
Emission Standards

I. SUBJECTIVE STANDARDS

Limits on emissions are both subjective and objective. Subjective limits are based on the visual appearance or smell of an emission. Objective limits are based on physical or chemical measurement of the emission. The most common form of subjective limit is that which regulates the optical density of a stack plume, measured by comparison with a Ringelmann chart (Fig. 27.1). This form of chart has been in use for over 90 years and is widely accepted for grading the blackness of black or gray smoke emissions. Within the past four decades, it has been used as the basis for "equivalent opacity" regulations for grading the optical density of emissions of colors other than black or gray.

The original Ringelmann chart was a reflectance chart; the observer viewed light reflected from the chart. More recently, light transmittance charts have been developed for both black [1] and white [2] gradations of optical density, which correlate with the Ringelmann chart scale. It is now common practice in the United States to send air pollution inspectors to a "smoke school" where they are trained and certified as being able to read the density of black and white plumes with an accuracy that is acceptable for court testimony.

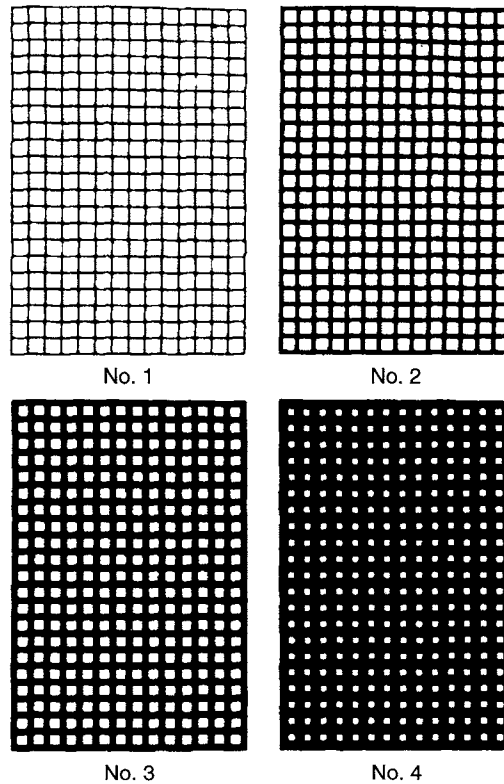


Fig. 27.1. Ringelmann smoke chart.

Before the widespread acceptance of the Ringelmann scale, smoke was regulated by prohibiting the emission of black smoke. Now regulatory practice prohibits the emission of smoke whose density is greater than a specified Ringelmann number. Over recent decades, there has been a progressive decrease in the Ringelmann number thus specified, culminating in the specification of number 1 for large new steam power plants in the United States. In addition to subjective observation of smoke density, continuous emission monitoring systems (CEMs) have been developed to measure objectively, by means of a photocell, the decrease in intensity of a beam of light projected through the plume prior to its emission (Fig. 27.2). Such systems are discussed in Chapter 32.

Subjective evaluation of odor emission is made difficult by the phenomenon of odor fatigue, which means that after persons have been initially subjected to an odor, they lose the ability to perceive the continued presence of low concentrations of that odor. Therefore, all systems of subjective odor evaluation rely on preventing olfactory fatigue by letting the observer breathe odor-free air for a sufficient time prior to breathing the odorous air

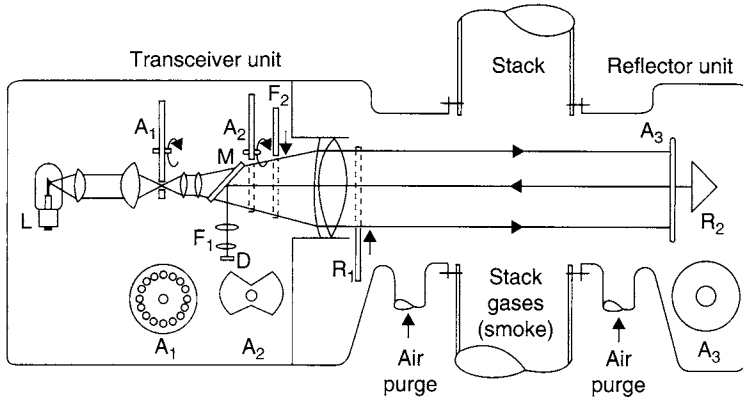


Fig. 27.2. Double-beam, double-pass transmissometer for measuring smoke density in stacks. A_1 , chopper wheel; A_2 , beam gating wheel; A_3 , aperture; D, detector; F_1 , spectral filter; F_2 , solenoid-activated neutral density filter; L, lamp; M, half-mirror/beam splitter; R_1 , solenoid-activated zero calibration reflector; R_2 , retroreflector (alignment bullseye not shown). Design patented. Source: Drawing courtesy of Lear Siegler, Inc.

and evaluating its odor content. Usually an activated charcoal bed is used to clean up the air in order to provide the odor-free air required by the observer.

II. OBJECTIVE STANDARDS

There are two major categories of objective emission limits: those which limit the emission of a specific pollutant, regardless of the process or equipment from which it is emitted, and those which limit the emissions of a specific pollutant from a specific process or type of equipment. Regulations may require the same emission limit for all sources, regardless of size or capacity; or they may vary the allowable emission with the size or capacity of the source. Limits may be stated in absolute terms, i.e. not more than a specified mass of pollutant per unit of time, or in relative terms, i.e. not more than a specified mass of pollutant per unit mass of fuel burned, material being processed, or product produced or per unit of heat released in a furnace. In the case of gaseous pollutants, limits may be stated in volumetric rather than gravimetric terms. Emission limits are sometimes stated as mass of pollutant per unit volume of effluent. Effluent volume varies with gas temperature and pressure, the presence or absence of diluting air, and the amount thereof. Therefore, volumes must be reduced to a specified temperature, pressure, and percent of diluting air. In the case of flue gases from fuel combustion, dilution is usually expressed as percentage of excess air or percentage of carbon dioxide or oxygen in the flue gas.

The pollutants, source categories, and affected facilities for which the United States has established New Source Performance Standards (NSPS) are listed in Table 27.1. Certain categories listed in Table 27.1 are subject to US

TABLE 27.1

US National New Source Performance Standards

Source category (in sequence of promulgation)	Affected facility	Pollutants regulated									
		Particulate matter	Opacity	SO ₂	NO _x	H ₂ S	CO	TRS	VOC	Pb	Total F
Fossil fuel and electric utility steam generator ^d [>73 MW (>250 million BTU h ⁻¹ input) (264 KJ h ⁻¹)	Solid fossil fuel and wood residue-fired	x	x	x	x	—	—	—	—	—	—
	Oil- or gas-fired boilers	x	x	x	x	—	—	—	—	—	—
Incinerators ^a	>45 metric tons day ⁻¹	x	—	—	—	—	—	—	—	—	—
Portland cement plants ^a	Kiln and clinker cooler	x	x	—	—	—	—	—	—	—	—
	Fugitive emission points	—	x	—	—	—	—	—	—	—	—
Nitric acid plants ^a	Process equipment	—	x	—	x	—	—	—	—	—	—
Sulfuric acid plants	Process equipment	x ^b	x	x	—	—	—	—	—	—	—
Asphalt concrete plants	Dryers, etc. ^c	x	x	—	—	—	—	—	—	—	—
Petroleum refineries ^a	Fluid catalyst regenerator	x	x	—	—	—	x	—	—	—	—
	Fuel gas combustion	—	—	x	—	x	—	—	—	—	—
	Claus sulfur recovery TRS X ^d	—	—	x	—	—	—	x	—	—	—
Storage vessels for petroleum liquids ^a	Storage tanks	—	—	—	—	—	—	—	x	—	—
Secondary lead smelters ^a	Reverberatory and blast furnaces	x	x	—	—	—	—	—	—	—	—
Secondary brass and bronze plants ^a	Pot furnaces	—	x	—	—	—	—	—	—	—	—
	Reverberatory furnaces	x	x	—	—	—	—	—	—	—	—
Iron and steel plants ^a	Blast and electric furnaces	—	x	—	—	—	—	—	—	—	—
	Basic O ₂ and electric arc furnaces	x	x	—	—	—	—	—	—	—	—
	Dust-handling equipment	—	x	—	—	—	—	—	—	—	—

Sewage treatment plants	Sludge incineration	x	x	—	—	—	—	—	—	—	—
Primary copper smelters	Dryer	x	x	—	—	—	—	—	—	—	—
	Roaster, furnace, convertor	—	x	x	—	—	—	—	—	—	—
Primary lead smelters ^a	Blast and reverberatory furnaces ^e	x	x	—	—	—	—	—	—	—	—
	Electric furnace converter ^f	—	x	x	—	—	—	—	—	—	—
Primary zinc smelters	Sinter machine	x	x	—	—	—	—	—	—	—	—
	Roaster	—	x	x	—	—	—	—	—	—	—
Primary aluminum reduction plants ^a	Potrooms and anode baking	—	x	—	—	—	—	—	—	—	x
Phosphate fertilizer plants ^d	Wet process phosphoric acid ^g	—	—	—	—	—	—	—	x	—	—
Coal preparation plants ^a	Coal cleaning and dryer	x	x	—	—	—	—	—	—	—	—
	Transfer, loading ^h	—	x	—	—	—	—	—	—	—	—
Ferroalloy production facilities	Electric submerged-arc furnaces	x	x	—	—	—	x	—	—	—	—
	Dust-handling equipment	—	x	—	—	—	—	—	—	—	—
Kraft pulp mills ^a	Smelt tanks and lime kilns	x	—	—	—	—	—	x	—	—	—
	Recovery furnaces	x	x	—	—	—	—	x	—	—	—
	Digester, washer, etc. ⁱ	—	—	—	—	—	—	x	—	—	—
Glass manufacturing plants	Melting furnaces	x	—	—	—	—	—	—	—	—	—
Grain dryers	Dryers	x	x	—	—	—	—	—	—	—	—
Grain elevators	Truck-loading stations ^j	x	x	—	—	—	—	—	—	—	—
Gas turbines > 1000 hp (10 ⁷ GJ h ⁻¹)	Simple, regen., and combined	—	—	x	x	—	—	—	—	—	—
	Lime hydrators	x	—	—	—	—	—	—	—	—	—
Automobile and truck surface coating	Prime, guide, and topcoat	—	—	—	—	—	—	—	x	—	—
Ammonium sulfate manufacturing	Dryers	x	x	—	—	—	—	—	—	—	—
Lead acid battery manufacturing	Casting, mixing reclamation and oxide manufacture	—	—	—	—	—	—	—	—	x	—
Phosphate rock plants ^a	Drying, calcining, grinding	x	x	—	—	—	—	—	—	—	—

(continued)

TABLE 27.1 (Continued)

Source category (in sequence of promulgation)	Affected facility	Pollutants regulated									
		Particulate matter	Opacity	SO ₂	NO _x	H ₂ S	CO	TRS	VOC	Pb	Total F
Rotogravure printing	Each press	—	—	—	—	—	—	—	x	—	—
Large appliance surface coating	Each coating operation	—	—	—	—	—	—	—	x	—	—
Metal coil surface coating	Each coating operation	—	—	—	—	—	—	—	x	—	—
Asphalt processing and roofing manufacture	Saturator	x	x	—	—	—	—	—	—	—	—
	Blowing still	x	—	—	—	—	—	—	—	—	—
	Storage and handling	—	x	—	—	—	—	—	—	—	—
Beverage can surface coating	Each coating operation	—	—	—	—	—	—	—	—	x	—
Bulk gasoline terminals	All loading racks	—	—	—	—	—	—	—	x	—	—

Note: TRS, total reduced sulfur; VOC, volatile organic carbon; F, fluorides.

^a Subject to PSD review if emission potential exceeds 90 metric tons year⁻¹.

^b Acid mist.

^c Screening and weighing systems; storage, transfer, and loading systems; and dust handling equipment.

^d Reduced sulfur compounds plus H₂S.

^e Sintering machine discharge.

^f Sintering machine.

^g Superphosphoric acid, diammonium phosphate, triple superphosphate, and granular triple superphosphate.

^h Processing and conveying equipment and storage systems.

ⁱ Evaporator, condensate stripper, and black liquor oxidation systems.

^j Truck unloading stations, barge, ship, or railcar loading and unloading stations; grain and rack dryers and handling operations.

Source: Pahl, D., *J. Air Pollut. Control Assoc.* 33, 468–482 (1983).

Prevention of Significant Deterioration (of air quality) (PSD) review if their emission potential of a regulated pollutant exceeds 100 tons per year. In addition, PSD review is required for the following sources, whose emission potential exceeds 100 tons per day: hydrofluoric acid plants, coke oven batteries, furnace process carbon black plants, fuel conversion plants, taconite ore processing plants, gas fiber processing plants, and charcoal production plants.

III. TYPES OF EMISSION STANDARDS

The most common rationale for developing emission limits for stationary sources is the application of the best practicable means for control. Under this rationale, the degree of emission limitation achievable at the best designed and operated installation in a category sets the emission limits for all other installations of that category. As new technology is developed, what was the best practicable means in 1993 may be short of the best attainable in 2003. Because there is thus a moving target, means must be provided administratively to allow the plant which complied with a best practicable means limit to be considered in compliance for a reasonable number of years thereafter. It is important to note that best practicable means limits are set without regard to present or background air quality or the air quality standards for the pollutants involved, the number and location of sources affected by the limit, and the meteorology or topography of the area in which they are located. However, an additional limit on minimum stack height, or buffer zone, based on these noted factors may be coupled with a best practicable means limit on mass or emission.

The other major rationales for developing emission limits have been based on some or all of the noted factors—air quality, air quality standards, number and location of sources, meteorology, and topography. These include the rollback approach, which involves all these factors except source location, meteorology, and topography; and the single-source mathematical modeling approach, which considers only the air quality standard and meteorology, ignoring the other factors listed.

IV. VARIANT FORMS OF EMISSION STANDARDS

Some variants of best practicable means were spelled out in the US Clean Air Act of 1977. One is the requirement that Best Available Control Technology (BACT) for a specific pollutant be employed on new “major sources” that are to be located in an area that has attained the National Ambient Air Quality Standard (NAAQS) for that pollutant. BACT is also required for pollutants for which there is no NAAQS [e.g. total reduced sulfur (TRS), for which emission limits are specified by a Federal NSPS]. BACT must be at least as stringent as NSPS but is determined on a case-by-case basis.

Another variant is the lowest achievable emission rate (LAER) for a specific pollutant required for a new source of that pollutant to be located in a nonattainment area (i.e. one which has not attained the NAAQS for that pollutant). LAER is the lowest emission rate allowed or achieved anywhere without regard to cost or energy usage. LAER is intended to be more stringent than BACT or NSPS and is also determined on a case-by-case basis.

This changed with the passage of the Clean Air Act Amendments of 1990 and the subsequent regulations. The Maximum Achievable Control Technology (MACT) standards continued for some years, but incrementally have been phased-out in favor of standards to address the margin of risk that remained from the technology-based standards. This is known as residual risk. Section 112(f) of the Act directs the Environmental Protection Agency (EPA) to prepare a report to Congress on the methods to be used to address this residual risk from sources that emit hazardous air pollutants (HAPs) have been promulgated and applied. The EPA presents a discussion of how it intends to provide the Act's mandate to "provide an ample margin of safety to protect public health" or to set more stringent standards, if necessary, "to prevent, taking into consideration costs, energy, safety, and other relevant factors, an adverse environmental effect." This includes both human and ecological risk.

All of the 96 MACT regulations for 174 industry source categories are being reviewed to eliminate 1.5 million tons per year of 188 toxic air pollutants listed in the Clean Air Act. The 1989 National Emission Standard for Hazardous Air Pollutants (NESHAP) for benzene¹ presented the following risk management framework for cancer risk, which reflects the two-step approach suggested by the court. The benzene rule preamble states that in determining acceptable risk:

The Administrator believes that an MIR [maximum individual risk] of approximately 1 in 10 thousand should ordinarily be the upper-end of the range of acceptability. As risks increase above this benchmark, they become presumptively less acceptable under Section 112, and would be weighed with the other health risk measures and information in making an overall judgment on acceptability. Or, the Agency may find, in a particular case, that a risk that includes MIR less than the presumptively acceptable level is unacceptable in light of the other health risk factors.

The MIR, the distribution of risks in the exposed population, incidence, the science policy assumptions and uncertainties associated with risk measures, and the weight of evidence that a pollutant is harmful to health are all key determinants used to judge safety and risk. To ensure protection of public health and the environment, the Section 112(f) requires a human health risk and adverse environmental effects based "needs test" in the second regulatory phase of the air toxics program. This residual risk standard setting considers the need for additional national standards on stationary emission sources following regulation under Section 112(d) to "provide an ample

¹ US Environmental Protection Agency, 1989, National emission standards for hazardous air pollutants; benzene. *Fed. Regist.* 54 (177), 38044–38072, Rule and Proposed Rule, September 14.

margin of safety to protect public health.” The section also mandates the EPA to determine whether residual risk standards are necessary to prevent adverse environmental effects, taking into consideration “costs, energy, safety, and other relevant factors” in deciding what level is protective. Adverse environmental effect is defined in Section 112(a)(7) as “any significant and widespread adverse effect, which may reasonably be anticipated, to wildlife, aquatic life, or other natural resources, including adverse impacts on populations of endangered or threatened species or significant degradation of environmental quality over broad areas.”

On March 31, 2005 the EPA issued final amendments to reduce emissions of toxic air pollutants, or air toxics, from coke oven batteries; these were the first of a series of emissions reductions under the new residual risk standards. Across the industry, this rule will require reductions of allowable emissions from 11.3 tons per year under the 1993 MACT to 9.8 tons per year under the amendments. This rule was also designed to ensure that the affected batteries do not increase their emissions back to the levels allowed in 1993. The final amendments include more stringent requirements for certain processes at several coke oven batteries to address health risks remaining after implementing EPA’s October 1993 air toxics emission MACT standards.

The final amendments also include requirements for new or reconstructed coke oven batteries that reflect improvements in emission control practices that have occurred in the years since the 1993 MACT standards. This applies to coke oven emissions from nine batteries at five coke plants for which the 1993 MACT standard applied. There are approximately 14 other coke oven plants in the country that are not affected by this rule because they chose to install more stringent controls than the MACT the LAER, beginning in 1993. Because these LAER batteries opted to reduce their emissions by more than the 1993 MACT required, they do not have to comply with residual risk rule until the year 2020. The final amendments apply to charging, leaks, and bypass stacks at coke oven batteries. Emissions from these processes occur at the start of the process of turning coal into coke, primarily as the coke ovens are heating up. Thus, residual risk measures focus in a number of areas, beyond technology.

V. MEANS FOR IMPLEMENTING EMISSION STANDARDS

When owners wish to build a new source which will add a certain amount of a specific pollutant to an area that is in nonattainment with respect to that pollutant, they must, under US federal regulations, document a reduction of at least that amount of the pollutant from another source in the area. They can effect this reduction, or “offset,” as it is called, in another plant they own in the area or can shut down that plant. However, if they do not own another such plant or do not wish to shut down or effect such reduction in a plant they own, they can seek the required reduction or offset from another owner.

Thus, such offsets are marketable credits that can be bought, sold, traded, or stockpiled ("banked") as long as the state or local regulatory agency legitimizes, records, and certificates these transactions. The new source will still have to meet NSPS, BACT or MACT, and/or LAER standards, whichever are applicable.

A. Bubble Concept

When a new source has been added to a group of existing sources under the same ownership in the same industrial complex, the usual practice has been to require the new source independently to meet the offset, NSPS, BACT, and/or LAER, disregarding the other sources in the complex. Under the more recent "bubble concept" (Fig. 27.3) adopted by some states with the approval of the EPA, the addition of the new source is allowed, whether or not it meets NSPS, BACT, or LAER, provided the total emission of the relevant regulated pollutants from the total complex is decreased. This can be accomplished by obtaining the required offset from one or more of the other sources within the the complex, by shutdown, or by improvement in control efficiency. The bubble concept has been subject to litigation and may require a ruling or challenge to make it acceptable.

B. Fugitive and Secondary Sources

In computing the potential for emission of a new source or source complex, it is necessary to consider two other source categories, "fugitive" and "secondary" sources. Fugitive emissions are those from other than point sources, such as unpaved plant roads, outdoor storage piles swept by the wind, and surface mining. Secondary sources are those small sources with emissions of a different character from those of a major source, necessary for the operation of the major source, or source complex.

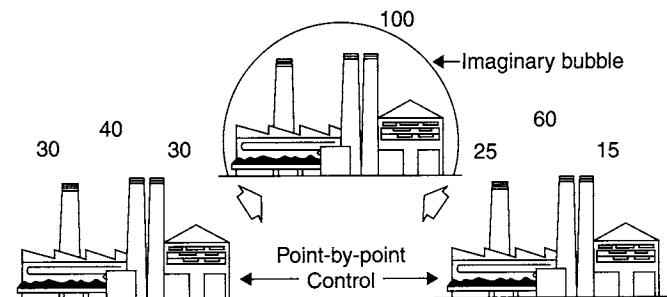


Fig. 27.3. Bubble concept. This pollution control concept places an imaginary bubble over an entire industrial plant, evaluating emissions from the facility as a whole instead of requiring control point-by-point on emission sources. Numbers represent emissions from individual sources, some of which can be fugitive sources, and from the entire industrial plant. *Source:* Drawing courtesy of the Chemical Manufacturers Association.

C. Indirect Sources

The term *indirect sources* is used to describe the type of source created by the parking areas of shopping malls, sports arenas, etc. which attract large numbers of motor vehicles, frequently arriving and leaving over relatively short periods of time. Of somewhat similar character are traffic interchanges, as at an intersection of major highways, each highway being a line source in its own right.

D. Rollback

The rollback approach assumes that emissions and atmospheric concentrations are linearly related, i.e. that a given percentage reduction in emission will result in a similar percentage reduction in atmospheric concentrations. This is most likely a valid assumption for a nonreactive gas such as carbon monoxide, whose principal source is the automobile. The model is

$$R = \frac{g(P) - D}{g(P) - B} \times 100 \quad (27.1)$$

where R is the required percentage reduction in emission, P is the present air quality, D is the air quality standard, B is the background concentration, and g is the growth factor in emissions (g is projected to a year in the future when emissions are expected to apply to all vehicles on the road).

An example of a set of emission limits based on the rollback approach is the limits adopted by the United States for carbon monoxide, hydrocarbons, and oxides of nitrogen emissions from new automobiles (Table 27.2).

E. Standard for Hazardous Pollutants

Before the US Clean Air Act Amendments of 1990 [3], HAPs were regulated through federal promulgation of the NESHAPS. The EPA listed only eight HAPs under NESHAPS.

Title III of the 1990 amendments completely changed the US standards for the hazardous air pollutant control program. Stensvaag [6] has summarized these changes as follows:

- Massively expand the list of HAPs. This initial list contained 189 HAPs.
- Direct the EPA to list source categories of major sources and area sources.
- Promulgate technology-based emission standards for listed pollutants and sources.
- Set up programs to control accidental releases.
- Establish structures for future risk assessment.
- Require regulation of solid waste combustion facilities.

Useful life, intermediate ^{b, d} (full)	5	5	5	5	5	5	5	5	5	5	10	10	10	10	10	10
	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 50 000	years/ 100 000	years/ 100 000	years/ 100 000	years/ 100 000	years/ 120 000	years/ 120 000
	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles	miles

^a The test procedure for measuring exhaust emissions has changed several times over the course of vehicle emissions regulations. The 7-mode procedure was used through model year 1971 and was replaced by the CVS-72 procedure beginning in model year 1972. The CVS-75 procedure became the test procedure as of model year 1975. While it may appear that the total HC and CO standards were relaxed in 1972–74, these standards were actually more stringent due to the more stringent nature of the CVS-72 test procedure. Additional standards for CO and composite standards for NMHC and NO_x tested under the new Supplemental Federal Test Procedure will be phased-in beginning with model year 2000; these standards are not shown in this table.

^b All emissions standards must be met for a useful life of 5 years/50 000 miles. Beginning with model year 1994, a second set of emissions standards must also be met for a full useful life of 10 years/100 000 miles; these standards are shown in parentheses. Tier 1 exhaust standards were phased-in during 1994–96 at a rate of 40%, 80%, a 100%, respectively.

^c The cold CO emissions standard is measured at 20 F (rather than 75 F) and is applicable for a 5 year/50 000 mile useful life.

^d The “Prior to control” column reports emissions estimates of a typical newly manufactured car in the years before exhaust emissions certification standards were implemented.

^e No estimate available.

^f Manufacturers can opt to certify vehicles for a full useful life of 15 years/150 000 miles and have either (1) intermediate useful life standards waived or (2) receive additional NO_x credits.

^g In 1968–1969, exhaust emissions standards were issued in parts per million rather than grams per mile and are, therefore, incompatible with this table.

^h No standard has been set.

ⁱ The term “tier” refers to a level of standards and is associated with specific years. Interim Tier 2 refers to an intermediate level of standards that move manufacturers toward compliance with Tier 2 standards. Interim Tier 2 and Tier 2 standards are established as “bins.” Each bin is a set of standards for NO_x, CO, NMOC, formaldehyde, and particulate matter; HC and NMHC standards are dropped for Tier 2 and Interim Tier 2. Manufacturers may certify any given vehicle family to any of the bins available for that vehicle class as long as the resulting sales-weight corporate average NO_x standard is met for the full useful life of the vehicle. The Tier 2 corporate average NO_x standard is 0.07 g mile⁻¹. Interim corporate-based average NO_x standards are based on vehicle type. The interim sales-weighted average for light-duty vehicles (LDVs) is 9.3 g mile⁻¹. For LDVs, Tier 2 standards will be phased-in at a rate of 25% in 2004, 50% in 2005, 75% in 2006, and 100% in 2007. During this period, all LDVs receiving the Tier 2 standards must meet Interim Tier 2 standards.

CO, carbon monoxide; CVS, constant volume sampler; HC, hydrocarbons; NMHC, non-methane hydrocarbons; NMOC, non-methane organic gases; NO_x, nitrogen oxides.

Source: 40 CFR 86, Subpart A (July 1, 2000).

Federal Register, Vol. 65, No. 28, pp. 6851–6858.

F. Emission Standards for Existing Installations in the United States

The states and cities of the United States sometimes have emission standards for existing installations, which are usually less restrictive than those federally required for new installations, i.e. NSPS, BACT, MACT, LAER. The Clean Air Act Amendments of 1990 will change most of these state and local emission standards. The amendments instruct the state air pollution control agencies to submit, by enumerated deadlines, highly detailed revisions to their existing implementation plans. The term "revision" appears almost 250 times in the 1990 amendments [6].

G. Emission Standards for Industrialized Countries of the World

The most recent compilation of emission standards for processes and substances emitted from processes in the industrialized countries of the world was the companion Volume II of the source of Table 24.10 (see Jarrault in Suggested Reading).

H. Fuel Standards

To reduce emissions from fuel-burning sources, one can limit the sulfur, ash, or volatile content of fuels. A listing of such limitations as they existed in 1974 is given in Martin and Stern (see Suggested Reading).

The US EPA required major gasoline retailers to begin to sell one grade of unleaded gasoline by July 1, 1974. This mandate was primarily focused on protecting emissions control systems (e.g. catalytic converters). It was at this time that the working definition of "unleaded" gasoline was to mean "gasoline containing not more than 0.05 gram of lead per gallon and not more than 0.005 gram of phosphorus per gallon" [38FR1255, January 10, 1973]. The agency also called for the gradual phase-out of leaded gasoline. The schedule for reduction of lead content in automobile gasoline was 1.7 grams per gallon (g gal^{-1}) in 1975, to 1.4 g gal^{-1} in 1976, 1.0 g gal^{-1} in 1977, 0.8 g gal^{-1} in 1978, and 0.5 g gal^{-1} in 1979 [38FR33741, December 6, 1973]. Subsequent regulations reduced the allowable lead content to 0.1 g gal^{-1} in 1986 [50FR9397, March 7, 1985], and prohibited leaded gas use after 1995 [61FR3837, February 2, 1996]. The EPA established a limit of 1.1 grams per gallon for the content of leaded gasoline beginning on July 1, 1985 and announced its intent to further reduce lead in gasoline to 0.5 g gal^{-1} after July 1, 1985, and 0.1 g gal^{-1} after January 1, 1986. An EPA program to allow trading in lead credits among refiners facilitated this schedule of lead reduction. Without trading in lead credits, two alternatives were likely: (1) the phase down would be protracted or (2) short-term contractions may occur in the supply of gasoline and possible supply disruptions in some areas.

On July 1, 1983 EPA allowed refiners and importers of gasoline to trade lead reduction credits to meet the limit for the average lead content of gasoline.

Refiners and importers that reduced the average lead content of their gasoline below the EPA limit generated credits that could be sold to refiners or importers that exceeded the limit. Once the limit for the average content of leaded gasoline reached 0.1 g gal^{-1} , trading would not be allowed because of concern that gasoline with less than 0.1 grams of lead per gallon could cause excessive valve seat wear in older vehicles. In 1985 EPA allowed refiners to bank lead credits for subsequent use before the end of 1987 [5].

The Council of the European Economic Community, established under the 1957 Treaty of Rome, in 1973 issued a declaration on the environment [4], which the European Commission in Brussels has interpreted as giving it authority to issue directives on matters related to the emission of air pollutants, such as one limiting the sulfur content of fuel oil [5].

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2. Connor, W. D., Smith, C. F., and Nader, J. S., *J. Air Pollut. Control Assoc.* **18**, 748–750 (1968).
3. Public Law No. 101–549, 101st US Congress, *Clean Air Act Amendments of 1990*, November 1990.
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5. US Environmental Protection Agency, *The United States Experience with Economic Incentives to Control Environmental Pollution*, 230-R-92-001, Washington, DC, July 1992.
6. Proposal for a council directive on the use of fuel oils, with the aim of decreasing sulfurous emissions. *Official J.* **19**, C-54 (March 1976).
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SUGGESTED READING

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QUESTIONS

1. Discuss remote sensing equipment for measurement of emissions after they have left the stack and have become part of the plume.
2. Discuss the means for determining the strength of an odorous emission from a source and of definitively relating the odor to the presumed source.
3. Discuss the relative merits of the prototype testing of automotive vehicles for certification and of certification based on production line testing of each vehicle produced.
4. Select one source category and affected facility from Table 27.1 and determine the detailed performance standards for the pollutants regulated.
5. Discuss some of the variants of the rollback equation (Eq. 27.1) that have been proposed, and evaluate them.
6. In some countries, the enforcement agency is allowed to exercise judgment on how much emission to allow rather than to adhere to a rigid emission limit. Discuss the advantages and disadvantages of this system.
7. Discuss the availability and reliability of in-stack continuous emission monitors when they are required by US NSPS.
8. Discuss the extent to which cost-benefit analysis should be considered in setting emission standards.
9. Trace the history of fuel standards for control of air pollution.