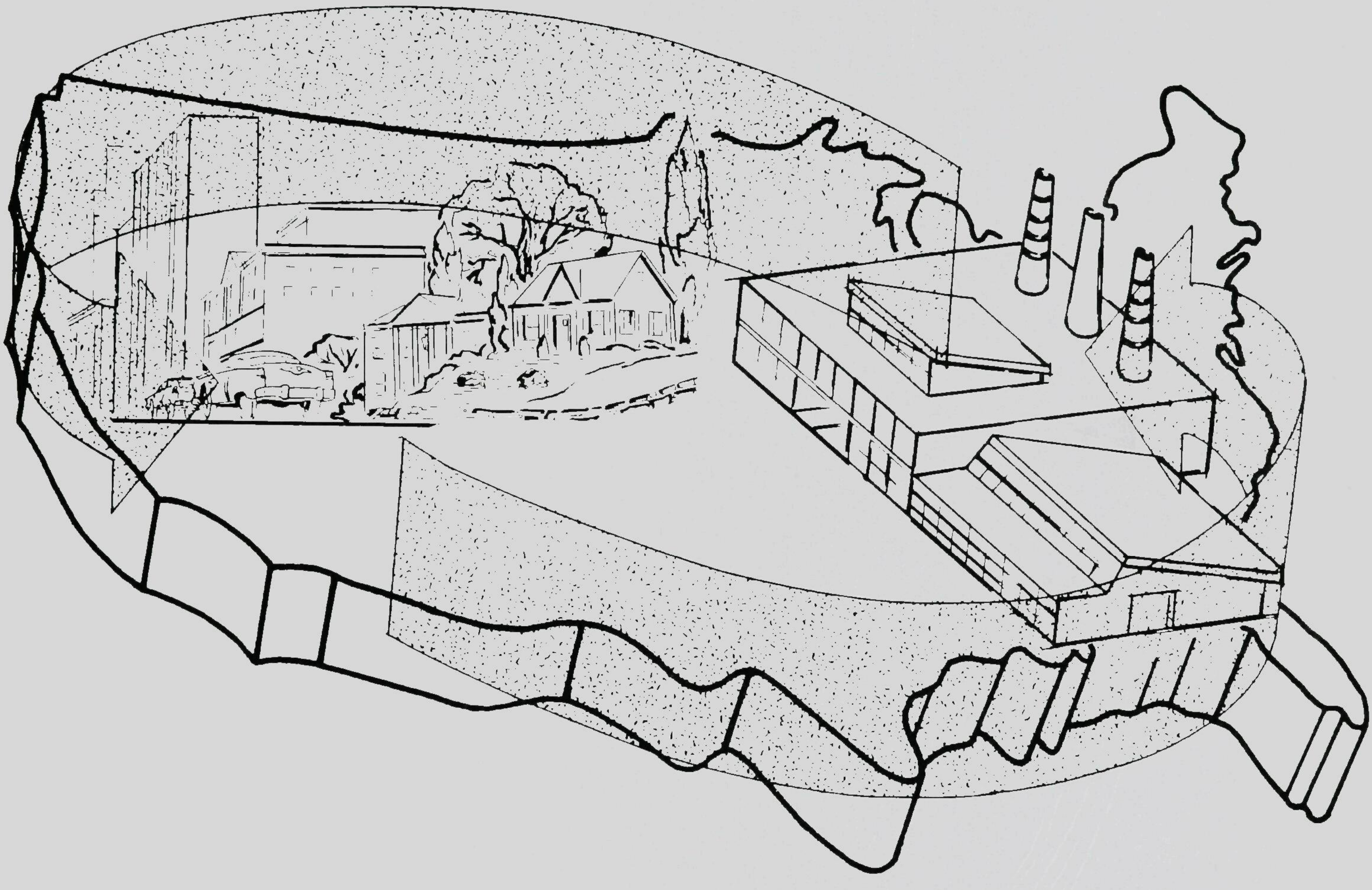
# LEWISTON, IDAHO,—CLARKSTON, WASHINGTON
# AIR POLLUTION ABATEMENT ACTIVITY



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

TECHNICAL REPORT

# LEWISTON, IDAHO—CLARKSTON, WASHINGTON AIR POLLUTION ABATEMENT ACTIVITY

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
National Center for Air Pollution Control
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## SECTION I—SUMMARY AND CONCLUSIONS

Air pollution in Lewiston, Idaho, and Clarkston, Wash., has been a matter of concern to residents of the bi-state area for the past several years. There are numerous sources of air pollution in the community; the largest of these is the Potlatch Forests, Inc., kraft pulp mill located just east of Lewiston. Most complaints about air pollution have been directed at this mill.

Investigations of air pollution in the community have been concerned with air quality, meteorology, sources of pollutants, and various effects of air pollution. The interstate movement of pollutants, particularly odorous gases emitted by the pulp mill in Idaho and transported to Clarkston, Wash., has been demonstrated. In a public opinion survey in Clarkston, Wash., more than 90 percent of the persons interviewed perceived air pollution in the community as a malodor problem.

One investigation conducted jointly by Federal, state and local agencies resulted in recommendations in 1963 that a regional air resource management council be established in 1964. It was recommended that this agency have certain responsibilities, including surveillance of air quality and planning for control of pollutant emissions. By December of 1965 no such agency had been organized and the Secretary of Health, Education, and Welfare initiated an interstate air pollution abatement action.

Personnel of the Idaho Department of Health, the Washington State Department of Health, and the Public Health Service, visited the Potlatch Forests, Inc., pulp mill in May 1966. Potlatch Forests, Inc., gave full cooperation and provided a detailed report on emissions of air pollutants from its pulp and paper mills, and its wood products operations at Lewiston. The Company reported emissions amounting to about 1,800 pounds of hydrogen sulfide, 2,500 pounds of mercaptans, and 1,000 pounds of organic sulfide gases per day from the pulp mill; about 23,000 pounds of particulates, consisting mostly of sodium sulfate and sodium carbonate per day, from the mill's recovery furnaces; and an average of about 9,700 tons of water vapor per day from all operations.

An inventory of air pollutant emissions from sources other than Potlatch Forests, Inc., was conducted in the Lewiston-Clarkston area in the fall of 1966. Calculated daily emissions of selected pollutants included about 4,000 pounds of particulates, 100,000 pounds of carbon monoxide, and more than 20,000 pounds of hydrocarbons. The particulates are generated primarily by industrial processes and by burning of fuel and refuse; carbon monoxide and hydrocarbons come, for the most part, from motor vehicles. About two-thirds of the community emissions are released in Idaho and about one-third in Washington.

The valley topography of the Lewiston-Clarkston area tends to channel winds in easterly and westerly directions. The predominant wind direction is east; winds from this direction occur more than one-fourth of the time on an annual basis. Wind speeds are very low; the annual average in Lewiston is less than 4 miles per hour. Temperature inversions tend to confine air pollutants in the valley, and they occur frequently. High concentrations of air pollutants occur at the surface when layers of pollutants which have been carried over the cities are brought to the ground during inversion break-up. Hydrogen sulfide concentrations in Clarkston were calculated by using meteorological diffusion equations and emission rates reported by Potlatch Forests, Inc. The calculated concentrations agree well with the 10 to 15 parts per billion actually measured in earlier investigations.

The results of various technical investigations of air pollution, studies of meteorology, and determinations of pollutant emissions in the Lewiston-Clarkston area lead to the following conclusions:

1. Terrain configuration and prevailing winds in the Lewiston, Idaho-Clarkston, Wash., area result in the transport of air pollutants alternately from either of the states to the other. The confining effect of the valley walls, the high frequency of temperature inversions, and the low average wind speed in the area all favor the accumulation of pollutants in the valley.

2. A number of sources in the area emit air pollutants. The major source, and the only one that emits large quantities of the odorous gases (hydrogen sulfide, mercaptans, and organic sulfides) that are characteristic of kraft pulping operations, is the Potlatch Forests, Inc., kraft pulp mill. Odorous gases from this mill are transported across the state boundary from Idaho to Washington.

3. Particulate material, consisting primarily of sodium sulfate, emitted from the pulp mill recovery furnaces can, under certain circumstances, cause damage to some types of paint on ferrous metals and expose the metals for corrosion.

4. Technology is adequate to control the escape of pollutants from kraft pulping processes to the atmosphere.

5. Potlatch Forests, Inc., has made efforts to control emissions of pollutants from its pulp mill at Lewiston, and plans for additional effort have been reported. Accomplishments to date have been inadequate to control the problem.

6. Industrial incineration and the burning of refuse produce smoke which contributes to air pollution in the community. Means are available to reduce or eliminate emissions of pollutants from such sources.

## SECTION II—INTRODUCTION

The cities of Clarkston, Wash., and Lewiston, Idaho, are located on opposite banks of the Snake River at its confluence with the Clearwater River on the boundary between Washington and Idaho. These two cities, and their adjacent unincorporated areas comprise a bi-state community of some 39,000 people. Of these 39,000 people, approximately 26,000 live in Idaho and 13,000 in Washington (Figure 1).

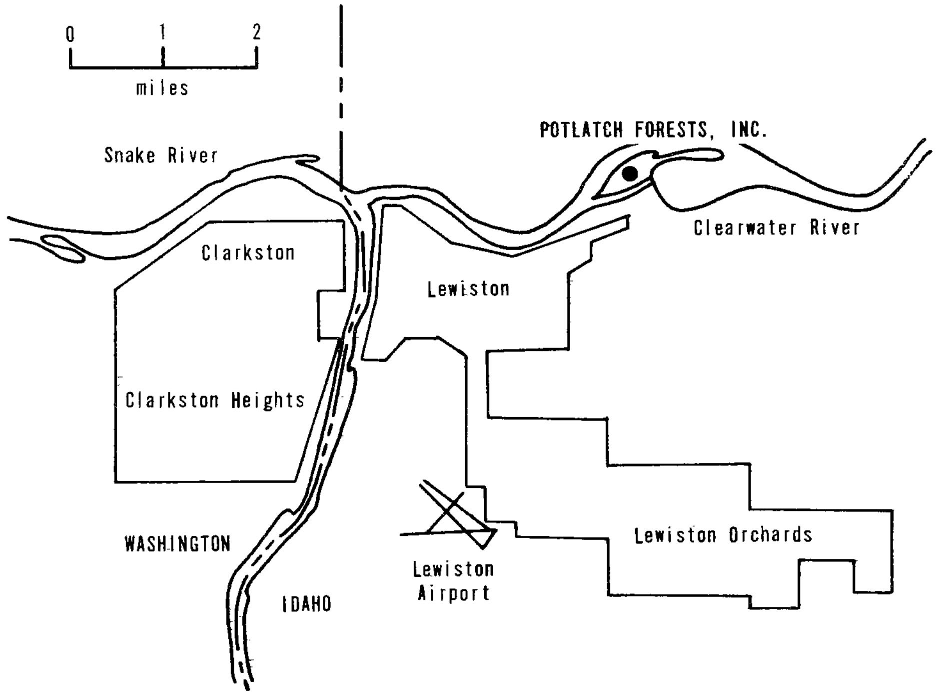


Figure 1. Lewiston-Clarkston study area.

Asotin County, Wash., in which Clarkston is located, has a population of about 13,400; and Nez Perce County, Idaho, in which Lewiston is located, has a population of about 29,000. Adjacent counties nearest to Lewiston and Clarkston are Whitman County, Wash., with a population of about 34,000, and Latah County, Idaho, with a population of 22,300. The trading area served by Lewiston and Clarkston has a total estimated population of about 110,000 people.

Lewiston and Clarkston are set in a rather narrow valley oriented east and west with a range of hills on the north sloping abruptly to about 2,000 feet above the valley floor. To the south, the terrain rises more gradually to a flat bench about 700 feet above the valley.

The area is important as an agricultural center. The manufacture of forest products is, however, the largest single category of business. There are several lumber mills in the area.

Just to the east of Lewiston, about 2 miles east from Clarkston, are the Potlatch Forests, Inc., kraft pulp mill, paper mill, and wood products plant. The pulp mill has an average current production rate of 755 tons of pulp per day. It has for several years been the object of complaints regarding air pollution in the area.

By letter of November 4, 1960, to the Chief, Division of Air Pollution, Public Health Service, the Mayor of Clarkston requested assistance in resolving the air pollution problem of the Clarkston-Lewiston area. In response the Public Health Service communicated with the air pollution agencies of the States of Washington and Idaho; subsequent events resulted in agreement to undertake a cooperative study of the area's air pollution problem by Federal, State, and local agencies.

During the period October 1961 to April 1962 this study was conducted; the following agencies participated:

The City of Clarkston, Wash.
The City of Lewiston, Idaho
Idaho Air Pollution Control Commission
North Central District Health Department, Idaho
State of Washington, Department of Health
Public Health Service, U. S. Department of Health, Education, and Welfare

The study report, entitled "A Study of Air Pollution in the Interstate Region of Lewiston, Idaho, and Clarkston, Washington," was published by the Public Health Service, U. S. Department of Health, Education, and Welfare, in 1964.[1/] In becoming signatory to the report, the Idaho Air Pollution Control Commission took exception and withheld its approval from portions of the report. The Commission did, however, give its wholehearted and unqualified concurrence and endorsement to the recommendations of the report. These recommendations, which were agreed to by the participating agencies at the conference held in Coeur d'Alene, Idaho, July 6-10, 1963, follow:

## RECOMMENDATIONS

In making these recommendations, the participating agencies recognize that the protection of air resources is essential to human well-being and orderly development of the area. Accordingly, it is recommended that:

1. An Air Resource Management Council should be organized and activated in 1964. The Council would consist of representatives from appropriate county and municipal agencies and from each of the respective state governments. The Public Health Service would act in an advisory capacity.

2. The Council should develop a program that might include the following:

   (a) Establish an air quality monitoring network, including meteorological instrumentation.

   (b) Assist in the development of a plan to control emissions of air pollutants at the sources.

(c) Arrange for personnel and other resources needed to implement the program.

(d) Determine the need for additional studies and arrange for their implementation.

The manner, method, and time scheduled for accomplishing these goals will be decided by local and state officials with the guidance of the public and representatives of commercial and industrial interests of the area.

3. The Council should release annual reports to permit evaluation of progress and to engender continued support.

4. Every opportunity should be given to resolve air pollution problems in the area without resort to legal redress so long as reasonable progress is evident as determined by the Council.

5. Local, city, and county governments should take steps to minimize the air pollution problem from the burning of refuse by individuals. Further, the City of Clarkston should eliminate the open burning of municipal refuse.

By December 1965 implementation of the recommendations had not been initiated and concern for the air pollution problem continued among residents of the area.

Pursuant to the provisions of Section 5 of the Clean Air Act, Public Law 88-206 (42 U.S.C. 1857d et seq) the Secretary of Health, Education, and Welfare, on December 23, 1965, requested that representatives of the air pollution control agencies of the States of Washington and Idaho consult with Department representatives concerning the problem of air pollution in the area. In his letter the Secretary stated that on the basis of reports, surveys, and studies, he has reason to believe that air pollution originating in Idaho is endangering the health and welfare of persons in Clarkston, Wash. The consultation was held in Seattle, Wash., on February 7, 1966. Following this consultation, arrangements were made by the Idaho Department of Health for technical representatives of the Public Health Service, U. S. Department of Health, Education, and Welfare, the Washington State Department of Health, and the Idaho Department of Health to examine the Potlatch Forests, Inc., kraft pulp mill at Lewiston. This examination was made on May 19, 1966. At the time of this visit officials of Potlatch Forests, Inc., agreed to supply to the Idaho Department of Health, for forwarding to the Public Health Service, information on emissions of air pollutants from the Lewiston operations. In response to questions developed by the Public Health Service, Potlatch Forests, Inc., assembled and supplied detailed information on emissions to the Idaho Department of Health in August 1966. The excellent cooperation of the Potlatch Forests, Inc., in permitting the visit to its facilities and in supplying information on emissions of air pollutants from its Lewiston operations is acknowledged.

About March 1, 1966, a Tri-County Air and Water Quality Control Committee was organized. The concern of this Committee is maintenance of the quality of air and water resources in Whitman and Asotin Counties, Wash., and Nez Perce County, Idaho. The Committee is composed of nine persons, one officially appointed by the governing body of each of the following:

Whitman County, Wash.
Asotin County, Wash.
Nez Perce County, Idaho
Port of Lewiston
Port of Clarkston
Port of Whitman County
Lewiston, Idaho
Clarkston, Wash.
Asotin, Wash.

The Charter of this Committee states that unacceptable levels of air and water pollution exist in portions of the tri-county area, and that the Committee shall undertake action leading to recommendations for controlling and abating such pollution. The function of the Committee is advisory only; regulation and enforcement actions shall be the responsibility of the parent municipal corporations or appropriate legislative bodies. The Charter of the Tri-County Air and Water Quality Control Committee is reproduced in Appendix A of this report.

Emissions of air pollutants occur in the vicinities of Lewiston and Clarkston from sources other than Potlatch Forests, Inc. An inventory of emissions from industrial, commercial, municipal, and domestic sources was conducted by Public Health Service personnel during the autumn of 1966. During this same period, special meteorological observations were made in the area by Public Health Service personnel. Results of both of these efforts are contained in this report.

## SECTION III—REVIEW OF PAST STUDIES

### A STUDY OF AIR POLLUTION IN THE INTERSTATE REGION OF LEWISTON, IDAHO, AND CLARKSTON, WASHINGTON.

This joint study of air pollution in the Lewiston-Clarkston area was conducted by State and local agencies and the Public Health Service during the winter of 1961-1962.[1/] The purpose of the study was to determine the nature and extent of air pollution in the two communities, and to assemble data and information needed as a basis for remedial action. The study included the following activities:

1. Analysis of past and current data on meteorology.
2. An emission inventory.
3. Measurement of atmospheric pollutants.
4. Measurement of visibility.
5. Assessment of ambient odors.
6. Measurement of materials deterioration.
7. Interview of local physicians concerning health effects.
8. A survey of public opinion.

Meteorological studies included a review of past climatological and meteorological data, and observations of wind speed, wind direction, temperature, and relative humidity at a station in the valley to supplement concurrent data collected at the Lewiston airport. The cities frequently experience poor atmospheric ventilation because of low wind speed and low-level inversions. The predominant wind direction is from the east, particularly at night. Stationary high-pressure systems conducive to air pollution and lasting several days can be expected twice yearly. Low-level inversions occur most frequently in the fall, when they may be expected to occur about 50 percent of the time. Meteorological measurements during the sampling period showed wind speeds higher and frequency of easterly winds lower than normal. These factors tended to remove pollution from the area.

An estimate of major air contaminant emissions for the area was made from information provided by the communities and industries in the area. No stack sampling was done, and all estimates were based on information from the literature and other sources.

The major contributor of hydrogen sulfide and other malodorous organic gases is the kraft pulp mill. In addition, the pulp mill contributes about 77 percent of the estimated gaseous emissions and about 82 percent of the estimated particulate emissions. It also contributes an estimated 4,640 tons of water vapor each day to the atmosphere. (About this same amount is emitted by the paper mill and other Potlatch operations.) The latter is believed to have a significant effect on the humidity in the valley under certain meteorological conditions. The pulp mill has installed many control devices, but the recovery furnaces and kilns may, from time to time, emit odorous compounds to the atmosphere. A sulfate pulp mill also has innumerable small sources of odor emission that in total constitute a difficult problem.

The amounts of emissions from other industrial operations are relatively small. Home heating is the largest source of sulfur oxides, and transportation (gasoline engine exhaust) contributes a substantial amount of carbon monoxide to the atmosphere. Refuse disposal is a relatively minor source of air contamination on a weight basis, but the odors produced by burning garbage and refuse cause a local nuisance.

The evaluation of air quality included measurement of ambient concentrations of hydrogen sulfide, sulfur dioxide, and suspended particulate matter at five sampling stations in the Lewiston-Clarkston area, and at a control station in Moscow, Idaho.

Concentrations of hydrogen sulfide were highest in November and February, which were periods of more frequent inversions. Hydrogen sulfide levels in Moscow were consistently low and showed no diurnal variation. Significant morning peaks occurred between 8 and 10 a.m. at the two Clarkston Stations, and between 10 a.m. and 12 noon in the Lewiston commercial area. The time difference results from the unique topography of the study area. Two stagnant weather episodes were observed in which hydrogen sulfide concentrations exceeded 10 parts per billion.

Atmospheric sulfur dioxide concentrations were highest in January (range 0 to 25 ppb, average 4.7 ppb) during the coldest period, indicating fuel burning for space heating as the primary source. Maximum daily concentrations occurred at 9 a.m., at the time of inversion breakup. Atmospheric contamination by sulfur dioxide is not currently a problem in the Lewiston-Clarkston area.

Data on suspended particulate matter revealed both natural and industrial sources of pollution. Sulfate and sodium contents of the suspended particulates were significantly higher in the Lewiston-Clarkston area than in Moscow, Idaho, a nearby non-industrial city of comparable size.

Paint and silver specimens were exposed to measure deterioration caused by hydrogen sulfide and other sulfide compounds. Silver plates were also exposed at a control station in Moscow, Idaho. Data from these tests showed negligible silver tarnishing in Moscow. Silver plates exposed in the valley were tarnished more than those exposed in the upland sites. The relative severity of tarnishing, as an indicator of sulfide gases in the air, is greater in Lewiston than in Clarkston. The results obtained from exposed paint samples were inconclusive.

Odor surveys made in November and in April show that pulp mill odors represent the largest single odor category; the odors affect Lewiston most in November and Clarkston most in April.

## COMMUNITY PERCEPTION OF AIR QUALITY—AN OPINION SURVEY IN CLARKSTON, WASHINGTON

A survey of public opinion concerning air pollution in Clarkston, Wash., was conducted by personnel of the Public Health Service, the Washington State Department of Health, and the Research Triangle Institute, Durham, N. C.[2/] By use of statistical procedures a sample of 104 households was selected for interview. Interviews were conducted during the period May 20 through 25, 1962: the head of the household or spouse was interviewed in each case. Almost 80 percent of the persons interviewed stated that Clarkston has an air pollution problem and almost two-thirds stated that they were bothered by it in some degree. More than 90 percent associated air pollution with frequent bad smells in the air, and almost 75 percent associated air pollution with frequent haze or fog. More than 70 percent of the 104 persons interviewed, or more than 90 percent of those who recognized an air pollution problem, mentioned the pulp mill first among the major sources of air pollution in the area.

## AN AIR QUALITY STUDY IN THE VICINITY OF LEWISTON, IDAHO, AND CLARKSTON, WASHINGTON

The Division of Industrial Research, Washington State University, conducted a 13-month study of air quality in the Lewiston-Clarkston area at the request and with the financial support of Potlatch Forests, Inc., beginning in December, 1961.[3/] Two-hour interval sampling for soiling index and hydrogen sulfide was accomplished at three sites, 24-hour sampling for suspended particulates at two sites, and 30-day dustfall and sulfation rate samples at 14 sites in the survey area. Wind speed, wind direction, and air temperature at the surface were recorded at three sites, and air temperatures at 20, 40, 60, 80, and 100 feet elevation in the lower atmosphere were recorded at one site.

The concentration of hydrogen sulfide was measured by the darkening of paper tape impregnated with lead acetate. Data reported for the study indicate that hydrogen sulfide concentrations averaged about 10 to 15 parts per billion parts of air at the Clarkston sampling site during the months of October, November, December, January, and February. The months with highest concentrations reported for the Lewiston sampling site, November and December, averaged about 7 to 9 parts hydrogen sulfide per billion parts of air. The concentrations reported for the North Lewiston site, the Idaho State Highway garage, for October, November, and December (the highest months) averaged about 25 to 30 parts hydrogen sulfide per billion parts of air.

Average values for soiling index for Clarkston, Lewiston, and North Lewiston were reported as 0.76, 0.64, and 0.42 COH per 1,000 lineal feet respectively.

Dustfall ranged from 7.4 to 315 tons per square mile per month above background values. Average values of 26.41 and 68.78 tons per square mile per month were reported for sodium and sulfate respectively at the Idaho State Highway garage site in North Lewiston. Much lower values for these materials were found in samples from other sites. Heavy dustfall in downtown commercial areas of Lewiston and Clarkston was reported to contain high percentages of self-generated materials such as incompletely burned carbonaceous material not related to a specific industrial source.

The report concluded that substantially higher levels of pollutants were obtained during the heating season, indicating that emissions resulting from combustion of fuels for space heating contributed significantly to overall air pollution. Winter meteorological stagnation also contributed significantly to higher winter-time pollutant levels.

## SECTION IV—INVENTORY OF COMMUNITY ATMOSPHERIC EMISSIONS

Inventories of emissions to the atmosphere in the Lewiston-Clarkston area conducted in 1961-1962 have been reported.[1,4] An inventory was conducted in the fall of 1966 to determine whether substantial changes have occurred since the earlier surveys. The 1966 inventory differs in some respects from the earlier inventories; the differences result in part from changes in fuel use patterns, increased motor vehicle use, differing sources of information, and use of revised pollutant emission factors for some processes or pollutant sources. In general, emissions from the community have not changed markedly since the 1961-1962 inventories.

### INDUSTRIAL PROCESS EMISSIONS EXCLUDING POTLATCH FORESTS, INC.

The main industrial operations that could contribute to air pollution in the Lewiston-Clarkston area, in addition to operations of Potlatch Forests, Inc., include three lumber mills, three meat packing operations, two frozen food packing plants, two asphalt road mix plants, a number of grain mills and elevators, and four concrete mixing plants. Industrial operations with little or no atmospheric pollution potential include bakeries, ammunition manufacturing plants, machine shops, and bottling plants. The following discussions are based upon the emissions inventory conducted during 1966.

#### Lumbering Operations

The three lumber mills in this area all use teepee-type wood waste burners. The two burners observed in Clarkston and the one in Lewiston were not operating under good combustion conditions. Large quantities of air entering through cracks, open doors, and air ports rapidly cooled the fire and prevented adequate burning of the wood waste material. A continual grayish smoke plume was visible at each teepee burner.

In addition to the three lumbering operations in Lewiston and Clarkston, there is a large lumber mill in Clearwater, Idaho. This plant, located about 8 miles east of Lewiston on the Clearwater River also burns large quantities of scrap wood in a teepee burner. Under certain meteorological conditions, the smoke from this burner drifts down valley toward the Lewiston-Clarkston area.

Estimates of the atmospheric emissions from the three burners in the Lewiston-Clarkston area were based on estimates of the amount of wood burned. It was assumed that 50 percent of the raw wood is reduced to scrap in the form of bark, slabs, and sawdust,[5] and that 40 percent of this scrap material, which weighs about 2.25 pounds per board foot, is burned in the teepee burners. These burners usually operate 5 days per week and are estimated to burn a total of about 68 tons of wood per operating day. Most of this burning takes place during the daylight hours, although the fires smoulder during the night.

Calculated atmospheric emissions from teepee burners based on estimates of the amounts of wood burned and published emission factors[6/] are shown in Table I.

## Asphalt Mix Plants

Two asphalt road mix plants operate in the area very intermittently, depending on demand for asphalt mix and on the weather. These plants contribute large amounts of fine dust to the atmosphere when operating even though they are equipped with gas-cleaning devices. To calculate emissions from these plants, production rates and published emission factors[7/] were used. It was estimated that the gas-cleaning equipment collects 75 percent of the particulate matter generated. Calculated emissions are shown in Table I.

TABLE I

ESTIMATED ATMOSPHERIC EMISSIONS FROM INDUSTRIAL OPERATIONS EXCLUDING POTLATCH FORESTS, INC.

| Source | Avg Process Weight tons/day | Emissions, lb/day | | | |
|---|---|---|---|---|---|
| | | Particulate | Carbon Monoxide | Hydrocarbons[b] | Aldehydes[c] |
| 1. Clarkston, Wash. | | | | | |
| Guy Bennett Lumber Co. (teepee burner) | 36[a] | 360 | 720 | 720 | 71 |
| J. B. Lumber Co. (teepee burner) | 18[a] | 180 | 360 | 360 | 35 |
| United Paving Co. | 200 | 150 | | | |
| Sub Total, Washington | 254 | 690 | 1080 | 1080 | 106 |
| 2. Lewiston, Idaho | | | | | |
| R. W. Lumber Co. (teepee burner) | 14[a] | 140 | 280 | 280 | 24 |
| Asphalt & Paving Co. | 50 | 40 | | | |
| Grain-Handling Operations | 103 | 600 | | | |
| Concrete Mixing | 230 | 12 | - | | |
| Sub Total, Idaho | 397 | 792 | 280 | 280 | 24 |
| GRAND TOTAL | 651 | 1482 | 1360 | 1360 | 130 |

[a]Quantity burned. [b]Expressed as methane. [c]Expressed as formaldehyde.

## Food Processing Plants

The meat packing plants in this area use natural gas for process heating and do not normally cause any visible emissions other than steam plumes. They are, however, intermittent sources of localized odor. The frozen food plants also utilize natural gas for process heating and generally emit only water vapor and gas combustion products to the atmosphere. Calculated emissions from these sources are insignificant; no emissions are listed for them in Table I.

### Concrete Mixing and Grain Handling

The concrete batch plants and the grain-handling operations both emit dust to the atmosphere. These emissions are decreased by the use of wet mixing techniques at the concrete plants and cyclone collectors at the grain mills. A localized dust problem is, however, still caused by these intermittent operations.

Production or process weights were not obtained for concrete-mixing and grain-handling operations during the 1966 inventory. In the absence of more recent data, values reported by Tuttle and Adams were used.4/ For concrete plants an emission factor of 0.1 pound of dust per cubic yard of concrete mixed was used to calculate emissions, and for grain handling an emission factor of 0.3 percent by weight of the grain handled was used. Because data for individual plants were not available, only total emissions for these operations are shown in Table I.

## FUEL USAGE

### Non–Industrial Fuels

Atmospheric emissions result from the combustion of fuels used for space heating. Fuel consumption varies inversely with the ambient temperature, and is highest when temperatures are lowest. Distillate fuel oils and natural gas are the two main types of fuel used for heating purposes in this area. They are currently used in approximately equal amounts. Natural gas consumption is rising much more rapidly than fuel oil consumption, however, and should become the predominant fuel within a few years. Both gas and the light fuel oils burn fairly cleanly in modern, properly adjusted furnaces and are not major sources of air pollution.

A survey of fuel consumption in the Lewiston-Clarkston area in October 1966 showed that approximately 4.4 million gallons of number 1 and 2 fuel oil is sold annually in the area for non-industrial heating purposes. About 63 percent of this fuel is burned in the Lewiston area. Average sulfur content of this fuel, as reported by the U. S. Bureau of Mines, is 0.31 percent by weight. 8/

Total annual natural gas consumption by approximately 3,250 customers amounts to 5,730,752 therms or 536 million cubic feet excluding that used by Potlatch Forests, Inc. Approximately 82 percent of this fuel is used for non-industrial, i.e. commercial and domestic heating purposes. This gas contains 0.005 grain of sulfur per cubic foot. Some liquefied propane is also burned as fuel; however, it represents only a small percentage of the total fuel usage.

Approximately 200,000 gallons of residual fuel oil is also burned annually by non-industrial consumers. This fuel contains about 1.2 percent sulfur. The Lewis-Clark Normal School in Lewiston is the primary consumer of this fuel.

Approximately 6 percent of the heating-fuel requirements in this are are supplied by coal. During 1965 about 3,600 tons was consumed; about 65 percent of this coal was consumed in the Lewiston area. In addition to domestic consumers, a small number of public buildings burn coal for heating purposes. Coal used in the area is mined in Utah and has an average sulfur content of 0.6 percent and an ash content of about 6.5 percent.

Wood, largely in the form of "Presto Logs," is also used for heating, mainly as a supplement to other heating fuels. About 10,000 tons of wood was burned in 1965.

Average estimated atmospheric emissions resulting from non-industrial fuel usage are shown in Table II. Total fuel consumption was obtained from the various fuel suppliers in Lewiston and Clarkston, and published emission factors were used to calculate total emissions.[7/] An average heating season of 205 days was used to relate annual fuel use to emissions during an average heating day.

TABLE II
ESTIMATED AVERAGE ATMOSPHERIC EMISSIONS RESULTING FROM THE COMBUSTION OF FUELS FOR NON-INDUSTRIAL HEATING[a]
(pounds per day)

| Type of Fuel | Solids | Carbon Monoxide | Sulfur Oxides[b] | Nitrogen Oxides[c] | Hydro-carbons[d] | Aldehydes[e] | Ammonia | Organic Acids[f] |
|---|---|---|---|---|---|---|---|---|
| Natural Gas, 430 million $ft^3$/yr | 40 | 1 | 3 | 240 | | | 1 | 120 |
| Light Fuel Oils, 4.4 million gal/yr | 260 | 45 | 925 | 1550 | 45 | 45 | 22 | 320 |
| Residual Fuel Oil, 0.2 million gal/yr | 12 | 1 | 183 | 80 | 3 | 2 | 1 | 12 |
| Coal, 3600 tons/yr | 1150 | 90 | 420 | 140 | 175 | 1 | | |
| Wood, 10,000 tons/yr | 150 | 245 | 8 | 60 | 490 | 50 | | 20 |
| TOTAL | 1612 | 382 | 1539 | 2070 | 713 | 98 | 24 | 472 |

[a]Based on a 205-day heating season. [b]Expressed as sulfur dioxide. [c]Expressed as nitrogen dioxide.

[d]Expressed as methane. [e]Expressed as formaldehyde. [f]Expressed as acetic acid.

## Industrial Fuels

Most of the industries in the Lewiston-Clarkston area burn natural gas for process heating purposes. Industrial natural gas consumption, not including Potlatch Forests, Inc., was about 106 million cubic feet during 1965. An estimated 100,000 gallons of residual fuel oil was also consumed for process and industrial space-heating needs.

Estimated atmospheric emissions of the more significant pollutants from industrial fuel consumption are shown in Table III.

TABLE III
ESTIMATED ATMOSPHERIC EMISSIONS
FROM THE COMBUSTION OF FUEL FOR INDUSTRIAL PURPOSES
EXCLUDING EMISSIONS FROM POTLATCH FORESTS, INC.
(pounds per day)

| | Solids | Sulfur Oxides | Nitrogen Oxides |
|---|---|---|---|
| Natural Gas, 106 million $ft^3$/yr | 7 | — | 80 |
| Residual Fuel Oil 0.1 million gal/yr | 5 | 95 | 32 |
| TOTAL | 12 | 95 | 112 |

## REFUSE DISPOSAL

The domestic and commercial burning of refuse is a chronic source of localized air pollution. Many commercial establishments, especially food markets, burn large quantities of cardboard and wooden boxes. Many homeowners burn refuse in their backyards. This type of burning frequently occurs under extremely poor combustion conditions and results in the intermittent release of dense smoke and other atmospheric pollutants.

Mandatory refuse collection exists in the incorporated areas of both Lewiston and Clarkston. Voluntary collection service is available in the Lewiston Orchards area. Clarkston Heights has no mandatory refuse collection service, and many residents burn their own refuse or haul it a distance of 2 or 3 miles to the local dump area. The Lewiston sanitary landfill, located near the airport, rarely burns. At the Clarkston dump site, however, brush is separated from the balance of the refuse and periodically burned. In addition, other fires caused by hot coals or other burning material dumped by individuals frequently occur.

No accurate estimate of the amount of refuse burned daily exists. However, based on discussions with local officials concerning the amount of refuse collected for disposal other than by burning, and using an estimate of 1400 pounds of refuse per capita per year, approximately 30 tons of refuse are burned per day about 300 days a year in this area. Table IV lists calculated atmospheric emissions created by open burning of refuse in the Lewiston-Clarkston area. Emission factors were obtained from the literature.[7,9/]

Lewiston and Clarkston each has its own municipal primary sewage treatment plant. Neither of these plants causes any significant air pollution during normal operation. Localized odor problems may result during plant upsets.

## VEHICULAR EMISSIONS

There are presently about 16,500 motor vehicles in the Lewiston-Clarkston area. These vehicles burn an estimated 12 million gallons of gasoline each year. In addition, trucks

TABLE IV

ESTIMATED ATMOSPHERIC EMISSION FROM BURNING REFUSE

| District | Amount Burned, tons/yr | Emissions, lb/day | | | |
|---|---|---|---|---|---|
| | | Solids | Carbon Monoxide | Hydrocarbons[a] | Organic Acids[b] |
| Lewiston | 1950 | 115 | 540 | 202 | 100 |
| Lewiston Orchards | 3500 | 204 | 965 | 362 | 181 |
| Clarkston (backyard) | 1200 | 70 | 330 | 124 | 62 |
| Clarkston (dump) | 800 | 49 | 220 | 82 | 42 |
| Clarkston Heights | 1250 | 72 | 345 | 130 | 65 |
| TOTAL | 8700 | 510 | 2400 | 900 | 450 |

[a]Expressed as methane.

[b]Expressed as acetic acid.

burn about 87,000 gallons of diesel fuel each year. Tail pipe and crankcase blowby emissions are the major vehicular sources of atmospheric pollution.

Evaporation of gasoline both from automobile gas tanks and carburetors, and from gasoline station tank-filling operations also add to the total hydrocarbon emissions. The increased use of engine blowby devices and exhaust control systems on 1968 model cars will decrease the emissions from automotive vehicles in the future.

Table V presents the estimated atmospheric emissions currently resulting from vehicular fuel consumption and service station tank-filing operations.

## SUMMARY OF COMMUNITY EMISSIONS (EXCLUDING POTLATCH FORESTS, INC.)

A summary of community-wide calculated pollutant emissions by source category in each State appears in Table VI.

TABLE V

ESTIMATED ATMOSPHERIC EMISSIONS FROM MOTOR VEHICLES

(Pounds per day)

| | Solids | Carbon Monoxide | Sulfur Oxides[a] | Nitrogen Oxides[b] | Hydro-Carbons[c] | Aldehydes[d] | Ammonia | Organic Acids[e] |
|---|---|---|---|---|---|---|---|---|
| Gasoline, 12 million gal/yr | 330 | 99,000 | 230 | 3,300 | 17,830 | 165 | 65 | 130 |
| Diesel fuel, 87,000 gal/yr | 25 | 12 | 10 | 55 | 45 | 5 | | 7 |
| TOTAL | 355 | 99,012 | 240 | 3,355 | 17,875 | 170 | 65 | 137 |

[a]Expressed as sulfur dioxide.
[b]Expressed as nitrogen dioxide.
[c]Expressed as methane.
[d]Expressed as formaldehyde.
[e]Expressed as acetic acid.
[f]Include evaporative losses from tanks and filling operations.

TABLE VI

EMISSIONS INVENTORY SUMMARY TABLE

LEWISTON-CLARKSTON ABATEMENT ACTIVITY, 1966

(pounds per day)

| Pollutant | Process Emissions Excl. PFI | | | Industrial Fuel Excl. PFI | | | Non-Industrial Fuel | | | Refuse Disposal | | | Vehicular | | | Grand Total Excl. PFI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Idaho | Wash. | Total | Idaho | Wash. | Total | Idaho | Wash. | Total | Idaho | Wash. | Total | Idaho | Wash. | Total | Idaho | Wash. | Total |
| Solids | 792 | 690 | 1482 | 10 | 2 | 12 | 1020 | 592 | 1612 | 322 | 188 | 510 | 245 | 110 | 355 | 2,389 | 1,582 | 3,971 |
| Carbon Monoxide | 280 | 1080 | 1360 | - | - | - | 242 | 140 | 382 | 1510 | 890 | 2400 | 68,400 | 30,610 | 99,012 | 70,432 | 32,722 | 103,154 |
| Sulfur Oxides[a] | - | - | - | 86 | 9 | 95 | 1018 | 521 | 1539 | - | - | - | 165 | 75 | 240 | 1269 | 605 | 1,874 |
| Nitrogen Oxides[b] | - | - | - | 101 | 11 | 112 | 1319 | 751 | 2070 | - | - | - | 2,310 | 1,045 | 3,355 | 3,730 | 1,807 | 5,537 |
| Hydrocarbons[c] | 280 | 1080 | 1360 | - | - | - | 450 | 263 | 713 | 568 | 332 | 900 | 12,300 | 5,575 | 17,875 | 13,598 | 7,250 | 20,848 |
| Aldehydes[d] | 24 | 106 | 130 | - | - | - | 60 | 38 | 98 | - | - | - | 117 | 53 | 170 | 201 | 197 | 398 |
| Ammonia | - | - | - | - | - | - | 15 | 9 | 24 | - | - | - | 45 | 20 | 65 | 60 | 29 | 89 |
| Organic Acids[e] | - | - | - | - | - | - | 308 | 164 | 472 | 284 | 166 | 450 | 95 | 42 | 137 | 687 | 372 | 1,059 |

[a] Expressed as sulfur dioxide [b] Expressed as nitrogen dioxide. [c] Expressed as methane. [d] Expressed as formaldehyde.

[e] Expressed as acetic acid.

## SECTION V—ATMOSPHERIC EMISSIONS FROM POTLATCH FORESTS, INC., KRAFT PULP MILL AND LUMBER MILL

Potlatch Forests, Inc., supplied to the Public Health Service, through the Idaho Department of Health, detailed data regarding emissions of atmospheric pollutants from its Lewiston plants. In transmitting the data Potlatch Forests, Inc., stated, "These are a sincere effort on our part to give the best information we have available; however, many of these tests are the result of only one or two testings and may require additional information in the future." Implicit in this statement is recognition of the variability of emissions from individual sources in a kraft pulp mill. Emissions can, and do, vary from hour to hour, and from day to day. They vary with production rate, with conditions of operation, and with the adequacy of performance of control facilities. Precise emissions data usually require repeated tests for various conditions of operation and over considerable periods of time.

The data provided by Potlatch Forests, Inc., have been used in discussions of emissions in this report. It is recognized that emission values somewhat different from those reported might be yielded by repeated testing. This reservation is not intended as criticism of the information supplied by Potlatch Forests, Inc.; to the contrary, the Company is commended for having developed at our request such a large array of data in so short a period of time.

### REVIEW OF KRAFT PULP PROCESS

The kraft pulp industry has enjoyed spectacular growth during the past 25 years, and annual production is currently about 23,000,000 tons. The kraft pulping process utilizes an alkaline solution of caustic soda (sodium hydroxide) and sodium sulfide to separate cellulose fibers from lignin and other non-cellulose portions of wood. The cellulose fiber, or pulp, is washed and used to manufacture paper. The non-fiber portion of the wood is burned to recover chemicals and to provide process heat.

To separate cellulose from lignin, wood in the form of small chips is fed into large vessels called digesters where it is cooked for 2-1/2 to 3 hours in an alkaline solution called white liquor.

The white liquor is composed largely of sodium hydroxide and sodium sulfide. Steam is injected into the digesters until a pressure of 110 psi is attained. Gases generated by the chemical process are vented periodically during the cooking period.

After completion of the cooking period, a digester charge is blown into a receiver called a blow tank. During this sudden decrease in pressure, the softened wood chips disintegrate, furthering the separation of the cellulose pulp fibers from the lignin. The pulp is filtered and washed free of spent cooking chemicals. The spent cooking liquor and wash water, called black liquor, is concentrated in a series of evaporators.

The concentrated black liquor is sprayed into recovery furnaces, and the lignin and other combustible materials in the liquor are burned to generate process steam. Chemical recovery is accomplished by drawing off the molten mixture of sodium compounds from the furnaces. This melt is dissolved in water to form green liquor, which in turn is reacted with lime to convert sodium carbonate to sodium hydroxide. The sludge, or lime mud, produced in this reaction is settled out and returned to a lime kiln. The resulting clear solution, called white liquor, is reused as cooking liquor in the digesters. A lime kiln is used to calcine the lime mud to calcium oxide for reuse in converting green liquor to white liquor.

A block diagram of the pulping and chemical recovery process is shown in Figure 2.

## DESCRIPTION OF POTLATCH FORESTS, INC., PULP MILL PROCESSES AND THEIR EMISSIONS

The Potlatch Forests, Inc., pulp mill produces an average of 755 tons of air-dried pulp per day, although maximum daily production rates have been as high as 825 tons.

### Digestion and Blow System

The pulp mill contains nine batch digesters with a total capacity of 30,800 cubic feet. In addition, there are two continuous digesters. The wood chips are 42 percent pine and 41 percent fir, with the balance comprised of cedar, larch, and spruce. Cooking with steam and white liquor at a temperature of 350$^{o}$F at 110 psi dissolves the lignin and other similar material in the wood, freeing the cellulose fibers.

During the cooking period, gases are periodically released from the digester. These relief gases are passed through a cyclone separator and a condenser. The condensate and uncondensed gases are passed to an accumulator tank where they are sprayed with a hypochlorite solution from the pulp-bleaching process. The non-condensable gases are released to the atmosphere.

When a cooking cycle is completed, the digester contents are suddenly released into a blow tank. This sudden decrease in pressure and violent agitation aids in separating the pulp from the lignin. Gases released in the blowing operation are vented through a condenser to the deodorizer tank where they are sprayed with hypochlorite solution; the remaining non-condensable gases are released to the atmosphere.

Atmospheric emissions from the digester and blow tank systems occur intermittently. Under normal operating conditions, 72 batches of wood chips are cooked and blown each day,

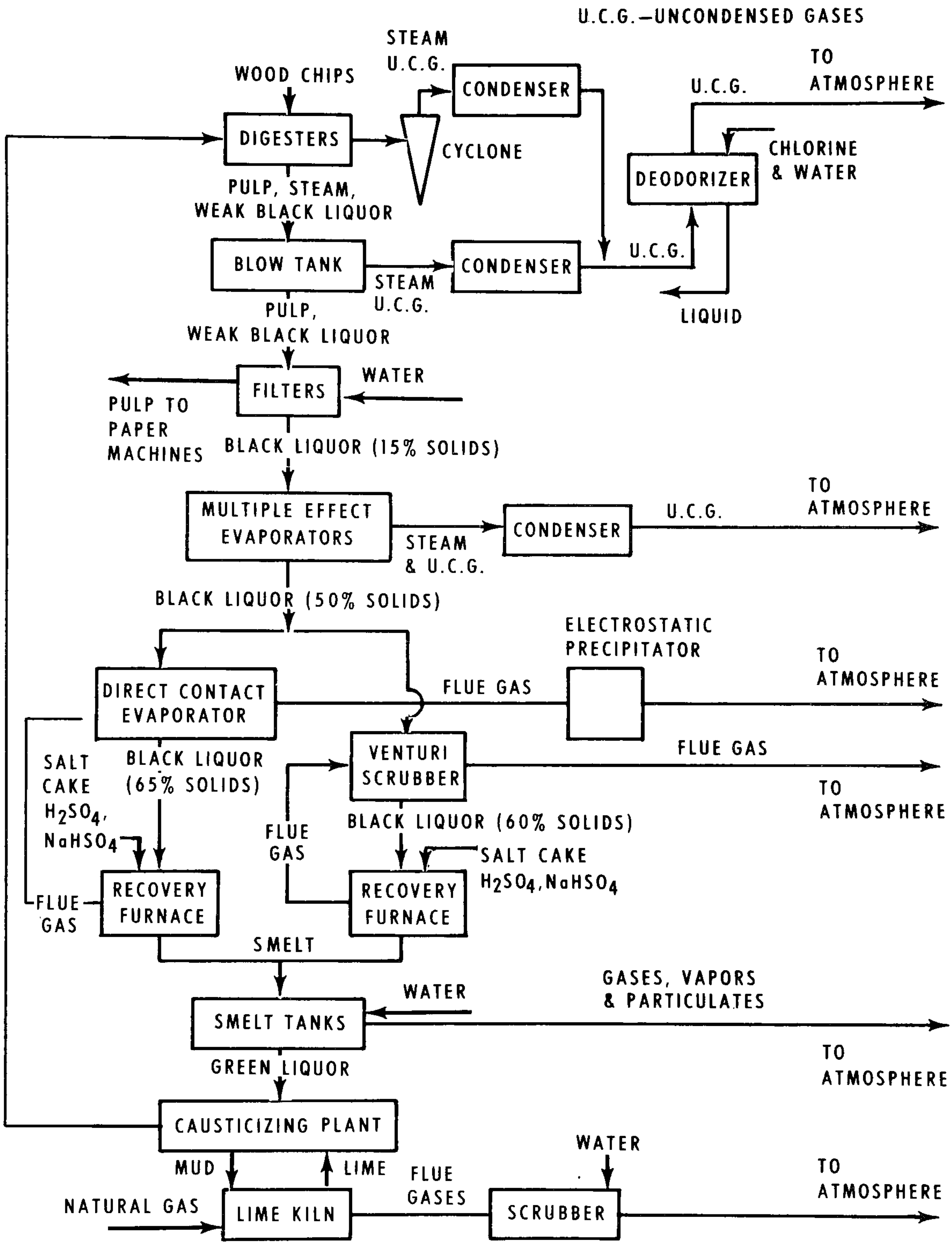


Figure 2. Schematic diagram of Potlatch Forests, Inc., kraft pulping process.

an average of 3 per hour, or one every 20 minuts. Thus, emissions from this batch operation approach those from a continuous system.

According to data received from Potlatch Forests, Inc., there are no detectable atmospheric emissions, except water vapor, from this part of the process. This would indicate a 100 percent efficient gas scrubbing system. Without a control system, emissions in the order of 0.45 pound of hydrogen sulfide, 2.5 pounds of methyl mercaptan, and 1.4 pounds of dimethyl sulfide per ton of pulp could be expected.[10/] Such emissions would amount to 2,100 pounds of sulfur per day for a 755-ton-per-day production rate.

## Multiple-Effect Evaporators

The digested wood pulp is filtered and washed with water to recover chemicals used in the digestion process. This washing process yields a liquid called black liquor. Black liquor is concentrated by passage through four sets of countercurrent multiple-effect evaporators. The liquor enters the evaporators at a concentration of about 15 percent solids and leaves at a concentration of 50 percent.

Because of the high concentration of sulfurous compounds in the black liquor entering the evaporators, large quantities of odorous gases are given off in the evaporation process. Particulate emissions are, however, not produced by the evaporators. Emissions from the multiple-effect evaporators, as reported by Potlatch Forests, Inc., are shown in Table VII.

TABLE VII
ATMOSPHERIC EMISSIONS FROM MULTIPLE-EFFECT EVAPORATORS[a]
(pounds per day)

| Evaporator | Sulfur Dioxide | Hydrogen Sulfide | Mercaptans | Alkyl Sulfide | Alkyl Disulfide | Water Vapor |
|---|---|---|---|---|---|---|
| Set 1 | 0 | 50.1 | 11.2 | 20.6 | 1.1 | 135,000 |
| Set 2 and 3 | 0 | 107 | 555 | 169 | 6.0 | 92,000 |
| Set 4 | 0 | 0.7 | 0.2 | 1.6 | 0.9 | 6,520 |
| TOTAL | 0 | 157.8 | 566.4 | 191.2 | 8.0 | 233,520 |

a. Sulfur-containing compounds are expressed as pounds of sulfur.

## Direct—Contact Evaporators and Recovery Furnaces

After leaving the multiple-effect evaporators, the black liquor is split into three streams. Two of these streams enter direct-contact disc-type evaporators while the third stream enters a recovery furnace flue gas scrubbing system. In all three cases contact with hot flue gases further concentrates the black liquor to a concentration of about 65 percent solids. Contact with the hot flue gases releases odorous sulfurous gases that are carried by the flue gases into the atmosphere.

The concentrated black liquor and make-up sodium sulfate is sprayed into the recovery furnaces where organic materials in the black liquor are burned. The heat evolved is used to generate steam for various plant processes. Three recovery furnaces are used at Potlatch Forests, Inc. Make-up sodium sulfate is added at the rate of 98 pounds per ton of air-dried pulp, which is equivalent to 16,700 pounds of sulfur per day, based on a daily production rate of 755 tons. Spent liquor from the chlorine dioxide plant, composed of sulfuric acid and sodium bisulfate, is used along with salt cake as part of the chemical make-up. This make-up is equivalent to 8.6 pounds of sulfur per ton of pulp produced.

By limiting the amount of air entering the first combustion zone of the recovery furnaces, a reducing atmosphere is maintained and a portion of the sodium sulfate ($Na_2SO_4$) is reduced to sodium sulfide ($Na_2S$). In addition, sodium carbonate ($Na_2CO_3$) is formed by the burning of organic sodium compounds. A molten residue of sodium sulfide and sodium carbonate thus formed is tapped from the furnaces and dissolved in water to form green liquor.

Hot flue gases from the furnaces contain gaseous sulfur compounds, solid particles, water vapor, carbon dioxide, nitrogen, and at times some oxygen. The hot flue gases from two furnaces pass through direct-contact disc evaporators that serve as the final evaporation stage for black liquor, then pass through a single electrostatic precipitator to the atmosphere. The present electrostatic precipitator was installed to replace two less-efficient units that were in use at the time of the 1961-62 survey. The flue gas from the third furnace passes through a venturi scrubber that serves as a direct-contact evaporator by using black liquor as the scrubbing medium. Solid material collected in the electrostatic precipitator is returned to the direct-contact evaporators by a stream of black liquor.

The design rate for furnaces one and two, which are equipped with the electrostatic precipitator, is 1,575,000 pounds of solids per day. Furnace number three, equipped with a venturi scrubber, is designed to handle 900,000 pounds of solids per day. The electrostatic precipitator is reported by Potlatch Forests, Inc., to be 95 percent efficient in collecting particulate; the collection efficiency of the venturi scrubber is reported to be 74.2 percent. Particulate emissions from the recovery furnaces represent a major source of atmospheric pollution from this plant.

Malodors result from the burning of black liquor, especially when an excess of oxygen is not maintained in the secondary combustion zones of the furnaces, and by passage of the furnace flue gases through the direct-contact evaporators. Secondary combustion air injected into the upper portion of the recovery furnaces decreases the amount of odorous sulfur gases emitted. Potlatch Forests, Inc., reported that the oxygen content of the flue gas varies from 0 to 3 percent by volume, which would indicate that excessive amounts of odorous compounds could be released during periods of insufficient air supply to the furnace.

Table VIII summarizes atmospheric emissions from the three recovery furnaces as reported by Potlatch Forests, Inc.

TABLE VIII
ATMOSPHERIC EMISSIONS FROM POTLATCH FORESTS, INC. RECOVERY FURNACES[a]
(pounds per day)

| Furnace | Sulfur Dioxide | Hydrogen Sulfide | Mercaptan | Alkyl Sulfide | Alkyl Disulfide | Particulate | Water Vapor |
|---|---|---|---|---|---|---|---|
| 1 and 2 | 2.3 | 806 | 93.6 | 0 | 61.2 | 5,140 | 1,742,000 |
| 3 | 8.4 | 627 | 981 | 7.3 | 5.7 | 17,700 | 1,806,000 |
| TOTAL | 10.7 | 1,433 | 1,074.6 | 7.3 | 66.9 | 22,840 | 3,548,000 |

[a]Sulfur-containing gases are expressed as pounds of sulfur.

Calculations based on other data provided by Potlatch Forests, Inc., show that total hydrogen sulfide emissions may reach a rate of 5,400 pounds per day from all three recovery furnaces. This rate of hydrogen sulfide emission from recovery furnaces of a mill of this size having no facility for controlling hydrogen sulfide emissions from the furnaces is not extraordinary.

**Smelt Tank, Causticizing Tank, and Lime Kiln**

The molten chemical residue tapped from the furnace bottom is water quenched in smelt tanks. This sudden cooling of the molten chemicals causes the material to shatter and results in the release of solid particles and some sulfurous gases. Relief gases from the three smelt tanks pass through a demister where liquid droplets are removed before the gases are discharged to the atmosphere.

Total vent gas from the smelt tanks is approximately 6,800 cfm at a temperature of $180^{\circ}$ to $240^{\circ}F$. Reported atmospheric emissions are shown in Table IX.

Green liquor goes from the smelt tanks to a clarifier, or settling tank, where solids are removed. The green liquor then goes to a slaking tank where lime (CaO) is added, and to a causticizer where the reaction between lime, water, and sodium carbonate occurs to form sodium hydroxide. The reactions that result in a solution called white liquor are

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2\,NaOH$$

There are six causticizers at the Potlatch Forests, Inc., mill; however, these chambers are not significant sources of atmospheric pollution.

The lime mud, largely calcium carbonate that settles out in the causticizers and subsequent clarifiers, is returned to the lime kiln after washing and filtering. A single large, gas-fired, rotary lime kiln calcines the lime to calcium oxide (CaO). This kiln processes about 10 tons of lime per hour. Hot gases composed largely of carbon dioxide, water vapor, sulfurous compounds, oxygen, and nitrogen pass from this kiln through a venturi water spray scrubber that removes particulate matter. This high-energy scrubber utilizes a pressure drop of about 16 inches of water and has a particulate collection efficiency of about 97.6 percent. This lime kiln venturi scrubber combination was installed to replace three less efficient units that were in use at the time of the 1961-62 survey. Atmospheric emissions from the lime kiln scrubber, as reported by Potlatch Forests, Inc., are shown in Table IX.

TABLE IX

ATMOSPHERIC EMISSIONS FROM POTLATCH FORESTS, INC., SMELT TANKS AND LIME KILN[a]

(pounds per day)

| | Sulfur Dioxide | Hydrogen Sulfide | Mercaptans | Alkyl Sulfide | Alkyl Disulfide | Parti-culate | Water Vapor |
|---|---|---|---|---|---|---|---|
| Smelt Tanks | 1.1 | 0 | 2.6 | 0 | 2.8 | 410 | 106,400 |
| Lime Kiln | 1.3 | 72.4 | 18.1 | 161.0 | 87.6 | 760 | 1,070,000 |
| TOTAL | 2.4 | 72.4 | 20.7 | 161.0 | 90.4 | 1170 | 1,176,400 |

[a]All sulfur-containing gases are expressed as pounds of sulfur.

### Steam Boiler Plants

Two boiler plants provide additional process steam for pulp mill operations at Potlatch Forests, Inc. These units normally burn natural gas and are not a major source of atmospheric pollution. During the winter months, however, additional heating requirements are supplied by residual fuel oil. This fuel contains between 1.1 and 1.45 percent sulfur, and for an average daily rate of 9,800 gallons, approximately 1,950 pounds of sulfur dioxide would be emitted per day during periods of its use.

The lumber division of Potlatch Forests, Inc., utilizes four boilers rated at 1,100 horsepower each. These boilers are fired with natural gas and scrap wood material. Particulate emissions from these boilers varies with the type of fuel used and the firing rates. Data reported by Potlatch Forests, Inc., show a daily emission of 1,080 pounds of solids resulting from the production of 20,000 tons of steam.

### Other Sources of Atmospheric Pollution

Other relatively minor sources of pollution include paper driers and leaks in process equipment. A large silo-type wood waste burner is also used occasionally; it causes a local smoke problem when in operation. When operated properly, these processes are not a major source of air pollution.

## SUMMARY OF PULP MILL EMISSIONS

Table X presents a summary of atmospheric emission data reported by Potlatch Forests, Inc. Emissions from the various pulp mill sources vary greatly and depend on the prevailing operating conditions. Average emissions are difficult to estimate precisely without a great deal of effort and cost.

TABLE X

SUMMARY OF ATMOSPHERIC EMISSIONS FROM POTLATCH FORESTS, INC., PULP MILL AND POWER BOILERS (pounds per day)[a]

| Source | Sulfur Dioxide | Hydrogen Sulfide | Mercaptans | Alkyl Sulfide | Alkyl Disulfide | Particulates | Water Vapor |
|---|---|---|---|---|---|---|---|
| Multiple Effect Evaporators | 0 | 158 | 566 | 191 | 8 | | 233,520 |
| Recovery Furnaces | 11 | 1433 | 1075 | 7 | 67 | 22,840 | 3,548,000 |
| Smelt Tanks | 1 | 0 | 3 | 0 | 3 | 410 | 106,400 |
| Lime Kilns | 1 | 72 | 18 | 161 | 88 | 760 | 1,070,000 |
| Power Boilers | 31[b] | | - | - | 20 | 1,080 | 10,349,000 |
| TOTAL | 44[b] | 1663 | 1662 | 359 | 186 | 25,090 | 15,306,920 |

[a]All sulfur-containing gases are expressed as sulfur.

[b]Reported emissions for summer months; emissions during the winter can be as high as 1,950 pounds per day.

## SECTION VI—DISCUSSION OF CONTROL TECHNOLOGY

Potlatch Forests, Inc., has reported that since the survey of 1961-1962 several changes in operation or equipment that may affect emission of air pollutants have been made. These include:

1. Oxidation of weak black liquor has been discontinued because of operating problems. This would tend to increase emissions of odorous gases from the recovery furnace direct-contact evaporator system.
2. Use of lime kilns numbers 1 and 2 has been discontinued: kiln number 3 has been extended, and a new scrubber has been installed. Emissions from lime burning should be substantially lower than the 1961 levels.
3. The electrostatic precipitators of recovery furnaces number 1 and 2 have been replaced with a single electrostatic precipitator of higher collection efficiency. This installation is reported to have substantially reduced emission of particulates from these two furnaces.
4. Steam atomizing nozzles were installed in the venturi evaporator on the number 3 recovery furnace in an effort to increase its efficiency in collection of particulates from the furnace flue gases; however, satisfactory collection efficiency has not been achieved.
5. The chlorine dioxide tower vent scrubber was replaced with a larger unit. Increased efficiency in the collection of chlorine dioxide is reported.
6. The digester gas oxidation tank was rebuilt: it is reported that there is now no emission of sulfurous gases from the digester relief blow tank system.
7. A scrubber was installed on the chlorine dioxide storage vent.

In addition to these changes, it was reported that a new blow heat recovery system and a scrubber for bleach plant chlorine vents were expected to become operational during the latter part of 1966.

### DIGESTER AND BLOW SYSTEM

Digester relief and non-condensable gases from the blow heat recovery system ordinarily are rich in hydrogen sulfide, mercaptans, and organic sulfides. The present practice of scrubbing all gases from digester relief and the blow system operation with a chlorine and water solution appears, on the basis of reported data, to be effective in reducing emissions of these odorous gases. This system operates effectively, however, only when sufficient chlorine is available to contact and react with the sulfurous gases. This is especially important during periods of peak gas flow. The chlorine-water solution leaving the scrubbing unit should be routinely monitored for residual oxidant content, and means should be provided for supplemental chlorine when the scrubbing medium supplied from the bleach plant is inadequate.

## MULTIPLE—EFFECT EVAPORATION

Non-condensable gases from multiple-effect evaporators are among the kraft mill emissions having the greatest concentrations of malodorous gases. Emissions from the evaporators represent about 10 percent of the hydrogen sulfide and about 30 to 40 percent of the organic sulfides and mercaptans reported to be emitted from the mill. The proportion of total pulp mill emissions released from this source is unusually high. Control of evaporator emissions has been accomplished in other mills by scrubbing with an oxidizing medium such as chlorine solution. Incineration, by catalytic oxidation or in lime kilns or recovery furnaces, is also a possible means of control.

An engineering evaluation should be made to determine the feasibility of ducting all non-condensable gases from the multiple-effect evaporators to the chlorinated water scrubbing system presently used on the digester and blow system relief gases. This change would approximately double the gas flow through the scrubbing system, and thus would require an increase in liquid throughput, and possibly an increase in scrubber size.

Evaporator and blow condensates can be sources of odorous gases when sewered or used elsewhere in the pulp mill process. One suggested control process is steam stripping of such condensates and incineration of the odorous gases produced.

## DIRECT—CONTACT EVAPORATORS

Common practice in kraft pulp manufacturing in the United States is to concentrate strong black liquor to 60 to 65 percent solids in direct-contact evaporators. In this type of evaporator, strong black liquor is contacted directly with the hot flue gases from a recovery furnace. These flue gases contain nitrogen, some oxygen, water vapor, and about 10 to 12 percent carbon dioxide. They also contain minor amounts of sulfur dioxide and may contain odorous sulfides, including hydrogen sulfide. The black liquor in contact with these gases contains sodium sulfide and other alkaline sodium salts as well as dissolved materials from wood. Two types of direct-contact evaporators are used in the Lewiston mill: furnaces number 1 and 2 are equipped with disc-type units with rotating transfer surfaces; furnace number 3 has a venturi evaporator equipped for steam atomization.

The equilibrium partial pressure of hydrogen sulfide above the black liquor is given by the relationship,

$$P_{H_2S} = (K)\ (C_{Na_2S})\ (C_{H^+}),$$

in which $P_{H_2S}$ is the equilibrium pressure of hydrogen sulfide above a solution in which the concentration of sodium sulfide and hydrogen ion are $C_{Na_2S}$ and $C_{H^+}$, respectively. The term K is a proportionality constant.

When carbon dioxide contacts the alkaline black liquor, the gas is absorbed and the pH of the liquor decreases ($C_{H^+}$ increases). As a result, $P_{H_2S}$ increases and hydrogen sulfide tends to be released from the black liquor. Methyl mercaptan is also released by acidification of its sodium salts.

As shown by the equilibrium equation, the release of hydrogen sulfide during direct-contact evaporation can be reduced in two ways: (1) by maintaining a high pH level (low value of $C_{H^+}$) in the black liquor (since the liquor is in contact with the flue gas stream that contains a large proportion of carbon dioxide, this usually is not practicable) and (2) by reducing the concentration of sodium sulfide ($C_{Na_2S}$) to zero or as near zero as is possible. The latter can be achieved by oxidizing the sodium sulfide in the black liquor, thus converting it to sodium thiosulfate. When the complete conversion of sodium sulfide is achieved, $C_{Na_2S}$ is zero and $P_{H_2S}$ also is zero. If the liquor is thoroughly oxidized before it enters the direct-contact evaporator, the release of hydrogen sulfide from this source may be greatly reduced.

The oxidation of weak black liquor was attempted at the Potlatch Forests, Inc., mill. The attempt was unsuccessful, however, because of the stability of the foam produced, and the effort was abandoned. Oxidation of strong black liquor prior to direct-contact evaporation should be entirely feasible.

Non-contact type forced-circulation evaporators have been used for concentrating black liquor to 60 to 65 percent solids in other countries. Hot flue gases do not come in contact with the black liquor in such evaporators. Less hydrogen sulfide is formed, and none of it or of other sulfurous gases are released to the flue gas. Non-condensable gases released from the black liquor in the evaporation process can be treated in a gas scrubbing system such as that serving the digester vent system or incinerated in the recovery furnace. Although use of forced-circulation evaporators is reported to effect heat economies,[11/] it increases the complexity of operation and has higher initial and maintenance costs than does use of direct-contact types. Oxidation of strong black liquor would seem to be the more feasible approach for the Lewiston mill.

## RECOVERY FURNACES

Two recovery furnaces in the pulp mill are served by an electrostatic precipitator with a reported particulates collection efficiency of 95 percent. Even with this collector these furnaces emit more than 5,000 pounds of particulates per day. Effort should be made to increase the efficiency of the precipitator or otherwise decrease the emission of particulates from the furnace stacks. Substantial improvement could be expected from secondary scrubbing of the flue gases. Particulate emissions from the third furnace are still a major problem. The existing venturi scrubber, with a reported collection efficiency of 74.2 percent, is not adequate and should be replaced or followed by another control device such as a high-efficiency electrostatic precipitator. Recommended practice for control of dust emissions in combustion for indirect heat exchangers[12/] having heat input equal to the three recovery furnaces would limit emissions to about 5,000 pounds of inert particulate per day even for locations in flat terrain. The valley location and the chemical nature of emissions from the recovery furnaces justify limiting emissions to a substantially lower value.

Odorous sulfide emissions from the recovery furnaces can be reduced by proper furnace operating conditions, namely:

1. Adequate excess oxygen for complete combustion.
2. Thorough mixing of furnace gas with combustion air.
3. Adequate combustion temperature and time to complete the oxidation reaction.

The furnaces are reported to operate in the range of 0 to 3 percent excess oxygen. Oxygen content in the flue gas leaving the furnace should be at least 3 percent by volume. Since a reducing atmosphere must be maintained in the lower part of the furnace to reduce the sulfide compounds, this additional air must be injected into the oxidizing zone of the furnace. Data provided by Potlatch Forests, Inc., indicate that none of the three furnaces is overloaded; therefore, maintenance of 3 percent excess oxygen in the flue gas should not cause overheating. The presence of combustibles in furnace flue gases is an indication of need for additional secondary combustion air. Monitoring of flue gases for combustibles can be a valuable aid in maintaining proper furnace operation for odor control.

## PERSONNEL RESPONSIBILITIES

Installation of air pollution control equipment is only part of the solution to kraft mill odors. Operating or maintenance personnel must be assigned responsibilities to ensure that all control equipment is operating properly. Consideration should be given to designating one person directly responsible to management as pollution control officer for the mill. In the case of Potlatch Forests, Inc., this person would probably be the effluent engineer. His duties should include the location of odorous emissions, regular testing to ensure that control equipment is operating well, recommendations for additional control equipment, and submission of periodic reports to the mill manager on pollution releases and equipment operation.

## CONTROL OF COMMUNITY EMISSIONS

The control of community emissions depends largely upon performance by individual citizens. The proper maintenance of automobiles and furnaces and the disposal of trash by a scavenger or by burying all help reduce the local air pollution burden. Mandatory collection of all refuse should be practiced in both Lewiston and Clarkston, and in the unincorporated areas adjoining these cities. All refuse should be taken to a landfill area and buried, not burned.

Smoke from the teepee burners in this area is another local problem. Burners observed in the fall of 1966 were poorly operated and in need of repair. Periods of high charging rate, too much dilution air, and inadequate mixing of air and combustion gases are some of the main problems. Strong efforts should be made by the operating companies to eliminate smoke from these burners. Prohibition of these burners should be considered if smoke abatement practices are not successful.

No industrial process with a history of atmospheric pollution problems should be allowed to locate in Lewiston or Clarkston without specifying in detail the type of air pollution control equipment they agree to install. These plans should be subject to approval by air pollution control officials of both Idaho and Washington.

# SECTION VII—METEOROLGY

## EFFECTS OF TERRAIN

Topography and its effects on the atmosphere more than anything else affects the behavior of air pollution in Lewiston, Idaho, and Clarkston, Wash. Because of the valley configuration, particularly the wall-like hills rising about 2,000 feet on the north side of the Clearwater and Snake Rivers, north and south winds are greatly weakened and usually fail to penetrate to the valley floor. Air movement is channelled to move either east or west along the Clearwater River and the east-west portion of the Snake River in the vicinity of Clarkston.

In addition to obstructing and channelling the wind, topography causes air motion where the uneven surface of the ground heats and cools unevenly. Incoming solar radiation results in air pollution moving upslope, or up valley, as the heated air rises; whereas the loss of heat from slopes or high ground during hours of darkness causes it to move down the valley as the cooled, more dense, air drains to a lower elevation by the force of gravity.

Described above is what may be called "normal" behavior of the air resulting from effects of topography. Variations in this behavior are caused by the action of meteorological features of cyclonic scale, for example, the occasional passage of a low-pressure system with some local frontal activity. The low-pressure systems are usually associated with stronger westerly winds aloft that come lower with the approach of the disturbance and sometimes reach the ground, causing gusty conditions that ventilate the valley.

## EFFECTS OF CLOUDS, FOG, AND SNOW COVER

Other factors that disturb the normal behavior of the air are overcast skies, fog, and snow cover. Overcast skies not only reflect incoming solar radiation from cloud tops, they also act as a blanket, reducing heat loss from the ground so that surface temperatures are more uniform and at the same time reducing the effects of topography.

Fog has a similar effect, but it is also important that the top of the fog layer acts as a radiating surface at night. The top of the fog layer cools and intensifies a trapping temperature inversion layer aloft. Consequently, with the cooling aloft, a vertical temperature profile develops in the fog layer, so that air pollutants in stack plumes are carried to the ground.[13/] This process is illustrated in Figure 3. Fog has occurred with the most serious air pollution incidents in the Lewiston-Clarkston area.

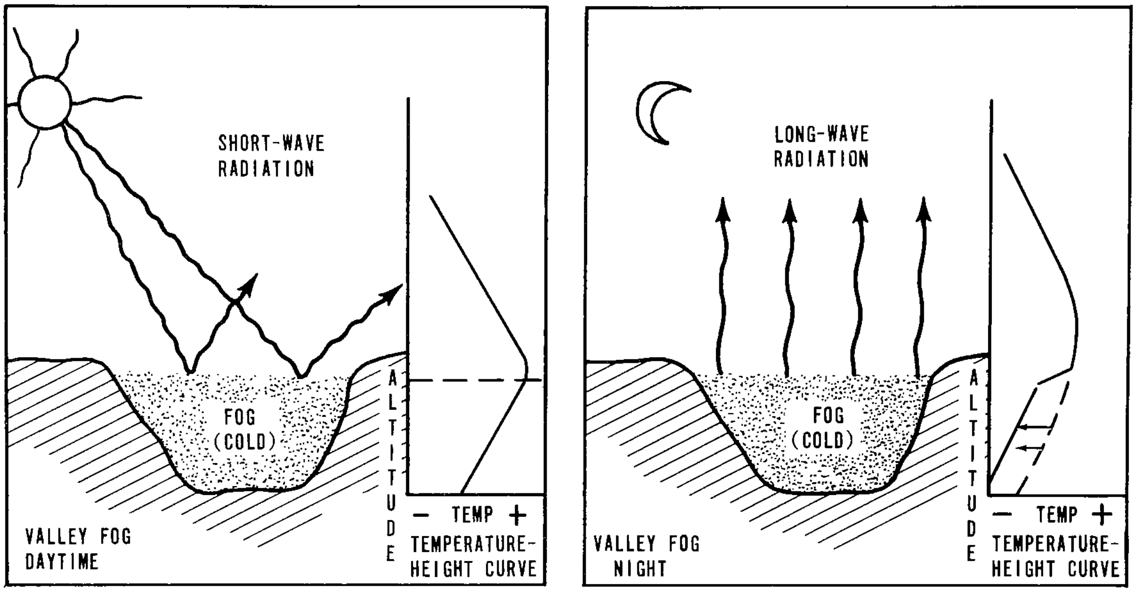


Figure 3. Function of fog in maintaining valley stability.

The worst air pollution conditions occur with complex, multi-layer, inversions that occur when a stratus cloud overcast persists over the area for several days and fog forms at the valley floor. Solar radiation is insufficient to penetrate both of these layers and warm the ground sufficiently to destroy the surface-based inversion. Under these conditions air pollutants continue to accumulate from day to day.

Adams states, "Some 20 days of heavy fog are recorded annually in the valley. Fog formation may on occasion be accentuated by large volumes of steam introduced into the valley air. This steam rapidly disappears as the relative humidity decreases. However, during the winter months of higher relative humidity, the steam may persist and become indistinguishable from natural fog."[3/]

During rainy, damp weather the odor of the pulp mill sometimes seems unusually strong. The stronger odor may in part result from the more acute sense of smell associated with a moist atmosphere, or may be the result of down currents caused by the falling precipitation. As already stated, vertical mixing of the air can occur below an inversion lid when there is a fog; this may occur with or without precipitation.

Snow cover reflects solar radiation so there is less surface heating and upslope and up-valley winds may not develop. At night, snow is a much better radiator of heat than bare ground and colder more dense air results. Downslope winds and downvalley winds are likely to be stronger, and valley inversions can be expected to be deeper and more intense when the ground is snow covered.

## WIND SPEED AND DIRECTION

Lewiston seems to have the lowest average annual wind speed of any city for which U.S. Weather Bureau records are available. The annual average for a period of 23 years at the Weather Bureau City Office location in downtown Lewiston was only 3.8 mph.[14/] The following average annual wind speeds in other cities are given for comparison:

| | |
|---|---|
| Los Angeles (Civic Center), Calif. | 6.2 mph |
| Salt Lake City, Utah | 8.8 mph |
| Kansas City, Mo. | 10.0 mph |
| Washington, D. C. | 9.5 mph |

Lewiston also has a high percentage of calms, which occur mostly at night and during the early morning. At 0400 hours in the fall 28.3 percent of wind observations were calm.

The predominant wind direction is east; wind from this direction occurs 27 percent of the time annually. (U.S. Weather Bureau City Office, December 1927-November 1932). East winds occur most nights and during many daylight hours in winter. Westerly winds are most frequent during the afternoon.

During the period Oct. 5 through 11, 1966, a brief meteorological investigation of the Lewiston-Clarkston area was conducted by Abatement Program personnel. During this period, a variety of conditions were observed. There were both clear and cloudy skies and two periods of rain. Winds were generally light, although on one day wind speeds were moderately strong. Neither significant fog nor a period of prolonged atmospheric stagnation occurred. Forty-five upper wind soundings were taken, and Weather Bureau records on file at the airport were examined for possibly significant observations.

Upper wind soundings were taken from the Lewiston Fire Station, 13th and F Streets, elevation 740 feet MSL. The period of observation was October 5 through 11. Regular observation times were 0500, 0700, 0900, 1100, 1500, 1900, and 2300 hours; however, observations were also made at other times at the discretion of the observer. Pilot balloons used for the soundings were tracked by theodolite for 8 minutes whenever possible; observations were recorded at 20-second intervals. Based on a standard rate of ascent for a balloon, an 8-minute sounding made possible calculations of wind speed and direction up to an elevation of 3,560 feet above surface, which is an elevation 1,700 feet above the top of the Lewiston Hill.

Results of the upper wind soundings are tabulated in Appendix B. The data are notable primarily for the very low wind speeds that were especially common up to several hundred feet above the surface, and for the large changes in wind direction, sometimes even reversals, with increasing elevation.

## TEMPERATURE INVERSIONS

When there exists a large decrease of temperature with height, the air is unstable and mixing occurs readily; however, when there is a small decrease, or an increase of temperature with height (i.e., an inversion), the air is stable and vertical motions are damped out. Inversions are more intense in a valley than over flat terrain because the coldest air seeks the lowest elevation and pushes aloft the warmer air.

Instrumentation for the Adams study included two wind speed and direction recording systems, one on the north side of the Snake River northwest of Clarkston and one in Clarkston.[3/] Wind data were also obtained from a third station at Lewiston Airport. A 100-foot meteorological tower was operated for 10 months at the first-mentioned site for recording temperatures at six levels, or temperature inversion data. Figure 4 and Figure 5 taken from the Adams report show the percentage of the days per month inversions occurred

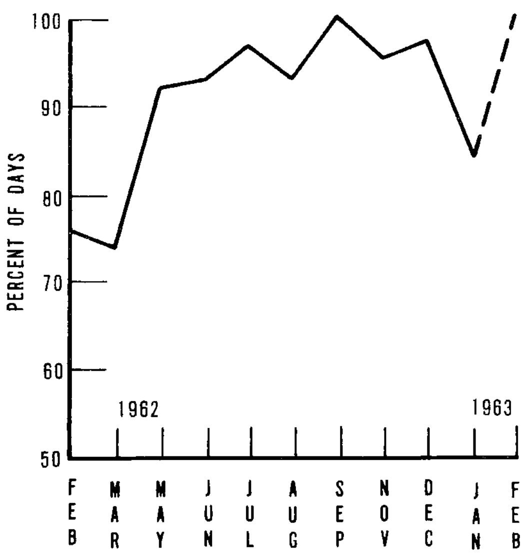


Figure 4. Percent of days per month having inversions.

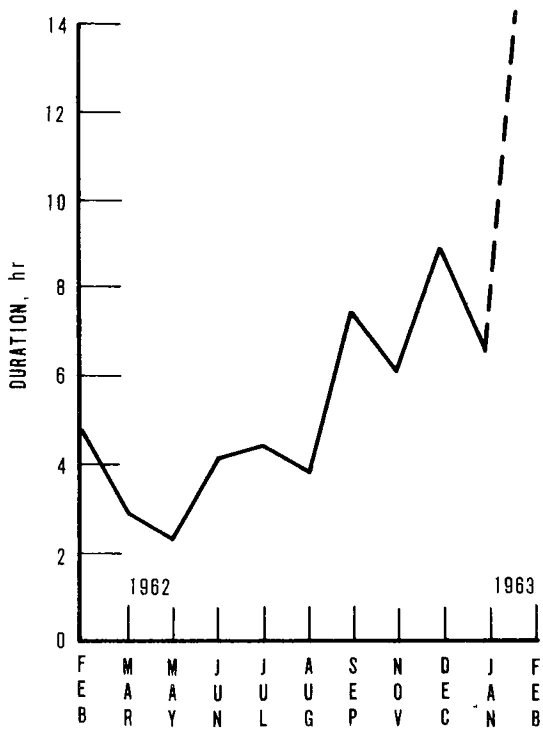


Figure 5. Average hours of inversion duration.

during the study period and the average durations of continuous inversions in the lower 100 feet of the atmosphere at the tower site. Shortest inversion periods occurred during the late spring and early summer, whereas inversions persisted longer during the late fall and winter months. The frequency of inversions is greater during summer than during winter.

The emissions from a tall stack, or air pollution that rises because it has been heated at the source, remains aloft under inversion conditions, but it is confined by valley walls unless it is removed by wind or permitted to escape aloft by the dissipation of the inversion.

## FUMIGATION

If a volume of air is displaced in an upward or downward direction in an unstable atmosphere, the air continues to move in the up or down direction. In an unstable atmosphere the temperature decrease with height is greater than 1°C per 100 meters (5.4°F per 1,000 ft). Hardly any air pollution from the pulp mill results in the Lewiston-Clarkston area when the air is generally unstable. Looping of plumes can cause high concentrations near the mill, but this condition is most likely to occur during the afternoon when westerly winds transport the pulp mill plume away from the populated areas.

Moderately high concentrations of air pollutants from the pulp mill can be transported interstate under neutral meteorological conditions, i.e., when the temperature decrease with height is 1°C per 100 meters. Neutral conditions occur with windy or cloudy conditions or during transitions between unstable and stable conditions. Neutral conditions with easterly winds that transport air pollution from the pulp mill to Clarkston occur very infrequently.

By far the most important cause of high concentrations of air pollution at ground level in Lewiston and Clarkston is the atmospheric process called "fumigation." Wherever the ground receives solar radiation, the air heats from the surface upward. After sunrise a layer of warm air is formed at the base of the stable layer that fills the valley, and the layer thickens as heating continues. When this layer becomes thick enough, convective currents form within it , depending on the character of the surface. Significant factors would be roughness caused by trees or other vegetation, man-made objects, and minor topographic features. The upward-moving currents may, or may not, join together in a shallow up-valley breeze at this time of day. Wind directions may be variable, or westerly; and wind speeds 3 to 7 miles per hour. However, with sufficient time, usually before mid-morning, the layer of heated air becomes deep enough to reach the pulp mill plume spread out several hundred feet overhead. Mixing of the material of the plume occurs throughout the heated layer. Although the mixing seems to begin over Clarkston, or westward from there, where there may be more surface heating, it works back to Lewiston. With continued heating as the morning progresses, the layer in which mixing is occurring becomes deep enough to envelop all of the plume. At first the plume material is brought nearly straight downward by the air currents. The material in the plume that reaches the ground is relatively highly concentrated, since the plume has never diffused much in the stable layer. Obviously, the rate of heating is a factor in determining the maximum ground concentration and the duration of the generally high concentrations resulting from fumigation. In the summer the average duration of the fumigation process may be 30 minutes to 1 hour, whereas in the fall and winter the average duration may be 2 or 3 hours or longer.

When viewed from a distance, the material being mixed downward during fumigation appears to be uniform. It gradually obscures visibility between the ground and the plume without showing any signs of the vertical currents causing the mixing. Following the fumigation, visibility gradually improves. A change in horizontal visibility during fumigation is sometimes noticeable for a brief period in downtown Lewiston and Clarkston, when a mid-morning haze can be seen between the observer and objects such as trees or buildings a city block or two away. Overhead, the plume becomes thinner and later becomes indistinguishable from the more tenuous material mixed throughout the heated layer of air.

Near the pulp mill the vertical air currents, if strong, may cause looping of the plume to the ground while the fumigation is taking place at some further distance downwind.

By the time the fumigation has been completed, wind directions are likely to be variable, with light speeds, so the plume over the pulp mill rises nearly straight up under good diffusion conditions, or if the winds have become westerly, the plume moves up valley away from Lewiston.

Air pollution that comes down in fumigation over Clarkston can be carried back over Lewiston with a west wind. This seems to be much less of a problem, however, than it might first appear because of the strong vertical motions that are likely to be occurring. Going westward, aloft, the plume remains concentrated; but returning and going eastward toward the pulp mill, it is likely to be well dispersed. In some instances, heating is sufficient to eliminate the stable layer in the valley and any air pollution is free to escape upward. In this case, the valley quickly clears and ground concentrations are inconsequential in the return flow.

Figure 6 illustrates the fumigation process.

There is also another situation when the pulp mill odor can be noticeable in downtown Lewiston with a west wind. Odors from the water discharge of the mill at the confluence of the Clearwater and Snake Rivers may be noticeable when the wind is light and the air is stable, with little vertical mixing.

## EPISODES

Air pollution potential forecasts of weather conditions conducive to accumulation of air pollutants in the atmosphere are prepared at a facility of the National Center for Air Pollution Control in Cincinnati, Ohio, by meteorologists on assignment from the Environmental Science Services Adminstration (ESSA), U.S. Department of Commerce. These forecasts are based on reports received hourly via teletype from the Weather Bureau stations in the United States and on numerous analyses and forecasts provided by the National Meteorological Center in Suitland, Md. Since the air pollution potential forecast program was begun for the

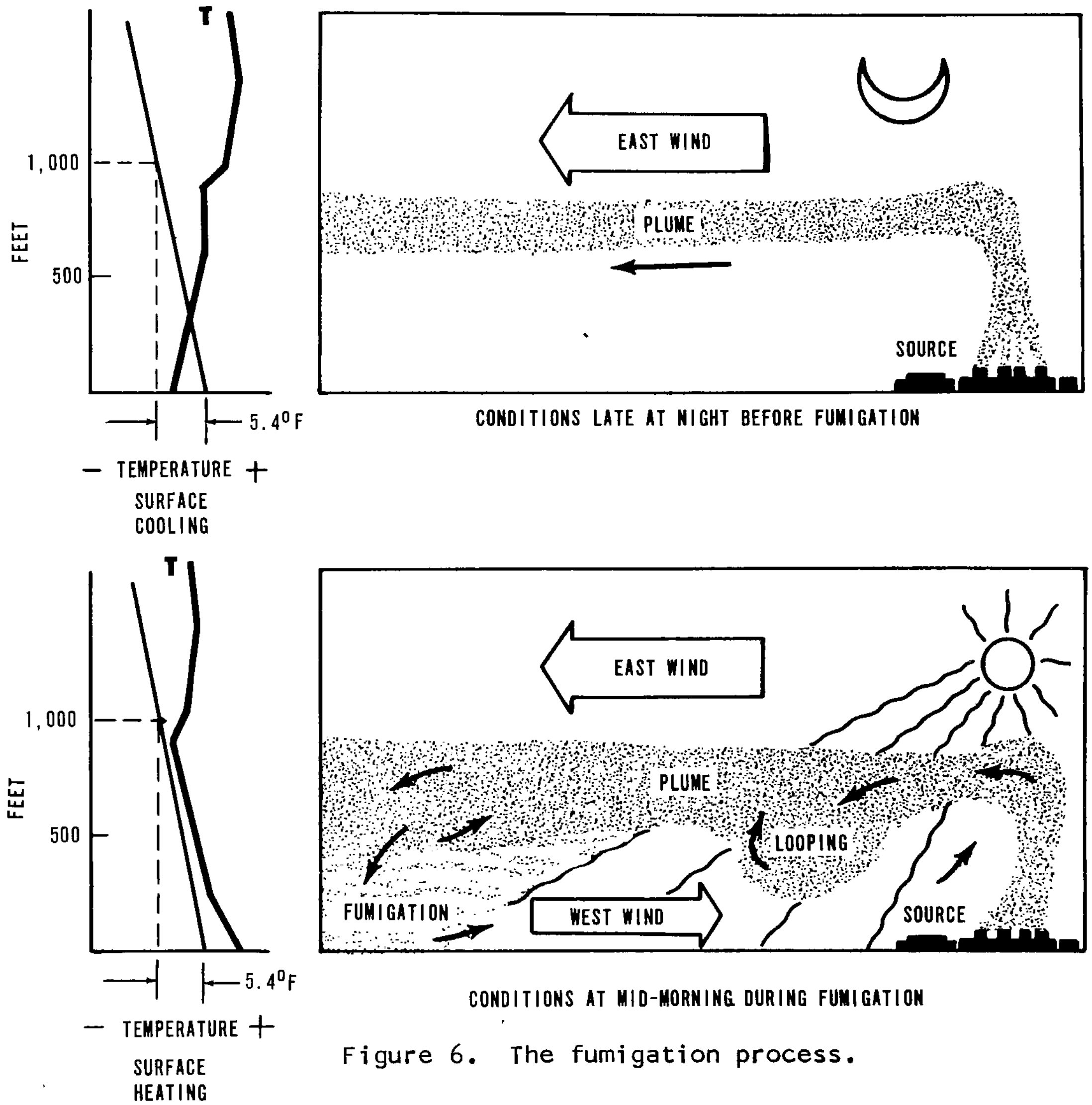


Figure 6. The fumigation process.

western part of the United States in October 1963, air pollution advisories have been issued for the Lewiston-Clarkston area for a total of 32 days during the periods listed below:

| | |
|---|---|
| Nov. 30 - Dec. 7, 1963 | Feb. 18 - Feb. 19, 1965 |
| Nov. 18 - Nov. 22, 1964 | Oct. 23 - Oct. 28, 1965 |
| Jan. 16 - Jan. 19, 1965 | March 25 - March 27, 1966 |
| | (No other advisories in year 1966) |

Weather Bureau records at the Lewiston Airport were independently scanned to determine possible dates of high air pollution situations in Lewiston, Idaho. The dates selected are listed below:

1961

January 8-13; 15-23; and 24 - February 12

November 4-10; 12-21; and 27 - December 3

1962

January 28 February 1

February 15-21

March 5-8

October 10 - November 3

November 12-17

December 7-12; 16-23; and 25-31

1963

January 4-8 and 20-24

February 4-16 and 18-25

[a]November 30 - December 7

December 12-21

1964

October 21-28

[a]November 6-10 and 13-22

December 2-6 and 27-31

1965

[a]January 10-22

[a]October 23-21

November 3-18 and 22-27

December 5-11

1966

February 17-22 and 24-26

March 8-14

[a]March 24 - April 1

April 3-9 and 17-24

April 29 - May 5

May 7-9

October 9-16

October 22 - November 14

November 17 - December 6

December 17-20 and 29-31

[a]Include dates of advisories.

Meteorological conditions on these dates were characterized by an unusual number of hours with smoke over the city or in the valley, sometimes with fog, and calm or light wind. The periods that coincide with periods of air pollution advisories are marked. These dates would not be expected to correspond exactly because air pollution potential forecasts are limited to areas at least as large as 75,000 square miles (roughly the size of the state of Oklahoma), in which stagnation conditions are expected to persist for at least 36 hours.

The report 999-AP-8[1/] contains a graph, "Seasonal Variation of Airport Observations of Smoke Over the City, 1948-1959," which shows average days per month for which smoke was reported in the valley for each month of the year. This graph is replotted in Figure 7, which shows the days per month smoke was reported in the valley during each month of 1965 and 1966. Excluding January and February it appears that smoke in the valley was reported considerably more often during 1965-66 than during the 1948-59 period.

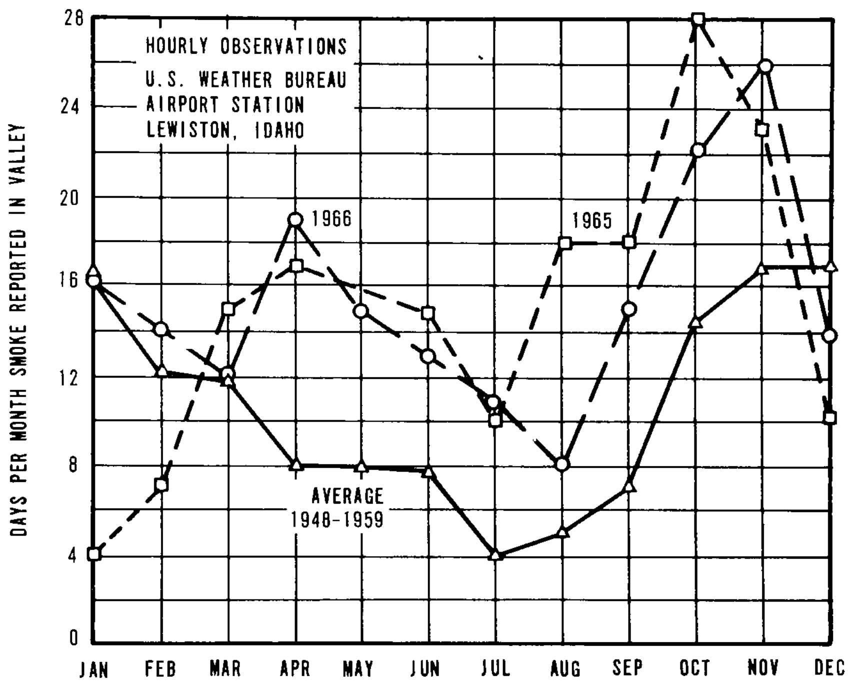


Figure 7. Seasonal variation of airport observations of smoke over the city.

## SECTION VIII—ESTIMATED CONCENTRATIONS OF AIR POLLUTANTS

### ODOROUS GASES

It was reported that 1,660 pounds of sulfur is emitted daily from the pulp mill stacks as hydrogen sulfide along with the same amount emitted as mercaptans. Meteorological diffusion computations were made for four different conditions by using these emission rates and the method of Turner and Gifford.[15,16] Table XI gives estimated concentrations that would be expected in downtown Clarkston. A fumigation case is shown by photograph and drawing in Figure 8. Effective stack heights for all stacks of the paper mill were computed by using the method of Holland.[17] Example of effective plume heights are given below for neutral meteorological conditions:

| | Effective Height, m | |
|---|---|---|
| 2 and 3 evaporator | 38 | |
| 1 and 2 recovery | 71 | (assumed wind speed 2 mps ) |
| 3 recovery | 70 | |

Heights for stable conditions were computed to be somewhat lower.

Observations of the plume show that the calculated heights underestimate true heights because practically all of the stacks of the paper mill act as heat sources and their plumes merge. Other available methods of computing plume rise also do not fit this situation; therefore, computations of downwind concentrations were made for effective stack heights of 100 meters and 150 meters, since with light winds the height of the plume usually appears to be within this range. In all but the uniform mixing case, ground concentrations would be normally distributed across the long axis of the plume. The values given would occur beneath this long axis. The effect of the shape of valley cross section was considered in the uniform mixing case, but the valley walls did not seem to restrict the plume dispersion significantly at a distance 3 miles downwind at the selected wind speed of 5 mph.

The report 999-AP-8[1] states that sampling station 6, in Clarkston, yielded maximum concentrations of 9 ppb under unstable conditions, 33 ppb under neutral conditions, and 44 ppb under fumigation conditions. Adams gives average concentrations of $H_2S$ with respect to time of day at station I-2, also in Clarkston.[3] For mid-day, when conditions are generally unstable, he shows a concentration of about 5 ppb, and between 0600 and 0800, which are hours possibly associated with fumigation, he shows about 13 ppb. He also presents monthly distributions by hours for this station. These distributions indicate average peak fumigation values of about 20 ppb during some months.

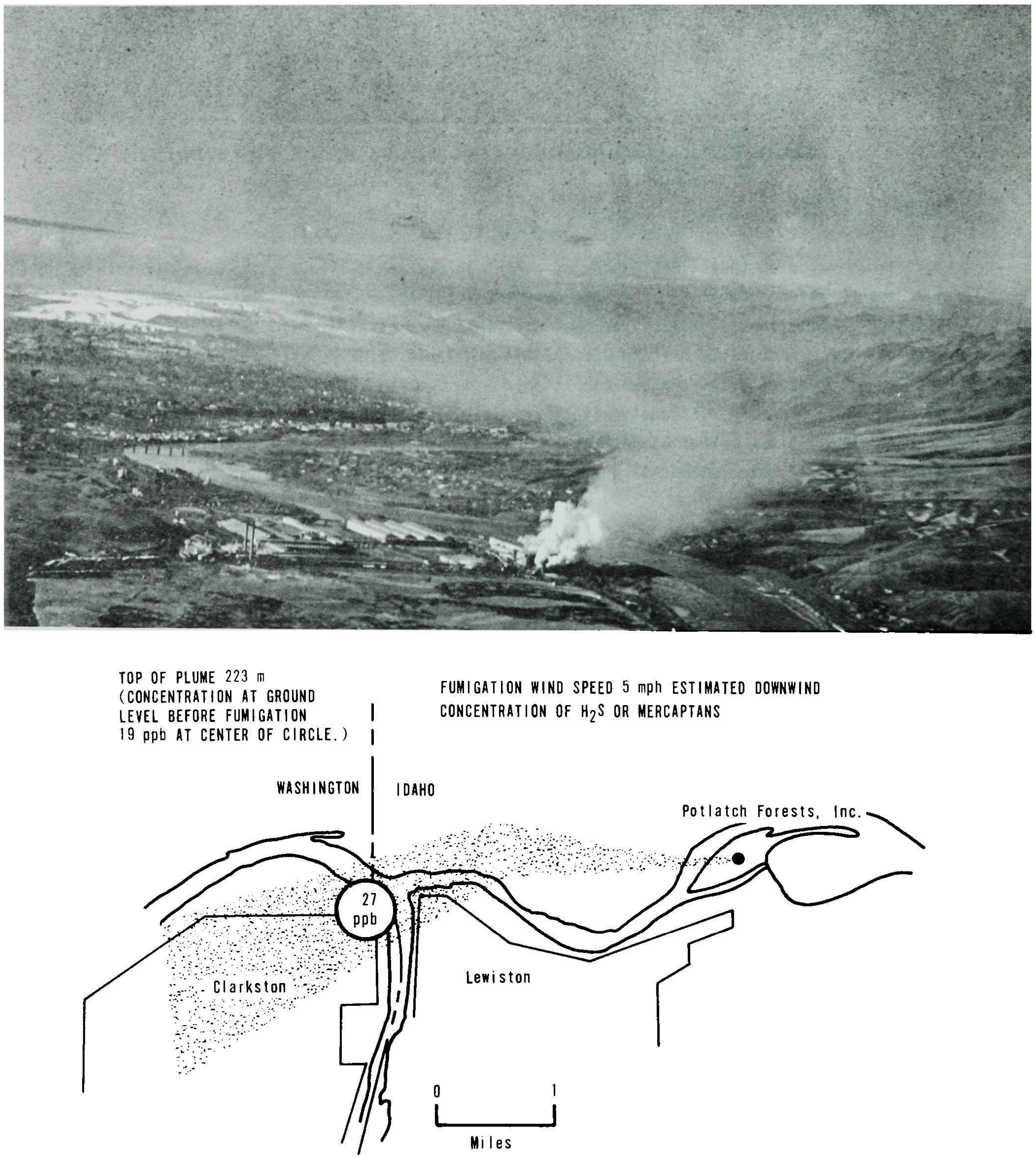


Figure 8. A typical fumigation of the study area.

With wind speeds as low as 2 miles per hour (<1 mps) and the possible reduction of wind direction fluctuations caused by the valley configuration, the actual concentrations may at times be double those shown in the Table XI. Both the estimates and the available measurements indicate that concentrations of $H_2S$ and mercaptans range from about 5 to 50 ppb over periods of 3 to 15 minutes in Clarkston most of the time when it is downwind of the operating pulp mill, depending on atmospheric stability and wind speed. The estimates also suggest that emissions of the pulp mill have not changed significantly since 1961-62.

TABLE XI

ESTIMATED DOWNWIND CONCENTRATIONS
OF EITHER HYDROGEN SULFIDE OR MERCAPTANS
Distance, about 3 miles (5,000 m)
Rate of emission of $H_2S$ or Mercaptans:
1,660 lb/day of sulfur each

(Emission rate of $H_2S$ = 1,764 lb/day = 9.2 g/sec)

(Emission rate of mercaptans, assumed to be all methyl mercaptan, $CH_3SH$ = 2,490 lb/day - 13.1 g/sec)

NOTE: Calculated concentrations are the same for both gases. 1 ppb $H_2S = 1.4 \times 10^{-6}$ g/m$^3$, 1 ppb $CH_3SH = 2 \times 10^{-6}$ g/m$^3$.

| Meteorological Condition | Concentration, ppb: 3- to 15-min avg | | Concentration, ppb: 2-hr avg | |
|---|---|---|---|---|
| Wind speed 5 mph (2 mps) | H 100 m | H = 150 m | H = 100 m | H = 150 m |
| Moderately Unstable | 9 | 8 | 5 | 5 |
| Neutral | 22 | 15 | 13 | 9 |
| Moderately Stable | 19 | 5 | 11 | 3 |
| Fumigation[a] | 27 | 22 | | |
| Uniform Mixing[b] | 16 | 13 | | |

[a]Fumigation concentration $\chi_f = \dfrac{Q}{\sqrt{2\pi}\,\bar{u}\,\sigma_y\,H'}$

H = effective stack height

H'= H + 123 m. (123 m = estimated vertical extent of plume above effective stack height)

Q = emission rate, g/sec

$\bar{u}$ = average wind speed, mps

$\sigma_y$= standard deviation of plume concentration in the horizontal

[b]Rectangular cross section 1000 m (H + 123 m). No time limit.

## PARTICULATES

Details of the physical characteristics of the approximately 12 tons of particulates emitted daily by Potlatch Forests, Inc., operations are unavailable. Without information such as particle diameters and densities, a quantitative determination of the fall-out per unit area of ground surface cannot be made. Particles of small diameter, which make up the visible plume persisting after evaporation of moisture, are, however, consistently carried over Clarkston and brought to the ground by atmospheric diffusion processes and fumigation. Larger particles appear as fine snow grains that are observed to fall from the plume within a mile or two of the mill. Such grains are seen primarily in North Lewiston, where on the ground they resemble a trace of snow. They fall through the air, blow over surfaces, and accumulate in cracks and corners as would a dry snow. The distance these larger, easily visible particles are carried depends on wind speed. They can on occasion, however, be transported by the wind as far as downtown Lewiston or Clarkston.

## WATER VAPOR

The report 999-AP-8 discusses the possible effect of the stack effluent from the pulp mill on visibility within the Lewiston-Clarkston valley. In order to further investigate this effect, downwind concentrations of water vapor were calculated for the distance of Clarkston by using the reported rate of emission of water vapor, 9,000 tons per day; and these concentrations were used to estimate the increase in relative humidity caused by the pulp and paper mill emissions at three different temperatures. These estimates are shown in Table XII. The relative humidities listed may be added to any existing relative humidity of the air at the temperature shown to obtain the resulting effect. For example, if the relative humidity of the air would otherwise be 80 percent at 32$^{o}$F, fumigation with a 5-mph wind speed would be expected to produce a relative humidity of 88 percent at ground level; whereas 100 percent humidity, plus water droplets, would occur in the core of the plume under moderately stable conditions. It can be seen from Table XII that the effect of the plume is much greater at low temperatures.

The pulp and paper mill plume also contains solid particles too small to be visible when the air is dry and they are well-dispersed. Such particles do, however, adsorb any water vapor present and become effectively larger. The fact that the plume contains a large amount of water vapor in addition to the particles means that it can be seen when otherwise it would be virtually invisible; and since the particles would be expected to grow rapidly as the humidity becomes high, e.g., higher than 90 percent, the plume can be an obscuring factor when the relative humidity is well below 100 percent.

Since at times the relative humidity of the air is high as a result of natural causes, the estimated humidity increases seem consistent with visual observational data. This would explain the frequently seen, cloud-like layer that often nearly fills the valley as well as the considerable amount of fog that occurs during the colder months. When wind speeds are very light the moisture added to the air in the valley is sometimes not cleared out from one day to the next. It continues to accumulate and its effect increases until a change in meteorological conditions removes it.

TABLE XII

PERCENT INCREASE IN RELATIVE HUMIDITY

CAUSED BY PAPER MILL PLUME

AT DISTANCE OF CLARKSTON[a]

| Condition | Temperature | | |
|---|---|---|---|
| | 10°F | 32°F | 50°F |
| 1. Atmosphere Moderately Stable (Ground Level) | 12 | 5 | 3 |
| 2. Atmosphere Moderately Stable (Plume Centerline) | 59 | 25 | 13 |
| 3. Fumigation (Ground Level) | 18 | 8 | 4 |
| 4. Uniform Mixing | 10 | 4 | 2 |

[a]Rate of emission of water vapor: 9,000 tons/day.
Distance: 3 miles (5,000 meters).
Pressure assumed: 1,000 mb.
Wind speed: 5 mph (2 mps).
Concentrations averaged over 3- and 15-minute periods.

## GENERAL COMMENT

The plume from the Potlatch Forests, Inc., mill is often a dominant feature of the valley. If the mill were located in flat country, in an area where there is more natural haze, or in a heavily industrialized, urban area as exists along parts of the East Coast, the plume would be considerably less conspicuous to the eye. Aside from the fact that it contains air pollution in the form of odors and particulates, it affects the behavior of people and the economy of the Lewiston-Clarkston area in the following ways:

1. There is no other plume of remotely comparable size in the entire area; therefore, the Potlatch Forests, Inc., plume is singled out as a prominent and objectionable feature.
2. The plume contains an enormous amount of moisture that under certain frequently occurring meteorological conditions either can be seen or noticeably obstructs visibility.
3. In absence of the plume, visibility would generally be unlimited except for precipitation and some fog that would occur almost entirely during the colder months.
4. The plume viewed from above can be clearly seen even when very tenuous because it strongly reflects light. When seen from the side, it is more conspicuous against the walls of the valley than it would be against the sky.
5. Many persons travel into and out of the Lewiston-Clarkston area. Travellers are reluctant to descend from the very clean, dry air of hill tops where visibility is unlimited into the valley where the air appears to be less clean. Upon leaving the valley they experience relief as they look back at the obscuration below. Some people with real or imagined health problems avoid travelling to Lewiston on days when air pollution may be high.

## SECTION IX—EFFECTS OF ODORS

Of all man's senses, least is known about olfaction. The nose is so sensitive that no scientific instrument approaches it in sensitivity or versatility as an odor meter. It can respond to thousands of distinct odor stimuli and can detect odors in extremely dilute gaseous concentrations.

Response to an odor is, however, almost entirely subjective. What is pleasant or fragrant to one person may be unpleasant or malodorous to another. Kraft pulp mill odors are, however, almost universally displeasing and repulsive; consequently, such mills frequently are located in one-industry towns whose livelihood depends on the success of the mills. Although communities that are economically dependent on such a single industry are not likely to complain, people in neighboring jurisdictions, who may be less dependent and whose comfort, enjoyment, and welfare are disturbed by the malodors, are not so tolerant or constrained.

Effects of odors on behavior have been given insufficient attention. It is known, however, that the physiological processes of any individual with respiratory ailments are adversely affected, however slightly, by odors and other air pollutants. Thus, the condition of an afflicted person under the influence of odors is exacerbated to the level of a person with a more advanced respiratory deficiency. This can result in loss of sleep, general weakness, greater susceptibility to other diseases, irritability, loss of appetite, and loss of work days.

Although he may not be greatly affected by low-level chemical and particulate pollutants, a healthy individual undoubtedly is affected by noxious odors. Odors may not cause organic disease, but they can seriously affect a healthy individual's behavior adversely, both physiologically and psychologically.

Offensive odors such as those that originate from the Potlatch Forests, Inc., pulp mill generally are recognized as capable of producing nausea, vomiting, and headache; curbing appetites; disturbing sleep; upsetting stomachs; hampering proper physiologic breathing; offending the senses; and interfering with comfortable enjoyment of property. They can mar good dispositions and provoke irritability.

Sociologically, such odors reduce personal and community pride, interfere with human relations in various ways, discourage capital investments, lower socio-economic status, and damage a community's reputation. Economically, they can stifle growth and development of a community. Both industry and labor prefer to locate in areas that are desirable places to live, work, and play; the natural tendency is for them to avoid areas with obvious odor problems. Tourists shun polluted areas. The resulting decline in market or rental property values, tax revenues, payrolls, and sales can be disastrous to a community.

## SECTION X—DETERIORATION OF MATERIALS

### SILVER TARNISHING

Metallic silver is sensitive to various sulfur compounds, especially hydrogen sulfide. Hydrogen sulfide reacts chemically with metallic silver, causing a black-purple film or tarnish upon the metal surface. Because of the sensitivity of silver to hydrogen sulfide, the tarnishing of exposed specimens of the metal is often used as an indicator of hydrogen sulfide in the atmosphere. The percent decrease in light reflectance from the exposed silver plate is the generally accepted measure of the amount of tarnishing.

In the 1961 study of air pollution in the Interstate Region of Lewiston, Idaho and Clarkston, Washington, silver in the Lewiston area was found to lose about 45 percent of its reflectance in 30 days.

From May to December 1966, silver specimens were exposed for periods of approximately 1 month each at the State Highway Garage in North Lewiston. Exposures of these specimens resulted in an average of about 86 percent decrease in reflectance. During the months of November and December 1966, silver specimens were exposed at three locations in the Lewiston-Clarkston area and one location in Pullman, Wash. Results of these exposures, as percent decrease in reflectance during 30-day exposures, are listed in Table XIII.

TABLE XIII
PERCENT DECREASE IN REFLECTANCE OF
METALLIC SILVER SPECIMENS - 30 DAY EXPOSURES

| Location | November, 1966 | December, 1966 |
|---|---|---|
| Pullman, Wash. | 17 | 20 |
| North Lewiston, Idaho | 89 | 81 |
| Lewiston, Idaho | 77 | 54 |
| Clarkston, Wash. | 88 | 76 |

These results are indicative of the presence of hydrogen sulfide in the atmosphere of the Lewiston-Clarkston area. Specimens from Pullman, Wash. show only moderate tarnishing.

## PAINT DAMAGE AND STEEL CORROSION

Potlatch Forests, Inc., has reported that particulate emissions from recovery furnaces are currently 78.9 percent sodium sulfate and 13.2 percent sodium carbonate. The ratio of sodium to sulfate in this distribution of sodium compounds is about 0.6 to 1.0, a relationship that permits use of these chemical constituents as crude tracers for furnace particulate emissions. Data reported for dustfall samples taken at the State Highway Garage in North Lewiston during the period December 1961 through December 1962 show sodium and sulfate as the major constituents. [3/] The ratio of sodium to sulfate in these samples is about 0.4 to 1. During the summer and early fall of 1966 qualitative dustfall samples were obtained at the State Highway Garage in North Lewiston. These samples yielded a sodium to sulfate ratio of about 0.6 to 1 and averaged about 40 percent by weight sodium and sulfate.

Special dustfall samples have been obtained at or near the site of Henderson Motors, Inc., in North Lewiston, only a short distance from the State Highway Garage. One of these was taken on July 27, 1966, during a 2-hour period when the area was being showered with white particulate material, and another collected in a piece of farm machinery over an undetermined period of time; both yielded a sodium to sulfate ratio of about 0.7 to 1. The latter sample contained sulfate, carbonate, and a minor amount of bicarbonate in stoichiometric proportion to its sodium content. These sodium salt constituents accounted for 43 percent of the total sample.

These data are consistent with reports by Potlatch Forests, Inc., of substantial emissions of sodium sulfate and sodium carbonate from its recovery furnaces.

Particulates emitted from kraft pulp mill recovery furnaces have been associated with paint damage and corrosion of ferrous metals in the Lewiston area. It is reported that for a number of years vehicles at the State Highway Garage in North Lewiston have suffered paint damage and corrosion. Similar damage to vehicles has been reported and demonstrated at the Henderson Motors, Inc., site in North Lewiston. Steel coupons exposed at the State Highway Garage during the summer and fall showed only light to moderate corrosion. These flat plate specimens were placed in the customary angled exposure position that does not accumulate particulate when the surface is dry. Corrosion results indicate that the metal surfaces were seldom wet during the exposure periods or that the gaseous components of the atmosphere had only mild corrosive effect.

The mechanism of liquid blister formation during prolonged immersion of paint coatings on metal is of interest to paint manufacturers whose products may be applied to ships' bottoms, dock works, water tanks, and similar structures. The mechanism has been described by investigators concerned primarily with paint blistering in 3.7 percent sodium chloride solutions, the concentration of sea water. [18/] The mechanism is identified as "electroendosmosis," which is defined as the movement of water through a capillary or membrane under the influence of an electrical potential gradient. Studies showed that when painted steel was submerged in sea water, blistering of the paint occurred shortly after corrosion of the metal occurred. The blisters occurred in the vicinity of the corrosion but not at the corrosion site. The electrical force drawing the water through the paint is that set up by the corroding metal itself.

Inspection of some of the vehicles at the State Highway Garage and at the Henderson Motors, Inc. site in North Lewiston indicated that, in fact, the coating of paint on the vehicles was not intact and was not protecting the metal surface underneath.

An investigation of the corrosive properties and the paint blistering capabilities of sodium sulfate and sodium carbonate was undertaken by the Abatement Program, National Center for Air Pollution Control. Results of this investigation indicated the following:

1. Sodium sulfate, a neutral salt, neither greatly inhibits nor greatly accelerates corrosion of ferrous metal.

2. Sodium carbonate, an alkaline salt, inhibits corrosion of ferrous metals.

3. A mixed solution (4 to 1) of sodium sulfate and sodium carbonate inhibits the corrosion of ferrous metals.

4. Sodium sulfate solutions, like sodium chloride solutions, are capable of blistering paint from ferrous metal surfaces. This blistering capability is greatly accelerated by nearby corrosion of the metal.

5. Sodium carbonate solutions do not blister paint from ferrous metal surfaces.

6. A mixed solution of 4 parts sodium sulfate and 1 part sodium carbonate is capable of blistering paint from ferrous metal surfaces.

7. A 10 percent solution of sodium sulfate caused blistering of paint after 16 hours of exposure. The blistering was visible to the unaided eye.

8. A solution containing 10 percent sodium sulfate and 2.5 percent sodium carbonate caused blistering of paint on steel in approximately 4 days.

9. In a laboratory trial, a 1 percent solution of the fall-out sample collected from a farm machine adjacent to the Henderson Motors, Inc., site blistered paint on steel in a period of 1 hour. In this trial only the painted side of the metal was exposed to the sample solution while the unpainted side was subjected to corrosion caused by distilled water. A synthetic sample having the same proportions of $Na_2SO_4$ and $Na_2CO_3$ as the fall-out sample caused paint blistering under the same test conditions.

10. Seven different types of automobile paints were tested by submersion of specimens of painted automobile body sheet metal in a 10 percent sodium sulfate solution.

Three specimens blistered within a 24-hour period and a fourth blistered during a 4-day exposure.

It is concluded that damage to some types of paint and subsequent natural corrosion of the metal the paint was meant to protect can occur in the Lewiston-Clarkston area, depending upon the type of paint and its exposure to dustfall rich in sodium sulfate.

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## APPENDIX A

## TRI-COUNTY AIR AND WATER QUALITY CONTROL COMMITTEE CHARTER

An unacceptable level of Air and Water pollution exists now in portions of the Tri-County area. Unless reasonable standards of Air and Water quality control are established soon, the expected increase of industry, commerce, and population may increase the now unsatisfactory pollution levels to an intolerable point.

The Committee shall limit its activity and scope of operations to matters pertaining to maintenance of a high standard of purity and quality for air and water resources.

The Committee shall undertake and pursue a course of action which will expeditiously lead to recommendations for controlling and abating air and water pollution incidents existing upon creation of the committee; and shall establish and forward for enactment into ordinance, resolutions, statutes and other controlling media, standards for air and water quality control.

The function of this Committee shall be advisory only; the regulatory and punitive matters required to enact and enforce air and water quality control standards, ordinances, regulations and like actions shall be the responsibility of the parent municipal corporation or appropriate legislative body.

The geographic area of concern to the Committee shall include the entire areas of Nez Perce County, Idaho, Asotin and Whitman Counties in Washington.

It is anticipated that this Committee shall function for a limited time only. Initially the life of this Committee shall be limited to 18 months. If this term becomes impractical and/or must be extended, such extension shall be voted upon by each member, agreement for such extension must be unanimous.

Roberts Rules of Order will constitute the parliamentary guide for committee operations except insofar as this guide be in conflict with the committees' adopted policy rules or regulation.

The operations, functions, and meetings of the committee being of public concern and dealing with public matters shall be advertised in advance and shall be open to the news media and the general public. Executive sessions with the general public and news media barred therefrom are prohibited.

The committee shall seek expert advice and opinion in its operations pertaining to air and water quality control investigations. Committee deliberation and decision however remains at the discretion of the Committee.

From time to time, it may become necessary for the Committee to acquire and expend public funds in the furtherance of its aims and goals. In these instances the Committee shall request such required funds from the parent municipal corporation, each parent municipal corporation providing its fair share based upon an agreed distribution.

If private funds become available by donation these may be accepted upon vote of the Committee.

Upon dissolution, funds remaining under the control of the Committee shall be returned to the apportioning municipal corporation in the same manner prorated as received.

In the event that the Committees' recommendations are disregarded, or refused by the municipal corporation empowered to act in the instant matter, the Committee shall then find itself a non-functioning entity serving no public purpose. In this event or in any case where the Committee becomes a non-functioning body, its last official act prior to dissolution shall be to advise the appropriate State and Federal agencies that it cannot function and invite their intervention to establish and enforce the required standards of air and water quality control.

## APPENDIX B

## PILOT BALLOON OBSERVATIONS, LEWISTON, IDAHO, OCTOBER, 1966

Pilot Balloon Observations, Lewiston, Idaho

October 1966

| DATE: | 05 | | 05 | | 06 | | 06 | | 06 | | 06 | | 06 | | 06 | | 06 | | 06 | | 06 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME: | 2000 | | 2200 | | 0600 | | 0612 | | 0625 | | 0800 | | 0815 | | 0830 | | 1000 | | 1010 | | 1020 | |
| Ht ft | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph |
| 0000 | 160 | 01 | - | 00 | - | 00 | 276 | 01 | - | 00 | 339 | 01 | 358 | 01 | 296 | 02 | 259 | 03 | 217 | 03 | 284 | 04 |
| 0170 | 120 | 03 | 094 | 04 | 071 | 02 | 076 | 01 | 042 | 01 | 349 | 02 | 301 | 01 | 268 | 02 | 265 | 02 | 226 | 04 | 199 | 01 |
| 0330 | 106 | 06 | 080 | 08 | 071 | 04 | 082 | 04 | 088 | 02 | 348 | 02 | 274 | 02 | 260 | 03 | 253 | 05 | 248 | 02 | 216 | 02 |
| 0500 | 100 | 06 | 078 | 10 | 064 | 04 | 073 | 05 | 072 | 04 | 307 | 02 | 267 | 03 | 260 | 04 | 251 | 03 | 310 | 01 | 226 | 02 |
| 0650 | 090 | 06 | 078 | 11 | 056 | 05 | 060 | 04 | 057 | 04 | 290 | 04 | 283 | 03 | 262 | 03 | 240 | 02 | 086 | 01 | 273 | 01 |
| 0810 | 090 | 06 | 078 | 12 | 051 | 04 | 048 | 02 | 025 | 02 | 290 | 03 | 316 | 03 | 341 | 01 | 236 | 02 | 046 | 02 | 030 | 01 |
| 0960 | 090 | 06 | 078 | 12 | 041 | 04 | 035 | 03 | 018 | 01 | | | 019 | 02 | 035 | 02 | 214 | 01 | 063 | 04 | 046 | 03 |
| 1113 | 076 | 06 | 078 | 10 | 004 | 02 | 067 | 02 | 075 | 02 | | | 072 | 04 | 064 | 04 | 039 | 02 | 073 | 05 | 072 | 05 |
| 1267 | 055 | 02 | 084 | 10 | 037 | 02 | 074 | 06 | 094 | 04 | | | 080 | 08 | 078 | 07 | 069 | 04 | | | 097 | 06 |
| 1420 | 219 | 01 | 101 | 10 | 071 | 03 | 081 | 08 | 108 | 05 | | | | | | | 072 | 05 | | | 099 | 07 |
| 1573 | 203 | 01 | 108 | 06 | 065 | 06 | 098 | 08 | 138 | 06 | | | | | | | 074 | 04 | | | 099 | 07 |
| 1727 | 113 | 02 | 112 | 04 | 068 | 08 | 104 | 08 | 153 | 08 | | | | | | | | | | | 107 | 04 |
| 1880 | 092 | 02 | 145 | 04 | 082 | 10 | | | 153 | 12 | | | | | | | | | | | 110 | 03 |
| 2020 | 086 | 02 | 153 | 04 | 094 | 09 | | | 157 | 12 | | | | | | | | | | | 108 | 02 |
| 2160 | 079 | 04 | 171 | 05 | 108 | 08 | | | 166 | 11 | | | | | | | | | | | 104 | 02 |
| 2300 | 090 | 05 | 190 | 09 | 116 | 07 | | | 169 | 10 | | | | | | | | | | | 114 | 03 |
| 2440 | 117 | 05 | 192 | 12 | 122 | 08 | | | | | | | | | | | | | | | 125 | 03 |
| 2580 | 144 | 05 | 193 | 10 | 122 | 09 | | | | | | | | | | | | | | | 133 | 02 |
| 2720 | 169 | 05 | 193 | 10 | | | | | | | | | | | | | | | | | 171 | 03 |
| 2860 | 169 | 06 | 210 | 10 | | | | | | | | | | | | | | | | | 177 | 05 |
| 3000 | 183 | 10 | 210 | 11 | | | | | | | | | | | | | | | | | 191 | 06 |
| 3140 | 188 | 13 | 210 | 14 | | | | | | | | | | | | | | | | | 209 | 06 |
| 3280 | 190 | 14 | 210 | 14 | | | | | | | | | | | | | | | | | | |
| 3420 | 195 | 15 | 212 | 14 | | | | | | | | | | | | | | | | | | |
| 3560 | 198 | 19 | 212 | 15 | | | | | | | | | | | | | | | | | | |

Pilot Balloon Observations, Lewiston, Idaho

October 1966

| DATE: | 06 | | 06 | | 06 | | 07 | | 07 | | 07 | | 07 | | 07 | | 07 | | 07 | | 07 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME: | 1200 | | 1709 | | 2300 | | 0500 | | 0800 | | 0905 | | 0915 | | 1100 | | 1500 | | 1800 | | 1900 | |
| Ht ft | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph |
| 0000 | 208 | 03 | 169 | 01 | 163 | 04 | 124 | 04 | 059 | 05 | 044 | 06 | 060 | 05 | 050 | 02 | 175 | 02 | 266 | 13 | 200 | 13 |
| 0170 | 184 | 04 | 041 | 01 | 095 | 06 | 099 | 06 | 062 | 05 | 073 | 06 | 069 | 04 | 063 | 02 | 231 | 02 | 279 | 14 | 211 | 14 |
| 0330 | 166 | 03 | 018 | 02 | 088 | 09 | 098 | 04 | 072 | 07 | 076 | 08 | 069 | 06 | 079 | 02 | 236 | 03 | 279 | 17 | 214 | 16 |
| 0500 | 157 | 02 | 352 | 02 | 075 | 12 | 017 | 02 | 078 | 06 | 082 | 08 | 069 | 05 | 082 | 04 | 263 | 02 | 279 | 17 | 235 | 11 |
| 0650 | 100 | 02 | 307 | 01 | 073 | 12 | 328 | 03 | 080 | 06 | 082 | 07 | 057 | 04 | 069 | 04 | 314 | 02 | 279 | 16 | 271 | 09 |
| 0810 | 102 | 02 | 252 | 02 | 073 | 10 | 299 | 02 | 083 | 06 | 071 | 06 | 052 | 04 | 069 | 03 | 316 | 02 | 279 | 17 | 280 | 14 |
| 0960 | 109 | 02 | 252 | 03 | 073 | 07 | 295 | 06 | 078 | 05 | 063 | 05 | 055 | 05 | 107 | 01 | 314 | 02 | 275 | 16 | 280 | 14 |
| 1113 | 112 | 03 | 256 | 03 | 073 | 06 | 296 | 10 | 040 | 03 | 067 | 05 | 071 | 06 | 136 | 02 | 336 | 01 | 270 | 14 | 280 | 12 |
| 1267 | 112 | 04 | 266 | 04 | 083 | 04 | 296 | 10 | 040 | 02 | 074 | 06 | 078 | 08 | 136 | 04 | 013 | 01 | 270 | 14 | 280 | 14 |
| 1420 | 112 | 04 | 282 | 04 | 110 | 03 | 295 | 08 | 048 | 02 | 074 | 07 | 083 | 07 | 147 | 05 | 303 | 01 | 273 | 14 | 279 | 19 |
| 1573 | 112 | 03 | 295 | 05 | 176 | 01 | 288 | 10 | 061 | 02 | 080 | 06 | 098 | 06 | 165 | 06 | 297 | 01 | 275 | 15 | 277 | 21 |
| 1727 | 130 | 02 | 300 | 06 | 285 | 04 | 280 | 16 | 114 | 02 | 104 | 06 | 124 | 05 | 196 | 05 | 296 | 02 | 275 | 15 | 277 | 17 |
| 1880 | 147 | 02 | 303 | 06 | 302 | 10 | 280 | 16 | 130 | 02 | 119 | 06 | 151 | 05 | 220 | 05 | 286 | 03 | 275 | 16 | 273 | 16 |
| 2020 | 118 | 02 | 303 | 06 | 306 | 11 | 282 | 14 | 142 | 03 | 127 | 05 | 160 | 05 | 235 | 05 | 286 | 04 | 269 | 13 | 269 | 16 |
| 2160 | 065 | 03 | 295 | 07 | 298 | 11 | 282 | 14 | 164 | 03 | 139 | 05 | 161 | 06 | 246 | 05 | 279 | 04 | 268 | 13 | 264 | 16 |
| 2300 | 059 | 04 | 296 | 08 | 289 | 12 | 282 | 14 | 171 | 04 | 151 | 06 | 170 | 07 | 247 | 05 | 264 | 04 | 268 | 12 | 255 | 18 |
| 2440 | 050 | 05 | 297 | 09 | 280 | 16 | 281 | 14 | 173 | 06 | 178 | 10 | 177 | 10 | 247 | 04 | 254 | 04 | 265 | 12 | 251 | 19 |
| 2580 | 038 | 06 | 301 | 10 | 275 | 22 | 285 | 13 | 178 | 08 | 192 | 12 | 162 | 10 | 247 | 05 | 248 | 04 | 265 | 12 | 251 | 18 |
| 2720 | 028 | 08 | 300 | 09 | 268 | 25 | 264 | 15 | 192 | 07 | | | 165 | 10 | 248 | 06 | 233 | 06 | 253 | 14 | 251 | 16 |
| 2860 | 023 | 09 | 298 | 09 | 263 | 22 | 255 | 20 | 197 | 07 | | | 169 | 10 | 248 | 05 | 226 | 07 | 250 | 15 | 248 | 16 |
| 3000 | | | 296 | 10 | 263 | 18 | 255 | 22 | 206 | 08 | | | | | 248 | 06 | 224 | 09 | 250 | 16 | 243 | 17 |
| 3140 | | | 293 | 10 | 260 | 18 | | | 216 | 08 | | | | | 248 | 06 | 223 | 10 | 250 | 16 | 243 | 18 |
| 3280 | | | 290 | 10 | 260 | 17 | | | 216 | 08 | | | | | 248 | 07 | 223 | 10 | 250 | 16 | 242 | 18 |
| 3420 | | | 284 | 09 | 260 | 19 | | | 216 | 08 | | | | | 248 | 07 | 222 | 10 | 250 | 15 | 240 | 16 |
| 3560 | | | 284 | 08 | 260 | 22 | | | 216 | 08 | | | | | 248 | 07 | 222 | 09 | 250 | 15 | 240 | 16 |

Pilot Balloon Observations, Lewiston, Idaho

October 1966

| DATE: TIME: | 07 2300 | | 08 0500 | | 08 0900 | | 08 1100 | | 08 1110 | | 08 1500 | | 08 1900 | | 08 2300 | | 09 0500 | | 09 0700 | | 09 0900 | | 09 1100 | | 09 1500 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ht ft | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph |
| 0000 | 170 | 05 | 084 | 02 | 270 | 14 | 232 | 12 | 270 | 20 | 270 | 16 | 200 | 06 | 150 | 03 | 150 | 04 | 050 | 02 | 360 | 02 | 275 | 02 | 193 | 04 |
| 0170 | 097 | 05 | 092 | 04 | 270 | 16 | 250 | 12 | 252 | 22 | 257 | 20 | 227 | 09 | 193 | 04 | 120 | 04 | 090 | 03 | 025 | 02 | 316 | 02 | 214 | 02 |
| 0330 | 077 | 08 | 086 | 04 | 267 | 25 | 258 | 13 | 250 | 43 | 255 | 32 | 254 | 11 | 193 | 06 | 105 | 06 | 098 | 05 | 066 | 02 | 316 | 02 | 217 | 03 |
| 0500 | 075 | 06 | 107 | 01 | 268 | 25 | 265 | 21 | 253 | 48 | 257 | 32 | 261 | 14 | 197 | 04 | 105 | 08 | 086 | 06 | 066 | 03 | 307 | 02 | 194 | 03 |
| 0650 | 073 | 04 | 261 | 01 | 268 | 23 | 259 | 28 | 250 | 50 | 260 | 22 | 269 | 12 | 276 | 05 | 092 | 09 | 083 | 06 | 085 | 04 | 307 | 01 | 175 | 03 |
| 0810 | 089 | 02 | 268 | 04 | 268 | 22 | 263 | 32 | 245 | 60 | 263 | 20 | 271 | 16 | 291 | 08 | 092 | 08 | 081 | 04 | 087 | 06 | 319 | 01 | 160 | 03 |
| 0960 | 129 | 01 | 274 | 08 | | | | | 249 | 53 | 263 | 20 | 267 | 22 | 288 | 07 | 087 | 06 | 076 | 04 | 077 | 07 | 344 | 01 | 151 | 02 |
| 1113 | 231 | 01 | 275 | 18 | | | | | 249 | 24 | 263 | 18 | 265 | 17 | 278 | 08 | 082 | 06 | 083 | 04 | 068 | 06 | 057 | 02 | 194 | 01 |
| 1267 | 234 | 02 | 279 | 26 | | | | | 253 | 09 | 265 | 17 | 261 | 16 | 278 | 10 | 082 | 04 | 093 | 04 | 063 | 04 | 076 | 05 | 210 | 02 |
| 1420 | 224 | 04 | 274 | 20 | | | | | 253 | 06 | 265 | 19 | 260 | 14 | 283 | 10 | 109 | 04 | 099 | 04 | 070 | 04 | 090 | 05 | 212 | 03 |
| 1573 | 218 | 06 | 274 | 16 | | | | | 270 | 04 | 265 | 18 | 259 | 15 | 280 | 14 | 120 | 05 | 099 | 04 | 082 | 04 | 097 | 04 | 246 | 03 |
| 1727 | 224 | 07 | | | | | | | 270 | 03 | 267 | 18 | 253 | 16 | 273 | 14 | 120 | 04 | 099 | 04 | 106 | 03 | 107 | 04 | 284 | 05 |
| 1880 | 231 | 06 | | | | | | | 270 | 06 | 272 | 21 | 246 | 15 | 268 | 12 | 116 | 02 | 123 | 05 | 127 | 04 | 144 | 03 | 297 | 05 |
| 2020 | 249 | 07 | | | | | | | 275 | 10 | 272 | 20 | 248 | 14 | 270 | 14 | 115 | 02 | 151 | 06 | 117 | 05 | 189 | 03 | 285 | 05 |
| 2160 | 245 | 07 | | | | | | | 275 | 22 | 272 | 19 | 247 | 14 | 270 | 14 | 113 | 04 | 137 | 04 | 115 | 06 | 200 | 04 | 281 | 04 |
| 2300 | 264 | 12 | | | | | | | 275 | 34 | 274 | 20 | 248 | 13 | 270 | 16 | 140 | 07 | 126 | 04 | 129 | 08 | 198 | 04 | 288 | 04 |
| 2440 | 262 | 14 | | | | | | | 275 | 30 | 274 | 19 | 258 | 12 | 270 | 18 | 140 | 10 | 186 | 16 | 150 | 10 | 194 | 06 | 297 | 04 |
| 2580 | 233 | 11 | | | | | | | 275 | 20 | 274 | 22 | 267 | 12 | 267 | 18 | 117 | 08 | 194 | 20 | 169 | 09 | 187 | 07 | 303 | 04 |
| 2720 | 217 | 10 | | | | | | | 275 | 12 | 275 | 25 | 269 | 13 | 267 | 17 | 117 | 04 | 167 | 08 | 180 | 11 | 189 | 08 | 306 | 03 |
| 2860 | 210 | 10 | | | | | | | 275 | 14 | 275 | 22 | 272 | 14 | 267 | 16 | 172 | 03 | 179 | 08 | 184 | 11 | 195 | 08 | 304 | 03 |
| 3000 | 209 | 09 | | | | | | | 275 | 20 | 277 | 22 | 273 | 20 | 265 | 18 | 257 | 04 | 196 | 07 | 184 | 11 | 197 | 09 | 308 | 04 |
| 3140 | 209 | 10 | | | | | | | 275 | 12 | 277 | 22 | 273 | 23 | 265 | 18 | 277 | 10 | 188 | 05 | 182 | 11 | 199 | 09 | 301 | 04 |
| 3280 | 207 | 09 | | | | | | | | | 278 | 24 | 273 | 24 | 265 | 18 | 270 | 10 | 198 | 03 | 180 | 10 | 202 | 09 | 296 | 04 |
| 3420 | 201 | 09 | | | | | | | | | 278 | 25 | 273 | 25 | 268 | 19 | 262 | 08 | 205 | 03 | 175 | 10 | 206 | 10 | 291 | 05 |
| 3560 | 200 | 10 | | | | | | | | | 278 | 26 | 273 | 25 | 268 | 20 | 261 | 09 | 205 | 04 | 175 | 10 | 205 | 10 | 286 | 05 |

Pilot Balloon Observations, Lewiston, Idaho

October 1966

| DATE: TIME: | 09 1900 | | 10 0500 | | 10 0700 | | 10 0900 | | 10 1100 | | 10 1500 | | 10 1900 | | 10 2300 | | 11 0500 | | 11 0700 | | 11 0900 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ht ft | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir ° | Vel mph | Dir | Vel mph | Dir | Vel mph |
| 0000 | 181 | 02 | 170 | 01 | - | 00 | 020 | 01 | 245 | 02 | 180 | 02 | - | 00 | - | 00 | - | 00 | 130 | 03 | 045 | 02 |
| 0170 | 131 | 04 | 119 | 02 | 118 | 02 | 011 | 01 | 254 | 03 | 190 | 02 | - | 00 | 090 | 06 | 098 | 04 | 094 | 04 | 028 | 02 |
| 0330 | 112 | 04 | 103 | 04 | 111 | 04 | 264 | 01 | 254 | 03 | 190 | 02 | - | 00 | 072 | 09 | 084 | 07 | 086 | 06 | 066 | 03 |
| 0500 | 117 | 03 | 095 | 04 | 086 | 04 | 252 | 01 | 247 | 03 | 195 | 02 | 086 | 02 | 071 | 09 | 078 | 07 | 081 | 07 | 076 | 04 |
| 0650 | 080 | 02 | 094 | 03 | 059 | 03 | 345 | 01 | 245 | 02 | 212 | 01 | 040 | 02 | 071 | 10 | 065 | 04 | 083 | 06 | 084 | 04 |
| 0810 | 237 | 01 | 104 | 02 | 048 | 03 | 043 | 01 | 322 | 01 | 274 | 01 | 058 | 02 | 071 | 10 | 047 | 03 | 083 | 04 | 088 | 02 |
| 0960 | 298 | 02 | 131 | 01 | 059 | 03 | 058 | 03 | 053 | 02 | 274 | 03 | 080 | 03 | 071 | 10 | 043 | 03 | 083 | 03 | 068 | 01 |
| 1113 | 324 | 03 | 282 | 01 | 073 | 04 | 063 | 06 | 065 | 03 | 270 | 03 | 085 | 02 | 069 | 10 | 061 | 04 | 038 | 01 | 127 | 01 |
| 1267 | 341 | 04 | 265 | 02 | 073 | 08 | 063 | 08 | 087 | 04 | 265 | 04 | 102 | 02 | 069 | 08 | 086 | 04 | 049 | 02 | 210 | 01 |
| 1420 | 356 | 05 | 171 | 01 | 055 | 10 | 054 | 08 | 062 | 02 | 257 | 04 | 134 | 02 | 073 | 09 | 136 | 02 | 069 | 02 | 147 | 02 |
| 1573 | 006 | 06 | 072 | 05 | 064 | 08 | 060 | 07 | 027 | 03 | 256 | 03 | 157 | 02 | 078 | 07 | 204 | 01 | 165 | 04 | 184 | 02 |
| 1727 | 020 | 05 | 070 | 08 | 085 | 07 | 064 | 05 | 081 | 03 | 265 | 02 | 104 | 01 | 087 | 04 | 115 | 01 | 220 | 04 | 290 | 04 |
| 1880 | 024 | 05 | 078 | 08 | 108 | 07 | 106 | 07 | 092 | 05 | 278 | 03 | 055 | 02 | 094 | 05 | 159 | 02 | 238 | 04 | 301 | 07 |
| 2020 | 016 | 05 | 100 | 06 | 118 | 08 | 140 | 08 | 103 | 06 | 287 | 03 | 055 | 04 | 097 | 10 | 204 | 03 | 250 | 04 | 301 | 07 |
| 2160 | 012 | 06 | 135 | 09 | 151 | 11 | 147 | 10 | 130 | 07 | 287 | 02 | 044 | 04 | 096 | 08 | 253 | 04 | | | 302 | 09 |
| 2300 | 007 | 05 | 147 | 10 | 164 | 14 | 150 | 14 | 160 | 08 | 302 | 02 | 054 | 04 | 096 | 04 | 270 | 05 | | | 302 | 12 |
| 2440 | 017 | 05 | 160 | 12 | 173 | 17 | 158 | 15 | 180 | 08 | 315 | 02 | 061 | 04 | 105 | 04 | 282 | 07 | | | | |
| 2580 | 037 | 03 | 169 | 18 | 180 | 18 | 180 | 13 | 188 | 04 | 315 | 02 | 084 | 04 | 112 | 04 | 287 | 12 | | | | |
| 2720 | 057 | 02 | 171 | 20 | 189 | 16 | 210 | 08 | 302 | 01 | 331 | 03 | 095 | 04 | 112 | 06 | 287 | 16 | | | | |
| 2860 | 064 | 03 | 175 | 22 | 193 | 12 | 245 | 06 | 043 | 02 | 010 | 04 | 104 | 05 | 115 | 04 | 287 | 18 | | | | |
| 3000 | 058 | 02 | 177 | 22 | 204 | 08 | 275 | 06 | 060 | 04 | 014 | 07 | | | 115 | 06 | 283 | 17 | | | | |
| 3140 | 058 | 03 | 180 | 17 | 208 | 06 | 275 | 06 | 052 | 04 | 014 | 07 | | | 120 | 06 | 280 | 19 | | | | |
| 3280 | 077 | 03 | 180 | 14 | 214 | 06 | 275 | 06 | 055 | 04 | 014 | 08 | | | 123 | 06 | 278 | 22 | | | | |
| 3420 | 106 | 04 | 180 | 12 | 228 | 08 | 278 | 06 | 046 | 03 | 012 | 08 | | | 123 | 06 | 278 | 24 | | | | |
| 3560 | 115 | 04 | 180 | 09 | 234 | 10 | 278 | 06 | 028 | 02 | 012 | 08 | | | 123 | 06 | 280 | 27 | | | | |