à-vis the prior art. The PTO then proceeds to examine the patent much the same as it would with an original application.

Foreign Countries

International Convention for the Protection of Industrial Property The important provision of the convention is that any person who has duly applied for a patent in one of the contracting states shall have a right of priority for 12 months in making application in the other states.

Patent Cooperation Treaty (PCT) and European Patent Convention (EPC) To simplify the process of obtaining foreign patents, it is now possible to file a single application, e.g., in the United States, and have that application mature into a patent in each country worldwide which is a member of the Patent Cooperation Treaty. Similarly, if the focus of intended patent protection is in Europe, a single application in the European Patent Office located in Berlin, Munich, or the Hague can be issued as a patent in most of the countries on the European continent under the European Patent Convention.

Use of either the PCT or EPC provisions will generally be cost-effective versus separate filings in individual countries, since, for example, translation costs are usually minimized or eliminated. However, as in all such complex matters, knowledgeable patent professional counsel should be consulted.

TRADEMARKS

REFERENCES: Callman, ''Unfair Competition, Trademarks and Monopolies,'' Callaghan and Co., Chicago. McCarthy, ''Trademarks and Unfair Competition,'' Lawyers Cooperative, Bancroft-Whitney. Gilson, ''Trademark Protection and Practice,'' Matthew Bender.

United States

[Section references (§) refer to Lanham Act of 1946, and 15 U.S.C., both section numbers being given.]

What Is a Trademark? The term *trademark* includes any word, name, symbol, or device or any combination thereof adopted and used by manufacturers or merchants to identify their goods and distinguish them from those manufactured or sold by others (§45, §1127). A *service mark* is defined as a mark used in the sale or advertising of services to identify the services of one person and distinguish them from the services of others (§45, §1127).

How Rights in a Mark Are Obtained Unlike a patent, but somewhat like a copyright, ownership of a mark is obtained by use. If use occurs only within a state, a mark may be registered in that state. Forms for registering marks under state law are obtainable from the Secretary of State of each state. If use occurs only in interstate or foreign commerce, a mark may be registered in the U.S. Patent and Trademark Office (PTO) by filing an application in the form prescribed (37 C.F.R. Pt. IV).

After federal registration the symbol ® may be used with the mark. Prior to federal registration, the symbols **TM** for a trademark or **SM** for a service mark may be used to give notice of a claim of common law or state law rights.

A person who has a bona fide, good-faith intention to use a trademark in commerce, but is not actually using the mark, may apply for registration by filing an Intent To Use application in the PTO. Thus, a person who is not actually using a mark may still obtain federal registration provided that person commences using the mark in interstate commerce within a specified period after allowance of the Intent To Use application.

Tests for Registrability and Infringement A mark may be registrable on the Principal Register only if, when applied to the goods or used in connection with the services, it is not likely to cause confusion or mistake or to deceive. The same test is used to determine whether a mark infringes on an earlier mark. Marks that are descriptive, misdescriptive, geographical, or primarily merely a surname may not be registrable on the Principal Register, if at all, until after 5 years of substantially exclusive and continuous use in interstate commerce (§2[f], §1052[f]). Marks not registrable on the Principal Register may be registrable on the Supplemental Register if they are capable of becoming distinctive as to the applicant's goods or services (§23, §1091).

Term of Registration Federal registrations remain in force for 10 years unless canceled. However, unless an affidavit is filed during the sixth year after registration showing that the mark is still in use, the Commissioner of Patents and Trademarks will cancel the registration of the mark (§8, §1058). In addition, federal registrations only remain in force for marks which are actually in use. Nonuse of a registered mark can result in a finding that the mark has been abandoned by its owner. The law currently provides that nonuse of a mark for 2 years or longer is prima facie evidence that the mark has been abandoned. Within the sixth year after registration on the Principal Register a registered mark may become more secure from legal challenge, i.e, ''incontestable'' upon the filing of the required affidavit (§15[3], §1065[b]). During the last 6 months of the registration term an application for renewal may be filed (§9, §1059). The terms of state registrations vary.

Preliminary Search Before adopting a mark, it is advisable to have a search made in the PTO to determine whether the mark under consideration would conflict with any pending application, registrations, or others' use of the mark in connection with any similar goods or services.

Cost of Registering a Mark Government fees and time for payment are fixed by law (§31, §1113) but attorneys' fees vary.

Effect of Federal Registration Federal registration of a mark affords nationwide protection, and once the certificate has been issued, no person can acquire any additional rights superior to those obtained by the federal registrant. Federal registration of a mark establishes federal jurisdiction in an infringement action, can be the basis for treble damages, and is admissible as evidence of trademark rights. Registration on the Principal Register constitutes constructive notice, constitutes prima facie or conclusive evidence of the exclusive right to use the mark in interstate commerce, may become incontestable, and may be recorded with the United States Treasury Department to bar importation of goods bearing an infringing trademark.

Assignment of a Mark A mark can be assigned only in conjunction with the goodwill of the business or that portion thereof with which the mark is associated. Assignments of registered marks or of applications for registration should be recorded in the United States Patent and Trademark Office within 3 months after the date of assignment (§10, §1060).

Foreign Countries

Registration In general, most foreign countries require the registration of a mark in compliance with local requirements for trademark protection. In most countries registration is compulsory and provides the sole basis for protection of a trademark. A few countries afford common-law protection to unregistered marks. Because the laws and regulations in foreign countries regarding trademark registration vary so much, it is not practicable to summarize the requirements for registration in the space allocated to this note. Anyone interested in foreign protection of a mark should consult an attorney.

COPYRIGHTS

REFERENCES: Nimmer, ''Nimmer on Copyright,'' Matthew Bender. Copyright Office Regulations, 37 C.F.R., Chapter 2.

United States

[Section references (§) refer to Copyright Act of 1976, 17 U.S.C.]

Subject Matter of Copyright Copyright protection subsists in works of authorship in literary works, musical works including any accompanying words, dramatic works, including any accompanying music, pantomimes and choreographic works, pictorial, graphic, and sculptural works, motion pictures and other audiovisual works, and sound recordings, but not in any idea, procedure, process, system, method of operation, concept, principle, or discovery [§102]. However, copyright protection may be obtained for computer programs, including both the source code and object code. In addition, owners of copyrights covering computer programs (including any tape, disk, or other medium embodying such program) generally have the right to authorize or prohibit commercial rental to the public of the originals or copies of their copyrighted work. Noncommercial transfers of lawfully made copies of computer programs by a nonprofit educational institution to another nonprofit educational institution or to faculty, staff, and students does not constitute rental, lease, or lending under the copyright laws.

Method of Registering Copyright After publication (sale, placing on sale, public distribution), registration may be effected by an application to the Register of Copyrights along with the fee ($20.00) and two copies of the writing (§401; 407; 409). The Copyright Office (Register of Copyrights, Library of Congress, Washington, DC 20540) supplies without charge the necessary forms for use when applying for registration of a claim to copyright.

Form of Copyright Notes The notice of copyright required (§401) shall consist either of the word ''copyright,'' the abbreviation ''Copr.,'' or the symbol ©, accompanied by the name of the copyright owner and the year date of first publication.

The copyright notice for phonorecords of sound recordings should contain the symbol Ⓟ, the name of the copyright owner, and the year date of first publication.

Who May Obtain Copyright Only the author or those deriving their rights through the author can rightfully claim copyright protection. Where a copyrighted work is prepared by an employee within the scope of his or her employment (a ''work made for hire''), the employer and not the employee is considered to be the author. The name of the author (creator of the work) is normally used in the copyright notice even though an assignee may file the application for registration.

Duration of Copyright Copyright in a work created on or after January 1, 1978, subsists from its creation and, with certain exceptions, endures for a term consisting of the life of the author and 50 years after the author's death (§302). Copyright in the work created before January 1, 1978, but not theretofore in the public domain or copyrighted, subsists from January 1, 1978, and endures for the term provided by §302. In no case, however, shall the copyright term in such a work expire before December 31, 2002; and, if the work is published on or before December 31, 2002, the term of copyright shall not expire before December 31, 2027 (§303). Any copyright, the first term of which is subsisting on January 1, 1978, shall endure for 28 years from the date it was originally secured, with certain exceptions (§304). All terms of copyright provided by §302–304 run to the end of the calendar year in which they would otherwise expire (§305).

Infringement of Copyright A violation of any of the exclusive rights (§1) by a person not licensed could lead to liability (§101) for infringement. Actions for infringement of copyright are brought in the U.S. district courts.

Consulting Attorneys An attorney should be consulted before publication unless the author or proprietor has previously registered copyrights. A mistake could cause the copyright to be lost if the work is published without proper notice.

Foreign Countries

Universal Copyright Convention Under this convention a U.S. citizen may obtain a copyright in most countries of the world simply by publishing within the United States using the prescribed notice, namely, © accompanied by the name of the copyright proprietor and the year of first publication placed in such manner and location as to give reasonable notice of claim of copyright. While the term ''Copyright'' on the notice is adequate for copyright under U.S. law, only the © is recognized under the convention.

18.5 MISCELLANY

Staff Contribution

The engineering environment may be broadened to include the professional working environment in which engineers conduct their practice. Ultimately, the engineers' endeavors result in a product of some sort, be it a tangible item or drawings, specifications, inspection documents, research reports, and the like. Keeping that in mind, the subjects which follow address briefly some aspects pertinent to the practice of engineering.

PERSONNEL

The engineer often will employ other persons, and as an employer, the engineer is subject to all applicable laws and regulations related to the employer-employee relationship. The administration of personnel matters will involve the engineer directly or will be delegated to a surrogate within the organization. Among the things which relate to personnel are worker's compensation insurance; accident and health insurance; antidiscrimination laws related to hiring, termination, and promotion; general liability insurance; and so on. Depending upon the staffing and the type of work which is performed in the engineer's office, it may prove prudent to carry employer's liability insurance to cover situations which are excluded from worker's compensation and general liability insurance. In these regards, it is wise to seek legal counsel.

If the employees are affiliated with organized labor, collective bargaining will be involved with the one or more unions representing the employees, and it will encompass matters such as pay, fringe benefits, and working conditions.

The objective of good personnel administration is to have the entity run smoothly, with maximum interpersonal harmony and good will so that the organization will prosper.

Some other pertinent details related to personnel administration are discussed briefly in Sec. 17.1.

PROFESSIONAL ENGINEER LICENSING AND REGISTRATION

Many engineers, whether self-employed or employed by others, may seek to obtain a license as a registered professional engineer. Generally, the terms *licensed professional engineer* and *registered professional engineer* are synonymous.

The licensing of professional engineers (and of those in other professions and trades) falls under the aegis of the individual state education departments, which control and administer professional licensing within the state's jurisdiction. In years past, some states granted the license as a professional engineer to a few persons who, although lacking formal credentials (education and otherwise), had a demonstrated record of performance of the duties of a professional engineer. The licenses were granted under ''grandfather'' clauses. This is now very seldom the case.

The usual route to obtain a license as a professional engineer is via a combination of education, experience, and written examination. The successful attainment of an undergraduate degree in engineering will admit the applicant to a first examination, the successful completion of which results in the applicant being granted a certificate as Engineer in Training (EIT). Additional suitable experience for another 4 years admits the EIT into the final written examination for professional engineer. The successful completion of the final examination results in the award of a license as Professional Engineer.

Federal, state, and most local municipalities require that their key engineering personnel be licensed professional engineers. Engineering documents submitted to those bodies, likewise, will require that the signatory thereto be a licensed professional engineer.

There are minor variations from state to state as to acceptable experience, the degree to which academic experience may be acceptable as engineering experience, etc.; but by and large, there is a degree of uniformity among the state education departments in the matter of licensing professional engineers.

Professional engineers active in several state jurisdictions may be required to obtain a license as professional engineer in those different states. To that end, most states have established procedures to grant a license as professional engineer by comity, but usually this will be possible only if the original license was granted on the basis of a written examination. Comity is often initiated through the offices of the National Society of Professional Engineers as a service to its members.

The work bearing the professional engineer's seal is considered creative work and is so addressed in most stated education laws. The work carries an implicit copyright, even though a statement to that effect may not be placed on the documents. Said work is the property of the professional engineer; unauthorized copying of such documents is illegal, and violators are subject to legal action and redress.

The basic intent of formal licensing of professional engineers is to protect the public from incompetent practice. A licensed professional engineer whose competence is called into question is subject to formal investigative procedures, and when the circumstances warrant it, the license may be revoked or suspended.

Detailed information regarding license as a professional engineer can be obtained from the state education department having jurisdiction, and it will set forth the requirements, privileges, and responsibilities inherent in the granting of the license.

PRODUCT LIABILITY

In the current consumer and/or user climate, the matter of product liability has assumed a large role and often impacts upon the engineer's input to certain products. In some cases, the engineer may be held personally responsible and liable for some outcome even though the engineer may have been employed by others. The case reports of litigation involving product liability are voluminous, and it is not surprising that identical circumstances will result in verdicts different from one jurisdiction to another. The laws related to product liability are based principally on two concepts: negligence and strict liability. The details are not addressed here; suffice it to say that the engineer who faces product liability litigation must retain competent legal counsel to prepare and implement an appropriate defense.

PROFESSIONAL LIABILITY INSURANCE

This type of insurance is often carried by engineers in private practice to protect the engineer as well as to provide relief to an injured party, when the latter may result from error(s) and/or omission(s) in the documents prepared by the engineer; hence, the term *errors and omissions insurance,* or E&O insurance. The nature of professional liability insurance is quite complex and is usually handled between the engineer and the insurer, often with the active participation of the engineer's legal counsel. Essentially, in obtaining professional liability insurance, the engineer enlists a broader financial entity (the insurance company) to absorb the major portion of the costs of claims in exchange for a premium paid to the insurance company. Decisions related to professional liability insurance evolve from the management decisions made by the engineer (or the firm), as part of the overall conduct of the engineering practice and consideration of the financial risks incurred thereby.

In many cases, before any work proceeds, the client will require that the engineer provide evidence that professional liability insurance is in effect, and that evidence often is incorporated into the contractual agreement between engineer and client.

Professional liability insurance policies are traditionally of the claims-made type. Claims arising out of work undertaken and performed while the policy is in effect will be covered. Claims arising from that work at a later date will **not** be covered unless the insurance has continued in effect to the time the claim is made. All coverage ceases when the policy is canceled or not renewed.

Insurance premiums depend on several factors: limits of liability, deductibles, type of work performed and the services rendered in connection therewith, experience of engineer and his or her ''track record,'' and the geographic location of the work (there are low-risk states and high-risk states). There are other factors which may be subject to consideration by the insurer.