

Background Information-

**Proposed
National
Emission
Standards
For
Hazardous
Air
Pollutants:**

**ASBESTOS
BERYLLIUM
MERCURY**

U. S. ENVIRONMENTAL PROTECTION AGENCY

**BACKGROUND INFORMATION —
PROPOSED
NATIONAL EMISSION STANDARDS
FOR HAZARDOUS AIR POLLUTANTS:**

Asbestos

Beryllium

Mercury

ENVIRONMENTAL PROTECTION AGENCY
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INTRODUCTION

This document provides background information on the derivation of the proposed national emission standards for asbestos, beryllium, and mercury. The proposed standards, published in the Federal Register under Title 36 CFR Part 62, are being distributed concurrently with this document. The information presented herein was prepared for the purpose of facilitating review and comment prior to promulgation of the standards.

The proposed national emission standards were developed after consultation with appropriate advisory committees, independent experts, and appropriate representatives of the Federal government. The National Air Quality Criteria Advisory Committee has been consulted on air quality considerations, the assessment of adverse effects, and the approaches and protective philosophy underlying the proposed standards. Members are outstanding scientists and/or administrators concerned with the quality of the environment and resident in universities, State or local governments, research institutions, or industry. They are selected for their recognized expertise and/or interest in the establishment of air quality criteria or for their recognized expertise in the evaluation and interpretation of scientific evidence indicative of adverse and preventable effects of atmospheric pollutants.

Review meetings were held with the Federal Agency Liaison Committee and the National Air Pollution Control Techniques Advisory Committee. The proposed standards reflect consideration of comments provided by these committees and by other individuals having knowledge regarding the control of these pollutants.

The National Air Pollution Control Techniques Advisory Committee is made up of 16 persons who are knowledgeable concerning air quality, air pollution sources, and technology for the control of air pollutants. The membership includes state and local control officials, industrial representatives, university professors, and engineering consultants. Members are appointed by the EPA Administrator pursuant to Section 117 (d), (e), and (f) of the Clean Air Act of 1970, Public Law 91-604. In addition, persons with specific expertise regarding these pollutants participated in the meeting of the Advisory Committee.

The Federal Agency Liaison Committee includes persons knowledgeable concerning air pollution control practices as they affect Federal facilities and the nation's commerce. The committee is made up of representatives of 19 Federal agencies.

The promulgation of national emission standards for asbestos, beryllium, and mercury under Section 112 of the Clean Air Act does not prevent state or local jurisdictions from adopting more stringent emission limitations for these pollutants. Furthermore, the promulgated standards themselves may require revision from time to time because of the development of additional technical information.

TECHNICAL REPORT NO. 1 —

ASBESTOS

SUMMARY OF PROPOSED STANDARDS

Because routine, standardized techniques for sampling and analyzing asbestos emissions are not available, the proposed standards for asbestos are not given in terms of numerical values. Instead, the standards are expressed in terms of required control practices that limit emissions to an acceptable level. In part, control of atmospheric emissions would be achieved by:

1. Utilizing industrial fabric filters to clean forced exhaust gases from asbestos mining, milling, and manufacturing industries and from fabricating operations that involve materials containing asbestos.
2. Eliminating visible emissions of particulate matter from ore dumps, open storage areas, external conveyors, and tailing dumps associated with asbestos mining and milling facilities as well as from manufacturing and fabricating operations carried out with asbestos-containing materials in areas directly open to the atmosphere.
3. Prohibiting certain applications of asbestos fireproofing and insulation by spraying processes.

Also, indirect atmospheric emissions of particulate matter would be controlled at manufacturing and fabricating sites where visible emissions normally result from operations using commercial asbestos. The maximum allowable emissions would be equivalent to those attained by either ventilating an entire work space through a fabric filter or by hooding emission sources and subsequently passing the required dust-control air through a fabric filter.

EFFECTS ON HEALTH

The inhalation of asbestos fibers has been related to a number of human diseases. Among these is asbestosis, which has been related to occupational exposures and is characterized by interstitial fibrosis, pleural fibrosis, and pleural calcification.¹

It is presently thought that exposure to asbestos concentrations much larger than those likely to be present in community air is required for the development of clinically significant asbestosis.¹

Calcification of the pleura, which has been noted in asbestos workers, typically occurs after an extended period of time following exposure and is frequently accompanied by pulmonary fibrosis, i.e., asbestosis. The asbestos dosage that causes pleural calcification has not been established; however, nonindustrially exposed populations have exhibited substantial incidences of such disease.^{2,3}

It has been recognized since 1947 that among industrial employees asbestos workers have an increased risk of bronchogenic carcinoma.⁴ For populations exposed to asbestos only in ambient air, there are no data that define the excess risk, if any, of developing this disease.

An association between asbestos exposure and mesothelioma, a fatal malignant tumor of the pleura and peritoneum, was established in 1960 by a study of 33 cases of mesothelioma in South Africa.¹ Seventeen of the patients were occupationally exposed, and 15 resided in the vicinity of an asbestos mine. No history of asbestos exposure was discovered for one patient. A subsequent study of mesothelioma malignancies identified patients with minimal or no known exposure to asbestos. The existence of a prolonged period, averaging 40 years, between initial exposure and appearance of a mesothelioma tumor complicates the study of this disease. There are no data that specify the minimum amount of asbestos exposure associated with an increased risk of developing mesothelioma.

A quantitative definition of the asbestos air pollution problem can not be formulated at this time because of the lack of a dose-response relationship between levels of airborne asbestos and the resulting human diseases. Nevertheless, available evidence clearly implicates asbestos as a serious air pollution threat. This evidence includes the discovery of asbestos fibers in lungs of nonoccupationally exposed persons,¹ the qualitative demonstration that asbestos fibers are present in ambient air,⁵ and the cited epidemiologic studies relating asbestos exposure to disease.

Research efforts directed toward the establishment of a dose-response relationship for human exposure to airborne asbestos are in progress. The only measure available at this time to protect the public health from airborne asbestos is to control asbestos emissions to the greatest degree practicable for the following reasons:

1. A safe exposure level to asbestos has not been established.
2. Exposure to asbestos in community air may produce disease.

3. The consequences of asbestos-caused disease can be extremely serious.

NATURE OF ASBESTOS AIR POLLUTION PROBLEM

Asbestos fibers enter the atmosphere from a wide variety of sources extending from the weathering and disturbance of natural deposits of asbestos-bearing materials to operations for the ultimate disposal of products containing asbestos. Intermediate emission sources include asbestos mining and milling sites, manufacturing facilities for asbestos-containing products, and construction sites employing asbestos insulating, fireproofing, and structural materials. More than 3,000 products contain commercial asbestos. As these products are used, asbestos is frequently emitted to the atmosphere. Among these products are automotive brake linings and asbestos-asphalt concrete for paving roadways. Asbestos is also present as a natural contaminant in some widely employed materials, such as talc. The asbestos emissions from use of these materials can be significant.

Because asbestos is exceptionally resistant to thermal degradation and chemical attack, settled particles are persistent in the environment and subject to reentrainment into the atmosphere. It can readily be mechanically subdivided into fibers of submicron diameter, which can remain airborne for long periods of time. These factors, coupled with the presence of large numbers of emission sources, as noted above, would indicate the presence of a background level of asbestos in the atmosphere. Semiquantitative data confirm this conjecture and show that urban background concentrations are significantly larger than nonurban ones.

Asbestos emissions are now being controlled to a limited extent, primarily from milling and manufacturing sources to which gas-cleaning devices are readily applicable. The formulation of recommended codes of trade practices governing such operations as the transport, fabrication, application, and disposal of asbestos-containing materials has not proved to be an effective emission control technique. Control of asbestos emissions from some sources, for example, spray-applied asbestos fireproofing, has been made possible by the use of substitute materials for asbestos. It is also true, however, that there is interest in expanding the already vast number of applications for asbestos fibers.

DEVELOPMENT OF PROPOSED STANDARDS

The intent of these proposed standards is to minimize asbestos emissions into the atmosphere from all clearly identifiable stationary sources, subject to the availability of a sufficiently definitive characterization of emissions from such sources and subject to the availability of feasible control techniques. Where practical, these control techniques include direct prohibition of activities that generate asbestos emissions.

Asbestos mining and milling operations produce much larger total atmospheric emissions of asbestos than any other single domestic source category and would be regulated by these standards.⁶ Several specific manufacturing operations that incorporate commercial asbestos into products have been identified as significant emission sources.⁶ These, as well as the numerous manufacturing facilities for other asbestos-containing products, would be subject to these proposed standards. From among the many end uses of asbestos-containing products, a relatively small number has to date been singled out as contributing significantly to the overall problem of air pollution. The field fabrication of asbestos-bearing products, particularly insulating materials, and the spray application of asbestos fire-proofing are two specific end uses that would be controlled by the proposed standards. The direct limitation of asbestos emissions from mobile sources, such as those associated with the wearing of automotive brake linings, the transport of asbestos-containing materials, and the dispersion of powdery asbestos-bearing materials from vehicles, lies outside the authority of Section 112 of the Clean Air Act. A program for determining the extent and nature of asbestos emissions from automotive brake linings is now in progress in the Office of Air Programs. Other asbestos emission sources are now under study for possible inclusion within proposed standards at a future date. Included in these studies are roadways paved with asbestos-asphalt concrete and talc mines, in which asbestos occurs as a natural contaminant.

Current standardized measurement techniques for asbestos, namely those for testing occupational asbestos exposures, are not designed for isokinetic sampling, which is necessary for the determination of the asbestos content of forced-gas streams. Further, these methods fail to take into account large numbers of asbestos fibers present in the samples. At least three ambient air sampling and analysis techniques, which employ electron microscopy to render visible even the smallest asbestos fibers, are currently undergoing development. To date, these methods are capable of providing estimates of asbestos mass concentrations, but not number concentrations of asbestos fibers in unprocessed samples, and reproducibility of results obtained by the three methods has not been established. Until these new techniques are perfected, emission control must be based upon the best feasible control technology. Accordingly, the proposed standards would require the operation of specified control equipment.

Fabric filtering devices have been specified as the mainstay of these standards because they possess (1) demonstrated high-efficiency collection across a wide range of solid particulate sizes and (2) reasonable investment and operating costs. It is prudent to require control techniques that provide high collection efficiency for submicron-size particulates because research studies have shown that the largest number of asbestos fibers in emissions generated by some industrial

operations is concentrated in the range of smallest particle sizes. Many fabric filters are already in service at asbestos milling and manufacturing facilities, and some operations routinely recycle filter-cleaned air for ventilation of work spaces. In exceptional operations amenable to emission control by gas cleaning, but where technical difficulties preclude the application of fabric filters, these standards would permit the use of other control equipment of somewhat lesser efficiency.

The proposed regulations that would prohibit visible emissions apply to sources not readily controlled by gas-cleaning devices. Flexibility with regard to choice and development of the most effective control techniques would be provided in that the proposed standards would not specify control equipment. The exception of uncombined water from the prohibition would be made to accommodate situations in which water would be used as a control medium. Processes that are properly operated could be controlled by feasible techniques to secure compliance.

The surfacing and resurfacing of roadways with asbestos tailings would be banned because of the probable ineffectiveness of control measures during both application and an extended period of usage. The proposed ban on the spray application of products that contain asbestos is based upon experience with spray-fireproofing operations wherein efforts to control emissions by the use of containment and good housekeeping practices have repeatedly failed. Several large municipalities in the United States have already put into effect procedures that exclude the use of sprayed asbestos materials. Asbestos-free substitute materials are available for both sprayed asbestos fireproofing and high-temperature asbestos insulation.

ECONOMIC IMPACT OF PROPOSED STANDARDS

The basic processing of domestic asbestos ores is carried out in nine mills with production capacities ranging from 200 to 65,000 tons per year. These mills produce approximately one-sixth of the total consumption of asbestos in the United States. The estimated additional annualized costs required of these existing sources for compliance with the proposed standards range from zero to \$5.96 per ton of asbestos fiber produced per year; this represents a range of zero to 6.7 percent of the average selling price per ton of domestically produced asbestos in 1969. The average investment, for the entire industry, is estimated to be \$0.78 (0.9 percent) per ton of asbestos fiber produced per year. Actual investments range from \$2,780 for an essentially uncontrolled mill of 200-ton/year capacity to \$183,000 for a partially controlled mill of 40,000-ton/year capacity.

For the major categories of industries that manufacture products containing commercial asbestos, i.e., producers of asbestos-cement products, asbestos-containing floor tile, asbestos-reinforced friction materials, asbestos paper, and asbestos textiles, a total additional investment of \$5,281,000 is estimated to be required to bring existing, partially controlled sources into compliance with the proposed standards. This represents an investment of 0.6 percent of the total value of product output, or an annualized cost of 0.3 percent of the output product value. In terms of alterations in product price, there would result an average increase of 0.3 percent; the most significant increase would be 2.6 percent for asbestos paper products.

The use of asbestos in spray-applied fireproofing and insulation represents only approximately 0.5 percent of the annual domestic consumption of asbestos. No major impact on the price of asbestos or upon producers of asbestos would result from the prohibition on spray application of asbestos fireproofing and insulation. Further, increased costs for substitute materials, available or scheduled for introduction in the near future, range from zero to a maximum of 15 percent. The use of these asbestos-free substitute materials does not require new equipment or extensive retraining of personnel.

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TECHNICAL REPORT NO. 2 —

BERYLLIUM

SUMMARY OF PROPOSED STANDARDS

The proposed beryllium standards are designed to protect the public from 30-day average atmospheric concentrations of beryllium greater than 0.01 microgram per cubic meter ($\mu\text{g}/\text{m}^3$). Experience over more than 20 years has shown this to be a safe level of exposure. For short-term, periodic exposures, the safe level has been determined to be 25 $\mu\text{g}/\text{m}^3$ for a maximum of 30 minutes.¹ This periodic exposure limit is the basis for the standard pertaining to rocket-motor firings.

The proposed beryllium emission standards for extraction plants, machine shops, foundries, ceramic plants, propellant plants, and incinerators designed or modified for disposal of toxic substances allow the operator to demonstrate compliance with either 1 or 2 below:

1. No more than 10 grams of beryllium emitted per 24-hour day.
2. No emission that will cause atmospheric concentrations of beryllium to exceed an average of 0.01 microgram per cubic meter of air for 30 days.

The beryllium emission standards given below are being proposed for rocket-motor test facilities:

1. No emissions that will cause atmospheric concentrations of beryllium to exceed 75 microgram-minutes per cubic meter of air* within the limit of 10 to 60 minutes.
2. No more than 10 grams of beryllium will be emitted per 24-hour day when rockets are fired into a tank and the exhausts are gradually released.

Two methods of sampling will be used to determine compliance: sampling of individual stacks or industry-operated networks sampling ambient air. The method used must be approved by the Administrator of the Environmental Protection Agency (EPA). If

*Defined as the product of the concentration (in $\mu\text{g}/\text{m}^3$) and duration of exposure (in minutes).

stack sampling is used, tests will be conducted each 90 days. Where outside networks are used, sampling will be continuous and filters will be collected every 4 days unless otherwise approved by the Administrator. When it is the opinion of the Administrator that the standards will not be exceeded, a waiver of stack-sampling requirements can be granted.

EFFECTS ON HEALTH

The adverse effects of airborne beryllium on human health were first recognized in 1940 as a result of the occurrence of lung disease in occupationally exposed workers. Beryllium workers develop two forms of lung disease. One form, an acute chemical pneumonitis, has been observed, with one reported exception,² only in workers who were occupationally exposed to beryllium. The chronic form, berylliosis - a progressive, interstitial, granulomatous disease located primarily in the alveolar walls - has been observed in individuals who have never been occupationally exposed to beryllium. Of the 60 people with non-occupationally incurred disease whose cases are on file with the Beryllium Registry, 27 were exposed to beryllium by washing clothes soiled with beryllium dust. Another 18 were exposed to beryllium in the form of air pollution surrounding beryllium plants, 13 were exposed both to polluted air and contaminated clothing, and the exposure of the remaining 2 was unknown.³

Most of the cases of berylliosis involved exposure to beryllium at a time when its hazard was not recognized and its concentration in the air was not measured. Retrospective estimates of the concentrations of beryllium that resulted in some cases of berylliosis from non-occupational exposure have been made. The report of this work states: "It may therefore be concluded that the lowest concentration which produced disease was greater than 0.01 microgram per cubic meter and probably less than 0.10 microgram per cubic meter."⁴

In 1949, a guideline limit for beryllium concentrations in community air was developed by the Atomic Energy Commission (AEC).⁵ The concentration selected was an average of 0.01 microgram of beryllium per cubic meter of air for 30 days. In the period since the implementation of this guideline, no reported cases of chronic beryllium disease have occurred as a result of community exposure.¹ Consequently, the Committee on Toxicology of the National Academy of Sciences has concluded that the average concentration 0.01 $\mu\text{g}/\text{m}^3$ for 30 days has proved to be a safe level of exposure. Therefore, an average of 0.01 $\mu\text{g}/\text{m}^3$ for 30 days should be used as a guide in developing emission standards.

NATURE OF BERYLLIUM AIR POLLUTION PROBLEM

Emissions of beryllium from the sources covered by these standards occur as dust, fume, or mist. Alteration of a beryllium product by burning, grinding, cutting, or

other physical means can, if uncontrolled, produce a significant toxicological hazard. In contrast, beryllium alloys in the form of strip or other wrought products are utilized in operations that do not generate dust, fume, or mist. The number of operations that use beryllium is estimated to be in the thousands. Approximately 300 operations such as machine shops, ceramics plants, propellant plants, extraction plants, and foundries comprise the major users of beryllium that could cause emissions to the atmosphere.

The distribution of the sources of beryllium is such that dangerous levels have not been recorded except in a few instances. Data from the National Air Surveillance Networks do not show the existence of dangerous levels.

Beryllium extraction plants, in present practice, determine effectiveness of control of emissions by measuring ambient air concentrations at various points in the vicinity of the plants. For control of wet chemical processes, scrubbers, packed towers, organic wet collectors, and wet cyclones are used. In dry operations, cyclones and fabric-filter units are often used. The following are typical air management practices:

1. Local pickup of contaminated exhaust from fully enclosed sources.
2. Tandem use of primary and secondary air-cleaning devices; the former is used mainly to take reactive gases and easily removable contaminants out of the exhaust air, and the latter is used to provide high-efficiency cleaning.
3. Use of high-energy wet collectors (or scrubbers) to obtain high particle-collection efficiency (in the removal of corrosive, wet, and/or hygroscopic contaminants).
4. Application of fabric tube filters for high-efficiency cleaning.

All extraction plants have the control equipment necessary to keep ambient concentrations below $0.01 \mu\text{g}/\text{m}^3$. Regardless of plant size and type of beryllium operation, the target concentration of $0.01 \mu\text{g}/\text{m}^3$ has been achieved readily. Operators of extraction plants indicate that their experience in operating government-owned beryllium plants under contract with the AEC within the 0.01 ambient air level, and voluntarily maintaining the same level of control in their own private facilities, has demonstrated that the required ambient air level can be met in an economically feasible manner. Results obtained from sampling sites in the vicinity of plants

show that all extraction plants are in compliance with the $0.01 \mu\text{g}/\text{m}^3$ standard or are very close to it.

In industries other than primary extraction plants, the control devices applied are usually dry collectors and a variety of pre-filter and high-efficiency particulate air (HEPA) (or absolute) filter equipment. Examples of the most thorough emission control practices may be found among ceramic manufacturing plants, machine shops, and propellant fabricating facilities. In many of these industries, air-cleaning equipment includes primary fabric tube filters followed by secondary HEPA filters, or dry collectors followed by pre-filter/HEPA filter units. Arrangements such as these are among the most effective in reducing beryllium emissions. The most poorly controlled operations occur in foundries and in shops that occasionally machine beryllium metal, alloy, or ceramic materials.

Since 1966, emissions from the firing of rockets utilizing beryllium as a propellant have been limited by PHS policy; since 1967, they have been limited as well by DOD directive.^{6,7} Both agencies direct that 75 microgram-minutes of beryllium per cubic meter of air not be exceeded. Both also suggest that rockets be fired into containment vessels if possible and, if not, that they be controlled by other positive engineering methods, such as the use of scrubbers.

DEVELOPMENT OF PROPOSED STANDARDS

The sources covered by these standards, if not controlled, can potentially release amounts of beryllium that will produce concentrations greater than $0.01 \mu\text{g}/\text{m}^3$ in the ambient air. No source known to have caused, or to have the potential to cause, dangerous levels is excluded from these standards.

Other sources of beryllium emissions to the atmosphere exist that are not included in the standards. The beryllium content of coal varies, but most coal contains from 1 to 2 parts per million (ppm). Present knowledge indicates that coal-fired power plants do not produce hazardous levels of beryllium in ambient air. Beryllium emissions from coal combustion have recently been and will continue to be documented by source testing. As additional sources of beryllium are discovered, the magnitude of their emissions will be evaluated and, if necessary, that source will be included among those covered by these standards.

Considering dispersion estimates, number and type of emission sources per facility, and average fence-line distances, a maximum emission of 10 grams of beryllium per day provides assurance that a concentration of 0.01 microgram of beryllium per cubic meter of ambient air will not be exceeded. Limiting the beryllium concentrations in ambient air to $0.01 \mu\text{g}/\text{m}^3$ has proved successful in protecting community populations from beryllium-caused disease since this limit was proposed in 1949.

Contacts made by EPA have indicated that the control systems required to meet this standard are already in use in many facilities. For example, one machine shop emits 0.4 gram per day; another large machine shop, which uses absolute filters, exhausts its air at concentrations below $0.01 \mu\text{g}/\text{m}^3$; and a third machine shop exhausts 5,000 cubic feet per minute, with a concentration of $2 \mu\text{g}/\text{m}^3$ of exhaust, for a total emission of less than 0.3 gram per day. At least 20 of the operations contacted use absolute filters as a final cleaner.

ECONOMIC IMPACT OF PROPOSED STANDARDS

In order to assess properly the economic impact of the beryllium standards, it must first be understood that the major portion of the beryllium industry already has the emission controls necessary to comply with the standards. This level of control has been the result of recommendations issued in 1949 by the Beryllium Medical Advisory Committee to the AEC.⁵ Compliance with the AEC recommendations has been required of all government facilities and government contractors. Other beryllium operators generally accepted them to protect themselves and their employees.

The cost of controlling beryllium emissions varies with the nature and size of the operation. In most cases, the percentage of capital costs allocated for control of emissions should approximate the values listed below:

<u>Source</u>	<u>Percentage of capital cost</u>
Foundries	13.0
Ceramic plants	19.0
Machine shops	8.0
Extraction plants	12.0

These percentages include all ventilation equipment inside the plant, some of which is necessary for good industrial hygiene. Because good inside control of emissions is necessary in all beryllium operations, it is difficult to separate emission control costs from the cost of controlling the inside atmosphere. For this reason, the stated costs of beryllium emission control are deceptively high.

The beryllium emission standards will have little economic impact on the industry. In addition to the fact that most of the potentially dangerous sources are already controlled, the beryllium collected in control equipment can in some cases be sold to the primary extraction plants for reprocessing.

Foundries may have to add control equipment and install stacks suitable for stack testing. Control equipment is generally lacking, but in most cases emissions do not exceed the proposed standards. In any case, beryllium is an expensive material and the cost of control is low in terms of consumer prices.

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TECHNICAL REPORT NO. 3 —

MERCURY

SUMMARY OF PROPOSED STANDARDS

The proposed standards are intended to protect the general public from adverse health effects contributed to by inhalation of atmospheric mercury. Mercury-cell chlor-alkali plants and primary mercury mines will be regulated by the proposed standards. Each facility of these two industries may not emit more than 5 pounds of mercury into the atmosphere during a 24-hour period.

The monitoring requirements of the proposed standards at each facility will be based on EPA-approved sampling and analytical techniques, and such measurements will be made at intervals of 90 days. All emission data, records of required operating parameters existing at the time of emission measurement, and operating records necessary to estimate the emissions from the facility during each 90-day period must be kept on file for inspection for a minimum of 2 years.

The above monitoring requirements may be waived by EPA if a facility installs and institutes control techniques and housekeeping procedures that EPA deems adequate for meeting the standards.

EFFECTS ON HEALTH

It has been stated that most mercury compounds degrade to elemental mercury under the action of sunlight.¹ Consequently, most atmospheric mercury is probably chiefly elemental mercury in vapor or aerosol form.² Airborne mercury may be inhaled directly by man or it may settle out of the atmosphere or fall with rain. It has been demonstrated³ that man will absorb 75 to 85 percent of inhaled mercury vapor at concentrations of 50 to 350 $\mu\text{g}/\text{m}^3$. Lower concentrations may be absorbed more completely.⁴

The central nervous system is the critical focal point in long-term exposure to mercury vapor.³ The vapor is absorbed into the blood from the lung where some of it remains unchanged, and some is oxidized to mercuric ions, a form whose action results in damage. Elemental mercury is lipid-soluble and can, therefore, diffuse

into the central nervous system and similar tissues where more of it is oxidized to mercuric ions. Mercury can accumulate in the brain, testes, and thyroid because its elimination from these sites is slow.

In cases of chronic exposure to mercury vapor, symptoms indicating central nervous system involvement are most commonly seen, the principal features being tremor and psychological disturbances.³ In addition, loss of appetite, loss of weight, and insomnia have been reported.⁵

In order to determine the level of mercury in the ambient air that does not impair health, the airborne burden must be considered in conjunction with the contribution of mercury from water and food. Swedish experts have concluded that an intake of 30 $\mu\text{g/day}$ of methyl mercury is safe.¹ An intake, however, of ten times that amount, or 300 $\mu\text{g/day}$, of methyl mercury can be expected to produce symptoms in the most sensitive humans.^{3,6} In a study of occupational exposures,⁵ a similar intake of mercury vapor was found to have some subtle effects, such as loss of appetite and loss of weight. Because similar intakes of methyl mercury and mercury vapor appear to produce detrimental effects, exposures to methyl mercury (diet) and mercury vapor (air) will be considered equivalent.

Data on the dietary (food and water) intake of mercury are scarce. Recent estimates in Sweden and the United States make some generalizations possible, however. Diets containing fish contaminated to the FDA limit (0.5 $\mu\text{g/g}$) would lead to intakes in excess of 30 $\mu\text{g/day}$ of mercury, a problem which must be resolved. From average diets, however, over a considerable time period, one could expect mercury intakes of about 10 $\mu\text{g/day}$; thus the average mercury intake from air would have to be limited to 20 $\mu\text{g/day}$ if the average total intake is to be restricted to 30 $\mu\text{g/day}$.

Assuming inhalation of 20 cubic meters of air per day, the air could contain an average daily concentration of no more than 1 $\mu\text{g Hg/m}^3$. Because chronic health effects occur with long-term exposure, emission standards should be designed to restrict air concentrations to a daily concentration, averaged over 30 days, of 1 $\mu\text{g Hg/m}^3$.

NATURE OF MERCURY AIR POLLUTION PROBLEM

Mercury, although a scarce metal, is widely distributed throughout the earth's crust and hydrosphere. Because of its high volatility, emissions of mercury emanate from any source where mercury is exposed to the atmosphere or where any material bearing mercury is processed. Some major sources of atmospheric mercury are considered to be coal-fired power plants, paint, primary non-ferrous smelters, incinerators, mercury-cell chlor-alkali plants, primary and secondary mercury-processing plants, and general laboratories and hospitals.

Mercury and its compounds enter the atmosphere through emission in the form of vapors and particulates from industries and also by evaporation from soil and water. Once in the atmosphere, mercury is widely transported by wind currents. Eventually, some of the atmospheric mercury returns to the earth's surface as settleable particulates, but most of it returns with rainfall. Because the mercury that falls on soil does not penetrate deeply, it can re-enter the atmosphere by evaporation or wash off into an aqueous system. Other ways by which mercury can gain entrance into aquatic systems are through settleable particulates, rainfall, and soil erosion. After entering the hydrosphere, all forms of mercury appear to be directly or indirectly capable of being converted by bacteria to highly toxic methyl and dimethyl mercury. The solubility of methyl mercury in water causes it to be incorporated into the body tissues of aquatic life forms and, ultimately, into the human food chain. Dimethyl mercury can evaporate from the water system and re-enter the atmosphere.

As is readily seen from the foregoing discussion, mercury is extremely mobile in the environment. Natural processes such as methylation, evaporation, and solution provide means for mercury compounds to cycle between air, water, and land for an indefinite period of time. Atmospheric mercury is not only a local inhalation hazard, but can contribute to contamination of food and drinking water or produce hazards in other ecological systems.

Currently there are few existing data concerning atmospheric concentrations of mercury. Those data that do exist, however, indicate that a concentration of $1 \mu\text{g Hg/m}^3$ may be approached, on a 24-hour basis, in large industrial cities. The measurement of mercury and its compounds in ambient air and from industrial-plant effluents has only recently received attention; as a result, measurement methodology is in a state of evolution.

Few industries currently control atmospheric mercury emissions solely for the sake of protecting public health. In general, economic reasons have dictated the use of those mercury emission controls that are employed. In the primary and secondary mercury industries, process efficiency improves with lower mercury emissions, thereby making reduction of mercury emissions profitable. Some primary non-ferrous smelters collect mercury from their gaseous effluents as a by-product. The basic control method employs condensation to remove mercury from a gas stream. The amount of cooling accomplished depends on the temperature of the ambient air and available cooling water. In the mercury-cell chlor-alkali industry, the hydrogen stream is cooled to collect valuable mercury that must be replaced if atmospheric losses occur. In certain cases, the hydrogen stream is either treated further with impregnated activated carbon or cooled to very low temperatures and sold as a by-product.

to the chemical industry. The mercury concentration in the chlor-alkali cell room is controlled to less than $100 \mu\text{g}/\text{m}^3$, as recommended by the National Conference of Governmental Industrial Hygienists (NCGIH), to protect operating personnel from mercury poisoning. The control is maintained by dilution of the cell-room air with large ventilation flow rates, resulting in sizable atmospheric emissions from the cell rooms.

DEVELOPMENT OF PROPOSED STANDARDS

Considering dispersion estimates, number and type of emission sources per facility, and average fence-line distances, a maximum emission of 5 pounds of mercury per day provides assurance that a concentration of 1 microgram per cubic meter of ambient air will not be exceeded. This level will protect the public from adverse health effects due to inhalation of mercury. A meteorological derivation is given in the Appendix. Of the major sources of mercury emissions, mercury-cell chlor-alkali plants and primary mercury-processing plants are the only two that are known to be emitting mercury in quantities and in a manner that will cause the ambient air concentration of mercury to exceed $1.0 \mu\text{g}/\text{m}^3$ (assuming a negligible background level). The proposed standards can be achieved, however, with existing technology in both the chlor-alkali and primary mercury industries. Additional control of mercury emissions from the primary industry can be achieved by cooling the effluent gases to lower temperatures. The additional cost incurred would put unbearable economic burdens on an already declining industry. Additional control of mercury emissions for the chlor-alkali industry is not feasible at this time. The cell room, which is responsible for the largest emissions from a chlor-alkali plant, is not readily adaptable to existing control methods because of the low mercury concentration contained in the large volumetric flow rate of cell-room ventilation systems.

Currently, work is in progress to determine additional mercury sources and the extent of mercury emissions to the atmosphere. Operators of those plants suspected of being sources of atmospheric mercury emissions will be required to submit the information necessary for quantifying mercury emissions from their operations.

ECONOMIC IMPACT OF PROPOSED STANDARDS

There are no known state regulations that control specifically the emissions of mercury to the atmosphere or control ambient-air levels of mercury. The City of New York, however, has revised its 1964 Code of City of New York, Article 9, to state: "No emission of air contaminants containing cadmium, beryllium, and mercury, or any compounds thereof, are allowed." This law became official on August 21, 1971.

Zero emission of mercury is defined as $0.1 \mu\text{g}/\text{m}^3$, or less, of effluents. Furthermore, the State of Wisconsin has issued a legal order to a mercury-cell chlor-alkali plant to reduce its total mercury emissions from both the hydrogen and end-box-ventilation gas streams to less than 0.9 pound of mercury per day. Although the order did not regulate the amount of mercury in the ventilation effluents from the cell room, mercury emissions from this source must be compatible with the present Occupational Health Standard of $100 \mu\text{g}/\text{m}^3$. The proposed Federal standard of 5 pounds of mercury per 24-hour period may require the chlor-alkali plant in Wisconsin to improve its present control. The proposed Federal standards should have no impact on the standard for mercury emissions set by the City of New York since the latter is more restrictive than the former.

Since mid-1970, the consumption of mercury in chlor-alkali plants, agricultural use, and paper industries has been reduced, largely because mercury emissions from these users were thought to contribute to environmental pollution. The total use of mercury has decreased by more than one-third of the consumption for the same period in 1969. A decrease in the price and production of mercury has followed the decrease in consumption.

Average primary mercury production has dropped from 29,640 flasks in 1969 to 27,303 flasks in 1970, and to 7,900 flasks in the first two quarters of 1971. Average price per flask of mercury was \$505 in 1969, \$405 in 1970, and \$286 in the second quarter of 1971. The August 1971 price was \$295 per flask. Marginal prices required for production range from \$360 to \$400 per flask for underground operations, and from \$270 to \$300 for open-pit operations. Current prices are so far below marginal costs that all but a few primary mercury mines have abandoned production. As a result, the number of mercury mines in operation has dropped from 109 in 1969 to fewer than 10 in August 1971.

A mine processing 100 tons of ore per day has a capital investment of \$300,000 to \$400,000 in its processing equipment and produces mercury valued at an average of \$518,000 per year. The amount of mercury emitted is estimated to be a minimum of 4 to 35 pounds per 24-hour day. Control devices to limit mercury emissions to 5 pounds per day require a capital investment of \$38,000 to \$42,000 and a yearly operating or annualized cost of \$12,500 to \$18,000.

The capital required for control devices for mercury mines is approximately 10 percent of the total capital investment for processing equipment. The total value of 1971 production, if it continues at the current rate, will be about \$5,200,000. The annualized cost of control equipment as a percentage of total product worth (at \$295 per flask) varies from 2.5 to 3.5 percent. Partial recovery of operating cost will be obtained from the value of additional recovered mercury.

Large, directly fired ore smelters are not meeting the proposed standards. Condenser gas, which is currently being emitted at 90° to 145° F, may have to be cooled to 55° F and demisted to meet the proposed standard. The control equipment cost is based on this control technique. Because of the currently depressed market, only the larger directly fired mercury smelters, which produce about 75 percent of the current U. S. mercury production, may be able to absorb the cost of required controls. The primary retort operations, which account for 10 to 15 percent of the U. S. mercury production, are probably already meeting the proposed standards, and little impact on this type of operation is expected.

The U. S. mercury production cannot substantially affect the international price of mercury, so that little of the cost increase required for control of emissions is expected to be passed on to the consumer. The current low mercury prices have caused the shutdown of both small retort operations and large, directly fired operations. These shutdowns were accelerated by the availability of only low-mercury ores.

The production of chlorine and alkali metal hydroxide is estimated to grow at a rate of 6 percent for the next 5 years. There are currently 16 companies operating 31 mercury-cell chlor-alkali plants in the United States. The total daily production is 7,556 tons of chlorine; the average plant produces 244 tons per day. The mercury-cell chlor-alkali process produces about 28 percent of the U. S. production of chlorine and caustic. The average plant in 1969, with no mercury emission controls, was emitting 60 to 80 pounds of mercury per day. Currently, plants with limited controls are emitting from 10 to 15 pounds of mercury per day. Original plant investment ranges from \$14,000,000 to \$20,000,000. Annual value of chlorine and alkaline metal hydroxide from an average plant is \$14,100,000.

Capital costs of control devices necessary for meeting the proposed standard of 5 pounds of mercury per 24-hour period vary from 1.7 to 2.7 percent of the original plant investment. The annualized cost of controls for an average chlor-alkali plant ranges from \$75,000 to \$120,000. These control costs depend largely on the sophistication and complexity of the control devices needed to meet the proposed standards, and will vary in different chlor-alkali plants. The annualized cost as a percentage of the total product worth will vary from 0.5 to 0.9 percent. The annualized cost includes allowances for labor and supervision, maintenance, payroll overhead, operating supplies, indirect costs, and capital charges at 14 percent per year. Amortization of this annualized cost will at least be partially absorbed by the consumer.

Currently, most chlor-alkali plants are probably not meeting the proposed Federal standards, but can do so by installing adequate control devices. The additional cost of control devices will effect the economics of the mercury cell and will reduce or eliminate the favored economics of mercury cells over diaphragm cells. With current technology, the mercury-cell operation produces high-grade sodium hydroxide at a lower price than is possible by the diaphragm-cell operation. In general, the cost required for producing chlorine by the mercury-cell process, however, is slightly higher.

Until recently, the need to supply the textile and plastics industries with low-priced, high-grade sodium hydroxide justified the fabrication of new chlor-alkali plants employing the mercury-cell operation. Construction of future chlor-alkali plants will probably favor the diaphragm cell to avoid environmental problems with mercury emissions to water and air, and the economics of the chlor-alkali processes will not be a deciding factor. Modern mercury-cell plants will be controlled and will continue to operate. Only those plants that are already obsolete or marginal will be abandoned.

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APPENDIX. ATMOSPHERIC DISPERSION ESTIMATES

GENERAL PROCEDURES

Dispersion estimation techniques were employed to assist in the development of national emission standards for mercury and beryllium. Because of the broadness of the estimation criteria and the generally conservative nature of the estimation techniques used, the results were used as a guide rather than as an absolute means of determining allowable emissions. The estimates made were intended to apply to a large number of sources characterized by diverse emission characteristics, climatic conditions, and topography. Selection of a calculation method and of meteorological assumptions, therefore, involved professional judgment based on diffusion theory and the limited, pertinent information that is available concerning existing plants.

In estimating allowable emissions, the following factors were taken into account:

1. The ambient air goals are $1 \mu\text{g}/\text{m}^3$ for mercury and $0.01 \mu\text{g}/\text{m}^3$ for beryllium, maximum 30-day average concentration. The 30-day averaging period necessitated use of a long-term dispersion estimation method.
2. The allowable emissions being estimated are intended to keep ambient pollutant levels from exceeding the given concentration goals. They should apply to all rather than to average source situations. Therefore, meteorology and topography at source locations with the most restrictive dispersion conditions, that is, where the least emissions would be allowed, form the basis for the calculations.
3. The nature of the locations of the more significant sources of mercury and beryllium (other than extraction and primary metal production plants) dictated that the meteorological assumptions used for each pollutant be somewhat different. The mercury sources that are affected by restrictive dispersion conditions are typically situated in relatively rural, valley locales. Correspondingly, such beryllium plants are typically situated in urban, coastal locations.
4. The estimation criteria are rather broad. Therefore, generally conservative assumptions were employed in order to be reasonably confident that the calculated allowable emissions will not result in ambient air concentrations in excess of the indicated ambient air concentration goals under any realistically possible circumstances.

CALCULATION METHOD

The general equation given by Turner¹ for estimating long-term dispersion is Equation 5.15. For this particular application it is assumed that:

1. A source emits at a constant rate.
2. Wind direction frequency is the maximum percentage occurrence of wind flow from one of sixteen 22.5-degree sectors during any 30-day period.
3. Wind flow is random from all directions within a sector during a 30-day period. Correspondingly, the effluent is uniformly distributed horizontally within a sector.

With relation to the pollutants being considered, further assumptions are that:

1. Mercury and beryllium are emitted in aerosol form.
2. All effluents are emitted from a single stack. (This assumption is rather conservative, for most sources have multiple emission points that permit greater initial dispersion.)
3. No loss of pollutants occurs from fallout, decay, or other natural removal processes.
4. Mercury or beryllium background is negligible and no interaction of plumes between sources occurs.

The equation in the form used to estimate maximum allowable daily emissions is:

$$Q_{\max} = \frac{8.64 \sqrt{2} \pi^{3/2} x_{\max} U \sigma_z X}{16F \exp \left[-1/2 \left(\frac{H}{\sigma_z} \right)^2 \right]} = \frac{4.23 x_{\max} U \sigma_z X}{F \exp \left[-1/2 \left(\frac{H}{\sigma_z} \right)^2 \right]}$$

where: Q_{\max} = maximum allowable daily emission, g/day

x_{\max} = maximum 30-day average concentration, $\mu\text{g}/\text{m}^3$

U = representative average wind speed, m/sec

σ_z = vertical dispersion term as function of stability and distance, m

X = distance downwind, m

F = maximum frequency of wind direction from a 22.5-degree sector, %

H = effective stack height, m

Effective stack height was assumed to be 10 meters (about 33 feet). This assumption was made since mercury and beryllium are usually emitted from roof vents or short stacks with little or no plume rise. The consequent release of pollutants at a relatively low height is compounded by aerodynamic downwash effects that often influence these sources. The result is to minimize the average effective height of emission.

METEOROLOGICAL ASSUMPTIONS

There are three principal meteorological parameters for which representative values were selected. These parameters are:

1. Average wind speed, U.
2. Average atmospheric stability, which determines values of the vertical dispersion term, σ_z .
3. Maximum frequency of wind direction from any one sector, F.

Restrictive meteorological conditions selected as representative of the site types indicated for mercury and beryllium for a 30-day period are as follows:

	<u>Mercury</u>	<u>Beryllium</u>
Average atmospheric stability	Neutral (class D)	Slightly unstable (class C)
Average wind speed	2 m/sec (4.5 mi/hr)	3 m/sec (6.7 mi/hr)
Maximum wind direction frequency	40 percent	40 percent

DISCUSSION OF METEOROLOGICAL ASSUMPTIONS

Representative meteorological conditions were selected from a range of alternatives. The purpose of this discussion is to indicate the effect on estimated allowable emissions of the various alternatives.

Average Atmospheric Stability

In selecting an average stability condition for site types with typically restrictive meteorological conditions, the choice was made between the Pasquill class C, D, and E stabilities for mercury and class C and D stabilities for beryllium. For a rural-valley mercury source site, D (neutral) is judged to be the most appropriate stability. Stability C (slightly unstable) would apply if the valley site experienced significant turbulence induced by buildings or topographic features. Class E (slightly

stable) would be the least likely choice and would apply in a well-protected valley under deep shadows during a large portion of the daylight hours. Most sources of beryllium, such as metal working or machine shops, would typically be located in metropolitan areas where the heat island effect and building-induced turbulence would be likely to result, on the average, in a class C stability condition. In smaller or suburban communities, class D would probably be a better choice.

The calculated maximum allowable emissions for the stability classes discussed are shown in Figure 1 for mercury and in Figure 2 for beryllium. These figures show maximum allowable emissions calculated not to exceed ambient concentration goals at corresponding distances from the source.

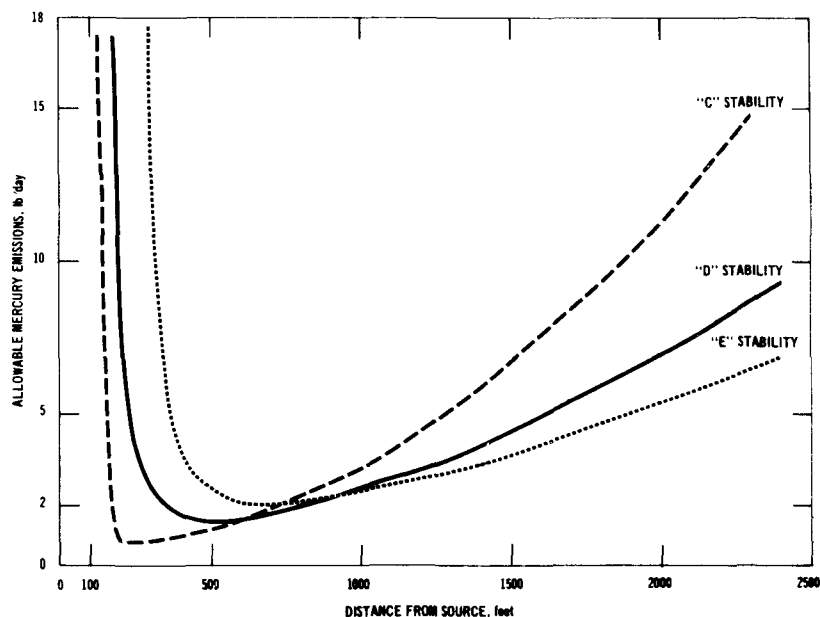


Figure 1. Calculated maximum allowable mercury emissions under applicable Pasquill stability classes (C, D, and E) and wind speed of 2 m/sec.

Average Wind Speed

For estimating allowable mercury emissions, the choice of 2 mps (4.5 mph) is conservative. However, an actual valley site in which a chlor-alkali plant is situated had an average wind speed of 4.6 mph during a recent annual period of measurement. The wind speed of 2 mps was chosen over a less restrictive wind speed of 3 mps (6.7 mph). The effect of a 3-mps wind speed on calculated allowable emissions is shown in Figure 3 for the three stability alternatives. For estimating allowable beryllium emissions, the choice of 3 mps was considered typical of some urban-coastal source sites and no other alternative was considered.

Maximum Wind Direction Frequency

The maximum wind direction frequency of 40 percent that was used to estimate mercury emissions is slightly conservative. Inspection of limited data available for a

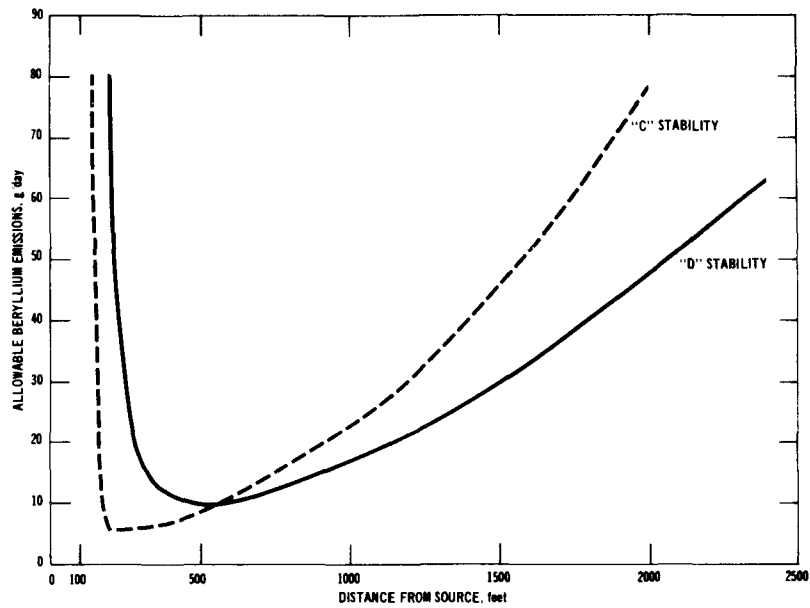


Figure 2. Calculated maximum allowable beryllium emissions under applicable Pasquill stability classes (C and D) and wind speed of 3 m/sec.

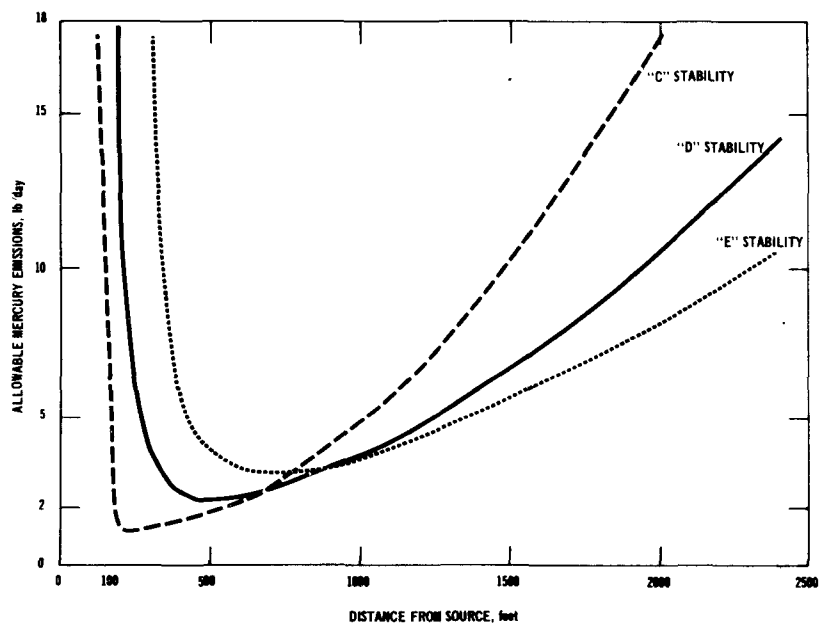


Figure 3. Calculated maximum allowable mercury emissions under applicable Pasquill stability classes (C, D, and E) and wind speed of 3 m/sec.

period of 1 year for four typical valley locations indicated maximum values in the range of 30 to 35 percent. It is likely that inspection of data for a longer period would have revealed values approaching or possibly exceeding 40 percent. It suffices to point out that, on the basis of available information, the 40 percent may

be slightly conservative. With respect to beryllium sources, inspection of available wind direction frequency data for a 5-year period did reveal values of 40 percent or greater at some coastal sites, apparently as the result of flow patterns associated with typical sea-breeze effects.

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