

Clearing the Air in Los Angeles

Although Los Angeles has the most polluted skies in the nation, it is one of the few cities where air quality has improved in recent decades

by James M. Lents and William J. Kelly

On some hot, sunny days, the 14 million residents of the Los Angeles area inhale a thick, brownish-gray haze, and no one can ignore its effect. The smog obscures the San Bernardino Mountains and the warm California sun; it irritates the eyes and nose; it restricts the activities of athletes and people who have breathing disorders; it injures the lungs of both young and old.

Southern California's air quality is the worst in the U.S. Air pollution in the region reaches unhealthful levels on half the days each year, and it violates four of the six federal standards for healthful air—those for ozone, fine particulates, carbon monoxide and nitrogen dioxide. In 1991 the South Coast Air Basin exceeded one or more federal health standards on 184 days.

Yet these statistics hide a remark-

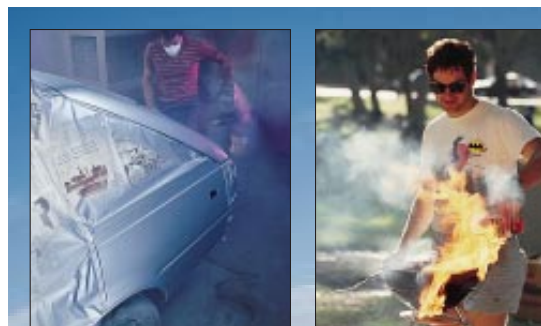
able accomplishment of the citizens of southern California. Los Angeles is one of the few places in the nation where air quality has improved dramatically since the 1970s. From 1955 to 1992 the peak level of ozone—one of the best indicators of air pollution—declined from 680 parts per billion to 300 parts per billion. The California Air Resources Board recently documented that population exposure to unhealthful ozone levels has been cut in half in just the past decade. Furthermore, the smog levels measured during each of the past three years have been the lowest on record.

All these improvements were achieved at a time when human activity in the Los Angeles area was increasing at a rapid rate. Since the 1950s the population has almost tripled, from 4.8 million to 14 million; the number of motor vehicles on the road has more than quadrupled, from 2.3 million to 10.6 million; and the city has grown into one of the most prosperous regions of the world.

Although the residents of southern

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AIR POLLUTION SOURCES have increased in size and number in Los Angeles, yet technical innovation and social policy have led to an improvement in air quality during the past two decades. Some typical sources of air pollution include (from left to right) industrial coatings, barbecues, trash incinerators, paints, dry cleaners, commercial ovens and motor vehicles.



California still face and continue to tackle many air pollution problems, they have an advantage in that they have spent 50 years studying the local atmosphere and experimenting with various policies. We hope the cities of all nations will learn from the experiences of Los Angeles [see "The Changing Atmosphere," by Thomas E. Graedel and Paul J. Crutzen; SCIENTIFIC AMERICAN, September 1989].

The movement to clean up the air in southern California began during the 1940s, a period of rapid industrialization. At the time, the region was plagued by sudden "gas attacks" that irritated the eyes, diminished visibility and produced an unpleasant odor. Then, as now, the smog was so obvious and odious to the public that elected leaders were compelled to take meaningful action. Yet their efforts provoked strong conflict. Some citizens and industries fiercely resisted suggestions to clean up sources of pollution. But the *Los Angeles Times* published dozens of editorials demanding

that the smog problem be solved. The paper also put its money behind its editorial mouth. In 1947 it retained Raymond R. Tucker, the former smoke regulation commissioner of St. Louis, to study air pollution in the area. Tucker identified and investigated several major sources of air pollution, including heavy industries, foundries, motor vehicles, backyard incinerators and smudge pots for protecting crops from frost.

In the same year, the oil industry paid the Stanford Research Institute (SRI) to give another perspective on the causes and control of pollution. The organization discovered that the hazy days were caused in part by a natural weather phenomenon known as an inversion layer. The warmest part of the atmosphere is, more often than not, that nearest to the ground, but under certain conditions a layer of cool air can slip underneath a stratum of warm air. Such inversions often form off the coast of Los Angeles as the Pacific Ocean cools the atmosphere just above it. After ocean breezes blow the air mass inland, the inversion layer traps air pol-

lutants in the cool air near the ground where people live and breathe. The mountains that surround the region compound the problem; they prevent the pollutants from dispersing.

SRI pointed out that natural materials such as dust, pollen, fibers and salt were important components of the haze. But the institute also recognized that industries and motor vehicles contributed to the problem by adding carbon particles, metallic dust, oil droplets and water vapor.

In the 1950s SRI and Arie J. Haagen-Smit and his colleagues at the California Institute of Technology began to examine the chemistry of the atmosphere above Los Angeles. Their work and the research of others have revealed the complexity of atmospheric chemistry. Automobiles, factories and other sources release such raw pollutants as hydrocarbons, water vapor, carbon monoxide and heavy metals. When these chemicals are exposed to intense sunshine, they react to yield a vast number of secondary pollutants—for instance, ozone, nitrogen dioxide, various organ-



ic compounds and acidic particles of nitrate and sulfate. This concoction then interacts with plants and animals, causing a variety of different effects. Many of these phenomena are still not understood, but 50 years ago even less information was available.

In 1953, with the public fearing that the Los Angeles haze might become as bad as London's "killer" fog, Governor Goodwin J. Knight appointed an air-pollution review committee. Chaired by Arnold O. Beckman of Beckman Instruments, the committee proposed five key ideas for reducing pollution over the short term. First, they asked that the emission of hydrocarbons be reduced by improving procedures for transferring petroleum products. Second, they set standards for automobile exhausts. Third, they encouraged the use of trucks and buses that burned liquefied petroleum gas instead of diesel fuels. Fourth, they considered whether industries that polluted the area heavily should be asked to slow their growth. Fifth, they advocated that the open burning of trash be banned.

The committee also hoped that over the long term Los Angeles would develop a sustained automotive pollution-control program, construct a rapid transit system and start a cooperative program to regulate industrial sources of pollution. Ironically, the report was issued while the region's public train system was being dismantled. Today Los Angeles is trying to get back on track, so to speak, by developing an extensive regional commuter rail network. The Beckman committee's recommendations eventually grew into a coherent air-quality management plan for the region, but it emerged slowly and was reshaped many times.

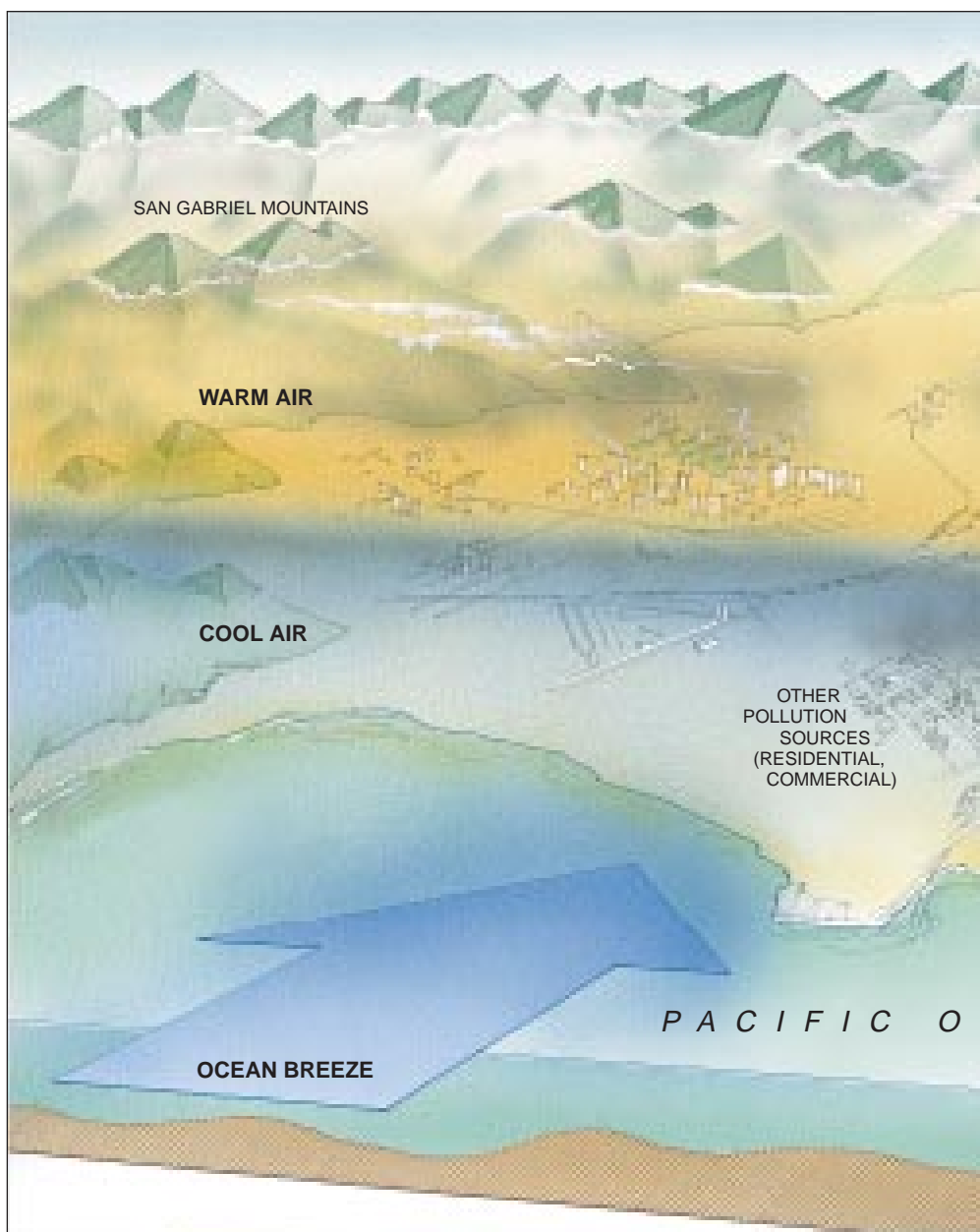
Soon after the Beckman report, the neighboring counties of Orange, Riverside and San Bernardino began their own pollution-control programs. During the past 40 years, these regions have experienced explosive growth in population and in vehicular traffic. The control programs in these regions were, for the most part, as energetic and innovative as those in Los Angeles. But residents of these counties soon realized that they needed to coordinate their efforts; smog

does not respect political boundaries.

In 1975 the regional governments tried voluntarily to consolidate their pollution-control programs. Two years later little progress had been made. So the California legislature forged an uneasy alliance between the local programs by creating the South Coast Air Quality Management District (AQMD). The AQMD was given jurisdiction over the counties of Los Angeles, Orange and Riverside and part of San Bernardino—an area of 13,350 square miles.

Initially, the AQMD was responsible for stationary sources of air pollution, and the California Air Resources Board was assigned to regulate mobile sources such as cars, trucks and buses. In its early years the AQMD adopted a viewpoint held by many business leaders.

It argued that many industries were as clean as they could get, the state was not doing enough to clean up cars and the region might never achieve clean air standards. As required by law, the AQMD adopted air-quality management plans in 1979 and 1982, but these were regarded as mostly paper exercises. At the time, the federal Clean Air Act required all American cities to achieve federal standards by 1987, although nearly everyone realized that the task would be impossible in Los Angeles. As that deadline drew near, however, environmentalists and even some business groups attacked the AQMD for its complacency and alleged lax enforcement. In 1987 the legislature restructured the AQMD governing board and granted broad powers to the new



WEATHER PATTERN known as an inversion layer traps air pollution above Los Angeles and neighboring counties. Air cools over the ocean and then is blown inland, creating a cold layer near the ground and a warmer layer above. The warm layer prevents most of the smog from escaping upward. The surrounding mountains keep the polluted air from moving farther inland.

board. The AQMD now has responsibility for achieving local, state and federal standards.

Despite all the political upheaval, the state and local governments had managed to curb many sources of air pollution in the South Coast Air Basin before the AQMD was formed in 1977. They gradually developed regulations that concentrated on reducing the major sources of air pollution: particles from trash incineration, emissions from industry and pollutants from motor vehicles.

In 1958, at the recommendation of the Beckman committee, backyard trash incinerators were banned despite opposition from the public and some waste-disposal managers. More

than 300,000 families owned such incinerators, and many were unwilling to give up the convenience and cost savings. But slowly attitudes changed; today most residents of Los Angeles would consider it shameful to burn their trash and subject their neighbors to the smoke and smell.

Waste-disposal managers objected to the ban for a different reason. These analysts realized that the economical alternative to burning trash was burying it, and therefore they correctly predicted that although replacing incinerators with landfills would reduce air pollution, the additional landfills would create other types of environmental problems. For example, as rain has seeped through the landfills and carried away soluble materials, it has contaminated

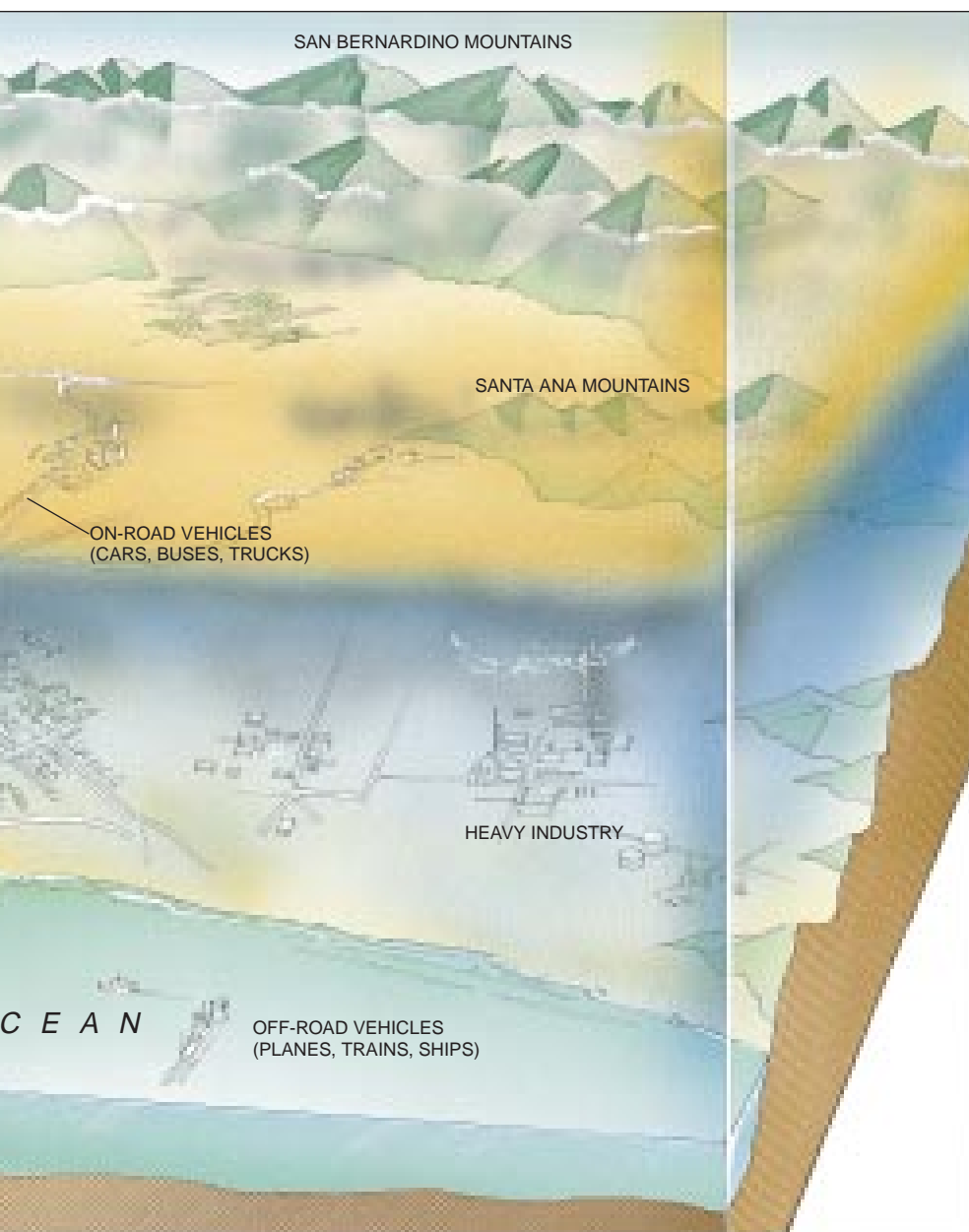
the local groundwater. Southern Californians are now working to clean up the groundwater, but the long-term plans are, first, to decrease the volume of trash through recycling and, second, to reduce further groundwater contamination by improving the management of landfills.

The ban of backyard incinerators generated relatively little public resistance when compared with attempts to clean up industrial sources of pollution. Historically, the control of industrial emissions has been challenging because of the need to balance the region's environmental interests with its economic needs. The Beckman report of 1953 quickly led to requirements that industries use vapor-recovery equipment when they transferred petroleum products, but service stations were not obliged to install such equipment on gasoline pumps until 1978. This equipment, while originally somewhat difficult for the motorist to handle, has been streamlined, so it is effective and easy to use today. Yet the measure is still resisted by most communities outside of California because of its expense and an undeserved reputation for being cumbersome.

Regulations were adopted during the 1960s to eliminate industrial solvents that play a major role in promoting the formation of ozone. The rules affected a wide variety of businesses, from construction to auto manufacturing to dry cleaning. To meet the requirements, most industries chose to use nonreactive solvents instead of installing control equipment because it was the less expensive solution. Sadly, the nonreactive solvents were later shown to destroy ozone in the stratosphere. (At high altitudes, ozone serves the critical function of shielding the earth from harmful solar radiation.) The solution to this problem is to find truly benign solvents; for example, Hughes Aircraft Company has recently developed a soldering flux made from citrus juice.

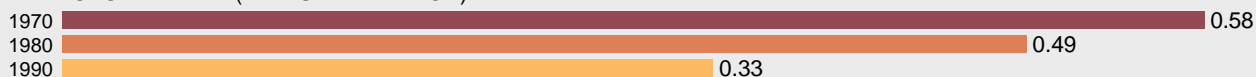
Although Californians succeeded in reducing the quantity of pollution generated by certain industrial sources, their efforts have been partially offset in recent decades. Many sources have been introduced as the region's economy has grown. To compensate for the growth factor, officials instituted, in 1976, "new source" regulations. These required expanding industries to use the cleanest technology available. The rules also specified that if a company planned to start a project that increased emissions, it was required to earn a certain number of credits by reducing emissions from another project.

The new source regulations have stim-

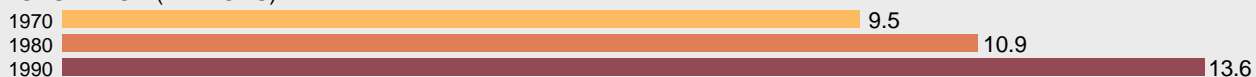


Air Pollution in the Los Angeles Area

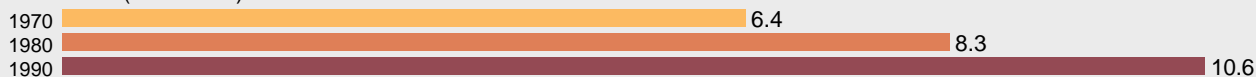
PEAK OZONE LEVEL (PARTS PER MILLION)*



POPULATION (MILLIONS)*



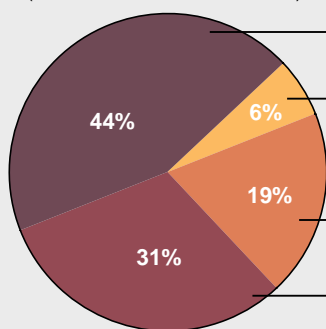
VEHICLES (MILLIONS)*



*For Los Angeles, Orange, Riverside and San Bernardino counties

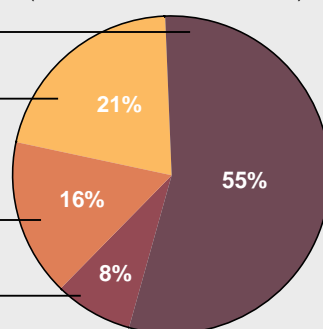
HYDROCARBON EMISSIONS, 1992

(TOTAL: 1,375 TONS PER DAY)

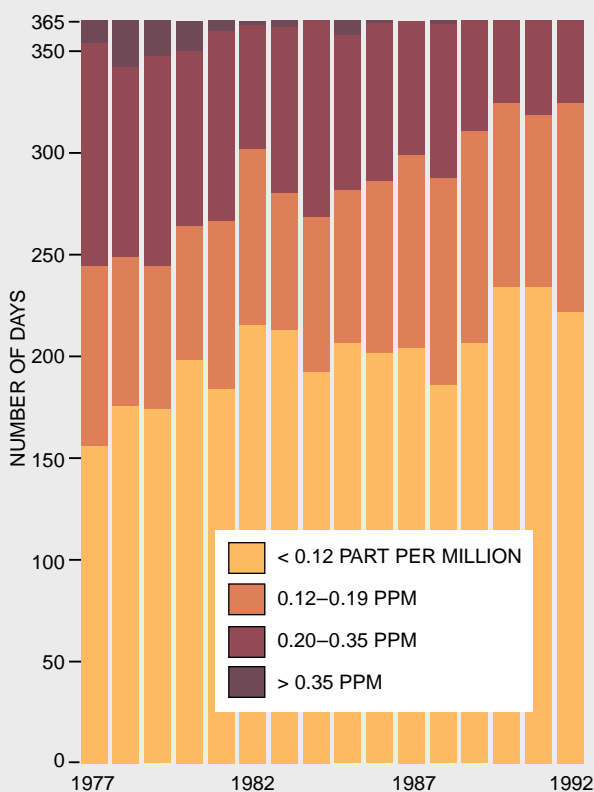


NITROGEN OXIDE EMISSIONS, 1992

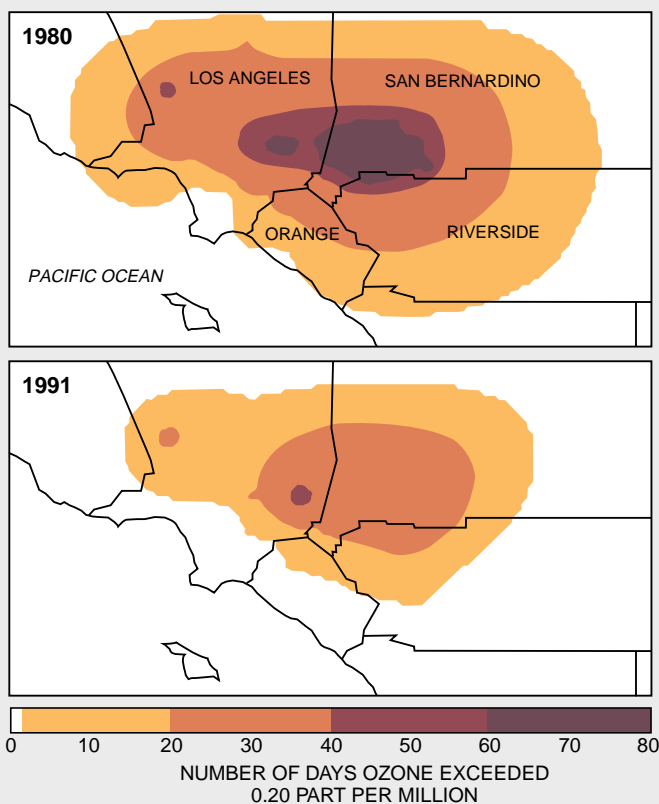
(TOTAL: 1,208 TONS PER DAY)



OZONE BY YEAR



OZONE BY REGION



SOURCE: South Coast Air Quality Management District

ulated considerable innovation. When researchers compared the best control technologies of 1976 with those available in 1990, they found that the amount of pollution generated during the manufacture of a product had dropped, on average, by 80 percent. Unfortunately, many businesses found a way to avoid the regulations. The rules exempted new projects that would emit daily less than 75 pounds of hydrocarbons or 100 pounds of nitrogen oxides. To exploit this loophole, many industries expanded by adding several small projects instead of a few large ones so that all the undertakings would be exempt. Furthermore, most small businesses were exempt, even though they have accounted for the fastest-growing segment of stationary source emissions during the past few decades.

Growth of these small sources, combined with increased population and motor vehicle use, tended to offset cleanup efforts through the 1980s. Consequently, in 1990 the new source regulations were revised to include projects that introduced small quantities of air pollution. Even then, some exemptions were allowed, and they continue to hurt the effort.

Los Angeles's difficulties with reducing industrial pollutants were similar in one respect to its attempts at diminishing automotive emissions. Although officials identified the problem and took action, they were slow to adjust to the scale of the matter. From the start, for example, the Beckman committee recommended controls on automotive emissions, but it did not anticipate how quickly auto travel would grow throughout the region. Nevertheless, Los Angeles has succeeded in three important areas: promoting the use of clean fuels, purifying engine exhaust and encouraging carpooling and the use of public transportation.

A significant first step in regulating automotive pollution was the reduction of "blowby" gases. Most car engines that were designed 30 years ago allowed the gaseous by-products of combustion to escape past the piston, through the crankcase and into the atmosphere. In 1960 such blowby gases accounted for one quarter of the total hydrocarbon emissions in the region. The gases could be eliminated by installing a \$5 device that routed the crankcase emissions to the engine intake manifold; in this way, the hydrocarbon fumes were burned instead of being released. In 1963 the state mandated that the devices be added to all motor vehicles, new and old. By the middle of the decade, a special police force was patrolling the roadways

in southern California, issuing citations to vehicles that smoked excessively.

The crankcase device proved effective on new vehicles, but objections were raised to equipping old cars with them. Many auto mechanics were not trained to install the devices, and rumors spread that even properly installed devices caused engine damage. That misinformation was the primary reason for the state legislature's decision in 1965 to stop requiring the installation of crankcase devices in cars made before 1963. It was not the first time, nor certainly the last, that inaccurate information has become the basis of political compromise.

In addition to installation of crankcase devices, Los Angeles tried to reduce automotive pollution by encouraging the production and use of clean gasolines. In 1960 officials required that all gasoline sold in the area have a low content of olefins, which are some of the most reactive compounds in petroleum products. Unfortunately, as the years passed by, the clean gasoline program lost its momentum. Then, in the early 1980s, the state government of Colorado revitalized the concept, hoping to reduce air pollution problems in Denver. Colorado required the blending of a methanol derivative into gasoline. In California, meanwhile, the AQMD and the state were pushing for methanol and other alternative fuels through regulatory programs. Faced with losing large market shares to methanol and other clean fuels, the Atlantic Richfield Company in Los Angeles came up with a constructive solution by developing a truly clean gasoline. These events stimulated California and the federal government to go beyond regulations and introduce new legislation for clean fuels.

Another development in reducing automotive emissions was the removal of pollutants from the exhausts of car engines through the use of catalytic converters. California required that beginning with the 1975 model year, all new cars have the converters. The converters and similar devices substantially reduced emissions, but for several reasons the program was not as successful as it might have been. First, researchers discovered that the performance of a converter decreases as the car accumulates mileage. Second, many motorists tampered with or even removed the emissions-control equipment. Third, many consumers damaged their converters by fueling their cars with cheap leaded gasolines instead of the more expensive unleaded varieties. Indeed, in 1983 the National Enforcement Investigations Center found that in almost one fifth of all the vehicles on

the road, the emissions-control equipment was either removed by the owner or damaged by the use of leaded fuels. The latter problem has abated in recent years as the price of unleaded fuels has moved closer to that of leaded gasoline.

To enforce legislation on automotive emissions, Los Angeles initiated an inspection program in 1976. The regulations specified that whenever a vehicle was sold, the new owner was required to bring the car to a special station where the emissions could be measured with the engine of the car running at normal cruising speeds. Los Angeles had many difficulties managing the program, and the state government was reluctant to help. Consequently, the city received innumerable complaints from car owners who were forced to wait in long lines to get their vehicles tested.

The California legislature was eventually persuaded to develop a new inspection program when the Environmental Protection Agency imposed sanctions that reduced highway funding. Under the new "smog check" program, each car in California is tested once every two years at a repair shop. Furthermore, the state gave local governments the option to conduct tests either while the engine was idling or while it was running at normal speeds—the latter option being more expensive but more effective. The program achieved pollution reductions, but the results were lower than expected. Today the federal government is again pressuring California to create a program that lives up to its potential.

Officials had much trouble encouraging southern Californians to share rides, thereby reducing congestion and emissions. One way to promote ride sharing is to reserve lanes on major highways for the use of cars transporting two or more people. When state transportation administrators proposed restricting one of four lanes of the Santa Monica Freeway, however, motorists opposed the idea so strenuously that the officials quickly withdrew it. Later they found that the public was less antagonistic if new lanes were added to existing highways for the use of high-occupancy vehicles. California now has an extensive network of such lanes.

In 1987 the AQMD required firms with 100 or more employees to offer incentives to institute carpooling. Although the regulation generated complaints, it has been successful. The rule applies to 5,200 work sites, harboring 1.2 million employees. A study of that group from 1987 to 1992 revealed that the number of employees per vehicle

rose from 1.13 to 1.24. The program has eliminated 90,000 trips a day and has achieved about half the desired reductions in emissions. In fact, southern California is one of the few places in the U.S. where ride sharing has increased over the past five years.

Today the motor vehicles and industries operating in California are among the cleanest in the world. A new car sold in California emits just one tenth of the pollution that a new car did in 1970. Such industries as electric utilities rely almost exclusively on clean-burning natural gas. Manufacturing plants and construction companies use advanced paints, solvents and adhesives that have been formulated to minimize pollution. For these reasons and others, southern California has made tremendous progress in reducing air pollution.

But despite all the successes, pollution in the South Coast Air Basin is still overwhelming. Average daily emissions total 1,375 tons of hydrocarbons, 1,208 tons of nitrogen oxides, 4,987 tons of carbon monoxide, 134 tons of sulfur oxides and 1,075 tons of particulates. Transportation, including cars, airplanes, trains and ships, adds 47 percent of the hydrocarbons, 70 percent of the nitrogen oxides, 90 percent of the carbon monoxide, 60 percent of the sulfur oxides and 89 percent of the particulates. Industry contributes 26 percent of the hydrocarbons, 18 percent of the nitro-

gen oxides and 30 percent of the sulfur oxides and smaller percentages of other pollutants. The remainder of the pollutants are emitted by households and service-oriented businesses, such as restaurants, dry cleaners, gas stations and operations in commercial buildings.

Los Angeles must reduce pollution even further to meet federal health standards. Computer projections indicate that southern Californians must cut hydrocarbons by 80 percent, nitrogen oxides by 70 percent, sulfur oxides by 62 percent and particulates by 20 percent. The consequences of complacency could be disastrous.

Air pollution in the South Coast Air Basin has already taken a staggering toll on residents. A growing body of evidence reveals that the smog is a serious health hazard.

In 1991 David Abbey, an epidemiologist at Loma Linda University, found a correlation between long-term exposure to air pollution and the development of chronic diseases. Abbey studied 6,340 Seventh-Day Adventists, 62 percent of whom lived in the basin (the remainder lived throughout California). In that group of 6,340, those who resided in areas that exceeded government standards for suspended particles on 42 days or more per year had a higher risk of respiratory disease, including a 33 percent greater risk of bronchitis

and a 74 percent greater risk of asthma. In addition, women living in those areas had a 37 percent greater risk of developing some form of cancer.

Roger Detels of the University of California at Los Angeles studied respiratory disease among residents in three areas of southern California that differ in air quality. During a five-year period, he periodically questioned and examined volunteers, aged seven to 59 years, to determine the health of their respiratory systems. In 1987 Detels discovered that residents who lived in high-pollution areas had more symptoms of respiratory disease, such as bronchitis and asthma, than did people who resided in low-pollution regions.

If the citizens of the South Coast Air Basin succeeded in meeting federal standards for ozone and particulates, a 1989 study by the AQMD predicted, they would gain \$9.4 billion in health benefits every year. If the residents could reduce just particulates to the federal standard, they would prevent 1,600 premature deaths annually among those who suffer from chronic respiratory disease. In addition, they would eliminate 15 million person-days on which people with respiratory disease are unable to go to work, school and other activities, and they would reduce the risk of dying prematurely from exposure to particulates. (The risk of death is about one in 10,000—about half the risk a Californian faces of dying in a car accident.)

If Los Angeles residents were able to achieve the federal standard for ozone, they would eliminate annually 18 million person-days of restricted activity, 65 million person-days of chest discomfort, 100 million person-days of headache, 120 million person-days of coughing, 180 million person-days of sore throats and 190 million person-days of eye irritation.

These terrible statistics have captured the attention of the federal and state governments. The federal Clean Air Act, which was amended in 1990, gives Los Angeles until 2010 to achieve federal health standards, but the law also requires the region to make incremental progress toward healthful air. The California Clean Air Act demands that the region reduce emissions by 5 percent a year until health standards have been met.

Between 1989 and 1991 the AQMD devised an air-quality management plan to respond to the strong mandates of the federal and state law. During the next 17 years, the plan seeks to reduce pollution from virtually all sources and foster the development of new and cleaner technologies. The AQMD will execute the plan with the cooperation of the



MESSENGERS for the Rapid Blueprint Company in Los Angeles were outfitted with gas masks in the fall of 1955 so that they would not suffer from the effects of the smog. Shortly thereafter, local officials began air-pollution control programs.

EPA, local governments and state Air Resources Board. Each organization has a well-defined role. The AQMD is charged with cleaning up stationary sources and encouraging carpooling. The EPA is to set standards for airplanes, trains and ships that travel through the region. Local governments will work to alleviate traffic through improvements in the transportation infrastructure and expanding mass transit. The Air Resources Board is responsible for motor vehicle standards. It has already taken aggressive action that should reduce automotive emissions by 85 percent by the next decade and should increase sales of electric cars.

The AQMD and its sibling agencies plan to attack the pollution problem in three stages. The first stage, dubbed Tier I, includes 135 measures that can be accomplished using existing technologies and are to be adopted by 1996. The measures limit and reduce pollutants from such sources as electric utilities, motor vehicles, small businesses and even backyard barbecues. The electric companies will be installing low-polluting burners and catalysts on power plants to reduce nitrogen oxide emissions. Pollution from backyard barbecues will diminish as households use reformulated charcoal lighter fluid and other products for lighting grills. Automotive emissions will decrease because of tailpipe standards as well as programs encouraging carpools and use of public transportation.

The second stage, or Tier II, will take the region into the 21st century. These measures rely on technologies that have just entered the commercial market. The list includes a new house paint, developed by the Glidden Company, that does not release hydrocarbons. Another initiative is developing automobile engines that run on methanol, natural gas or other alternative fuels. The third stage, Tier III, requires technologies that have not been fully developed but are likely to be available in the next decade or so. Researchers are fabricating paint coatings that dry under ultraviolet lamps, without emitting any significant quantity of pollutants. They are also working on fuel cells, such as those used in the space shuttle, which will power a kind of zero-emission electric vehicle.

To help develop these new technologies, the AQMD is working with government agencies and private corporations through its technology advancement office. To date, the office has contributed some \$40 million in seed money to facilitate almost 250 projects. Among the technologies now entering commercial-



L.A. MECHANIC at Green Motorworks, a local manufacturer of electric vehicles, converts a gas-fueled car to battery power. Such initiatives are receiving strong support from California state agencies as a way to meet ambitious air-quality standards.

ization are alternative-fuel vehicles, industrial emissions controls for nitrogen oxides, and cleaner paints, solvents and coatings.

After the AQMD released its ambitious plan to clean up the air, the organization quickly realized it could not simply play the role of tough pollution cop and expect companies, especially small ones, to follow the plan. The region's businesses, which were caught in a recession and faced cuts in defense spending, were reluctant to invest resources in pollution-control equipment.

To sustain progress, a different approach was required, especially to clean up the growing number of small sources of air pollution. In 1991 the AQMD outlined a series of reforms, which included providing free technical assistance and starting a guaranteed loan program so that small businesses could purchase pollution-control equipment.

In the long run the task of getting businesses to reduce pollution will hinge on technological innovation. One of the AQMD's most powerful incentives for developing these clean technologies is the Regional Clean Air Incentives Market Program. Under this program, a business is asked to meet emission standards not only for individual pieces of equipment but also for its entire operations and facilities. Those businesses that cut pollution below the standard will be granted emission-reduction credits. Those companies that generate more pollution than the standard must buy enough credits to make up the difference. The program gives firms flexibility to choose how to reduce emissions, and it also provides an incentive for innova-

tion because firms can make a profit by cleaning up the air.

During the past 40 years, the citizens of Los Angeles have been very active in the fight for clean air, but from time to time they have neglected the issue because they feared that air-quality regulations were incompatible with the region's economic interests. Today, despite occasional doubts about environmental regulation and legitimate concerns about the post-cold war economy of Los Angeles, residents and business people seem to recognize the need to solve the serious air-pollution problems.

We hope that by 2010 when our children climb the San Bernardino Mountains, they will see not a sea of smog but rather the Pacific Ocean and Catalina Island. We would like them to live in a region where technological innovation sustains both the economy and the environment. But most important, we want them to reap the benefits of healthy, fresh air.

FURTHER READING

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