Atmospheric and Terrestrial Effects of Closed-Cycle Cooling Systems: An Annotated Bibliography

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NOTICE

Prepared by
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Oak Ridge, Tennessee

ABSTRACT

Presented in the format of an annotated bibliography are almost 600 references dealing with the environmental impacts of closed-cycle cooling systems. The references were extracted from the open literature for the period up to the spring of 1979 and from environmental reports and impact statements prepared for or by the electric utility industry. Topics covered include atmospheric discharges from cooling towers, predicted cumulative effects of releases from energy parks, sensitivity of agricultural crops and native vegetation, salt deposition, aesthetic impacts, atmospheric dispersion and plume behavior, analytical methods and mathematical models and studies to assess the effects of closed-cycle cooling operations. References are arranged by subject category and indexes are provided to author's names, energy facility names and geographic location of field research.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

This annotated bibliography on atmospheric and terrestrial effects of closed-cycle cooling systems of electric power plants is one of a series of reports produced under Research Project 877: "The Cooling-System Effects Data Base." Bibliographies already published under this project include:

- Impingement: An Annotated Bibliography (EPRI Interim Report EA-1050)
- Entrainment: An Annotated Bibliography (EPRI Interim Report EA-1049)
- Chemical Effects of Power Plant Cooling Waters: An Annotated Bibliography (EPRI Interim Report EA-1072).

Contractors conduct searches of the data base on request and promote the use of the file. Critical reviews of selected topics are also published.

The coverage of the data base is being expanded to include all ecological effects associated with cooling systems.

PROJECT OBJECTIVE

The principal objective of this project is to develop a computer-searchable bibliographic data base containing literature on cooling-system effects on the environment. The publications pertaining to the annotated bibliographies described above are designed to provide a convenient access to users who wish to search the data base without using the computer.

PROJECT RESULTS

This report contains bibliographic information presently available on the specific subject area. Since the literature in this subject area is rapidly expanding, it is expected that this report series will be useful primarily as a guide to the data base.

EPRI is interested in receiving comments from users on how the system could be improved to better serve the needs of the industry.

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Ecological Effects Program
Energy Analysis and Environment Division

ACKNOWLEDGMENTS

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CONTENTS

SUMMARY

This is the sixth publication in a series of reports prepared for EPRI project RP 877: "The Cooling System Effects Database." This bibliography represents that portion of the database which specifically relates to the atmospheric and terrestrial effects of closed cycle cooling systems at electric power plants. The annotation of almost 600 references on closed cycle cooling systems represents literature on mechanical and natural draft cooling towers; freshwater and saltwater cooling towers; cooling lakes and ponds; and spray canals. The following eight categories identify the subject coverage provided by this bibliography:

- Atmospheric discharges from cooling towers
- Predicted cumulative effects of releases from energy parks
- Salt deposition (dry/wet deposition)
- Sensitivity of agricultural crops and native vegetation
- Aesthetic impacts
- Atmospheric dispersion and formation of plumes
- Mathematical models: development, analysis and verification
- Studies to assess effects of closed cycle cooling operations

The references are arranged in five sections as given in the table of contents. Entries are not arranged in any special order within sections. Each entry in the bibliography contains data on title of the publication, personal author, corporate author, publication date, and abstract. Indexes provided are: 1) personal author; 2) corporate author; 3) energy facility with planned or operating cooling system identified, and 4) geographic location.

Referenced publications from scientific journals, workshop or conference proceedings, etc., should be available from the respective libraries of the utility companies. Copies of site-specific data tables and reports, and environmental reports and impact statements are available at the library of the AIF/INFORUM project.

The Cooling System Effects Database was developed for EPRI by the Atomic Industrial Forum, Inc., (AIF) and the Ecological Sciences Information Center (ESIC)

at Oak Ridge National Laboratory (ORNL). The database (as of January, 1980) contains in excess of 11,000 references pertaining to thermal, chemical, entrainment, impingement and atmospheric effects of cooling systems at electric power plants.

EFFECTS OF CLOSED CYCLE COOLING SYSTEMS - GENERAL STUDIES

<1>

A Survey of Operating Experience with Saltwater Closed-Cycle Cooling Systems.
Chapter 1, Volume 1, Part 3, Ocean Sited Plants, Stone & Webster, Engineering Corp. for Utility Water Act Group, June 1978. 113 pp.

Report provides state-of-the-art information on operating experience at power plants utilizing seawater closed-cycle cooling systems. Data include the following: 1)type, size, and location of facility; 2) cooling system description, including construction materials and water treatment; 3) drift and thermal performance characteristics; 4) material performance and maintenance requirements, and 5) description of any operational problems and possible corrective measures and associated additional costs. Operating experience was also evaluated for inland power generating facilities using brackish surface or groundwater for cooling, small test cooling systems at power generating facilities using saltwater, and other facilities, such as refineries using saltwater as a coolant in various plant processes. Case studies at various U.S. and foreign facilities are presented. Results of the investigation include the following: 1) there is presently one operating seawater closed-cycle cooling system, at a 96-MW facility in England; 2) there are 10 operating coastal brackish water closed-cycle cooling systems serving plants from 150-850 MW; 3) there is one operating coastal brackish water helper tower system; 4) there is one coastal closed-cycle system which used brackish water temporarily; 5) there are 8 operating inland closed-cycle cooling systems using saline surface or groundwater; 6) there are 2 closed-cycle cooling systems, one coastal and one inland, which have converted from saline to freshwater, and 7) no known proposed U.S. facilities planning to use closed-cycle seawater systems, but 7 proposed systems planning to use brackish water. Section includes 22 tables, 2 figures, and references.

<2>

Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems.
Chapter 2, Volume 1, Part 3, Ocean Sited Plants, Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 224 pp.

Report addresses state-of-the-art engineering, environmental, and economic considerations of seawater closed-cycle cooling systems. Scope of the report includes the following: 1) identification of operating problems at existing installations using saltwater closed-cycle cooling systems; 2) identification of aspects of seawater closed-cycle cooling systems at large power generating facilities which will necessitate use of different designs from their freshwater counterparts; 3) review of environmental factors to be considered in assessing acceptability of closed-cycle cooling systems using seawater makeup, and 4) quantification of incremental costs associated with seawater closed-cycle cooling at large power generating facilities. Information is presented for power and nonpower generating facilities using brackish and seawater systems. Engineering aspects considered include cooling water treatment, drift control, site arrangement, construction materials, thermal performance, maintenance, and reliability. Environmental aspects considered include circulating water and blowdown characteristics, salt drift, land use, and air quality. Economic aspects of the study compare costs of saltwater closed-cycle cooling systems with freshwater closed-cycle and saltwater once-through systems. Cooling tower types discussed are limited to evaporative natural and mechanical draft; with power spray modules and spray canals also mentioned. Section includes 44 tables, 14 figures, 2 appendices, and references. Results from several case studies are cited.

<3>

Nonwater Quality Impacts of Closed-Cycle Cooling Systems and the Interaction of Stack Gas and Cooling Tower Plumes.
(EPA-600-7-79-090) United Engineers & Constructors, Inc. for U.S. Environmental Protection Agency, March 1979. 230 pp.

Report presents results of a literature survey on the non- water quality impacts of closed-cycle cooling systems and the interaction of power plant stack gas and cooling tower plumes. Purpose of the report is to document the state-of- the-art concerning the impact of drift from evaporative cooling towers (especially saltwater towers) and plume interactions at fossil-fueled steam electric generating stations. Unique cooling tower plume information includes plume types, behavior, salt drift generation and deposition, and weather modification, with emphasis on meteorological conditions which enhance salt deposition, icing and fogging, and cloud formation. Stack plume data include behavior (rise, long range transportation, and terrain effect) and stack gas composition (sulfur dioxide, nitrogen oxides, ozone, and particulates. Section on plume interaction includes the following topics: 1) categories of plume interaction; 2) mechanism of plume interaction; 3) acid precipitation enhancement; 4) selected case studies, and 5) methods of minimizing cooling tower-stack plume interactions. Data are intended to provide background information for the revision of water pollution regulations for steam electric power plants. Specific conclusions and recommendations are presented for each section of the report. Report includes 57 figures, 65 tables, and references.

<4>

Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, 120 pp.
1978
Torrance, K.E.; Watts, R.G.
Cornell University, Ithaca, NY
Institute for Energy Analysis, Oak Ridge, TN

Papers dealing with the state-of-the-art of the release of heat and moisture to the atmosphere as a result of man's activities, and with the environmental effects of these releases are compiled. Approximately one-half of the papers are concerned with cooling towers (drift deposition, weather modification, and cloud formation). The remainder of the papers deal with spray cooling, cooling ponds, and the environmental effects of large area sources. Twelve of the thirteen papers have been input into the data base. (ND)

<5>

Overview of the Chalk Point Cooling Tower Project, 1972-1979.
(PPSP-CPCTP-27) Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 157 pp.

Document provides a description of the concepts, design, data, and results of the Chalk Point Cooling Tower Project (CPCTP), an experimental program designed to study salt and water vapor emissions from the Chalk Point Generating Station, Prince Georges County, MD, and to establish effects of these emissions on the crops, soils, and native vegetation in the vicinity of the station. All units use brackish make-up cooling water from the Patuxent River. CPCTP consisted of 3 phases: 1) initial characterization, describing the internal tower plume in terms of updraft velocity, temperature, and dewpoint; 2) continuous monitoring, providing continuous cooling tower emission data concerning the stability of drift characteristics over time, and 3) seasonal intensive tests, conducted to provide full data sets for modeling over extreme meteorological conditions. A dyed drift test was also conducted in which a dyed tracer was added to the cooling tower water so that downwind cooling tower deposition could be easily separated from stack drift and ambient sea salt. Document contains 70 tables, 42 figures, references, and an appendix which tabulates the instrumentation used in the aquisition of data to meet the program's objectives.

<6>

Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions.
Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 189 pp.

Document assesses environmental effects associated with the 400-foot, natural draft cooling towers and stacks at the Chalk Point Generating Station, Prince Georges County, MD. Units 3 and 4 are oil-fired, 630-MW units utilizing closed-cycle cooling with saline make-up water drawn from the Patuxent River. Only Unit 3 is operational to date. Emphasis is placed on the magnitude of salt deposition in the area surrounding the cooling towers due to salt drift. Document also assesses salt loading due to salt drift from the stack, which uses saline river water in scrubbing flue gases. This salt loading, along with that of the ambient salt background, is assessed for its effects on soil, crops, vegetation, and man-made structures. Other atmospheric effects examined are the enhancement of ground level fogging and icing, enhancement of precipitation, and the flight hazards to aircraft. Report uses data collected by the Maryland Power Siting Program and a numerical model of drift deposition developed by the Applied Physics Laboratory of the Johns Hopkins University. The assessment techniques used are applicable to the elevation of impacts by natural draft cooling towers at other sites, according to the document. Document contains 39 tables, 35 figures, 2 appendices, and references.

<7>

Environmental Evaluation of Closed-Cycle Cooling.
Cooling Towers: A Technical Manual, Volume 2. American Institute of Chemical Engineers, New York City, NY, (p. 33-39), 110 pp.
1975
Moy, H.C.; Cohen, L.A.; Ku, P.S.; Szeligowski, J.J.
Consolidated Edison of New York, New York City, NY

Environmental evaluations for alternative cooling systems are discussed in relation to an existing large nuclear facility utilizing a once-through cooling system. Air quality and acoustic emission studies, which are considered the two most significant environmental factors, are discussed in detail. Operation of mechanical draft wet cooling towers would induce a moderate frequency of fogging and icing occurrences, which would be practically non-existent with a natural draft cooling tower. Botanical investigations indicate that the extent and risk of potential botanical injury due to saline drift from mechanical draft towers would be of far greater magnitude than that from a natural draft tower. Noise emissions from mechanical draft cooling towers would increase noise levels in the neighboring area and risk adverse community reaction, which is not expected from a natural draft tower. Atmospheric discharges from make-up power generation due to derating for a natural draft cooling tower system would be about 65% of that for a mechanical draft cooling tower system. Therefore, from an environmental point of view, mechanical draft cooling towers appear to be less desirable than a natural draft cooling tower. Decisions to select a cooling tower system, however, cannot be based solely on environmental assessment. Economic evaluation must complement the environmental evaluation in an engineering trade-off analysis to establish an optimum system for a specific steam-electric power plant. (ND)

<8>

Atmospheric Impacts of Wet Cooling Systems for Power Plants.
American Nuclear Society Annual Meeting, Proceedings of a Symposium, New York City, NY, June 12-16, 1977; Transactions American Nuclear Society 26:114-115
1977
Carson, J.E.
Argonne National Laboratory, Argonne, IL

The state-of-the-art of atmospheric knowledge and modeling is such that meteorologists are not now able to predict quantitatively how the atmosphere will react to the large amounts of heat energy and water vapor that it will be forced to absorb from limited areas of cooling towers, cooling ponds, and spray canals. In a study of the impacts of waste heat dissipation on the environment it was found that the primary impact of the operation of natural draft towers was their visual bulk and visible plumes. Cooling ponds and spray canals could cause frequent fogging over the water surface; drift and icing near spray canals could be heavy but restricted to a few hundred feet from the canal. None of the existing models predicting plume behavior (length, rise, fogging and drift deposition) has been shown to be able to predict these parameters accurately, in part because of a shortage of accurate plume observations at operating plants. Drastic weather changes from cooling tower discharges have been postulated but not observed. The possibility of severe storm generation by energy parks is real and should be studied further. It is concluded that the atmospheric effects of thermal discharges from power plants are small and usually acceptable if the system is properly located and maintained.

<9>

Atmospheric Effects of Energy Generation.
Atmospheric Sciences and Power Production, D. Randerson (Ed.), U.S. Department of Energy; ATDL Contribution File No. 77/9, 101 pp.
1978
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

The effects of excess heat and moisture released to the atmosphere as the result of energy production are discussed. Specific methods for estimating cooling system effects such as cloud formation or drift deposition are outlined. Current observed effects include sun shading, ground fog, drift deposition, winds, and cloudiness and precipitation changes. Modeling efforts for cooling towers (fogging, drift deposition, plume behavior, and cloud formation), direct cooling, cooling ponds, and power parks are reviewed. Models of cooling tower plumes and drift deposition exist which can satisfactorily estimate visible plume length and plume rise within a factor of two, and drift deposition within an order of magnitude. Larger scale models (heat dissipation and atmospheric circulation) require further development and testing to satisfactorily predict the effects of much larger facilities to be built in the future. (ND)

<10>

Effects on the Atmosphere of Heat Rejection from Large Wet or Dry Cooling Towers.
Lecture Series on the Mechanics of the Atmosphere and Industrial Energy, Proceedings of a Symposium, Jouy-en-Josas, France, October 12-20, 1978. Commissariat a L'Energie Atomique-Electricite de France, Vol. 2, 22 pp.
1978
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

Cooling towers at the largest operating power plants (about 5000 MW heat rejected) are observed to affect the atmosphere at distances of less than about 50 km. Median visible plume lengths are in the range 200 m to 1000 m, and occasionally medium-scale cumulus or stratus clouds are formed. On very few occasions, rain or snow showers fall from these clouds. Serious effects on vegetation due to drift deposition are observed only at distances less than a few hundred meters from wet mechanical draft cooling towers or spray ponds. As the capacities of power plants increase, the atmospheric effects can also be expected to increase. A primary question is at what level of power production will the increases in cloudiness, precipitation, fog, drift deposition, and winds be unacceptable? Similarity methods of estimating these effects using current knowledge are described. For example, it is shown that plume merging is minimized if large natural draft cooling towers are separated by distances greater than 1 km. A comparison of the effects of wet and dry mechanical and natural draft cooling towers is made, showing that clouds are more apt to be formed by plumes from dry towers than by plumes from wet towers. (Auth)

<11>

Modification of Local Weather by Power Plant Operation.
EPRI-EA-886-SR, 15 pp.
1978
Laurmann, J.
Stanford University, Stanford, CA
Electric Power Research Institute, Palo Alto, CA

Power plant operation can affect weather as a result of emissions of effluents and from release of waste heat. Effluent can cause acid rain and impaired visibility, research topics which are now being supported by EPRI. The release of waste heat can affect weather by changing local meteorology in a manner which stimulates an otherwise inactive convective instability. In general, however, the energy from waste heat from a conventional power plant is far less than that needed to trigger such events as thunderstorms or cyclones. Large power parks (upwards of 10,000 MWe), however, do have the potential for causing thunderstorms. Small power plants have an energy output comparable to that of a tornado but the heat rise is too buoyant to develop the vorticity needed for tornadoes. Much research is needed in gathering field data and in developing three-dimensional models for describing latent atmospheric instabilities. In view of the low probability of conventional power plants causing significant weather changes, and in view of the comprehensive research program on inadvertent weather modification by the Department of Energy, no additional EPRI research effort is needed at this time. (Auth)

<12>

Cooling Towers and the Environment - An Overview.
Proceedings American Power Conference 35:713-725
1973
Reisman, J.I.; Ovard, J.C.
Ecodyne Cooling Products Division, Santa Rosa, CA

Cooling tower drift and fogging, the primary environmental concerns for such installations, are examined with respect to current monitoring techniques and study results. In addition the unique behavior of a mechanical draft cooling tower plume is described. The results of 22 drift tests showed that a drift rate of 0.05 percent is typical for drift eliminator designs used in the industry for the last 20 years. The test results also showed that a new generation drift eliminator, where positive drainage and sealing are part of the design, results in a typical drift rate of 0.004 percent of the circulating water rate. The particle size and mass distribution tests showed that the exhaust droplet size ranged from 22 to 2400 microns in diameter. Further study revealed that the majority of the larger drops are created by drift and moisture collecting on structural members in the tower's plenum and their eventual reentrainment in the exhaust air stream. The assessment of the environmental effects caused by drift from a saltwater cooling tower leads to the conclusion that beyond some reasonable distance, usually within the plant site boundary, drift does not affect the environment. Under worst-case meteorological conditions of atmospheric stability, cold air temperature, high ambient relative humidity, and light to moderate winds, the fog plume will disperse very slowly and may extend a significant distance before becoming invisible. The problem is magnified for large tower installations near highways and populated areas. Current technology favors a combination wet/dry system for controlling fog plumes. The flexibility of the wet/dry system allows for efficient evaporative cooling in the warmer months, along with a variable-controlled dry heat exchange section for fog control during cold months. (ND)

<13>

Asbestos in Cooling-Tower Waters: Final Report.
(NUREG-CR-0770) Prepared by Lewis, B.G., Argonne National Lab. for U.S. Nuclear Regulatory Commission, March 1979. 103 pp.

Report assesses magnitude of asbestos fiber discharges from cooling towers using the following methods: 1) a literature review concerning the nature, occurrence, utilization, methods of analysis, and health effects of asbestos; 2) collection of relevant information from cooling tower suppliers, vendors, and users; 3) sampling of makeup, circulating, and blowdown waters at operating sites and sampling of ambient air at one site; 4) analysis of the quantity and mineral type of asbestos using electron microscopy, selected-area scanning electron diffraction, and energy-dispersive x-ray analysis, and 5) application of drift-deposition models to the emission of asbestos from cooling towers to estimate concentrations of asbestos in air at ground level. Report presents methodology used in analysis of data collected in air, water, and sediment samples, and methodology used to gather utility data. Results from several industry studies on the use of asbestos for cooling tower fill are summarized. Mitigative measures and recommended effluent monitoring procedures are also discussed. Chrysolite-asbestos fiber concentrations from 'none detected' to 10(8) fibers per liter were found in cooling tower blowdown from 18 cooling towers; suggested mechanisms for the release of these fibers are the freeze-thaw cycle and acid dissolution of cement. Report contains 23 figures, 14 tables, 4 appendices, and references.

<14>

(Asbestos Concentrations in Cooling Tower Liquid and Gaseous Effluents.)
Tables 6, 9, & 11, Asbestos in Cooling-Tower Waters: Final Report. (NUREG-CR-0770) Prepared by Lewis, B.G., Argonne National Lab. for U.S. Nuclear Regulatory Commission, March 1979. 4 pp.

Table 6 shows asbestos concentrations measured in cooling-tower and sediments at various towers on 18 dates in 1976 and 1977. Makeup water, basin water, and blowdown were sampled. In each case, lower limit of detection and observed concentration are shown. Table 9 shows the results of sampling at one power plant site. Twenty-two samples were taken at various locations in the circulating water system. Data shown are as follows: lower limit of detection, fibers per liter, mass concentration, fiber lengths (maximum-minimum and percent distribution), and range of aspect ratios (length-width). Table 11 shows estimated asbestos concentrations in air near ground level due to drift emissions from cooling towers. A drift-deposition model was applied to a hypothetical site with 6 mechanical draft cooling towers containing asbestos-cement bars as fill. Near-ground concentrations in nanograms per m(3) and fibers per cm(3) are estimated for downwind distances up 6 km. Asbestos concentration in the circulating water and the drift were presumed to be the same at 37 micrograms per liter.

<15>

Asbestos in Cooling-Tower Waters.
ANL/ES-63, 75 pp.
1977
Lewis, B.G.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL

Fill material in natural or mechanical draft cooling towers can be manufactured from a variety of materials, including asbestos cement or asbestos paper. To aid in the environmental impact assessment of cooling towers containing these asbestos types of fill, information on these materials was obtained from cooling tower vendors and users. Samples of makeup, basin, and blowdown waters at a number of operating cooling towers were obtained, and identification and enumeration of asbestos in the samples were performed by transmission electron microscopy, selected-area electron diffraction, and energy-dispersive x-ray analysis. Asbestos fibers were detected in cooling tower water at 10 of the 18 sites sampled in the study. At all but three sites, the fibers were detected in cooling tower basin or blowdown samples, with no fibers detected in the makeup water. The fibers were identified as chrysotile at all sites except one. Concentrations were on the order of 10(E+6) to 10(E+8) fibers/liter of water, with mass concentrations between $<$ 0.1 ug/liter to 37 ug/liter. The majority (65-100%) of the fibers were $<$ 5 um in length, with aspect ratios ranging from 3.5 to 1700. Settling ponds that receive cooling tower blowdown containing asbestos appear to substantially reduce the fiber concentrations in the effluent to off-site receiving waters. The maximum concentrations of asbestos fibers in air near ground due to drift from cooling towers were estimated (using models) to be on the order of asbestos concentrations reported for ambient air up to distances of 4 km downwind of the towers. Exceptions are rectangular mechanical draft towers where the current occupational standard of 2 fibers per cm(E+3) of air may be exceeded close to the towers. Assuming that the methods of data collection and analysis were reasonably accurate with respect to orders of magnitude, it seems likely that the off-site hazard to human health due to asbestos emissions in drift from cooling towers is negligible. The human health hazard due to asbestos in drinking-water supplies is less clear. Based on current information, the concentrations of asbestos in natural waters after mixing with cooling tower blowdown containing 10(E+6) to 10(E+8) fibers/liter will pose little health risk. These conclusions may need to be revised if future epidemiological studies so indicate. (Auth)

<16>

Cooling Systems: Towers, Ponds, and Once-Through Cooling - A Selected Bibliography.
ORNL-EIS-74-66, 122 pp.
1974
Combs, Z.; Huber, E.E.; Talmi, B.C.
Oak Ridge National Laboratory, Environmental Response and Referral
Group, Oak Ridge, TN
Oak Ridge National Laboratory, ORNL Program Planning and Analysis
U.S. Atomic Energy Commission

This bibliography contains 406 citations of documents related to cooling system selection and design, meteorology in relation to cooling towers, environmental effects, water treatment, economics, and hydrodynamics. It is categorized by primary and secondary subject areas, however, author, corporate author, and permuted title indexes are included. Citations from the Energy Data Base contain abstracts. (ND)

<17>

Cooling Towers: A Bibliography.
TID-3360, 90 pp.
1976
Galde, D.O.; Raleigh, H.D.
U.S. Energy Research and Development Administration Technical
Information Center, Oak Ridge, TN

This bibliography contains 905 citations and abstracts to references on cooling towers for fossil-fuel or nuclear power plants. A few citations are included on other types of condenser cooling systems, particularly cooling ponds and canals. Indexes are provided for corporate author, author, report number/availability, and subject. (ND)

<18>

Cooling Towers: A Bibliography.
TID-3360-S1, 96 pp.
1977
Galde, D.O.
U.S. Energy Research and Development Administration, Technical
Information Center, Oak Ridge, TN

This bibliography contains 485 citations to references on cooling towers for fossil-fuel or nuclear power plants. A few citations are included on other types of condenser cooling systems, e.g. cooling ponds and canals. The citations were taken from the ERDA Energy Information Data Base (EDB) covering the approximate period March 1976 to May 1977. Indexes are provided for corporate author, author, subject, and report number. (ND)

<19>

Cooling Towers: Environmental Studies (Citations from the Engineering Index Data Base)
PS-78/0900, 143 pp.
1978
Hundemann, A.S.
National Technical Information Service, Springfield, VA

Bibliographic citations and abstracts from worldwide research on thermal, meteorological, and ecological effects associated with cooling towers used primarily by fossil fuel and nuclear power plants are given. Citations cover plume behavior studies, including measurements of airborne particulate concentration, and characterization and management of drift, as well as noise pollution and salt deposition effects on vegetation. A few abstracts pertain to environmental effects from cooling towers used in wastewater treatment. Twenty-one of the 138 entries are new to this edition. Pertinent entries were selected and input into the data base. (Auth)(ND)

<20>

Cooling Towers: Citations from the NTIS Data Base.
PS-78/0898, 275 pp.
1978
Hundemann, A.S.
National Technical Information Service, Springfield, VA

Bibliographic citations and abstracts of Federally-funded research dealing with the design and environmental impacts of wet and dry cooling towers are presented. Cooling tower drift instrumentation and thermal and chemical pollution control systems are covered. Citations primarily pertain to cooling towers used in nuclear power plants, with a few pertaining to cooling towers used in wastewater treatment. Fifty-one entries are new to this edition. Pertinent entries were selected and input into the data base. (Auth)(ND)

<21>

Atmospheric Effects of Water Cooling Facilities.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January 29-31, 1973, 9 pp.
1973
Aynsley, E.; Carson, J.E.
Partical Data Laboratories, Ltd., Elmhurst, IL
Argonne National Laboratory, Argonne, IL

Potential environmental effects of water cooling facilities for electric generating stations are discussed. Of particular concern are the effects of towers and other cooling techniques used with alternative recirculatory cooling systems instead of the traditional once-through systems. Potential atmospheric effects include the visible plume and humid plume characteristics and dimensions, fog and ice effects caused by these moisture additions, and cloud initiation and modification of precipitation patterns. Plume models and field observations of atmospheric impacts of plumes (Keystone Generating Station) have shown that impacts from natural draft towers are insignificant. Predictions show that mechanical draft towers may be potentially more troublesome, but field observations have not shown this. With spray and lake cooling systems, fog predictions are meager, however, observations do confirm some fogging does occur. The problems of cloud initiation and formation and precipitation augmentation appear to be a minor. (ND)

<22>

Conference Summary: Cooling Tower Environment - 1974.
ATDL Contribution File No. 96, 6 pp.; Bulletin American Meteorological Society 8(8):870-871

1974
Hanna, S.R.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Atomic Energy Commission

The purpose of the Cooling Tower Environment symposium (College Park, MD, 1974) was to establish the state-of-the-art of knowledge of cooling towers. Major points noted in the papers are presented. Shadowing due to the cooling tower and its plume may be of importance, however, the analysis showed an insignificant reduction in sunshine. Fogging and drift deposition were not major problems in Britain. Large experimental programs on cooling tower drift deposition are planned at Chalk Point, MD, and Turkey Point, FL. Current drift deposition measurements are not adequate for validating models. Drift deposition models are accurate only within an order of magnitude. Studies of the effects of natural or laboratory salt spray on vegetation are underway. It appears that models have been carried as far as possible in the absence of detailed verification, validation data is needed. (ND)

<23>

Environmental Impact Assessment of Cooling Towers.
CONF-750401; Corrosion/75 (International Corrosion Forum on Protection and Performance of Materials), Proceedings of a Symposium, Toronto, Ontario Canada, April 14-17, 1975, National Association of Corrosion Engineers, Houston, TX, Paper No. 147, 7 pp.; Materials Performance 14(9):39-41
1975
Bartlit, J.R.; Williams, M.D.
Sierra Club National Water Resources Committee, Los Alamos, NM

Downstream and downwind environmental impact of cooling towers is reported and evaluated. Salt and chemical concentrations affecting downstream ecology in the atmosphere and in terrestrial and aquatic environs are calculated and specific examples of large scale effects given. Drift losses may result in deleterious effects on vegetation or on salt loading of the aquatic environs, and reduced visibility and other effects associated with particulate emissions. Long term availability of cooling water is explored briefly. Some economic consequences are reported with respect to the Colorado River. Drift losses from towers and the extent and severity of the concurrent effect of chemicals are discussed including the effects of chromium and zinc. Tower configuration, control measures, and climatic factors influencing mist distribution are explored and reported. (Auth)(ND)

<24>

Atmospheric Impacts of Evaporative Cooling Systems.
ANL/ES-53, 54 pp.
1976
Carson, J.E.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
U.S. Nuclear Regulatory Commission

Available information on the effects of the various cooling systems on the atmosphere is summarized. While evaporative cooling systems do sharply reduce the biological impacts of thermal discharges in water bodies, they do create (at least, for heat-release rates comparable to those of two-unit nuclear generating stations) atmospheric changes. For an isolated site such as required for a nuclear power plant, these changes are rather small and local, and usually environmentally acceptable. However, our understanding of the atmosphere is such that we cannot say with certainty that these effects will remain small as the number of reactors on a given site increases. There must exist a critical heat load for a specific site which, if exceeded, can create its own weather patterns, and thus create inadvertent weather changes such as rain and snow, severe thunderstorms and tornadoes. Because proven mathematical models are not available, it is not now possible to forecast precisely the extent and frequency of the atmospheric effects of a particular heat dissipation system at a particular site. Field research on many aspects of cooling system operation is needed in order to document and quantify the actual atmospheric changes caused by a given cooling system and to provide the data needed to develop and verify mathematical and physical models. The more important topics requiring field study are plume rise, fogging and icing (from certain systems), drift emission and deposition rates, chemical interactions, cloud and precipitation formation and critical heat-release rates. (Auth) (ND)

<25>

Environmental Factors in the Production and Use of Energy.
R-992-RF, 77 pp.
1973
Dole, S.H.; Papetti, R.A.
Rand Corporation, Santa Monica, CA
Rockefeller Foundation

The major undesirable environmental effects of energy production and use are described, including impacts to air, land, and water. Pollutants of interest include waste heat, water vapor, and mineral fallout from cooling towers. Topics for each pollutant include quantity and extent of pollution, environmental effects, environmental limitations, control techniques, and cost of control. Water vapor losses from evaporation and drift from cooling towers and evaporation ponds amount to about one percent of condenser flow. Annual water loss from a 1000 MWe plant using wet cooling towers would amount to 15,000 to 20,000 acre-feet. Problems from fog, icing, and plumes are noted for most cooling systems. Latent and sensible heat transfer to the atmosphere from heated bodies of water (cooling systems) is but one of four waste heat pollution categories. Mineral fallout from cooling towers include soluble minerals from water, algicides and other biocides added to the cooling water. The impact of dissolved solid fallout from evaporative cooling towers would be felt primarily on agricultural and grazing lands in dry areas where the rainfall is insufficient to leach out the soluble material as rapidly as they are deposited. In extreme cases, the physical nature of the soil may be altered and the yield of certain salt-intolerant crops can be reduced. Dissolved solid carry-over is more of a problem with mechanical draft cooling towers which typically release their plumes only 50 to 75 ft above the ground, concentrating the fallout in the area. The magnitude of the carry-over is also a function of the outlet air velocity while the area on which fallout can occur will depend on the meteorological conditions of ambient wind velocity, wind direction, air temperature profile, and relative humidity. (ND)

<26>

Some Terrestrial Considerations Associated with Cooling-Tower Systems for Electric Power Generation.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 393-407), 638 pp.
1975
Edmonds, P.R.; Roffman, H.K.; Maxwell, R.C.
Westinghouse Electric Corporation, Environmental Systems Department,
Monroeville, PA

Some of the major terrestrial considerations relevant to cooling tower systems for power plant facilities are evaluated in terms of the expected growth in electrical energy production by the year 2000. The projected increase in cooling tower use as an effective means of heat dissipation is related to both site specific and area concerns. An initial distinction between significant effects and potential impacts is discussed. Major areas of consideration include land use, noise, biota, soils, and groundwater and surface water hydrology. Site preplanning, design, and operational recommendations are made which may effectively mitigate potential terrestrial problems in these areas. (Auth)

<27>

Cooling Towers and Microclimate.
HHT Project Status Report, 18 pp.; OLS-78-425, 14 pp.
1975
Granicher, H.
Eidg. Institute fur Reaktorforschung, Wurenlingen, Germany

In connection with research on the atmospheric cooling of HHT power plants, the EIR has undertaken the investigation of possible effects on the microclimate. Possible impacts include changes in air temperature and humidity, formation or dissolution of fog near the ground and thus a change in the wetting of the ground, possible formation or dissolution of clouds at some elevation and thus a change in the shadowing of the ground, the removal of or the intermixing with the natural or man-made aerosols near the ground, and the triggering of storms or the breaking up of inversion layers. A one-dimensional model, FOG, was developed for the simulation of cooling tower plumes. The model is capable of calculating plumes from dry and wet cooling towers and their effects down to the ground. Model comparisons with field data are now underway. A two-dimensional, time-independent computer model is being developed. (ND)

<28>

Effects of Thermal Discharges from Large Cooling Towers.
Energiewirtschaftliche Tagesfragen 27(5):346-349
1977
Haessler, G.
Karlsruhe, Germany

Direct effects on the local climate at ground level from cooling towers are usually small, and thus do not represent a problem for meteorological environmental protection. This can be attributed to technical measures such as sufficient height of the cooling towers, preventing the discharge of large drops, and enabling the plumes to reach great heights. On the basis of existing knowledge, waste heat discharged via wet cooling towers with cooling capacities up to 3,000 MWe do not seriously damage the environment. This also applies to several cooling towers of similar size grouped in a single area. Small changes in some meteorological elements in the immediate vicinity of the towers are the same as those caused by major towns and industrial areas which have been known for a long time. (ND)

<29>

Hydrometeorological Aspects of Electric Power Production.
Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1976 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 563-596), 627 pp.; ATDL-77/23; ATDL Contribution File No. 76/23, 34 pp.
1977
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Commerce

Observed atmospheric effects due to waste heat release from cooling towers and ponds are reviewed, including sun shading, ground fog, drift deposition, interference with aircraft, interactions with chemical plumes, high winds, and changes in cloudiness, temperature, and precipitation. It is seen that effects are generally minor from current power production facilities, but that more serious effects can be expected if large energy centers (10,000 MW and up) are built. The status of physical and mathematical modeling is summarized, and it is concluded that two or three dimensional, second or third order closure models must be developed in order to assess the probability of vorticity concentration at large energy centers and adequately explain plume merging. (Auth)

<30>

Cooling Tower Environment-1974.
CONF-740302; ERDA Symposium Series 35; Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, 638 pp.
1975
Hanna, S.R.; Pell, J.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
Maryland Department of Natural Resources, Power Plant

Siting Program,
Annapolis, MD
U.S. Atomic Energy Commission, Division of Biomedical and
Environmental Research

This symposium represents a state-of-the-art of environmental assessment of cooling towers as an alternate means of condenser-water cooling. A total of twenty-nine papers and their accompanying discussions are included. Areas of discussion were: technology, plume rise, visible plumes, ecological effects (primarily terrestrial), and drift deposition measurement and models. All papers have been input into the data base. (ND)

<31>

The Environmental and Economic Impacts of Open-Cycle and Closed-Cycle Condenser Cooling Systems for Large Electric Generating Stations.
EPA-AICHE Second National Conference on Complete Water Reuse, Chicago, IL, May 4-5, 1975, 20 pp.
1975
Hedden, D.T.
Northeast Utilities, Hartford, CT

The environmental and economic impacts of open and closed-cycle condenser cooling systems are reviewed. Environmental impacts from open-cycle systems include intake impingement, condenser entrainment, and thermal effects. Environmental impacts from closed-cycle systems (cooling ponds, spray ponds, and towers) include fog and ice, noise (towers), water consumption, drift, aesthetics (towers), impingement, entrainment, and thermal discharges. Each impact topic is briefly discussed. (ND)

<32>

The Influences on the Environment by Cooling Systems of Thermal Power Plants Under the Conditions of the German Democratic Republic.
Energietechnik 24(7):293-297
1974
Heine, A.; Weidlich, H.G.

The environmental effects of fresh water cooling and of wet cooling towers are discussed. With wet cooling towers the evaporated water quantities and spraying losses may affect the local meteorological conditions and cause formation of fog near the ground and icy roads. The water droplets of the steam plume may have radii between 0.002 to 0.03 cm and a falling speed of 8 cm/sec. The droplets of the spraying loss are larger by a factor of ten than the plume droplets and thus a considerably larger quantity reaches the ground. Experimental studies in the vicinity of four cooling towers each with a discharge of 28,000 m(E+3)/hr and a construction height of 113 m yielded a precipitation maximum in dependence of the wind velocity at a distance of 200 to 450 m. This precipitation maximum reached between 0.005 and 0.01 mm/hr, depending on the ambient humidity. Larger precipitation (between 0.005 and 0.01 mm/hr) were still measured at 2 km distance. Agriculture and forestry is affected through early frosts in fall and late frosts in spring. The salt content emitted with the spray mist may fall to the ground in dissolved form or as aerosol after evaporation of the water. A chloride pollution by the spray water of 3.5 g/m(E+2)/day could be determined. Field examinations yielded a sodium chloride/potassium chloride deposition on forest trees of 15 g/m(E+2)/30 days which caused heavy damage and it is feared that all vegetation in the neighborhood of the cooling towers will die over the period of a decade. (Auth)

<33>

Power Plant Cooling Systems.
Journal Power Division (Proceedings ASCE) 98(PO2):247-52; American Society Civil Engineers National Water Resources Engineering Meeting, Proceedings of a Symposium, Atlanta, GA, January 24-28, 1972
1972
Kinsman, G.
Florida Power and Light Company, Miami, FL

Various aspects of the production and disposal of waste heat from power plants are briefly reviewed. Because of the increasing size of power plants and the scarcity of sites, closed systems such as reservoirs and cooling towers are receiving more consideration although towers reduce the net power available from the plant. Towers can be either of the dry or wet type. The two types of wet towers are natural draft and mechanical draft, the latter of which predominate. Local fogging and icing may occur from wet cooling towers in winter weather. Disadvantages of saltwater systems includes the effect of salt drift on neighboring areas. Even with the recent development of improved technology, vegetation and electrical apparatus damage is expected. Drift effects, maintenance and operational problems associated with spray modules are unknown at present. Environmental regulations involved in the cooling system selection process are briefly reviewed. (ND)

<34>

Environmental Effects of Cooling Systems at Nuclear Power Plants.
IAEA-SM-187; Physical and Biological Effects on the Environment of Cooling Systems and Thermal Discharges at Nuclear Power Stations, Proceedings of a Symposium, Oslo, August 26-30, 1974. International Atomic Energy Agency, Vienna, 830 pp.
1975
International Atomic Energy Agency, Vienna, Austria

Problems and promising alternatives concerning waste heat management for power plants are noted in the 49 papers presented at the symposium. The sessions included: (1) heat dissipation: the physical behavior of heated effluents in the atmosphere and various aquatic systems; (2) effects on biota and environment ecosystems, including synergistic effects; (3) criteria for the establishment of thermal release standards; (4) alternative methods for the management of heated effluents, and possible beneficial uses of waste heat, and (5) effects of cooling systems and themal discharges on siting policies for nuclear power plants. A panel discussion on the design of cooling systems and the use or dispersal of excess heat is included in the proceedings. Nine of the papers concerning atmospheric-related impacts from cooling towers have been input separately into the data base. (ND)

<35>

Report to the Committee on Electric Power on Environmental Consequences of Spray Cooling Systems.
Environmental Aspects of Cooling Systems of Thermal Power Stations, Proceedings of a Symposium, Zurich, Switzerland, May 13-16, 1974. United Nations, 10 pp.
1974
Rainwater, F.H.
U.S. Environmental Protection Agency, Corvallis, OR

Reports of environmental studies of spray cooling systems undertaken by manufacturers and electric utilities are reviewed. Environmental performance was directly related to module design, therefore, environmental observations are identified with a specific manufacturer's product. Spray cooling requires less than 5% of the land area of a cooling pond for the same cooling duty. No chemical additives are added to the circulating water, therefore air or water pollution by such additives is not a problem. Augmentation of fog and ice was noted with some spray systems. Little objection was raised concerning drift effects from fresh water systems, but some concern was expressed for saltwater systems for potential damages from salt fallout. Additional studies are being performed by Florida Power and Light, New York State University and Detroit Edison. (ND)

<36>

Are Cooling Towers a Burden on the Environment?
Energie: Zeitschrift fur Praktische Energietechnik 28(8): 238-240; ORNL-tr-4377, 11 pp.
1976
Roggenkamp, H.E.
Hamon Sobelco Kuhlturme und Apparatebau, Bochum, Germany

Environmental stresses attributed to cooling towers include alteration of the landscape, generation of noise, and meteorological consequences. Tower heights could be considered disturbances to the landscape, however, increasing the number of cooling tower units or reducing the height-diameter ratio leads to increased investment costs. Wet cooling towers, at the present large unit capabilities are points of noise concentration in the power plant because of their large radiation surface. Vapor plumes from wet cooling towers lead to very slight changes in temperature and humidity. Until large-scale testing has been performed it is impossible to determine the environmental impact of dry cooling towers. Modern natural draft cooling towers are equipped with drift eliminators which substantially reduce drift and precipitation augmentation. Cell cooling towers create a low frequency noise problem as well as increased drift and fogging. (ND)

<37>

Large Wet-Type Cooling Towers and Their Influence on the Environment.
Braunkohle 29(10):413-418
1977
Schiffers, A.

Large wet-type cooling towers with natural draft are ecologically beneficial today, especially concerning the heat emission from thermal power plants. A description is given of the influence of such cooling towers on the environment and the possible climatic influence are considered in detail. Recent investigations have shown that wet-type cooling towers represent no danger of any kind for fauna and flora as to the bacterial radiation. Physical studies have shown that neither the emitted water vapor nor the heat emitted into the atmosphere, can significantly change the macroclimate and microclimate. At present, wet-type cooling towers cannot be replaced by dry-type or so-called hybrid-type cooling towers, the technical development of which for large units being not yet guaranteed. (Auth)

<38>

The Magnitude of the Problem of Thermal Discharges from Nuclear Power Plants.
PL.SP/EG/3/72, 18 pp.
1972
Spurr, G.
Central Electricity Generating Board

Current knowledge of the magnitude of the problem of thermal discharges from electrical power generation is reviewed. The experience of the CEGB for both direct and cooling tower methods of cooling provided the basis of the review. Appendices outline a study of the water surface cooling mechanism and the observations made within the CEGB of the effect of natural draft cooling towers on the environment. The CEGB studies showed minor (0.01 mm/hr) drift rates, and no local changes in rainfall, icing or fog incidence, and sunshine. Cumulus clouds associated with cooling tower plumes were observed on a number of occasions particularly in the morning when the sky was otherwise clear. There was no evidence of precipitation arising from these clouds. Median droplet diameter over eliminators in modern towers ranged from 60 to 130 microns. Liquid water loss ranged between 0.003 and 0.013% of the water flow. The dominant, droplet growth mechanism in a tower was coalescence and for drops smaller than 50 microns diameter this was neglibible. The amount of growth increased roughly in proportion to the height of the tower. Plume persistence varied with humidity: shorter plumes were associated with 75%-or less humidity, and persistent plumes were associated with 90% or greater humidity. (ND)

<39>

Recent Central Electricity Generating Board Research on Environmental Effects of Wet Cooling Towers.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 205-220), 638 pp.
1975
Moore, D.J.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

Recent Central Electricity Generating Board research on wet cooling towers includes: 1. Development of an assisted-draft tower to reduce the visual impact of a power station and the surface area it occupies. 2. Reduction of droplet carry-over (drift) by reevaluation of an earlier very successful eliminator design. This work was supported by in-tower and field measurements of droplets and theoretical investigations of droplet production and removal processes. 3. Investigation of climatological effects of stations with cooling towers. 4. Collection of information on plume persistence and plume rise and attempts to correlate these with meteorological and station operating data. The more important aspects of this work are outlined. Work on plume rise is described in more detail and comments on the environmental aspects of the problem from a meteorologist's point of view are also provided. Actual environmental impacts from cooling tower operation have been minimal. (Auth)(ND)

<40>

Evaluation of Environmental Effects of a Natural Draft Cooling Tower at the Davis Besse Nuclear Power Station.
NUS Corp. for Toledo Edison Co., July 1971. 75 pp.

Document contains an evaluation of potential environmental impacts resulting from operation of a 493-foot natural draft cooling tower being installed at the Davis-Besse Nuclear Power Station, Ottawa County, OH. A representative 5-year period of meteorological data from the Toledo Airport was analyzed to determine those conditions related to natural fog occurrence. This data was then used to estimate the fogging potential of the cooling tower plume. Similar humidity distribution data was used to estimate icing potential. For both processes, an analytical model for hourly calculation of plume rise, dispersion, and transport was used with meteorological data input. The occurrence of downwash was also estimated. Report contains 13 figures, 15 tables, and references.

<41>

Initial Investigations of the Effects of Heat and Moisture Dissipation from a Large Natural-Draft Cooling Tower.
Atmospheric Diffusion and Air Pollution, Proceedings of a Symposium, Santa Barbara, CA, September 9-13, 1974. American Meteorological Society, Boston, MA, (p. 420-425), 435 pp.
1974
Peterman, W.A.; Frey, G.R.; Limbird, A.G.
Bowling Green State University, Department of Geography, Bowling
Green, OH
Toledo Edison Company
Cleveland Electric Illuminating Company

The initial efforts of investigators at Bowling Green State University to provide measurements regarding the effects of cooling tower effluents are discussed. This is but one portion of a comprehensive environmental study of the effects of the operation of a large natural draft cooling tower for the Davis-Besse Nuclear Station. The general problem of climatic fluctuations and the use of meteorological investigations in evaluating environmental impacts are addressed. A detailed discussion of the soil environment's role in the evaluation of atmospheric impacts is presented. Changes in soil temperature, soil chemistry, and soil texture can be the result of changes in atmospheric conditions, and in turn, can be significant enough to result in alterations in flora and fauna. Soil chemistry of the area and soil monitoring methods are described. The problem of inadvertent weather modification is reviewed. (ND)

<42>

Forked River Nuclear Station Unit 1 Natural Draft Salt Water Cooling Tower: Assessment of Environmental Effects.
Appendix B Attachment 5, Forked River Nuclear Station Unit 1 Environmental Report, Jersey Central Power & Light Co., Jan. 1972. 132 pp.

Appendix presents an analytical and experimental study concerning the environmental effects of a natural draft salt water cooling tower for the Forked River Nuclear Station, Ocean County, NJ. The study focuses on: 1) the nature of salt drift from a tower and its effects on vegetation, animals, fish, structures, soils, and surface and groundwater; 2) the nature of the blowdown from the tower basin and its effects on aquatic biota; and 3) the effect of the plume leaving the tower with respect to ground level fogging and icing. Appendix includes 19 tables, 27 figures, and 3 appendices.

<43>

The Forked River Program: A Case Study in Saltwater Cooling.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 509-557), 638 pp.
1975
DeVine, J.C. Jr.
GPU Service Corporation, Parsippany, NJ

In December 1971 the GPU Service Corporation, a subsidiary of General Public Utilities Corporation, announced its intention to use a natural draft saltwater cooling tower system at its proposed Forked River Nuclear Generating Station to be located near the New Jersey seacoast. The announcement by GPU followed 8 months of intensive feasibility studies, and since that time the company has extended its study program to encompass in-depth review of the potential environmental impact due to tower operation. This paper provides an overview of the GPU program, including analytical methods used and summary of results in the areas of cooling tower measurements, development of the salt transport model, wind-tunnel analyses to evaluate wake effects, plume rise observations, measurements of ambient salt levels in the Forked River environs, examinations into indigenous vegetation tolerances to salt, calculation of fogging and icing probabilities, blowdown effects, and others. The coordination and application of these diverse areas of study to the solution of a particular siting problem, including the establishment of acceptance criteria to be applied in the selection of a specific saltwater cooling tower system are emphasized. The feasibility study showed that the proposed cooling system would have no significant deleterious effects on the Forked River environs. (Auth)(ND)

<44>

Environmental Significance of Newbold Island Cooling Towers.
Smith-Singer Meteorologists, Inc., Massapequa, NY.
Appendix E, Hope Creek (Newbold Island) Nuclear Generating Station Units 1 and 2, Supplemental Environmental Report, Public Service Elec. & Gas Co., March 1972. 29 pp.

Appendix describes the cooling system for the Hope Creek generating station Units 1 and 2 in Burlington County, NJ. Each unit will have 2 hyperbolic towers. Tower configuration and emission parameters are described. Behavior of the tower plumes, chemical deposition, precipitation and weather modifications and tower chlorination are discussed. Seven references, 1 appendix, 2 tables, and 4 figures are included in the report.

<45>

Environmental Aspects of Cooling Tower Operation: Survey of the Emission, Transport, and Deposition of Drift from the K-31 and K-33 Cooling Towers at ORGDP.
K-1859, 74 pp.
1974
Jallouk, P.A.; Kidd, G.J. Jr.; Shapiro, T.
Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN
U.S. Atomic Energy Commission

The results of a program to evaluate the environmental aspects of cooling tower operation at the Oak Ridge Gaseous Diffusion Plant (ORGDP) are presented. The quantities of chemicals being introduced into the atmosphere as well as the deposition of these chemicals on the environs surrounding the cooling towers were measured. The study was performed by four groups: Environment Systems Corp., Battelle Pacific Northwest Laboratories, Atmospheric Diffusion Laboratory, and Oak Ridge National Laboratory (Ecological Sciences Division). The findings of the four component studies are combined and summarized. The data have been further analyzed, and an evaluation of the results from the various groups has been made. The areas where agreement exists are discussed and the areas where conflicting results are presented have been delineated. The results show that the ORGDP towers are operating within the limits of drift fraction specified when the towers were procured. The measurements of transport and deposition have provided limited experimental confirmation of analytical models so that these parameters can be calculated with better confidence for a wider range of operating and meteorological conditions. The studies of vegetation around the towers indicate that plants serve as reliable instruments for detecting small quantities of chemicals (chromium and zinc). Based on the tests performed, the cooling towers, under present operating conditions, are not causing any adverse effect on the native vegetation surrounding ORGDP. (ND)

<46>

Environmental Aspects of Cooling Tower Operation.
CONF-750967; ERDA 92 Vol. 1, (p. 418-441); ERDA Environmental Protection Conference, Proceedings of a Symposium, Chicago, IL, September 23, 1975
1975
Jallouk, P.A.; Kidd, G.J. Jr.; Shapiro, T.; Taylor, F.G. Jr.
U.S. Energy Research and Development Administration, Washington, DC
Oak Ridge National Laboratory, Oak Ridge, TN

Environmental effects of mechanical draft cooling tower operations associated with gaseous diffusion plants are discussed. Four studies at the Oak Ridge Gaseous Diffusion Plant towers which dissipate a heat load equivalent of 100 megawatts electrical are summarized. Total drift, air concentration, and deposition patterns were determined. Transfer of drift to the environment was studied. Measured field data was compared with a theoretical model for cooling tower drift. Chromium and zinc content of cooling tower drift and the associated environment including plants, soil, and air was determined.

<47>

Chalk Point Cooling Tower Study.
42 pp.
1973
Green, R.L.
University of Maryland, Water Resources Research Center, College Park,
MD
Maryland Department of Natural Resources, Power Plant Siting Program

The development and initiation of a program to evaluate the potential impacts of the Chalk Point cooling towers is described. The research and monitoring program includes examination of the meteorological aspects of emission from the cooling tower, evaluation of the accumulation of salt drift on vegetation and soil, and evaluation of salt drift effects on vegetation and soil. A minimal ten year study program utilizing pre- and post-operational studies was recommended. The report is divided into three sections (individually authored) corresponding to the three research areas. Each have been input separately into the data base. (ND)

<48>

Case Study of the Environmental Effects of the Chalk Point Natural Draft Cooling Tower.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, January 29-31, 1973, Houston, TX, Order No. TP 143A;
1975
Carlson, T.B.; Pell, J.; Shofner, F.M.
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program
Electric Power Research Institute, Palo Alto, CA
U.S. Energy Research and Development Administration

The first large natural draft hyperbolic cooling tower utilizing brackish water is scheduled to go into operation at the Potomac Electric Power Company Chalk Point Generating Station Unit 3 in February 1975. Environmental effects of the emissions from the tower are of concern in regard to possible deleterious effects such as fogging and downwind icing, but also with special regard to possible effects on vegetation by the deposition of salts originating from the brackish water drift. An instrumentation system has been designed to fully characterize the effluent properties of the plume. This automated instrumentation system consists of an electro-optic light scattering instrument as the primary device to measure the particulate size distribution for the approximate size range $50 \text{ um} < d < 1000 \text{ um}$. A calibrated sensitive paper technique serves as an auxiliary particle size distribution measurement system and an isokinetic sampling technique is used to measure mass emission. Standard sensors monitor the meteorological conditions and cooling tower water circuit parameters, and the ambient salt concentration is monitored with an airborne particle sampling system. All sensors are hard-wired to a minicomputer data acquisition system which controls the experiments and continuously acquires the data for later interpretation. (Auth)(ND)

<49>

The Chalk Point Cooling Tower Project.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 88-127), 638 pp.
1975
Pell, J.
Maryland Department of Natural Resources, Power Plant Siting Program,
Annapolis, MD
U.S. Atomic Energy Commission
Electric Power Research Institute, Palo Alto, CA

The world's first large natural draft hyperbolic cooling tower to use brackish (nonfresh) water has just been constructed at a fossil-fired power plant of the Potomac Electric Power Company. The Chalk Point Cooling Tower Project of the State of Maryland Pcwer Plant Siting Program has been launched to comprehensively characterize the atmospheric discharges and to fully assess the environmental effects of this installation when it goes on line in December 1974. This is the first long-term full-scale endeavor of its kind. The 400-ft-high crossflow tower is being rigged with a full-instrumentation package designed for three-dimensional traverses; parameters to be monitored include plume updraft velocity, temperature and humidity; brackish-water drift (carryover) size distribution and total liquid water content will be measured by laser light scattering, isokinetic sampling, and sensitive-paper techniques. Plume rise and trajectory will be monitored by stereo-photography. A major research and field program is under way to determine the impact of salt deposition on local vegetation and cash crops, notably the surrounding fields of 'Marlboro Country' tobacco. Plume dispersion and drift deposition models are under development, with ground 'truth' data being obtained by several complementary empirical techniques. Meteorological support is provided by three-level tower instrumentation with both analog and digital output and can be supplemented by radiosonde and pilot balloon ascents. This paper provides a general overview and sets the stage for the various aspects of the project that will be presented in detail as the meeting progresses. (Auth)

<50>

The Chalk Point Cooling Tower Project Integrated Experimental Design Document.
250 pp.
1976
Massicot, P.; Nietubicz, R.S.; Moon, M.L.
Maryland Department of Natural Resources
The Johns Hopkins University, Applied Physics Laboratory, Baltimore,
MD
Maryland Department of Natural Resources, Power Plant Siting Program
U.S. Energy Research and Development Administration
Electric Power Research Institute
Potomac Electric Power Company

The concepts, technical information, and operational requirements for the design and execution of an experimental program to study the emission and operating characteristics of the Chalk Point Cooling Tower are addressed. The initial project was designed to study the effect of salt deposition from brackish water cooling tower drift on soils and plants, but was expanded to include the acquisition of data on all parameters needed to characterize plume behavior. Long range project objectives are discussed in relative order of priority. Experimental designs, instrumentation systems, data management, analysis plans and field operations are described. Project plans for the participating groups with emphasis on the coordination of joint operations are presented, although revisions may be made as dictated by the preliminary experimental results and the analysis presently underway. (ND)

<51>

EPRI Research Program in Cooling Tower Technology and Environmental Impacts.
Transactions American Nuclear Society 26:112-113; American Nuclear Society Annual Meeting, Proceedings of a Symposium, New York City, NY, June 12-16, 1977
1977
Maulbetsch, J.S.
Electric Power Research Institute, Palo Alto, CA

EPRI research objectives in the cooling tower area include (1) the development and demonstration of dry and wet/dry cooling towers, (2) the improvement and field-test validation of models to predict the dispersion of drift and vapor plumes, and (3) the development of improved acceptance and siting criteria for cooling towers. Environmental impact research, in particular the Chalk Point Cooling Tower Project, is gathering field data for the validation of plume dispersion models and for the evaluation of environmental effects on saline drift. Hydraulic models in plumes are being validated as a predictive tool to reduce impaired cooling tower performance. (ND)

<52>

Cooling Tower Environment-1978 Proceedings.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Environmental Effects of Cooling Tower Emissions, Proceedings of a Symposium, College Park, MD, May 2-4, 1978, 2 Vols., 462 pp., 90 pp. (supplement)

1978
Nietubicz, R.S.; Green, R.L.
Maryland Department of Natural Resources, Power Plant Siting Program,
Annapolis, MD
University of Maryland, Water Resources Center, College Park, MD

The environmental impacts of waste heat from electric generating plant cooling towers (especially Chalk Point) are discussed and evaluated in 32 papers. The papers which were not received in time to be included are published in the supplement. In addition, the supplement contains an important technical note which was not included in the planned program. The symposium was divided into three subject areas: ecological effects, vapor plumes, and drift measurements and modeling. All of the papers have been input into the data base. (ND)

<53>

Environmental Effects of Cooling System Alternatives at Inland and Coastal Sites.

Nuclear Technology 25:640-649
1975
Miner, R.M.; Warrick, J.W.
URS Energy Service Company, San Mateo, CA
Pacific Gas and Electric Company, San Ramon, CA

The environmental effects of alternative cooling systems for power plants in California have been analyzed. At inland sites evaporative cooling systems must be used, with fresh water or waste water used as makeup. Because fresh water is scarce, most new plants would need to use agricultural or municipal waste waters. For agricultural waste water systems, disposing of the blowdown and dispersion of drift containing total dissolved solids are two significant problems requiring resolution. At coastal sites, once-through cooling systems or recirculating systems could be used. Once-through cooling causes fewer effects on the marine environment than do recirculating systems on the air and marine environment when ocean water makeup is used. In general, for a recirculating system, dispersing high-salinity blowdown in marine waters and the effects of saltwater drift on the terrestrial ecology outweigh the effects of once-through warm water on marine life. Case-by-case evaluations should be made for each power plant site. (AUTH) (ND)

EFFECTS OF CLOSED CYCLE COOLING SYSTEMS - ENERGY CENTERS

<54>

Preliminary Assessment of a Hypothetical Nuclear Energy Center in New Jersey.
BNL-50465, 423 pp.; BNL-20594, 20 pp. (Executive Summary)
1975
Brookhaven National Laboratory, Energy Policy Analysis Group, Upton, NY
Princeton University, Center for Environmental Studies, Princeton, NJ
Cornell University, College of Engineering, Ithaca, NY
The University of Pennsylvania, Regional Science Department, Philadelphia, PA
J.E. Edinger Associates
U.S. Energy Research and Development Administration

Results of a preliminary study of a site around the Delaware Bay and two southern New Jersey sites (Ocean County and Salem County) as possible nuclear energy center sites are presented. The study used as a basis an NEC eventually comprising 40 plants totalling 48,000 MWe by 2020, and occupying 75 square miles. Environmental impacts discussed relate primarily to water supply, cooling water discharges, maintenance of salinity levels in receiving estuaries, and local drift and salt deposition effects. Cooling technology choices and their environmental impacts are outlined. The most promising cooling alternative is the use of plume-control wet/dry towers. The preservation of the Pinelands, a delicate ecosystem, in New Jersey is mentioned. Topics discussed include energy demand analysis, transmission, land use, socio-economics, political issues, heat dissipation, and water quality. (ND)

<55>

Energy Parks and the Commonwealth of Pennsylvania - Issues and Recommendations Volume 1: Summary.
Vol. 1 of 2, 39 pp.
1975
Ferrar, T.A. (Project coordinator); Knight, C.G.; Latham, R.J.; Witzig, W.F.; Wolgemuth, C.H.
The Pennsylvania State University, Center for Environmental Policy, University Park, PA

Key issues in the formulation of a position on the energy park concept are addressed. Issues include environmental impacts, land use, safety, institutions, and socio-economics. Results show that the park alternative may require additional land requirements. The environmental consequences of a park do not differ qualitatively from the dispersed alternative, although such effects will be more intense at the site. The mixing of stack gases and particulate matter with the water vapor plume from cooling towers could accentuate acid rainfall. An energy park could threaten certain critical environmental resources, such as wild and natural areas. Reject heat dissipation (approximately 20,000 MW of reject heat) from the park will place substantial demands on the involved watershed. The meteorological impacts associated with evaporation and waste heat rejection may produce increased storm incidence, enhanced rainfall, and the combined shadowing/microclimatological effects of persistent plumes. The emission of SO2 and particulate matter from the fossil-fueled component of the park in conjunction with cooling tower plumes will affect local and regional ambient air quality and could accentuate acid rainfall. Final assessments will require specific sites for comparison purposes. Further research is recommended. (ND)

<56>

Energy Parks and the Commonwealth of Pennsylvania - Issues and Recommendations Volume 2: Appendices.
Vol. 2 of 2, 275 pp.
1975
Ferrar, T.A. (Project coordinator); Knight, C.G.; Latham, R.J.; Witzig, W.F.; Wolgemuth, C.H.
The Pennsylvania State University, Center for Environmental Policy, University Park, PA

A comprehensive set of questions and key issues to be addressed in the formulation of a position on the energy park concept for Pennsylvania were evaluated. The key issues in the formulation of a position on the energy park concept are addressed in Volume 1 of this set. Volume 2 presents the analysis upon which the conclusions (in Volume 1) are founded. This volume is a collection of semi-independent papers, each authored or co-authored as indicated on the separate title pages. Environmental impacts are addressed in Appendix C. Subject areas include, meteorological impacts, hydrological impacts, fossil fuel impacts, and land use impacts. The primary potential meteorological impacts of energy parks derive from two sources: the release of energy and moisture for dissipation of reject heat and from stack emissions from fossil generation. Synergistic interaction between the two (forming acid rain) may be a localized or a large-scale regional phenomenon. Suspected impacts from heat rejection are increased rainfall, increased incidence of violent storms, increased fog, icing of aircraft and roads, turbulence, and visible plumes. Each of the above phenomena are discussed. Most environmental impacts appear to differ little in kind under agglomerated versus dispersed siting, whereas the spatial locus and magnitude of impacts may differ significantly for each siting alternative and specific potential site. (ND)

<57>

Atmospheric Effects of Nuclear Energy Centers (AENEC) Program Annual Technical Progress Report for Period July 1975 - September 1976.
ORNL/TM-5778, 218 pp.
1977
Patrinos, A.A.; Hoffman, H.W.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

The objective of this program is to develop and verify methods for predicting the maximum amount of energy that can be dissipated to the atmosphere (through cooling towers or cooling ponds) from proposed nuclear energy centers (NEC's) without affecting the local and regional environment. This report contains preliminary information from the six participants of the Program describing their activities and presents the results obtained during the period July 1975 - September 1976. The birth of the program, its definition and evolution are described in the introduction, and a complete breakdown of responsibilities and tasks assigned to the six AENEC participants is presented. The modeling efforts described include near-field plume and cloud growth, vorticity enhancement, drift deposition, mesoscale cloud growth, deep convection, and turbulence closure models. Laboratory plume studies, cooling tower plume field studies and cooling pond surface heat exchange studies to verify the models are discussed. (ND)

<58>

A Comparison Between Dispersed Nuclear Power Plants and a Nuclear Energy Center at a Hypothetical Site on Kentucky Lake, Tennessee, Volume 3, Environmental Considerations.

ORNL/TM-5312, Vol. 3 of 4, 121 pp.
1976
Fitzpatrick, F.C.; Gray, D.D.; Hyndman, J.R.; Sisman, O.;
Suffern, J.S.; Tyrrell, P.A.; West, D.C.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

Hypothetical surrogate sites were used to illustrate the differences between generating electric power in nuclear energy centers (NEC) and dispersed sites. The differences studied are land use, heat dissipation, and electrical transmission. The surrogate sites are located in middle TN, and adjacent areas in western TN, southern In and KY, and northern AL and MS. The comparisons are between a 40 reactor NEC, 4 - 10 reactor NECs and 10 - 4 reactor dispersed plants; the reactors are assumed to be 1200 MWe each. Load centers are Evansville, IN; Paducah, KY; Nashville, TN; Memphis, TN, and Huntsville, AL. Transmission line corridors were selected to carry the power to the load centers. Volume 1 contains the summary of the results. Volume 3 compares environmental (atmospheric, aquatic, and terrestrial) impacts from heat dissipation, construction, operation, and transmission. Near field salt deposition was found to be negligible for both NECs and dispersed sites. Increased precipitation and concentration of vorticity are probable downwind of an NEC; however, no firm assessment of meteorological consequences can be made at this time. (ND)

<59>

Analysis of the Gulf States Utilities' River Bend Site for a Nuclear Energy Center.

ORNL CF-74-1-32; Nuclear Energy Center Evaluation Task Force, Evaluation of Nuclear Energy Centers. Appendices, WASH-1288 Vol. 2. (165 pp.), 559 pp.
1974
Oak Ridge National Laboratory, Oak Ridge, TN
Gulf States Utilities, Beaumont, TX
Stone and Webster Engineering Corporation
National Oceanic and Atmospheric Administration
U.S. Atomic Energy Commission

The use of the River Bend site in Louisiana as a nuclear energy center consisting of 28 units generating 1300 MWe each is discussed concerning plant design, transmission, environmental impacts, fuel cycle aspects, and licensing. This site was selected as an example; no judgement has been made on the adequacy of the site for the intended purpose nor have alternative sites been considered. Impacts from mechanical draft cooling towers were estimated at 2.2 in/yr of peak water deposition and 670 lb/acre/yr of salt drift deposition. Peak rates predicted for natural draft towers are 0.5 in/yr (water) and 150 lb/acre/yr (salt). (Ambient salt fallout is estimated at 12 lb/acre/yr). The peak rates are highly localized and decrease rapidly with distances from the source (estimates are given). Atmospheric impacts from cooling tower effluents include plume formation, increased temperature and humidity, increased vorticity, decreased solar radiation, and increased precipitation. The possible formation of acid rain is noted in conjunction with industrial emissions. Overall, the impacts of these modifications on the terrestrial environment are not expected to be significant. (ND)

EFFECTS OF CLOSED CYCLE COOLING SYSTEMS - COMPARATIVE STUDIES

<60>

Alternative Cooling Tower Systems Analysis for the Proposed Montague Nuclear Power Station Units 1 & 2.
Energy Impact Associates, Inc. for Massachusetts Energy Facilities Siting Council, May 1978. 57 pp.

Document examines the relative suitability of alternative cooling tower systems for the proposed 2-unit, 2300-MW Montague Nuclear Power Station, Franklin County, MA. The 5 types of wet cooling tower systems analyzed are as follows: 1) natural draft; 2) circular mechanical draft; 3) circular single fan; 4) linear mechanical draft, and 5) fan-assisted natural draft. A description and figure of each are provided. Air quality, water quality, acoustical, and visual impacts, as well as economics of the alternatives, are discussed. Study concludes that the natural draft tower alternative is the most economically appealing, but also presents the greatest aesthetic impact. The second choice economically would be the circular mechanical draft system, which would have less aesthetic impact. Public opinion regarding the relative importance of economics vs. aesthetics is cited as the possible determinant for the final decision. Conclusions, recommendations, 10 tables, and 15 figures are provided.

<61>

Economic and Environmental Impacts of Alternative Closed-Cycle Cooling Systems for Indian Point Unit No. 3.
Consolidated Edison Co. of N.Y., Inc., Jan. 1976. 642 pp.

Report was submitted to the Nuclear Regulatory Commission, in accordance with Paragraph 2.E.1(g) of Facility Operating License No. DPR-64, for Indian Point No. 3. Paragraph stipulates that full-term, full-power, or other operating license issued to Con Edison or its successor would be conditioned to require preparation of an economic and environmental impact evaluation of alternative closed-cycle cooling systems for Indian Point No. 3, which is designed with a once-through system. This report describes the existing once-through system and alternative closed-cycle systems including wet (evaporative), dry, wet-dry cooling towers, natural cooling ponds, and spray ponds and canals. Design feasibility for each alternative system is outlined. Economic parameters considered are direct and indirect capital costs and incremental generating costs. Environmental considerations evaluated are the following: 1) cooling tower plume impact (visible plume, fogging, and icing); 2) salt drift deposition; 3) chemical discharge impact; 4) radiological impact; 5) cooling tower noise impact; 6) cooling tower aesthetic impact; 7) fish impingement at intake structure, and 8) entrainment of aquatic life in the cooling system. Report includes 32 tables, 68 figures, and 3 appendices.

<62>

Environmental Effects of Atmospheric Discharges from Two Natural Draft Cooling Towers (Indian Point 2 and 3) at the Indian Point Site.
Appendix A, Economic and Environmental Impacts of Alternative Closed-Cycle Cooling Systems for Indian Point Unit No. 3, Woodard, K. and Laskowski, S.M., Pickard, Lowe and Associates, Inc., for Consolidated Edison Co. of N.Y., Inc., April 1975. 224 pp.

Report discusses potential environmental effects of operation of 2 natural draft cooling towers at the Indian Point nuclear plant on the Hudson River. Specifically investigated are the humid plume phenomenon and water droplets (drift) discharged from the towers. Induced fogging, icing, and salt deposition are also discussed. Data were compiled from 8006 hr of onsite meteorological observation. There are 4 references, 6 tables, 11 figures, 3 appendices, and 1 addendum.

<63>

A Model Study of Salt Drift Deposits, Induced Fogging, and Icing by Plumes from Four Postulated Types of Cooling Towers at Indian Point Unit No. 3.
Appendix B, Economic and Environmental Impacts of Alter- native Closed-Cycle Cooling Systems for Indian Point Unit No. 3. Consolidated Edison Co. of N.Y., Inc., Jan. 1976. 117 pp.

Report compares environmental impacts arising from the hypothetical operation of linear wet, linear wet-dry, round mechanical, and fan-assisted natural draft cooling towers at the Indian Point Unit 3 site on the Hudson River. Compared parameters include salt drift deposition, fogging, and icing in an 18 sq mi area around Indian Point Unit 3. The theoretical design and background of the various modeling techniques are discussed. Report includes 5 tables, 46 figures, and 1 appendix.

<64>

Lake Erie Generating Station Alternative Cooling Water System Study.
Appendix 72-B, Application to the New York State Board on Electric Generation Siting and the Environment, Lake Erie Generating Station. Niagara Mohawk Power Corp., 1977. 140 pp.

Appendix presents an evaluation of alternative cooling systems considered for the proposed 1700-MW, 2-unit Lake Erie Generating Station to be constructed at either the Pomfret or Sheridan sites in Chautauqua County, NY. In selecting the cooling water system, engineering, economic, and environmental factors were taken into consideration. Eleven alternative systems were analyzed, with cooling ponds and dry cooling towers rejected outright, due to land requirements in the case of the cooling pond, and the monetized cost and power requirements for dry cooling tower operation. For the 9 other systems (single natural-draft cooling tower, 2 natural-draft cooling towers, round and rectangular mechanical- draft cooling towers, plume abatement cooling towers, wet/dry cooling towers, spray canal, once-through cooling system with diffuser discharge, and once-through cooling system with shoreline discharge) information is presented in 2 parts: 1) an evaluation of closed cycle systems, and 2) a comparison of the preferred closed cycle system to once-through systems. Eight tables, 29 figures, and references are included.

<65>

JCP&L Company Oyster Creek Nuclear Generating Station Alternative Cooling Water System Study.
Appendix E-1, Oyster Creek & Forked River Nuclear Generating Stations: 316(a) & (b) Demonstrations. Prepared by Ebasco Services, Inc. for Jersey Central Power & Light Co., Nov. 1977. 590 pp.

Alternative cooling water systems for the Oyster Creek Nuclear Generating Station, in Ocean County, NJ, are discussed in this report. The station currently employs a once-through cooling system with water withdrawn from Barnegat Bay via the South Branch of the Forked River and returned to the bay via Oyster Creek. Six open-cycle and 10 closed-cycle options were evaluated on the basis of environmental, economic, and licensing considerations. Four systems, 3 closed-cycle and 1 open-cycle, were selected as the optimum design choices: 1) two fan-assisted natural draft towers; 2) a round mechanical draft tower; 3) one natural draft tower, and 4) modification of existing system to include a pipeline-to-bay extension on the discharge tunnel. Report also provides 3 appendices containing a computer program for an economic analysis, federal and state environmental regulations, and mathematical models for computing atmospheric effects. The final section of this study contains 227 exhibits consisting of various diagrams, tables, and graphs that were cited throughout the report.

<66>

Applicants' Direct Testimony with Respect to Use of Closed-Cycle Cooling at Seabrook and Analyses of Alternative Sites.
Presented before U.S. Nuclear Regulatory Commission, Atomic Safety and Licensing Board, 1977. 88 pp.

Report presents applicants' judgement on the closed-cycle cooling system considered for use at the proposed Seabrook nuclear plant site, Rockingham County, NH. Although the previous choice of a once-through cooling system was based on favorable environmental and economic effects, if closed-cycle cooling were mandated, the applicants would select a natural draft cooling tower system. Report describes the costs, environmental effects, performance, and direct impacts of a natural draft system at Seabrook and various alternative sites. Atmospheric effects associated with utilization of a closed-cycle system, including visible plumes, downwash, fogging, icing, and drift are evaluated. Alternative sites include: 1) New Hampshire, estuarine; 2) New Hampshire, coastal; 3) Maine, coastal; 4) northern New Hampshire, inland; 5) upper Merrimack River watershed, inland; 6) Litchfield, and 7) southern New England. Substantial economic and efficiency losses, as well as delay costs, would be incurred if a switch to closed-cycle cooling were mandated. Report includes 7 tables, 7 figures, 4 appendices, and references.

<67>

Evaluation of Environmental Effects from Evaporative Heat Dissipation Systems at the Seabrook Site.
Prepared by Koss, T.C., NUS Corp. for Public Service Co. of New Hampshire, Oct. 1972. 65 pp.

Report presents an analysis of potential environmental effects of alternative evaporative heat dissipation systems for the proposed Seabrook Nuclear Plant, in Rockingham County, NH. The 3 systems examined are spray channel, mechanical draft tower, and natural draft tower. Regional meteorological data were considered in estimating the increase in frequency of occurrence of fog, salt deposition due to drift, and long, visible plumes. Preliminary results indicate that the spray channel and mechanical draft cooling towers could interact with local meteorological conditions to produce significant fogging. Plume release from the natural draft tower is expected to be high enough to enter an offshore breeze system and thereby dissipate. Spray channels would result in a high rate of salt deposition in the immediate area of the system, but, beyond 0.5 km, salt deposition would be at a lower level than that produced by either cooling tower. Length and duration of visible plumes, icing, and downwash impacts were also compared. Report includes 16 tables, 10 figures, and references.

<68>

The Sterling Power Project, Cooling Tower Report.
Prepared by Rochester Gas & Elec. Corp., 1974. 259+ pp.

Report describes a study of alternative cooling system designs to be considered for use at the proposed Sterling plant in Cayuga County, NY. The applicant proposes a once-through cooling design with a surface discharge as being the most feasible design from environmental and economic views, but best practicable control technology could indicate cooling towers are necessary. Cooling ponds and spray canal systems were eliminated because of the large land requirement (1200 acres) and higher ground deposition rates of salt. Natural draft cooling towers were the preferred alternative to a surface discharge system. Discussion includes both the preferred Sterling site and the alternate Ginna site. Report includes 35 figures, 29 tables, references, and 4 appendices.

<69>

Evaluation of Environmental Effects from Evaporative Heat Dissipation Systems at Gulf States Blue Hills Station.
Lee, Jiin L. Prepared by NUS Corp. for Bechtel Power Corp. Included in entirety as Appendix B in Blue Hills Station Units 1 & 2 Environmental Report, Gulf States Utilities Co., March 1974. 142 pp.

Designs of 4 heat dissipation systems provided by Bechtel are analyzed by NUS Corp. to evaluate environmental effects. Types of cooling towers include mechanical draft (wet), mechanical draft (wet/dry), natural draft (wer) and fan-assisted natural draft. Deposition rate of dissolved solids and frequency of visible plume is predicted. Icing potential and reduction of ground level visibility are examined. Plume, fog, and ice models used are described and analyses are drawn, including recommended alternative configuration of cooling tower system. No significant impact predicted for any of the alternatives considered. Contains 23 tables, 57 figures and 34 references.

<70>

Heat Rejection for the Clinch River Breeder Reactor Plant.
American Power Conference, Proceedings of a Symposium, Chicago, IL, April 18-20, 1977. Illinois Institute of Technology, Chicago, IL; Proceedings American Power Conference 39:702-708
1977
Donaldson, A.M.
Burns and Roe, Inc., Los Angeles, CA

The optimization and selection of a cooling system for the Clinch River Breeder Reactor Plant (CRBRP) is detailed. Alternatives considered were mechanical draft wet towers, mechanical draft wet/dry towers, hyperbolic or natural draft towers, and spray ponds. The alternatives are discussed with respect to design, siting considerations, environmental impacts, and economics. However, it was concluded that the environmental considerations were not significant, and the selection was based primarily on economics. For the CRBRP, the mechanical draft wet cooling tower provided the best cost-effective selection, considering capital and operating cost and environmental effects (including fogging, drift, consumption of water, discharge of chemical and thermal plumes, land use, and aesthetics). (ND)

<71>

Chapter 8. Potential Impact of Cooling Tower Air Emissions.
Kohlenstein, L.C., 1976, Power Plant Site Evaluation Final Report Douglas Point Site, JHU PPSE 4-2, Vol. 1, Part 2
1976
Eagles, T.W.; Kagan, J.A.; Meyer, J.H.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The impacts of various types of cooling towers for the proposed Douglas Point Generating Plant are reviewed and compared. Cooling towers included in the comparison are a full-wet mechanical draft tower, two hybrid wet/dry mechanical draft towers, a round mechanical draft tower and a fan-assisted natural draft tower. The mechanical draft towers could produce much higher incidences of fog on-site, when compared with the natural draft towers. However, none of the figures were significant when compared to the natural fog occurrence. Some icing could occur with the mechanical draft towers, but it should not occur with the natural draft towers. Mechanical draft full-wet towers produce more plumes that extend to a length of up to 1000 m than do natural draft towers, however, natural draft towers are more likely to produce plumes beyond this length. The wet/dry mechanical draft towers are similar to the full-wet type except that they produce fewer plumes of every length. Mechanical draft towers were predicted to have the maximum salt deposition, and natural draft towers the minimum. Salt deposition impacts (corrosion and vegetation damage) would be severe for the mechanical draft towers. Natural draft towers are expected to have modest on-site impact and negligible off-site impact. (ND)

<72>

Power Facility Siting in the State of Illinois Part 2: Environmental Impacts of Large Energy Conversion Facilities.
IIEQ 75-03 Part 2 of 2, 303 pp.; PB-241 496;
1975
MacFarlane, D.R.; Hoglund, B.M.; Roberts, P.A.; Yates, J.J.
Environmental Technology Assessment, Inc., Oak Brook, IL
Illinois Institute for Environmental Quality, Chicago, IL

This report is part of a study of Power Facility Siting in the State of Illinois which is designed to provide the state with both the administrative and technical components of a procedure for approving sites for large energy facilities. Part 1, entitled Siting Regulation Alternatives, analyzed the administrative and regulatory practices currently being used for power plant site approval in Illinois and reviewed practices in other states and proposals at the federal level. Part 2 provides the necessary background information, compilation of data sources, and methods needed for a national approach to evaluate the environmental impact of large energy facilities. Impacts from once-through cooling, cooling ponds, spray canals, and cooling towers (evaporative, dry, and wet/dry types) are compared and evaluated. Atmospheric impacts (fogging, icing, and acid rain production) are noted. Drift (water droplets and airborne solids) is deposited over a wide area and could be detrimental to biota, depending upon the quantity and chemicals involved. Environmental impacts from routine operation of energy facilities are described. (ND)

<73>

The Impacts of Heat Dissipation Systems of Nuclear Power Reactors Upon Their Environment.
CONF-740910; Nineth World Energy Conference, Proceedings of a Symposium, Detroit, MI, September 22-27, 1974, 4 pp.
1974
Nelson, D.J.; Wichner, R.P.; Siegel, S.
Oak Ridge National Laboratory, Oak Ridge, TN

The environmental effects of alternative cooling systems are briefly reviewed. Cooling tower effects include plumes, increased humidity, and fogging. Mechanical draft wet cooling towers concentrate their effects closer to the tower location because the initial plume height is lower, and the liquid carryover is greater. There are potential terrestrial impacts associated with cooling towers from fogging, ice formation, and chemical drift. Saltwater towers may have adverse effects on local vegetation with consequent effects on bird and animal populations. (ND)

<74>

Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan.
PB-217 140, 119 pp.
1970
Pacific Northwest Water Laboratory, Corvallis, OR
U.S. Department of the Interior, Federal Water Quality Administration

An engineering and economic evaluation of various methods of dissipating waste heat from thermal power plants near Lake Michigan is presented. The effect of their operation on the environment is also reviewed. The analyses were directed towards determining the feasibility of various cooling methods, rather than to optimize any particular plant or site. The cooling systems evaluated include: evaporative and dry cooling towers (mechanical and natural draft) cooling ponds, and spray cooling canals. The results showed that while cooling devices do have the potential for producing undesirable environmental effects, such effects do not seem to be a problem for the Lake Michigan area. Careful pre-site selection surveys should eliminate sites which have a high potential for fog or drift problems, and blowdown treatment can be provided, if necessary. Site by site evaluation of the potential for comsumptive water loss by evaporation may be necessary. Lake Michigan temperature standards can be met by (1) design and operation of wet cooling systems with no, or essentially no, blowdown, (2) dilution of a residual blowdown with Lake Michigan water, (3) dry cooling towers, or (4) construction of closed cycle systems at sites independent of Lake Michigan as a source of water supply or sump for blowdown. (ND)

<75>

Feasibility of Alternative Cooling Systems for Power Plants in the Northern Great Plains.
PB-256 459, 40 pp.
1974
Tichenor, B.A.; Shaw, J.W.
Pacific Northwest Environmental Research Laboratory, Corvallis, OR
U.S. Environmental Protection Agency

The feasibility of alternate cooling systems for fossil fuel power facilities in Wyoming, North Dakota, and Montana is reviewed. The systems evaluated include once-through cooling, wet cooling towers, cooling ponds, spray systems, dry cooling towers, and wet/dry cooling towers. The engineering environmental and economic aspects of these alternative cooling systems are discussed. Wet cooling towers have potentially adverse side effects due to vapor plumes, drift, and blowdown. Dry cooling systems do not cause fogging, icing, drift or blowdown problems, but instead have warm air discharges and possible increased stack gas emissions. The fogging and icing potential of wet/dry towers is a function of design and operation which can be eliminated by proper design. Drift rate and blowdown from wet/dry towers should be similar or reduced compared to wet towers. It is concluded that for power plants in the Northern Great Plains, closed-cycle cooling with wet, dry, or wet/dry towers are all reasonable alternatives. (ND)

<76>

Combined Dry/Wet-Cooling Towers: Their Environmental Promise and Their Problems.
Bogh, P.; Bhargava, N., Motor-Columbus Consulting Engineers, Inc., Switzerland. In: Environmental Effects of Cooling Systems at Nuclear Power Plants, Proceedings of a Symposium Held in Oslo, Norway, Aug. 26-30, 1974. International Atomic Energy Agency, Vienna, 1975. pp. 45-62.
1974
Bhargava, N.; Bogh, P.

The advanced technology of natural-draught cooling towers has led to their adoption by most thermal power plants in Europe. Some impacts, such as the shadowing effect of the visible plume and the water consumption caused by the evaporation losses of the towers, are controversial matters at several sites. Also, the cumulative effect of the humidity release of the several large new plants, located not far from one another, may lead to problems due to increased cloud formation. The dry-cooling tower does solve the problem of the visible plume but the impact on the landscape owing to the tower's large dimensions cannot be ignored. Also, reduction of plant efficiency will lead to a greater consumption of natural energy resources. This paper presents briefly some ideas of combining wet and dry towers. The preliminary results of calculations with program SAMOA for a 900-MWe nuclear power plant with different cooling systems are discussed. The study has shown that the superheating of the plume at the tower outlet is a necessary but not sufficient condition for plume reduction. (AUTH)

<77>

Environmental Aspects of Cooling Tower Plumes.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, New Orleans, LA, January 26-28, 1970, TP-78A, 8 pp.
1970
Aynsley, E.
IIT Research Institute, Chicago, IL

The trend towards cooling towers and especially natural draft units in the electrical utility industry results primarily from considerations of thermal pollution of water courses and increasing scarcity of suitable locations. IIT is conducting a study of cooling towers at Keystone Power Plant with particular reference to atmospheric emissions. Potential impacts include inadvertent weather modification (fogging, icing, cloud formation, and increased precipitation) and mixing of tower and chimney stack plumes. Preliminary results include mixing of chimney and tower plumes. Increasing acidity of a drop was associated with progressively smaller drop size. (ND)

<78>

Precipitation in the Environment of Wet Cooling Towers.
Z. Meteorol. 27(6):366-377; ANL-Trans-1134, 22 pp.
1977
Marquardt, W.; Ihle, P.

The release of droplets from wet cooling towers and the precipitation due to condensation from cooling tower plumes can have an unfavorable effect upon the environment. Precipitation from cooling towers is a potential hazard to the safe operation of electric power lines and to road traffic. The experimental, theoretical, and statistical analysis of precipitation emitted from cooling towers is discussed. For the determination of even very small amounts of precipitation (down to 0.02 mm/h) the so-called acetone method was further developed. This method is based on conductivity measurements. In a field consisting of four cooling towers precipitation measurements were made. From these experiments conclusions on the intensity and the range of precipitation were obtained. On the average, the maximum of precipitation was observed at distances between 2 and 4 cooling tower heights. The position of the precipitation maximum originating from the superposition of several cooling tower plumes depends on the wind speed. There is a satisfactory agreement between the theoretical precipitation intensities for variable air temperatures and humidities and experimental data. From these investigations and the statistical analysis of meteorological observations, the frequencies of the occurrence of cooling tower precipitation and the frequencies of certain precipitation thresholds being exceeded as a function of direction and distance are obtained. The presentation of the frequencies of excess intensities are important for an optimum design of cooling towers, overhead line switch installations, and safety on roads. In the inland flat country of the GDR there is a minimum number of excess frequencies to the NW and S of cooling towers.

<79>

Cooling-Tower Experience and the Meteorological Consequence of Thermal Discharges from Nuclear Power Plants in the Federal Republic of Germany.
IAEA-SM-187/23; Environmental Effects of Cooling Systems at Nuclear Power Plants, Proceedings of a Symposium, Oslo, August 26-30, 1974. International Atomic Energy Agency, Vienna, (pp. 85-98), 830 pp.
1975
Bartels, H.; Caspar, J.W.
Deutscher Wetterdienst, Offenbach/M., Germany

A summary is given of studies made of the form and extent of thermal discharges in relation to the atmospheric conditions. The prevailing local meteorological conditions are of great importance for siting nuclear power plants. Apart from the dissipation of radioactive substances, they influence the local climate by heat released by the cooling systems. Therefore, sites are investigated in the Federal Republic of Germany before a power plant is planned and constructed. The measuring techniques are described and some examples are given of the results obtained by means of numerical models of the meteorological effects, in particular the extent of the changes of air temperature, air humidity, shadows due to clouds, and precipitation depending on the site and type of cooling tower. (Auth)

<80>

Effects of Wet Cooling Towers on Weather and Climate.
Energiewirtschaffliche Tagesfragen 27(5):343-346
1977
Faust, R.
Deutscher Wetterdienst, Wetteramt, Essen, Germany

Current knowledge indicates that wet cooling towers, up to 3, 000 MW, do not cause deleterious consequences for the environment. This is also valid for the concentration of several cooling towers of comparable size. Small changes of individual meteorological elements in the immediate neighborhood can no more be considered a hazard for the environment than negligible increases of temperature and rainfall in large cities and industrial agglomerations. Evaluating waste heat emission of large cooling towers set up in a flat, well ventilated terrain should not be considered as an important part in the official licensing procedure, instead the time consuming efficiency calculations should be evaluated only in individual cases or with especially unfavorable ground conditions. Climatic effects of a larger extent cannot be excluded if by application of higher cooling towers and concentration of groups of power stations the energy supply to the atmosphere occurs on larger areas and with higher vertical energy flows. Until now, the long-term effects on the regional climate which may arise as a consequence of the vapor release of a larger number of wet cooling plants by a change of the low-energy radiation conversion in the atmospheric boundary layer, could not be assessed. By this mechanism the assessment of lasting changes of the temperature level, the atmospheric stratifications, and the cloud climatology will be possible by means of variations of the conditions of insulation and emission of radiation. (Auth)(ND)

<81>

The Influence of a Power Station on Climate-A Study of Local Weather Records.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135 pp.; Atmospheric Environment 8(4):419-424
1973
Martin, A.
Scientific Services Department, Midlands Region, Nottingham, England

Local weather records collected near the 2000 MW Ratcliffe Power Station with eight natural draft cooling towers have been examined to see if any climatic effects due to the power station could be detected, for the four years of its operation so far. It was concluded that the emissions from the station have not affected the values of total rainfall, hours of bright sunshine, or incidence of morning fog recorded by climatological stations at distances of 4 km (the nearest station) and higher from the station. Fogs in the area have been decreasing over recent years, and in a town this is related to the decrease in domestic smoke concentrations. The frequency of fogs in a country district is already low and is not affected by variations in the low smoke concentrations there. (Auth)

<82>

Precipitation Studies Around Plant Bowen.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 9-40), 320 pp.; ORNL/TM-6248;
1978
Patrinos, A.A.; Chen, N.C.J.; Miller, R.L.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Department of Energy

The Nuclear Research and Applications and the Biomedical and Environmental Research Divisions of the Department of Energy are sponsoring a program called METER (Meteorological Effects of Thermal Energy Releases) to investigate the atmospheric effects of the heat and moisture releases from large cooling towers and ponds. The ORNL portion of the program deals with a precipitation modification study around Plant Bowen in northwest Georgia which utilizes four natural draft cooling towers. The study is composed of two parts: (1) the statistical analysis of historic National Weather Service climatological data from the general area of the plant and (2) a field study involving, primarily, a high-density recording rain-gage network. Both parts are aimed toward obtaining quantitative estimates of potential plant-induced precipitation augmentation and storm pattern disruption. A timetable of field study activities is given. (Auth)(ND)

<83>

Weather Modification and Cooling Towers - Evaporative Cooling Towers General.
Inadvertent Weather Modification, G.L. Wooldridge and D.F. Peterson (Eds.), Proceedings of a Workshop, Logan, UT, August 13-31, 1973. National Science Foundation, American Society of Civil Engineers, New York City, NY, and American Meteorological Society, Boston, MA, (p. 43-44), 330 pp.; PB-242 158;
1973
Hosler, C.L.
The Pennsylvania State University, University Park, PA

The environmental impacts of evaporative cooling systems are determined primarily by the elevation at which the water vapor is injected into the atmosphere, and the capacity of the atmosphere in the area for absorbing this rate of water injection. Plume rise formulae have been shown to give reliable estimates when compared with field observations. Drift and climatological data and estimates of water vapor additions can be used to speculate whether or not condensation or visible plume will occur at that point. Accuracy within a factor of five would be fortunate. (ND)

<84>

Potential Weather Modification Caused by Waste Heat and Moisture Release from Large Dry Cooling Towers.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-28, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 89-96), 120 pp.
1978
Lee, J.L.
Argonne National Laboratory, Energy and Environmental Systems
Division, Argonne, IL

A numerical model of a cooling tower plume was employed to study the possible atmospheric effects of thermal plumes from natural draft dry cooling towers. Calculations were performed for both single and multiple towers, each tower capable of dissipating the waste heat from a nominal 100 MWe LWR unit, and the results were compared with those from wet cooling towers associated with plants of the same generating capacity. It was found that dry cooling tower plumes have a higher potential for inducing convective clouds than wet cooling tower plumes under most summertime meteorological conditions. This result was due to the fact that both the sensible heat and momemtum fluxes from a dry tower in summer were approximately one order of magnitude larger than those from a wet cooling tower. These larger fluxes overcome the additional moisture impulse from the wet cooling tower primarily due to larger flux densities. The use of a combination of dry and wet towers eliminates most of the environmental problems associated with the individual tower types. (Auth)(ND)

<85>

Report on ATDL Research on Meteorological Effects of Thermal Energy Releases, August 1, 1976-September 31, 1977.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 69-132), 320 pp.; ORNL/TM-6248;
1978
Hanna, S.R.; Rao, K.S.; Hosker, R.P. Jr.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

The results of several NOAA studies concerning meteorological effects of thermal energy releases are summarized. The ATDL plume and cloud growth model was applied to new sets of data from four separate sites and was applied to contrived data as a part of a sensitivity study. An experimental program was conducted in which time lapse photographs of cooling tower plumes in Oak Ridge, Tennessee, and Paradise, Kentucky, were taken and analyzed to determine the magnitudes of secondary motions. Plume rise cross-sections were drawn and analyzed using raw data from the Chalk Point cooling tower. (ND)

<86>

Influence of Water Cooling Towers on Formation of Mist and Clouds.
Energie und Technik 23(3):87-89, 23(4):112-115; OLS-78-485, 10 pp.; OLS-78-486, 11 pp.;
1971

Henning, H.; Kliemann, S.
Entwicklund und Versuche Kuhlturmtechnik der MAG Balcke

The causes of fog and drift production from the operation of wet cooling towers are discussed. Causes of precipitation and fog formation from cooling towers are the carryover of circulating water by the cooling air, the formation of air oversaturated with water vapor when the warm saturated cooling tower plume is mixed with the colder ambient air, as well as condensation processes in the vapor cloud and in the fog plume within or outside of the cooling tower. The precipitation resulting from drift, as well as the area in which fogging is to be expected, can be calculated roughly as a function of wind conditions, the outside air condition, and the operating conditions of the cooling tower. At the present time no precise information can be given about the intensity of aftercondensation processes within and outside of the cooling tower; only the air of origin can be specified. Influencing drift and fogging through the design and operating conditions of a cooling tower is only possible within very narrow limits because of economic considerations. Drift can, however, be decisively decreased by the installation of drift eliminators. Since in general the pressure drop of a drift eliminator rises with the improvement of the degree of separation, a complete elimination of drift is not conceivable for economic reasons. The development of a combination of wet cooling tower and dry cooling tower seems to present new possibilities for influencing fogging on the cooling tower mouth and thus also aftercondensation processes. The only tested and successful measuring devices for checking published guarantees with relation to drift are the throttle calorimeter of TUV Essen e. V. and the measuring cyclone of MAG Balcke. Measurements to determine the quantity of precipitation in the environs of the cooling tower are interesting from the point of view of environmental protection, but the measuring methods known to date are not suitable for checking guarantees. (ND)

<87>

Moisture Pollution of the Atmosphere by Cooling Towers and Cooling Ponds.
Bulletin American Meteorological Society 51(1):21-22
1970
Hewson, E.W.
Oregon State University, Department of Atmospheric Sciences,
Corvallis, OR

The possible meteorological problems presented by cooling towers and cooling ponds are discussed, including reduced visibility (fog), increased precipitation, increased humidity, increased wetting and icing, reduced sunshine, altered temperature and wind patterns, and polluted atmosphere. Valley, shoreline, and urban modifications of the above plume effects are noted. It will not be possible to determine whether the possible meteorological problems are insignificant or important in any given situation without additional research. (ND)

<88>

Weather Modification and Cooling Towers - Inadvertent.
Inadvertent Weather Modification, G.L. Wooldridge and D.F. Peterson (Eds.), Proceedings of a Workshop, Logan, UT, August 13-31, 1973. National Science Foundation, American Society of Civil Engineers, New York City, NY, and American Meteorological Society, Boston, MA, (p. 37-40), 330 pp.; PB-242 158
1973
Hosler, C.L.
The Pennsylvania State University, University Park, PA

Meteorological impacts from heat dissipated by urban areas and power plants include fog enhancement, and precipitation enhancement. There has been a significant increase in the scope of observational programs which have been instituted to delineate the degree to which man is inadvertently modifying the weather. These effects may not all be disastrous, or undesirable, but they should be better understood so that they might either be eliminated or used to advantage. (ND)

<89>

The Effect of Localized Man-Made Heat and Moisture Sources in Meso-Scale Weather Modification.
Energy and Climate, Studies in Geophysics, Geophysics Study Committee. National Academy of Sciences, (p. 96-105), 172 pp.
1977
Hosler, C.L.; Landsberg, H.E.
The Pennsylvania State University, University Park, PA
University of Maryland, College Park, MD

Agricultural changes and urbanization have led to meso-scale climatic changes in rainfall, thunderstorm activity, and hail incidences. Similar changes have been indicated for the atmospheric heat and moisture releases by large power plants and power parks. The net effect of dry and wet cooling towers or cooling ponds on downwind convection is similar in most cases. Vapor plumes from evaporative cooling towers have a direct effect on atmospheric convection and an indirect effect of raising the humidity in downwind of the plant, which in turn will reduce the evaporation rate for precipitation falling from cloud bases higher than the plume. Plume visibility and persistence depends heavily on site and weather conditions. Studies performed at the Keystone power plant in Pennsylvania are reviewed. The altitude at which the water vapor is injected significantly affects the plume persistence and fogging. Cooling ponds and mechanical draft towers almost certainly produce large amounts of fog downwind. Drift from evaporative towers can cause additional impacts on area vegetation. A more comprehensive investigation and understanding of the consequences of man's activities is warrented. (ND)

<90>

Preliminary Report: Effect of Cooling Tower Effluents on Atmospheric Conditions in Northeastern Illinois.
Illinois State Water Survey, Circular 100, 37 pp.
1971
Huff, F.A.; Beebe, R.C.; Jones, D.M.A.; Morgan, G.M. Jr.;
Semonin, R.G.
State of Illinois, Department of Registration and Education, Urbana,

A two month investigation to assemble and evaluate information on the potential effects of cooling tower effluents on atmospheric conditions with major emphasis on the Zion installation was performed. The preliminary investigation was restricted to an extensive literature survey of existing information on the topic, and limited in-house research involving studies of meteorological factors pertinent to evaluation of the cooling tower problem. These include (1) determination of the relative magnitude of heat and moisture outputs that would be associated with the towers, (2) the potential weather effects from interaction between the lake breeze and cooling tower plumes, and (3) application of existing cloud modeling techniques to aid in evaluating the potential for tower plumes to initiate, trigger, or intensify the development of clouds and precipitation downwind of the Zion plant. The literature search revealed a lack of information on the subject. The study showed that the heat and moisture releases from the cooling towers represented a strong potential for affecting the local weather (intensify cloud processes, precipitation, or other natural weather events). From the examination of the known meteorological characteristics of the lake breeze circulation, it was concluded that plume interactions would likely result in some additional snowfall or fog. Only very occasionnally would a weather situation exist in which convective storms could be intensified by the lake-breeze-tower plume interaction. Numerical cloud modeling techniques employed to gain additional information on meteorological consequences supported the study results. However, these must be considered approximations only, in view of the limitations in the theory involved both in current cloud models and in the interaction between cooling tower plume and the atmosphere. (ND)

<91>

Atmospheric Effects from Waste Heat Transfer Associated with Cooling Lakes.
NSF GI-35841, 89 pp.
1973
Huff, F.A.; Vogel, J.L.
University of Illinois, Illinois State Water Survey, Urbana, IL

An investigation was made of the potential effects of cooling lakes on weather conditions in the vicinity of large power plants. The first phase involved detailed climatological analyses of the natural distribution of fog and related atmospheric elements whose modification by cooling lakes could conceivably lead to significant local changes in the distribution of fog, clouds, and, possibly, precipitation. The second phase involved preliminary numerical modeling and development of techniques to obtain first approximations of the potential changes in the frequency, intensity, duration, and extent of fog and clouds that might be induced from heat and moisture changes between cooling lakes and the atmosphere. The second phase was concerned also with evaluating deficiencies in current technology and developing recommendations to overcome the deficiencies so as to provide more reliable calculations of cooling pond effects in the future. Major emphasis was placed upon the fog problem, since it appears to be the most important environmental effect that would be associated with cooling lakes. The study results are based primarily upon Illinois data. However, because of the large variability of climate within its borders, the results derived from Illinois data should be generally applicable to the Midwest and other areas of similar climate. The study showed that the potential for producing heavy fog was highest for the hot pond (69-104 degrees F) and lowest for the cold pond. Icing potential was less than the fogging potential with the hot pond again showing the highest potential. The major fog problem was that of initiation not enhancement. The modeling experiment indicated that, under admittedly extreme conditions, the cooling pond might act as an initiator of some cumulus during the early part of the convective periods, but will have its major effect on the enhancement of cumulus clouds when the atmospheric conditions of the lower 3,000 ft of the atmosphere are near saturation. These investigations revealed definite deficiencies in our knowledge with respect to many of the pertinent physical processes associated with the heat and moisture output to the atmosphere from cooling ponds. Specific areas of research are listed and discussed. (ND)

<92>

On Possible Atmospheric Effects of Heat Rejection from Large Electric Power Centers.
R-1628-RC, 40 pp.; AD-A021-745
1974
Koenig, L.R.; Bhumralkar, C.M.
Rand Corporation, Santa Monica, CA

An assessment was made of potential atmospheric effects that might be caused by the dissipation of waste heat into the air from large electric power generating complexes. The assessment was based on three components: (1) an estimate of the thermal and moisture perturbation on the atmosphere (including shadowing, drift deposition, fogging, precipation or weather modification) that might be expected from power generating facilities, (2) a search for observations of how nature responds to perturbations of this kind (using evidence from heat island effects, urban effects, and forest fires), and (3) interpretation of numerical experiments dealing with atmospheric processes using similar pertubations. It was concluded that there is a strong possibility that large power complexes (20,000 MWE) will cause unacceptable disturbances in the atmosphere, such as modification of rain and cloudiness patterns. If this is true, then it follows that selective initiation of severe weather events will also occur. This work was exploratory, and avenues for more complete study are suggested. (ND)

<93>

Influence of Cooling Ponds on the Initiation of Cumulus Clouds.
American Geophysical Union 54th Annual Meeting, Proceedings of a Symposium, Washington, DC, April 16-20, 1973; Transactions American Geophysical Union 54:284;
1973
Ochs, H.T. III
Illinois State Water Survey, Urbana, IL

A time dependent numerical model of atmospheric convection was used for this study of cooling ponds. The model depicts convection in two dimensions (3.2 km in the vertical and 6.5 km in the horizontal) and condenses any water in excess of saturation. If necessary, cloud water is evaporated to maintain saturation within the bounds of a cloud. Various horizontal wind shears are used with central Illinois soundings on days for which small fair weather cumulus clouds were observed. A pond such as those used by many power plants for waste heat disposal is imposed at the lower boundary. The pond is 900 meters wide and typical data is used to specify its temperature and the hourly trend of the excess mixing ratio just above its surface. The mixing ratio at the ground to both sides of the pond is fixed while the temperature follows average diurnal trend data for central Illinois. Integration of the model is begun at 1030 hours and the ponds effect on initiation of cumulus clouds is investigated in a qualitative manor. (Auth)

<94>

Energy and the Weather.
Environment 15(8):4-9
1973
Peterson, J.T.
U.S. Environmental Protection Agency, National Environmental Research
Center, Research Triangle Park, NC
National Oceanic and Atmospheric Administration

Man-made heat emissions coupled with a surface change from vegetation to building materials are altering the climate on a local scale. Man has concentrated his use of energy over certain rather small areas of the earth. Cooling towers are prime examples of large, intense sources of heat and moisture, liberating 10,000 watts per square meter over a small area. Cumulus cloud formation and precipitation enhancement are meteorological impacts from such structures. The significance of cooling towers will not be clarified until more studies are made. Urban heat island effects are discussed in relation to local, intermediate, and global-scale effects. Additional research and modeling is recommended to evaluate the problem. (ND)

<95>

An Observation of Cooling Tower Plume Effects on Total Solar Radiation.
Atmospheric Environment 12:1223-1224; University of Michigan, Department of Atmospheric and Oceanic Science Contribution No. 243
1978
Ryznar, E.
University of Michigan, Department of Atmospheric and Oceanic Science,
Ann Arbor, MI
Consumers Power Company, Jackson, MI

Measurements of total solar radiation were made on March 7, 1977. The sky was cloudless but a cooling tower plume occasionally came between the sun and the pyranometer that was used. These measurements resulted in values that were greater than those expected with a cloudless sky. It is likely that reflections from the plume, whose average position was slightly north of an imaginary sun-pyranometer line, were responsible. (Auth)

<96>

Meteorology and Cooling Tower Operation.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135 pp.; Atmospheric Environment 8(4):321-324
1973
Spurr, G.
Central Electricity Generating Board, London, England

The climatic aspects have been studied at several of the many cooling tower stations in the U.K. Provided natural draft towers are designed properly and well maintained the impact of their operation has been found to have a negligible effect on the local climate. A saltwater tower station has also operated for many years with negligible effects. A persistent elevated plume, which occurs under conditions of high ambient relative humidity and aggravates the adverse visual impact of the large bulk of the cooling towers themselves, appears to be the most objectionable atmospheric feature. (Auth)(ND)

<97>

Cooling Tower Study.
APTD-0702, 123 pp.; PB-210 216, 123 pp.
1971
Stockham, J.
IIT Research Institute, Chicago, IL
U.S. Environmental Protection Agency, Durham, NC

The potential effects of emissions of water vapor and heat from natural draft cooling towers on the local environment, climate and nearby electrical power station emissions are described and evaluated. Field tests were conducted at the Keystone generating station near Shelocta, Pennsylvania. Observations and measurements were made intermittently during September, November, and December 1969. The Keystone plant produced no increases in fog, drizzle, cloud formation or rainfall during the observation period. The visible portion of the tower plume normally rose to an altitude of less than 200 meters and traveled downwind about 200 meters before evaporating. However, the dimensions of the visible portion of the plume were greatly dependent on the temperature and humidity of the air.

<98>

Measurements of Precipitation Downwind of Cooling Towers.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135 pp.; Atmospheric Environment 8(4):373-381
1973
Martin, A.; Barber, F.R.
Scientific Services Department, Midlands Region, Nottingham, England

Droplets of water falling from cooling tower plants have been collected on water-sensitive papers around several power stations at various distances and in different weather conditions. Details are given of the deposition rates and drop sizes found in particular cases. Before the Ratcliffe towers were modified, road-wetting was observed, both on- and off-site, from this carryover water. Bulk samples of the drizzle were collected for chemical analysis when the deposition was heavy, to compare with the tower water and with natural rainfall. After the Ratcliffe tower eliminators were modified, the deposition was considerably reduced and road-wetting could no longer be detected. The deposition-humidity relationships found indicate that road wetting is now unlikely to occur. (Auth)

<99>

Environmental Effects of Nuclear Cooling Facilities.
Bulletin American Meteorological Society 51(1):23-24
1970
Lowry, W.P.
Oregon State University, Department of Atmospheric Sciences,
Corvallis, OR

Forseeable but not quantifiable environmental effects of nuclear cooling facilities, i.e. fogging, are discussed. Cooling towers and ponds, by nature, introduce an extra burden of water vapor into the free air near the facility. Fog formation depends in a complex way on the temperature, moisture and wind conditions in the free air surrounding the facility. Under the climatic conditions of western Oregon, a significant fraction of the days of each year fall in the middle of the spectrum of uncertainty, thereby representing a potential or latent fogging problem. Meteorological research programs are now underway to develop and test theory with which to predict the various dimensions of the fogging and the wet plume from cooling towers. (ND)

<100>

Formation of Fog and Glazed Frost due to Cooling-Tower Operation.
Technische Mitteilungen 65(5):230-236
1972
Bach, H.
Deutscher Wetterdienst, Wetteramt, Essen, Germany

Fog and glazed ice formation under natural conditions and under conditions found in the vicinity of cooling towers is reviewed. Fog formation is not significantly increased by cooling tower operation but the number of icing incidents may be increased, depending on parameters such as droplet radius, temperature, relative humidity, and maximum distance from the cooling tower. Increased fog formation in the cooling tower vicinity is attributed to water vapor condensing in cold air and to losses by evaporation. It is especially noticeable during conditions of weather inversions and can be controlled by the use of tall cooling towers rather than low ones. The precipitation around cooling towers can be effectively controlled by drift eliminators. The maximum amount of potential precipitation can be lowered significantly by the use of natural draft cooling towers rather than fan-assisted cooling towers. The total area of precipitation ice formation around cooling towers is subsequently increased. The distance to which precipitation is possible is limited by the evaporation of the farthest airborne droplet. (Auth)

<101>

Behavior of Visible Plumes from Hyperbolic Cooling Towers.
Proceedings American Power Conference 38:732-739; American Power Conference, Proceedings of a Symposium, Chicago, IL, April 22, 1976, 22 pp.
1976
Brennan, P.T.; Smith, M.E.; Kramer, M.L.; Reeves, R.W.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation, Canton, OH

Airborne measurements programs were conducted at five generating stations in West Virginia, Ohio, and Kentucky, between November 1973 and March 1976. An accurate prediction of plume rise and persistence was made based on two parameters: the ambient saturation deficit and the capping inversion height. A relationship between plume rise and wind speed, or between surface temperature and either plume rise or length was not found. Only two important environmental effects were found: (1) visible plumes sometimes caused shadowing, and (2) light snow fell on ten occasions under the plumes. Other postulated effects (downwash, fogging, and icing) were not found during the test. It was noted that wind speeds in excess of 40 miles per hour were required to transport water droplets away from the towers. (ND)

<102>

Rainfall Enhancement Due to Scavenging of Cooling Tower Condensate.
BNWL-2295, 41 pp.
1977
Dana, M.T.; Wolf, M.A.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Energy Research and Development Administration

The question of precipitation scavenging of condensate droplets by natural precipitation, and the resulting enhancement of precipitation under the plume is considered theoretically. Estimates of rainfall enhancement resulting from scavenging of cooling tower condensate droplets were made using relevant aerosol scavenging theory and a range of meteorological conditions. For a large natural draft tower, releasing 1.7 x 10(E+5) g/sec of condensate, plume centerline rainfall enhancement is predicted to be measurably high at downwind distances between 100 m and 1 km for moderate wind speeds and rainfall rates. The cumulative removal of condensate by scavenging should be significant, even in a light rain (1 mm/hr) , where removal half-distances are predicted to be 2.5, 10, and 20 km for wind speeds of 1, 5, and 10 m/sec, respectively. (Auth)(ND)

<103>

Rainfall Enhancement Due to Scavenging of Cooling Tower Condensate.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 273-297), 320 pp.; ORNL/TM-6248;
1978
Dana, M.T.; Wolf, M.A.
Battelle Pacific Northwest Laboratories, Atmospheric Sciences
Department, Richland, WA
Oregon State University, Air Resources Center, Corvallis, OR

The question of precipitation scavenging of condensate droplets by natural precipitation and the resultant enhancement of precipitation under the plume is considered theoretically. The interaction between raindrops and condensate cloud droplets, generally called 'below-cloud' scavenging or 'washout'. Currently accepted below-cloud scavenging theory were used to estimate for somewhat ideal cases the degree of potential rainfall enhancement. Comments regarding the efficacy of this approach and recommendations for experimental evaluations and other calculations are provided. (ND)

<104>

Rainfall Enhancement Due to Washout of Cooling Tower Condensate.
Pacific Northwest Laboratory Annual Report for 1977 to the DOE Assistant Secretary for Environment, Part 3 Atmospheric Sciences, C.L. Simpson et. al., (p. 2.39-2.40), 200 pp.; PNL-2500 PT3
1978
Dana, M.T.; Wolf, M.A.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy

Theoretical calculations of the washout of cooling tower condensate droplets by frontal raindrops show that rainfall enhancement can be significant and is measurable under typical meteorological and cooling tower effluent source conditions. For the case of moderate rainfall rates and a wind speed of 5 m/sec, centerline rainfall enhancement was as much as 46%, cross-plume average enhancement as much as 7%, and distance to one-half depletion of the source 1 to 10 km. (Auth)

<105>

Potential Augmentation of Precipitation from Cooling Tower Effluents.
Bulletin American Meteorological Society 53(7):639-644
1972
Huff, F.A.
Illinois State Water Survey, Urbana, IL
National Science Foundation

A summary of present knowledge on the effects of waste heat and water vapor discharged from large cooling towers on augmentation of the natural precipitation downwind of such installations is presented. Available information is used to provide some insight into the potential quantitative effects. Major emphasis is placed upon midwestern conditions where a recent study has been made and upon effects from wet-type natural draft towers. It is concluded that atmospheric scientists have not acquired adequate information at this time to define in quantitative terms the meteorological consequences of the large amounts of heat energy and water vapor released into the atmosphere from cooling towers associated with large power plants, and that atmospheric research should be initiated at once to alleviate the lack of knowledge on this pertinent environmental problem. Some basic recommendations for the type and duration of needed research are presented. (Auth)(ND)

<106>

Local Precipitation Increases Caused by Scavenging of Cooling Tower Plumes.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 263-272), 320 pp.; ORNL/TM-6248;
1978
Koenig, L.R.
Rand Corporation
U.S. Department of Energy

The question of whether or not local rain rates can be increased by scavenging in cooling tower plumes is considered. Quantitative estimates are provided of the precipitation increase in the vicinity of wet cooling towers as a result of plume-droplet scavenging by natural rain. Rain rates from 1 to 5 mm/hr and wind speeds of 1 to 10 m/s are considered with source strength equal to moisture flux from a 1000-MW(e) power capacity. The increase in precipitation strongly depends on distance from the tower, wind speed, natural precipitation rate, source strength, and horizontal angle of plume spread. Under favorable conditions of light winds and steady rainfall, precipitation increases due to scavenging up to about 25% of the natural rate should occur as far as 1 km from plants as small as 1000 MW(e). (Auth)(ND)

<107>

Precipitation from Cooling Towers in Cold Climates.
PB-192 626, 30 pp.; Fluid Mechanics Laboratory Publication No. 707
1970
Overcamp, T.J.; Hoult, D.P.
Massachusetts Institute of Technology, Fluid Mechanics Laboratory,
Department of Mechanical Engineering, Cambridge, MA

A model is proposed for determining the conditions under which precipitation can occur from a natural draft cooling tower. Because the time scale for forming raindrops is large compared to the average residence time of droplets in the plume, there is no precipitation unless the plume mixes with the aerodynamic wake of the tower and is brought to the ground. When this occurs, the small fog droplets in the plume will diffuse to the ground causing a light precipitation. In cold climates, this could freeze on the ground and be hazardous for travel. A simple theory gives the heat transfer and the flux of water vapor emitted by the cooling tower. Equilibrium thermodynamics of mixing processes are used to calculate how much water vapor condenses as the plume is diluted with the surrounding air. Scaled experiments in a towing tank defined, in dimensionless variables, the conditions under which the plume will interact with the wake and strike the ground. A turbulent diffusion model combined with the thermodynamics of mixing is used to estimate the precipitation. These calculations showed that precipitation will only be significant in cold weather when it can be a tenth of a centimeter per hour. (Auth)

<108>

Rainfall Enhancement Due to Scavenging of Cooling Tower Condensate.
Prepared by Dana, M.T. and Wolf, M.A., Battelle Pacific Northwest Labs. for U.S. Energy Research & Development Administration, Sept. 1977. 50 pp.

Report examines the effect that large releases of water vapor and condensate from cooling towers have on the atmosphere in the immediate vicinity of a power plant. In particular, the interaction between raindrops and condensate cloud droplets, and the resulting enhancement of precipitation (via scavenging) under the plume are considered. The calculations of condensate droplets scavenging and estimates of rainfall enhancement were obtained for a model natural- draft cooling tower 150 m in height with a mouth diameter of 80 m. Geometric and source data were applied to major meteorological variables such as wind speed, rainfall rate, and raindrop size. Results predict that rainfall enhancement will be measurably high at downwind distances between 100 m and 1 km for moderate wind speeds and rainfall rates. The effect of enhanced rainfall on plume shape and extent is also discussed. Six tables, 11 figures, 2 appendices, and references are included.

<109>

Differences in Atmospheric Convection Caused by Waste Energy Rejected in the Forms of Sensible and Latent Heats.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p.168-183), 320 pp.; ORNL/TM-6248;
1978
Koenig, L.R.; Murray, F.W.; Tag, P.M.
Rand Corporation
Naval Environmental Prediction Research Facility
U.S. Department of Energy

The relative atmospheric effects caused by heat rejection in the sensible and latent forms were examined in order to provide information regarding the relative merit of wet and dry cooling towers with respect to cloud-scale atmospheric effects. A two-dimensional field-of-flow model of atmospheric convection was used to simulate heat rejection. The tentative conclusion indicated that it is unwise to assume that more costly dry rather than wet cooling towers will prove to be more acceptable from all environmental points of view. Dry towers would eliminate shadowing and drift that commonly occur at wet cooling tower sites, their use would increase the likelihood of atmospheric effects in the form of convective cloud initiation and associated effects such as rain anomalies. A cooling system rejecting solely latent heat might be ideal to minimize atmospheric effects, but such a device is not available to industry. A cooling pond may be a close substitute. (ND)

<110>

Analysis of Atmospheric Effects of Evaporative Cooling Systems, Quad Cities Nuclear Generating Station.
McVehil, George E., Sierra Research Corp., Mar. 1971. Appendix B, Environmental Impact Report: Supplemental Information to the Quad Cities Environmental Report, Commonwealth Edison Co., Nov. 1971. 50 pp.

Report presents a description and results of a study to determine likely environmental effects of evaporative cooling systems that could be used at the Quad Cities power station in Rock Island County, IL. The cooling systems considered in this analysis were mechanical draft cooling towers, natural draft (hyperbolic) cooling towers, and spray canals. Natural and mechanical draft cooling tower effects were analyzed with quantitative dispersion models, developed to predict the behavior of effluent air from cooling towers in various weather conditions. Local meteorological data were utilized, with results of the modeling calculations, to estimate the frequency of occurrence of ground fog and visible plumes. Spray canal effects were estimated as to potential fogging, icing and cloud formation. Report includes 10 references, 13 tables, and 3 figures.

<111>

Evaluation of Environmental Effects of Evaporative Heat Dissipation Systems at the Palisades Plant.
Koss, T.C.; Altomare, P.M., NUS Corp., Rockville, MD. Appendix A, Palisades Plant Environmental Report Supplement, Consumers Power Co., May. 1971. 93 pp.

Appendix presents an evaluation of the environmental effects of alternative evaporative heat dissipation systems for the Palisades power station in Van Buren County, MI. Two heat dissipation systems have been examined in this study: a mechanical draft cooling tower, and a natural draft cooling tower. To examine what effects the quantities of water evaporated from these systems might have on the local environment, meteorological data for the area have been examined to determine the probable frequency of occurrence of increased fog and icing conditions and the frequency of occurrence of a visible plume over the area. In Section II, the site area is described, and areas which might be affected by various heat dissipation system operations are identified. In Section III, the meteorology in the area of the Palisades station is discussed, along with the identification of conditions which are conducive to natural fog occurrence. In Section IV both systems are described, and the analytical methods for determining plume rise and vapor plume dispersion are summarized. The environmental effects which the operation of the 2 systems will have on the area are discussed in Section V. Report includes 19 figures, 9 tables, 1 appendix, and 29 references.

<112>

Atmospheric Effects of Alternative Cooling Systems.
Appendix 10B, Clinton Power Station Units 1 & 2 Environmental Report. Illinois Power Co., Oct. 1973. 24 pp.

Appendix analyzes atmospheric effects, including fogging, icing, and clouding of the cooling system alternatives (natural- and mechanical-draft evaporative cooling towers and sprays) for the Clinton plant. Report reviews the climate of the Clinton site and the sources of climatological data; describes the methods used for estimating effects of mechanical-draft towers; and explains the computations for natural-draft towers. Evaluation of all cooling alternatives assumes continuous station operation at full load. Appendix contains 5 tables and 1 figure.

<113>

Analysis of Atmospheric Effects of Evaporative Cooling Systems.
TR-0853, 60 pp.
1971
McVehil, G.E.

Sierra Research Corporation, Environmental Sciences Group, Boulder, CO
Commonwealth Edison, Co.

A study to evaluate the environmental effects of evaporative cooling systems that could be used at Commonwealth Edison Company's Quad-Cities Nuclear Generating Station was performed. The cooling systems considered in this analysis were mechanical draft cooling towers, natural draft (hyperbolic) cooling towers, and spray canals. Natural and mechanical draft cooling tower effects were analyzed with quantitative dispersion models developed to predict the behavior of effluent air from cooling towers in various weather conditions. Qualitative estimates of spray canal effects were obtained by sample calculations and reference to the cooling tower results. The results indicated that mechanical draft cooling towers would cause ground fog somewhere around the plant on up to 490 hours per year. Natural draft cooling towers were expected to produce fog at the ground on far fewer occasions: 12 to 30 hours per year total in all directions. Elevated plumes from natural draft towers would frequently extend for long distances, however it is estimated that they would equal or exceed 5 miles in length for approximately 7% of the time, or 620 hours per year. Observable changes in cloud cover, precipitation, or storm frequency and severity in the vicinity of the plant were not considered likely. However, the possibility of extremely small effects on local clouds and weather could not be ruled out. Spray cooling systems appeared to have less potential for fog and icing problems than mechanical draft towers in weather situations with moderate or strong winds. However, experience with large spray systems was non-existent, and operation of large spray fields in light wind conditions was not well understood. A possibility of severe fogging problems at these times exists. No firm conclusions on overall environmental effects of such a system at Quad-Cities could be drawn at this time. (ND)

<114>

Computer Simulation of Atmospheric Effects of Waste Heat Rejected from Conceptual Large Power Parks.
American Society of Mechanical Engineers Winter Annual Meeting, Proceedings of a Symposium, New York City, NY, December 5, 1976; ASME Paper No. 76-WA/HT-20, 8 pp.
1976
Bhumralkar, C.M.
Stanford Research Institute, Menlo Park, CA

Proposals to install large power complexes at single site (generating capacity 10,000 to 50,000 MWe) raise concern for the inadvertent weather modification by the attendant effluents. A mesoscale model which was specifically designed to simulate the inadvertent modification of the atmosphere caused by localized perturbations of heat and/or moisture, has been applied to a hypothetical development at a site near Baton Rouge, Louisiana. Numerical experiments have been performed to determine the relationships between local factors, and the resultant atmospheric effects. Evaluation of the preliminary results indicates that the model's treatment of the temperature and moisture perturbations caused by natural draft wet cooling towers is realistic and physically consistent. The preliminary results also provide clear indication that significant weather modification can result from the type of power park development proposed. It is believed that the model, with further refinement, can make vital and valuable contributions to the design of the facilities for disposing waste heat at large power complexes. (Auth)

<115>

Weather Modification Caused by Waste Heat Rejected into the Atmosphere from Cooling Towers at Large Power Parks.
Atmospheric Turbulence, Diffusion and Air Quality, Proceedings of the Third Symposium, Raleigh, NC, October 19-22, 1976. American Meteorological Society, Boston, MA, (p. 581-585), 600 pp.
1976
Bhumralkar, C.M.
Stanford Research Institute, Menlo Park, CA

Study results showed that a 'real' modification of atmosphere can be expected if power complexes such as those proposed in Louisiana, Florida, or Pennsylvania are constructed. The results presented here are preliminary, and it is evident that further scientific research is necessary before the problem can be evaluated adequately. Further refinement and modification of the existing model to include third-space dimension should enable the determination of power complex siting criteria in terms of: (1) the type of cooling towers used (wet/dry, natural/mechanical draft); (2) the number and size of cooling towers at a single site; and (3) spacing and orientation of cooling towers relative to the ambient wind. It will also be possible to determine critical limits which, if exceeded, will create significant modification of weather at, and in the vicinity of, a large power complex. (ND)

<116>

Meteorological Effects of Waste Heat Rejection from Power Parks.
Power Engineering 80(8):54-57
1976
Bhumralkar, C.M.; Alich, J.A. Jr.
Stanford Research Institute, Menlo Park, CA

A numerical model was used to assess the possible meteorological effects of discharges of large amounts of waste heat from a single power park (10,000 to 50,000 MW). Preliminary results indicate that significant weather modification might result from such discharges. The model could be used to aid in the design of waste heat disposal facilities for large power complexes. It could be instrumental in determining siting criteria in terms of the type of cooling towers used, the number, and the size of cooling towers relative to the ambient wind. The model is realistic and physically consistent in its treatment of the temperature and moisture perturbations caused by natural draft wet cooling towers. Specific evaluations for the Gulf States Utilities' River Bend site are discussed. (ND)

<117>

The Problem of Cooling Tower Agglomerates from a Meteorological Viewpoint.
VDI-Berichte 298:69-73; OLS-79-49, 11 pp.
1977
Fortak, H.

The energetic and dynamic effect of cooling tower clusters on the atmosphere is related to natural atmospheric phenomena. For this purpose a simple model is used to estimate lift, vertical component of speed and ground-level wind field. Following this, the power output from the cooling towers is relayed through the air loaded by this output to a vertical cylinder in which it produces meteorological effects. Since these effects are not known, natural atmospheric phenomena are subjected to the same model concept, so that the predicted effects can be estimated by means of analogy. This is visually accomplished by developing a diagram in which the thermal power output and the emission ground surface form the coordinates. It shows that clustered sources of thermal power are to be rejected from a meteorological standpoint if certain emission limits are exceeded. An areal distribution of smaller sources (smaller than about 3000 MWe) is, on the other hand, completely safe from the standpoint of environmental protection, if appropriate distances are maintained. (Auth)

<118>

Predicted Climatology of Cooling Tower Plumes from Energy Centers.
Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1976 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 531-556), 627 pp.; ATDL-77/23; ATDL Contribution File No. 76/20; Journal Applied Meteorology 16(9): 880-887; 1977
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources

Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN

A one dimensional plume and cloud growth model is applied to four months of radiosonde observations from Nashville, using as initial conditions the plume from single large cooling towers with waste heat outputs of 10(E+3), 10(E+4), 10(E+5) MW, and a complex of cooling towers with a total waste heat output of 10(E+5) MW. Estimates of average annual plume rise from the four energy sources are 580, 1180, 2460, and 780 m, respectively. The predicted plume rise, visible plume length, and cloud formation are given as functions of time of day, year, and weather type. For example, a cloud forms at the top of the plume from the 10(E+3) MW tower in 65% of the morning soundings during which ground level fog was observed. A cloud is predicted to occur 95% of the time at the top of the plume from the single 10(E+5) MW tower. It is found that if the towers in an energy center are separated by a distance greater than the average plume rise from one tower, then plume merging is minimized. Observations from TVA's Paradise Steam Plant are used to test the predictions of visible plume length from a single 10(E+3) MW tower. (Auth)

<119>

Meteorological Effects of Energy Dissipation at Large Power Parks.

Bulletin American Meteorological Society 56(10):1069-1076; ATDL Contribution File No. 75/1, Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1975 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 17-24), 590 pp.; ATDL-76/14

1975

Hanna, S.R.; Gifford, F.A.

National Oceanic and Atmospheric Administration, Air Resources

Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN

U.S. Atomic Energy Commission

Large (10,000 to 50,000 MW) power parks are being studied as one means of satisfying the nation's demand for energy. The dissipation of waste energy from these installations may result in significant meteorological effects. It is shown that the rate of atmospheric dissipation of the waste energy from these power parks is approximately equal to the atmospheric dissipation of energy by geophysical phenomena such as thunderstorms, volcanoes, and large bushfires. Cumulus clouds and whirlwinds often result from these energy releases. There is a possibility that natural vorticity will be concentrated by large power parks. A theory of multiple plume rise is used to estimate the enhancement of plume rise from multiple cooling towers. Calculations of plume rise, ground level fog intensity, and drift deposition due to emissions from cooling towers at a hypothetical 40,000 MW nuclear power park are made. The plume rise from 50 towers is estimated to be more than 110% of that from a single tower if the tower spacing is less than about 300 m. At locations within 100 km of the cooling towers, excess fog will occur about one or two percent of the time. The vapor plume will be appreciably longer than those from present installations; for instance it should be clearly visible from earth satellites most of the time. Drift deposition of water would average about 0.4 cm/yr at distances from 2 to 4 km from the towers. Since there are no power parks of this magnitude yet in existence, there are no measurements to test these calculations. The conclusions are highly tentative and indicate that much more research is required on this subject. (Auth)

<120>

The Hanford Nuclear Energy Center Study.

CONF-760469; American Power Conference, Proceedings of a Symposium, Chicago, IL, April 20-22, 1976, 17 pp.

1976

Harty, H.

Battelle Pacific Northwest Laboratories, Richland, WA

U.S. Energy Research and Development Administration

A study of a 40 reactor and a 20 reactor Hanford Nuclear Energy (HNEC) Center was performed. Factors considered were siting, environmental effects, resource use, economics, site characteristics, safety analysis considerations, hydrology, electrical transmission, and meteorology. Analysis of meteorological effects of cooling systems from a 20 or 40 reactor NEC showed a potential for increased frequency and density of fog in the surrounding cities and highways. Cooling ponds would create the worst fogging situation because of ground level releases; widespread use of mechanical draft cooling towers was questionable for similar releases. However, the state of the art is incapable of determining the meteorological effects from massive heat releases. The following heat sink management systems were determined to be economically and environmentally feasible: 20 reactor HNEC - 6 reactors with once-through cooling, 10 reactors with tall wet cooling towers, and 4 reactors with mechanical draft towers; 40 reactor HNEC - 10 reactors with once-through cooling, 26 reactors with tall wet cooling towers, and 4 reactors with mechanical draft towers. It is believed to be unlikely that there will be a great impact for the 20 reactors at Hanford. Major technical developments in meteorology are needed before an environmental report could be prepared for an NEC. (ND)

<121>

Meteorological Effects on Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977.

ORNL/TM-6248, 320 pp.

1978

Patrinos, A.A.; Hoffman, H.W.

Oak Ridge National Laboratory, Oak Ridge, TN

U.S. Department of Energy

The Meteorological Effects of Thermal Energy Releases (METER) Program was developed in 1976 to evaluate the potential environmental effects of future nuclear energy centers. The objective of the METER program is to develop suitable methodology and supporting data for predicting the nature and magnitude of each of the meteorological effects resulting from the release of heat and moisture from cooling tower and ponds. The Program utilizes field studies, mathematical modeling, physical modeling, analog studies and predictive methods. This report contains contributions by each METER participant (Argonne National Laboratory, Oak Ridge National Laboratory, NOAA Atmospheric Turbulence and Diffusion Laboratory, Pacific Northwest Laboratories, Pennsylvania State University and Rand Corporation) describing work carried out during the period October 1, 1976 to September 30, 1977. Eleven of the chapters have been input into the data base. (ND)

<122>

Potential Weather Modification from Cooling Tower Effluents at Conceptual Power Parks.
Atmospheric Environment 11:749-759
1977
Lee, J.L.
Argonne National Laboratory, Energy and Environmental Systems
Division, Argonne, IL
Federal Aviation Administration

A numerical model for multiple plumes is developed to study the enhanced convection of merged plumes from a cluster of cooling towers at a conceptual power park. The numerical model is employed to simulate the merged plume convection from clusters of (up to 40) natural draft cooling towers, where each tower serves to dissipate 2400 MW of waste heat. It was found that the plume rise from 40 towers is predicted to be approximately 360% and 130% of that from a single tower for an average July afternoon and average January morning sounding, respectively, taken in the Louisiana area if the towers are arranged in a near square grid and spaced at 300m apart. However, it is not uncommon to predict an induced convective cloud developing over 4000m in height from more than 5 towers in a group for an individual afternoon sounding in the southeastern United States. Comparison of the predicted precipitation using Kessler's (1969) microphysical parameterization with Marshall and Palmer's (1948) drop size distribution and the similar approach with available observed droplet size distribution from cooling tower drift is also made. The model predictions are in good agreement with observations at existing power plants up to 3000 MWe generating capacity. Proper tower spacing and grouping to ensure that the merged plumes cause the least environmental impact are site specific. The approach presented here provides a simple and fast means for the examination of the merged plume behavior from a cluster of cooling towers and can be used for the planning of the tower arrangement at the power park complex. (ND)

<123>

Planning Nuclear Energy Centers Under Technological and Demand Uncertainty.
ORSA/TIMS 1976 Joint National Meeting, Proceedings of a Symposium, Philadelphia, PA, April 2, 1976; BNL-21205, 28 pp.
1976
Meier, P.M.; Palmedo, P.F.
Brookhaven National Laboratory, Energy Policy Analysis Division,
Upton, NY
U.S. Energy Research and Development Administration
U.S. Nuclear Regulatory Commission

The issue of clustered siting of nuclear power plants and collocated fabrication and reprocessing facilities with respect to technological uncertainties is addressed. Questions must be asked regarding the relative adaptability of dispersed and clustered siting to possible technological changes. These changes include shifts in nuclear and transmission technologies. The most important environmental uncertainty concerns the meteorological impact of large, concentrated heat and moisture releases into the atmosphere from (20-40) cooling towers. Possible atmospheric responses range from increased precipitation to increased convective activity (and local thunderstorms) and to possible vorticity concentration. Overall the considerations provide somewhat greater support for the clustered concept. The NEC approach seems to provide somewhat greater flexibility in accomodating possible future electricity generating technologies. (ND)

<124>

The Impact of Waste Heat Release on Simulated Global Climate.
RM-76-79, 27 pp.
1976
Murphy, A.H.; Gilchrist, A.; Hafele, W.; Kromer, G.; Williams, J.
National Center for Atmospheric Research, Boulder, CO
Meteorological Office, Bracknell, England
International Institute for Applied Systems, Laxenburg, Austria

A two year study of the possible impacts of energy systems on climate was initiated. Particular emphasis is on the results of a study of the impact of waste heat from large-scale energy parks on global atmospheric circulation, as simulated by a numerical model. The general circulation model of the United Kingdom Meteorological Office (UKMO) was used to investigate the effects of thermal pollution from large-scale energy parks on climate. Two scenarios, with different locations for the energy parks, were considered. Emphasis was placed on finding an estimate of model variability (on the basis of three control cases), so that the significance of the change caused by the heat release could be evaluated. As far as the model climatology is concerned, significant changes were produced by the energy parks. In addition, the location of the parks influenced the model response. The presently available models do not simulate climate in a completely realistic way so that the results of sensitivity experiments must be interpreted very carefully. At the present stage it can be said that the results call for further investigations. (ND)

<125>

The Impact of a Hanford Nuclear Energy Center on Cloudiness and Insolation.
PNL-2638, 60 pp.
1978
Ramsdell, J.V.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy

Using a combination of 'back of the envelope' models, the changes in sky cover and solar radiation that might result from the operation of mechanical draft cooling towers at a Hanford Nuclear Energy Center (HNEC) were estimated. Based on the models and study assumptions, several conclusions were made. Increases in sky cover and decreases in solar radiation resulting from the HNEC would generally be small outside the immediate vicinity of the reactor clustors. The changes in sky cover and solar radiation in the immediate vicinity of the clusters would be statistically significant in the fall, winter and spring. During the summer, the decrease in solar radiation would also be significant. When worst case assumptions are made for the conversion of cooling system effluent concentrations to increases in sky cover, the estimated changes range from a few percent in January to a factor of 4 or more in July. Further studies are recommended to evaluate the social and ecological significance of the predicted changes. (ND)

<126>

The Significance of Atmospheric Effects of Heat Rejection from Energy Centers in the Semi Arid Northwest.
BNWL-SA-5820
1976
Ramsdell, J.V.; Drake, R.L.; Young, J.R.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Energy Research and Development Administration

Battelle is evaluating the concept of a Hanford Nuclear Energy Center for the Energy Research and Development Administration. In this evaluation the atmospheric effects of various heat sink management options have been examined. This evaluation has gone beyond a routine listing of potential effects. In particular the impact of moisture releases on fog has been extended to include estimates of increased hours in specific low visibility catagories. These estimates are based on relatively simple model predictions and Hanford fog statistics. The technique used to translate increased hours of fog to visibility is outlined. A single 4 reactor cluster with mechanical draft cooling towers is estimated to increase the hours of fog in the Tri-Cities by 15 and the hours of visibility $<1/2$ mi by 28. The increases for a 20 reactor energy center range from 15-240 and 28-162 hours, respectively depending on the cooling system mix modeled. For a 40 reactor center the projected increases range from 15-288 and 28-184 hours, respectively. The predicted increases have been examined statistically and found significant. Prediction of the impact in terms of visibility permits investigation of economic significance. A method for this evaluation is outlined. (Auth)

<127>

Postulated Weather Modification Effects of Large Energy Releases.
BNWL-2162, 100 pp.
1977
Ramsdell, J.V.; Scott, B.C.; Orgill, M.M.; Renne, D.S.; Hubbard, J.E.; McGinnis, K.A.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Nuclear Regulatory Commission

Postulated impacts of large energy releases have been examined in the light of existing technical information. The magnitudes of direct atmospheric modifications have been estimated and the ecological and economic implications of the modifications have been explored. Energy releases from energy centers (10 to 40 power plants at a single site) and individual power plant clusters (1 to 4 power plants) were considered. In the atmosphere the energy will exist initially as increased temperature (sensible heat), moisture (latent heat), and air motion (kinetic energy). Addition of energy could result in increased cloudiness and fog, and changed precipitation patterns. Potential secondary impacts include decreased daytime and increased nighttime temperatures, early initiation of convective clouds, and increased frequency of hail, lightening and convective vortices. The magnitude of air temperature increases and the volume of air affected would be functions of the cooling systems used. A large energy center may produce a heat island that is capable of influencing airflow and precipitation patterns; it is unlikely that a single cluster of power plants would significantly effect either. The moisture released by evaporative cooling systems could result in increased cloudiness and fog. A large energy center might increase precipitation amounts by up to 30%, depending upon cooling systems used and the region of the country. These increases might occur as far as 30 to 50 km from the energy center. Alternation of the atmospheric energy balance by addition of heat and moisture has secondary ecological implications, resulting in changes in species diversity and productivity. The direct physiological effects of the postulated atmospheric changes on human and animal populations would be minimal. A framework for economic analysis of the impacts of the postulated atmospheric modifications was established on the basis of costs and benefits. (ND)

<128>

Postulated Weather Modification Effects of Large Energy Releases.
Pacific Northwest Laboratory Annual Report for 1977 to the DOE Assistant Secretary for Environment, Part 3 Atmospheric Sciences, C.L. Simpson et. al., (p. 2.31-2.32), 200 pp.; PNL-2500 PT3
1978
Ramsdell, J.V.; Scott, B.C.; Orgill, M.M.; Renne, D.S.; Hubbard, J.E.; McGinnis, K.A.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy

The direct and indirect impacts of large energy releases have been studied to place impacts postulated in the literature in a perspective consistent with existing technical information. Increases in cloudiness and precipitation could occur as far as 30 to 50 km from an energy center, but they might be difficult to identify. Net ecosystem response to large energy releases would be highly site specific, and physiological effects on humans and animals would be minimal. A framework was established for economic analysis of the impacts; however, the specific economic consequences of a given release are site specific. (Auth)

<129>

Atmospheric Considerations Regarding the Impact of Heat Dissipation from a Nuclear Energy Center.
ORNL/TM-5122, 37 pp.
1976
Rotty, R.M.; Bauman, H.; Bennett, L.L.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

Potential changes in climate resulting from a large nuclear energy center are discussed. On a global scale, no noticeable changes are likely, but on both a regional and a local scale, changes can be expected. Depending on the cooling system employed, the amount of fog may increase, the amount and distribution of precipitation will change, and the frequency or location of severe storms may change. The analysis suggests that the cooling towers for a large nuclear energy center should be located in clusters of four with at least 2.5 mile spacing between the clusters. This is the equivalent to the requirement of one acre of land surface per each two megawatts of heat being rejected. Drift and atmospheric salt concentration considerations are discussed. The primary potential effect of drift is damage to vegetation. Potential secondary effects are increase in the salinity of soils and ground water and related ecological effects. Impacts from freshwater and saltwater drift are reviewed. (ND)

<130>

Further Studies of the Impact of Waste Heat Release on Simulated Global Climate: Part 1.
RM-77-15, 22 pp.
1977
Williams, J.; Kromer, G.; Gilchrist, A.
International Institute for Applied Systems Analysis, Laxenburg,
Austria
Meteorological Office, Bracknell, England

A recent IIASA Research Memorandum (RM-76-79) described two experiments with a numerical model of climate, which investigated the impact of waste-heat release from large-scale energy parks on simulated atmospheric circulation. This report describes a further experiment made with the same model and compares the results with those of the first two experiments. In addition a further analysis tool, zonal harmonic analysis, has been applied to the results of all three energy parks experiments. The general circulation model (GCM) of the United Kingdom Meteorological Office was used to investigate the impact of an imput of waste heat (1.5 x 10(E+14)W) into the atmosphere in a small area in the mid-latitude eastern Atlantic Ocean. The energy park produced significant responses in the surface pressure field, the temperature in the lowest layer of the model, and in the total precipitation distribution. The changes are of the same order of magnitude as the changes found in two earlier energy parks experiments, and there are some similarities between changes in this experiment and EX01, especially over the area immediately downstream of the energy park. The results of all three energy parks experiments have been investigated using zonal harmonic analysis, and the influence of the energy parks on the positions and amplitudes of waves in the temperature and wind fields are discussed. (Auth) (ND)

<131>

Further Studies of the Impact of Waste Heat Release on Simulated Global Climate: Part 2.
RM-77-34, 39 pp.
1977
Williams, J.; Kromer, G.; Gilchrist, A.
International Institute for Applied Systems Analysis, Laxenburg,
Austria
United Nations Environment Program

The general circulation model (GCM) of the Meteorological Office, UK (UKMO), has been used to investigate the impact of an input of waste heat (1.5 x 10(E+14) W equally divided between two energy parks) into the atmosphere. This experiment is the fourth of a series of experiments made to investigate the behavior of the simulated circulation with different scenarios and energy releases. The results of this experiment have been compared with those of three earlier experiments described in Murphy et al. (1976) and Williams et al. (1977). Although the total heat input was the same as in previous experiment, the different locations of the heat islands caused a different response in the various climatic variables. It also can be said that EX04, in general, produced smaller changes than the previous experiments. They are, however, still significant. Temperature and wind at sigma level 0.5 (i. e. that point in a column of the atmosphere where half of the atmosphere is below you and half is above you) have been considered for all experiments as this has not previously been done for any of the experiments. Finally, a new attempt has been undertaken to assess the model variability by using 10-day means instead of 40-day means for calculating the standard deviation of the control cases. The signal-to-noise ratios have been recalculated, and a much smoother distribution has been obtained. (ND)

<132>

First Annual Progress Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. and Baker, D.G., Univ. of Michigan, for Consumers Power Co., May 1973. 48 pp.
Report describes the first year of work on an investigation to determine what effects mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI, may have on several meteorological variables inland from the cooling tower site on the Lake Michigan shoreline. It included establishing 13 climatological stations and installing equipment for measuring temperature, relative humidity, and precipitation at all stations and thermal radiation, visibility, and wind velocity at 2 main stations. Station locations, equipment used, and data collected and processed are described in detail. Work on a fog prediction model is discussed. Report includes 11 figures, 1 table, 1 appendix, and references.

<133>

Second Annual Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. and Baker, D.G., Univ. of Michigan, for Consumers Power Co., June 1974. 86 pp.
Report describes the second year of research to determine the meteorological effects of mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI. Work was primarily directed toward establishing a meteorological data base for the pre-cooling tower phase of the study. Data were collected by a network of 13 meteorological stations; network instrumentation was improved; data processing routines were developed, refined, and applied, and data tabulations and analyses began. Results of these efforts are presented and discussed. Report includes 11 figures, 18 tables, and references.

<134>

Third Annual Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. et al., Univ. of Michigan, for Consumers Power Co., June 1975. 64 pp.
Report describes the third year of work on a study of the meteorological impact of mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI. Analyses and comparisons of results using both preoperational and operational network data and climatological data, summaries of observations of cooling tower plume behavior and effects for the 1976-1977 operational period, and brief descriptions of the status of network data collection and equipment performance are presented. Results of each facet of the study are presented and discussed. Report includes 19 figures, 21 tables, 1 appendix, and references.

<135>

Fourth Annual Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. et al., Univ. of Michigan, for Consumers Power Co., May 1976. 110 pp.
Report describes the fourth year of work on a study of the meteorological impact of mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI. Analyses of meteorological network data for the 1973-1974 preoperational period, summaries of observations and descriptions of photographs of cooling tower plume behavior and effects for the 1975 operational period, and brief descriptions of the status of network data collection and equipment performance in 1975 are presented. Results of each of these efforts are presented and discussed. Report includes 30 figures, 8 tables, 1 appendix, and references.

<136>

Fifth Annual Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. et al., Univ. of Michigan, for Consumers Power Co., June 1977. 112 pp.
Report describes the fifth year of work on a study of the meteorological impact of mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI. Analyses and comparisons of results using both preoperational and operational network data and climatological data, summaries of observations of cooling tower plume behavior and effects for the 1976-1977 operational period, and brief descriptions of the status of network data collection and equipment performance are presented. Results of each of these efforts are presented and discussed. Report includes 19 figures, 21 tables, 1 appendix, and references.

<137>

Sixth Annual Report: An Investigation of the Meteorological Impact of Mechanical-Draft Cooling Towers at the Palisades Nuclear Plant.
Prepared by Ryznar, E. et al., Univ. of Michigan, for Consumers Power Co., Aug. 1978. 115 pp.
Report describes the sixth year of work on a study of the meteorological impact of mechanical draft cooling towers at the Palisades Nuclear Plant, Van Buren County, MI. Analyses and comparisons of results using both preoperational and operational network data and climatological data, summaries of observations of cooling tower plume behavior and effects for the 1976-1977 operational period, and brief descriptions of the status of network data collection and equipment performance are presented. Results of each of these efforts are presented and discussed. Report includes 28 figures, 18 tables, 2 appendices, and references.

<138>

Hours Per Year in Which Icing May Occur Due to Cooling Tower Drift.

Table 5.1-4, Haven Nuclear Plant Units 1 & 2 Environmental Report Construction Permit Stage. Wisconsin Elec. Power Co.; Wisconsin Power & Light Co., and Wisconsin Public Service Corp., Jan. 1978. 1 p.

Table lists the number of hours per year during which icing could occur due to operation of the proposed natural draft cooling towers for the Haven Nuclear Plant in Sheboygan County, WI. Based on 1 year of meteorological data, the total number of hours is 1,927. Hours are presented for each of 18 wind conditions.

<139>

(Occurrence of Ground Fog or Ice at the North Valmy Station.)
Tables 7.1-8 & 7.1-9, Environmental Report for the North Valmy Station. Prepared by Westinghouse Elec. Corp. for Sierra Pacific Power Co., April 1977. 2 pp. 1977

Tables estimate the occurrence, location, and effects of ground fog and icing due to cooling tower operations at the proposed North Valmy Station in Humboldt County, NV. A summary of ground fog occurrences under conditions of relative humidities greater than 95%, stability classes A-F, ground interception distances, maximum intensities, and maximum horizontal visibility is presented in Table 7.1-8. Table 7.1-9 indicates the total number of hours per year that 2 railways, a highway, and the town of Valmy may experience ground fog or icing.

<140>

Calculations of Fogging.
Appendix F, Final Environmental Statement Related to the Proposed Catawba Nuclear Station Units 1 & 2. Duke Power Co. Prepared by U.S. Atomic Energy Commission, Dec. 1973. 6 pp.

Appendix presents a calculation of an approximate quantitative estimate of the additional fogging frequency caused by the operation of mechanical-draft cooling towers at the proposed Catawba power station, York County, SC. Calculations were possible from a knowledge of the ambient saturation deficit history in the area and the moisture content of the cooling tower plumes. The frequency distribution and the cumulative frequency distribution of the corresponding saturation deficits were calculated. The ground level moisture concentration in the cooling tower plume was calculated as a function of downwind distance using the Pasquill-Gifford equation. Report includes 1 table, 1 figure, and 3 references.

<141>

Number of Occurrences of Fogging and Icing at Various Distances and for Sixteen Directions from the Plant.
Table 3.1.4-12, Intermountain Power Project Preliminary Engineering and Feasibility Study, Environmental Assessment. Prepared by Westinghouse Elec. Corp. for Los Angeles Dept. of Water & Power, May 1977. 1 p.

Table lists distances from commencement of fogging and icing to end of fogging and icing, in kilometers, for 16 directions from the proposed Intermountain Power Project, Wayne County, UT. Total number of occurrences included for both distance and direction.

<142>

(Projected Impacts of Cooling Tower Operations, East Bend Station.)
Exhibits 182, 183, 185, & 186, Final Environmental Impact Statement - East Bend Station, Units 1 and 2. Cincinnati Gas & Elec. Co. Prepared by U.S. Army Engineer Dist., Louisville, June 1977. 6 pp.

Exhibits 182 and 183 are maps of the vicinity of the proposed East Bend Station, Boone County, KY, showing expected hours of onsite and offsite fogging and icing per year from operation of the mechanical draft cooling towers. Exhibit 185 is a map of the plant vicinity showing hours per year that the cooling tower plume will be visible in various sectors within a 2-km radius of the plant. Exhibit 186 is a table showing the spectrum of drift droplet sizes expected.

<143>

(Seasonal Incidence of Ground Level Fog from Mechanical Draft Cooling Towers.)
Figures 4-1 Through 4-4, Power Plant Site Evaluation Report: Dickerson Site. Prepared by Johns Hopkins Univ. for Potomac Elec. Power Co., Maryland Power Plant Siting Program, Jan. 1974. 4 pp.

Figures are maps of the vicinity of the Dickerson Steam Electric Station, Montgomery County, MD, showing expected incidence of ground level fog, in hours per season, if mechanical draft cooling towers are installed. Figures are revised from earlier estimates to reflect model tuning.

<144>

Annual Hourly Frequency of Tower-Induced Fogging and Icing.
Table 10.1-4, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.

Table analyzes the annual hourly frequency of induced fogging and icing at 4 locations near the WPPSS No. 3 and 5 site. Conditions are induced by operation of conventional rectangular, conventional round, plume abatement rectangular, and wet/dry mechanical draft cooling towers.

<145>

Summary of Fogging Impact Estimates.
Table 5.1-6, WPPSS Nuclear Project No. 2 Environmental Report (Operating License Stage), Washington Public Power Supply System, Mar. 1977. 1 p.

Table summarizes estimated ground-level interactions of cooling tower plumes from WPPSS No. 2, Benton County, WA. Average fogging and icing frequencies caused by the tower plume are given for 17 locations in the plant vicinity. Distance and direction of each of these locations from the plant are indicated.

<146>

Increase in Relative Humidity at Points of Maximum Potential Impact.

Table 5.1-7, WPPSS Nuclear Project No. 2 Environmental Report (Operating License Stage), Washington Public Power Supply System, Mar. 1977. 1 p.

Table gives the estimated increases in relative humidity resulting from operation of WPPSS No. 2 cooling towers, Benton County, WA. Plumes were considered for the June condition and evaluated every 4 hrs in the direction sectors clockwise between 45 and 135 degrees at distances of 8 and 10km from the plant.

<147>

Duration Range of Ground Fog Occurrence for Natural Draft Wet Cooling Tower System.
Table 10.1-7, Braidwood Station Environmental Report, Commonwealth Edison Co., Aug. 1973. 1 p.

Table lists calculated range of the number of hours of ground fog due to operation of alternative natural draft wet cooling tower at Braidwood. Calculations are given for wind frequency in a given direction.

<148>

Duration of Ground Fog Occurrence for Mechanical Draft Wet Cooling Tower System.
Table 10.1-8, Braidwood Station Environmental Report, Commonwealth Edison Co., Aug. 1973. 1 p.

Table lists the calculated number of hours of ground fog occurrence due to operation of alternative mechanical draft wet cooling towers at Braidwood Station. Calculations take into account wind frequency in each of 16 compass directions.

<149>

Frequency of Ground Fog Occurrence Mechanical Draft Wet Cooling Tower System.
Table 10.1-9, Braidwood Station Environmental Report, Commonwealth Edison Co., Aug. 1973. 1 p.

Table lists frequency of ground fog occurrence within an area de fined by radial distances of 0.25-12.0 mi. downwind of alternative mechanical draft wet cooling towers at Braidwood Station.

<150>

Predicted Average Annual Ground Fog Frequency (Hours/Year) Mechanical Draft Cooling Towers - Full Load - 1982 Mwe Clinton Site.
Table 10.1-6, Clinton Power Station Units 1 & 2 Environmental Report, Illinois Power Co., Oct. 1973. 1 p.

Table lists predicted average annual ground fog frequency at distances from 0.4-20.0km from mechanical draft cooling tower alternative considered for Clinton Power Station.

<151>

Visibility Reduction Mechanical Draft Wet Cooling Towers (Hours per Year).
Figure 10.1-1, Greenwood Energy Center Units 2 & 3 Environmental Report, Detroit Edison Co., Sept. 1973. 1 p.

Figure is a map of Greenwood Energy Center's surrounding area indicating the number of yearly hours that the ground level visibility is predicted to be 1,000 ft. or less due to alternative mechanical draft wet cooling towers.

<152>

Visibility Reduction - Mechanical Draft Wet-Dry Cooling Towers (Hours per Year).
Figure 10.1-2, Greenwood Energy Center Units 2 & 3 Environmental Report, Detroit Edison Co., Sept. 1973. 1 p.

Figure is a map of Greenwood Energy Center's surrounding area indicating the number of yearly hours that the ground level visibility is predicted to be 1,000 ft. or less due to alternative mechanical draft wet/dry cooling towers.

<153>

Ground Fog and Ground Ice - Wet Mechanical Draft Towers.
Figures 10.1-11 & 10.1-12, NEP 1 & 2 Environmental Report, New England Power Co., Sept. 1976. 1 p.

Figures show the results of a study conducted during alternative cooling system design analyses for NEP Units 1 and 2, Washington County, RI, to estimate the frequency of occurrence of ground fog and ground ice caused by the operation of wet mechanical cooling towers. Studies were based on a mathematical model.

<154>

Ground Fog and Ground Ice HRS/YR - Wet/Dry Mechanical Draft Towers.
Figures 10.1-18 & 10.1-19, NEP 1 & 2 Environmental Report, New England Power Co., Sept. 1976. 2 pp.

Figures show the results of studies conducted to estimate the frequency of occurrence of ground fog and ground ice caused by the operation of wet/dry mechanical draft towers at proposed NEP Units 1 and 2, Washington County, RI. Studies were based on a mathematical model.

<155>

Evaluation of Cooling Tower Effects at Zion Nuclear Generating Station.
McVehil, George E., Sierra Research Corp., Boulder, CO., Oct. 1970. Included as Appendix D, Supplement II to Zion Nuclear Power Station Environmental Report, Commonwealth Edison Co., May 1971. 55 pp.

Report presents an evaluation of the potential for increased fogging and associated environmental problems that could result from operation of cooling towers at the Zion station, Lake County, IL. Appendix includes a discussion of the data and procedures used for evaluating fog potential, the physics of cooling tower fog and the local climatology of the site. The analyses performed and their results, implications, and associated cooling tower problems are presented. Report includes 11 tables, 4 figures, 12 references, and 1 appendix.

<156>

Predicted Occurrences of Fog Generated from Natural Tower, and Tower with Fog Abatement Equipment.
U.S. Army Engineer District, Buffalo, New York. Figures 5.5-3 & 5.5-6, Oswego Steam Station Unit 5 Final Environmental Statement, Niagara Mohawk Power Corp., Dec. 1971. 2 pp.

Figures illustrates the frequency and limits of fogging patterns which might result from the natural draft cooling tower of the Oswego Steam Station, Oswego County, NY, and a tower with fog abatement equipment.

<157>

Frequencies of Round Mechanical Draft Cooling Tower Ground Fog.
Ebasco Services, Inc., New York. Table VI-C-3, George Neal Steam Electric Station Neal Unit 4 Environmental Impact Assessment, Iowa Public Service Co., Dec. 1974. 1 p.

Table presents predicted frequencies of alternative round mechanical draft cooling tower ground fog in the vicinity of Neal Unit 4 by season and annually. Information includes frequency of natural fog, direction of maximum frequency, and frequency of tower-induced fog at 1, 5, 10, and > 10 km from tower.

<158>

Potential Ground Fog Occurrence at Colstrip for Various Wind Directions.
Westinghouse Environmental Systems Dept. Table 2.6-36, Colstrip Generation and Transmission Project Environmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 1 p.

Table summarizes potential ground fogging occurrence resulting from operation of cooling towers at Colstrip Generation and Transmission Project, Rosebud County, MT. Data are expressed as number of hours of fogging and are given for 16 different wind directions.

<159>

Anticipated Ground Fogging From Colstrip Cooling Towers.
Westinghouse Environmental Systems Dept. Table 2.6-37, Colstrip Generation and Transmission Project Environmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 1 p.

Table gives information on anticipated ground fogging (per year) resulting from operation of cooling towers at Colstrip Generation and Transmission Project, Rosebud County, MT. Information is for area which may be adversely affected by fogging and icing, including the plant, the mining area, the state highway, 2 railroads, and 27 farms scattered in all directions around the plant.

<160>

Cooling Tower Effects, Vermont Yankee Generating Station.
Collins, G.F.; Case, C.R.; Mule, C.J., The Research Corp. of New England, Hartford, CT. Appendix A, Vermont Yankee Nuclear Power Station Supplement to the Environmental Report, Vermont Yankee Nuclear Power Corp., Aug. 1971. 15 pp.

Report summarizes a study of average plume conditions, by seasons, with 2 mechanical draft cooling towers operating at full capacity at the Vermont Yankee power station in Windham County, VT. The focus of the study is to describe the primary effect of the cooling tower plumes in terms of fogging and icing, in the Connecticut River Valley area. The analysis was accomplished by use of atmospheric diffusion models which are described in the report. The shape and extent of the visible plume were determined under a range of meteorological conditions (wind speed, atmospheric stability, temperature, and humidity). Report includes 1 table, 4 figures, and 1 appendix.

<161>

Hours of Induced Fog and Icing Per Year from Cooling Towers.
Figures 4.1-3 and 4.1-4, Portsmouth Gaseous Diffusion Plant Site Final Environmental Impact Statement, U.S. Energy Research and Development Administration, May 1977. 2 pp.

Figures are calculated plots of increased frequency of fog and icing, as a function of distance from the mechanical draft cooling towers at Portsmouth Gaseous Diffusion Plant, Pike County, OH. Plots were derived on the basis of a computer model and are shown for radii up to a 4-mile distance from the plant.

<162>

Seasonal Areal Frequency of Ground Level Fogging from Combined Operation of Unit 3 and Unit 4 Cooling Towers - Clay Boswell Site.
Table IV-B-1, Clay Boswell Steam Electric Station Unit 4 Environmental Report, Minnesota Power & Light Co., March 1976. 1 p.

Table lists the expected seasonal frequency of ground level fogging resulting from the combined operation of Clay Boswell Units 3 and 4 mechanical draft cooling towers. Unit 3 of the 500-MW, Itasca, MN, plant is operational, with Unit 4 scheduled to be completed in 1980. The hours of fogging per season are recorded for 16 directions circumscribing the plant and for .5, 1, 3, 5, and 10-kilometer distances from the plant site. Data is based on observations made from January-December 1955.

<163>

Annual Areal Frequency of Ground Level Icing from Combined Operation of Unit 3 Tower and Unit 4 Rectangular Tower - Clay Boswell Site.
Table IV-B-2, Clay Boswell Steam Electric Station Unit 4 Environmental Report, Minnesota Power & Light Co., March 1976. 1 p.

Table lists the expected annual frequency of ground level icing resulting from the combined operation of Clay Boswell Units 3 and 4 mechanical draft cooling towers. Unit 3 of the plant, in Itasca County, MN, is operational, with Unit 4 scheduled to be completed in 1980. The hours of icing are recorded for 16 directions circumscribing the plant, and for .5, 1, 3, 5, and 10-kilometer distances from the plant site. Data is based on observations made from January-December 1955.

<164>

Cooling Tower Plume Study.
Figures II-14 and II-15, Environmental Analysis of the Wansley Project for Oglethorpe Electric Membership Corp. and Georgia Power Co., March 1975. 2 pp.

Figures illustrate results of a study of monthly and annual fogging potential and plume length resulting from operation of mechanical draft cooling towers proposed at Plant Wansley, GA. The daily frequency of plume lengths, by wind direction, is shown.

<165>

Staff's Estimates of Hours of Additional Ground-Level Fog and Drift Deposition Caused by Operation of Natural Draft Cooling Tower at TEP.
U.S. Nuclear Regulatory Commission . Figures 9.3 & 9.4, Final Environmental Statement Related to Construction of Tyrone Energy Park, Northern States Power Co. of Minnesota and Northern States Power Co. of Wisconsin, April 1977. 2 pp.

Figures show the NRC staff's estimate of hours of additional ground level fog and drift deposition caused by operation of natural draft cooling tower at the Tyrone Energy Park.

<166>

Calculated CGS Cooling Tower Fog and Icing.
Tables II-38 & II-39, Final Environmental Statement - Coronado Project, Owned by Salt River Project . Prepared by Bureau of Reclamation, U.S. Dept. of Interior; Bureau of Land Management, U.S. Dept. of Interior, and U.S. Forest Service, U.S. Dept. of Agriculture, Aug. 1977. 1 p.

Tables give data on predicted occurrences of fogging and icing resulting from operation of mechanical draft cooling towers at the Coronado Generating Station in Apache County, AZ. Included are hours of icing and fogging at a distance of 1 and 2 mi for each of the principal directions. Also included is the number of hours of simultaneous natural fog and ice.

<167>

An Anomalous Snow at Oak Ridge, Tennessee.
Monthly Weather Review 90(5):194-196
1962
Culkowski, W.M.
Weather Bureau Research Station, Oak Ridge, TN

An isolated snowfall downwind of the massive cooling towers of the Oak Ridge Gaseous Diffusion Plant is described. Aside from a semi-permanent cumulus cloud over the plant site, no direct effect of the additional moisture had heretofore been reported. The snow was intermittent and fairly light. Downwind from the cooling towers, snow began falling about three miles distant and continued to be deposited noticeably on the ground up to five miles, with a possible width of approximately one mile. The snowfall provides evidence on the magnitude of what might be termed 'artificial cloud generation processes' and critical meteorological environments required for unique man-made precipitation. (ND)

<168>

Meteorological Effects of the Cooling Towers at the Oak Ridge Gaseous Diffusion Plant II. Predictions of Fog Occurrence and Drift Deposition.
ATDL Contribution File No. 88, 36 pp.; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1974 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 15-54), 250 pp.; ATDL-75/17
1974
Hanna, S.R.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Atomic Energy Commission

The frequency of occurrence of fogs and the rate of deposition of chromate due to emissions from the cooling towers at the Oak Ridge Gaseous Diffusion Plant are calculated. Observations of drift deposition agree fairly well with calculated values. A detailed summary of significant findings is given at the end of the report. It was predicted that the cooling towers would cause about 100 extra hours of fog per year at distances of 100 to 200 m from the towers. A visible plume aloft was calculated to occur over the city of Oak Ridge, 10 km to the NE, about 240 hours per year. Predictions of chromate deposition at distances from 10 m to 1500 m from the towers agreed fairly well with observations during the June 1973 experiment. Calculated average annual chromate deposition rates varied from about 20 ug/m(E+2) at distance of 5 m from the towers to 10(E-4) ug/m(E+2) at a distance of 20 km from the towers. (Auth)(ND)

<169>

Cooling Towers and the Environment.
American Electric Power Service Corporation Report, 9 pp.
1974
Smith, M.E.; Kramer, M.L.; Seymour, D.E.; Frankenberg, T.T.
Smith-Singer Meteorologists, Inc., Massapequa, NY
American Electric Power Service Corporation, NY

The effects of natural draft cooling towers on the atmosphere are examined. American Electric Power began an intensive study of cooling tower plumes in 1973 using aircraft surveys at three power plants (Muskingham River, Mitchell, and J.E. Amos). Three definite environmental effects were documented: aesthetic impacts of the visible plumes, shadowing effects, and occasional interference with aircraft operation. Impacts of fog, humidity, and precipitation near large natural draft cooling towers were found to be insignificant. (ND)

<170>

Snowfall Observations from Natural-Draft Cooling Tower Plumes.
Science 193:1239-1241
1976
Kramer, M.L.; Seymour, D.E.; Smith, M.E.; Reeves, R.W.;
Frankenberg, T.T.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation, Canton, OH

During the winter of 1975-1976, snowfall from the plumes of large natural draft cooling towers of five power plants in Kentucky, Ohio, and West Virginia has been observed. Snow accumulations up to 2.5 centimeters have been found on the ground at extended distances from the cooling towers, and visiblity has been restricted to less than 1600 meters in the tower plume near ground level. It is too early to assess the environmental importance of induced snowfall, however, it appears to be minor. (Auth)(ND)

<171>

Locally Heavy Snow Downwind from Cooling Towers.
NOAA Technical Memorandum NWS ER-62, 9 pp.
1976
Otts, R.E.
National Oceanic and Atmospheric Administration, National Weather
Service, WSFO, Charleston, WV
U.S. Department of Commerce

Two heavy snowfalls near Charleston, West Virginia (J.E. Amos Power Plant) appear to have been induced by large cooling towers. In each case similar meteorological and geographical conditions prevailed. Conditions favoring the development of locally heavy snows downwind from cooling towers appear to be as follows: (1) a strong influx of cold air into the area; (2) high relative humidity and an unstable lapse rate in the lower layers of the atmosphere; (3) a strong inversion layer near 5, 000 feet (1,500 meters), topping the unstable lower layer; (4) cyclonic curvature of the flow pattern; (5) an average temperature of minus 10 C or colder in the lower layer (from the ground to the bottom of the inversion); and (6) some initial orographic lifting or some other type of forced ascent to the airflow. Strongest effects occur downwind from the source near the axis of the mean wind in the 1,000 - 4,000 foot layer. Forecasters suspecting such influences in their area should closely inspect the precipitation patterns when favorable conditions exist. Knowledge of these influences can provide the potential for 'fine-tuning' the local weather forecasts. (ND)

<172>

Evaluation of Cooling Tower Effects at Zion Nuclear Generating Station.
TR-0824, 60 pp.
1970
McVehil, G.E.
Sierra Research Corporation, Environmental Systems Group, Boulder, CO
Commonwealth Edison Company, Chicago, IL

A study was conducted to evaluate the potential for fog and associated environmental problems that could result from operation of cooling towers at Commonwealth Edison's Zion Nuclear Generating Plant. The results showed that fog at the surface should be expected somewhere around the plant on a maximum of 650 hours per year. The maximum frequency at any one point on the ground was calculated to be 90 hours per year from 1-1/2 to 2-1/2 miles north of the plant site. These maximum fog frequencies would result from mechanical draft cooling towers. Natural draft or combination cooling towers would produce somewhat lower fog frequencies, the numbers decreasing with increasing height of the towers. Maximum ground-level fog frequencies for these towers ranged from 40 hours for 500 ft towers to 100 hours for 250 ft towers. The fog would occasionally persist for 10 miles or further downwind from mechanical draft towers. Plumes from taller towers would frequently extend much further in the free atmosphere; when the plumes contact the ground it would be at distances of 3 to 15 miles. Fog persistence would typically be two to four hours, and individual fog episodes could be expected to occur on 100 to 150 days per year with mechanical draft towers, and on 5 to 30 days per year with hybrid or natural draft towers. The plumes from tall natural draft towers would often be extensive and persistent. They should be expected to at times create appreciable increase in cloud cover over the lakeshore area, possibly interfering with aircraft traffic around Waukegan Airport. Lake breeze situations are particularly favorable for local cloud and haze increases. Most cooling tower fog will be produced in the winter, and during the hours between 3 and 9 AM. (ND)

<173>

Precipitation Studies Around Plant Bowen.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 47-58), 120 pp.
1978
Patrinos, A.A.; Chen, N.C.J.; Miller, R.L.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Department of Energy

Oak Ridge National Laboratory is conducting a precipitation study in the area of the Georgia Power Company's Bowen fossil electric generating station in Northwest Georgia as a part of a national program on the 'Meteorological Effects of Thermal Energy Releases (METER).' This plant utilizes four natural draft cooling towers. The study is composed of two parts: first, a collection of 30-year climatological data as supplied by the National Weather Service is being evaluated statistically by double-mass, frequency distribution, spatial correlation techniques, etc.; second, a field study involving a high-density recording rain guage network is planned. Both parts are aimed at obtaining quantitative estimates of potential plant-induced precipitation augmentation and storm pattern disruption. (Auth)

<174>

Rainfall Variations Around a Thermal Power Station.
Atmospheric Environment 10:963-968
1976
Selvam, A.M.; Manohar, G.K.; Ramana Murty, Bh.V.
Indian Institute of Tropical Meteorology, Poona, India

Rainfall data of Neyveli thermal power station and of stations within 100 km around were examined, after eliminating the secular trends for the period 1958-1974. The analysis suggested that, with respect to nearby stations in the distance range 12-25 km, rainfall at a gauge 1 km from the power station increased in the last 6 years of the period by over 25%. The cooling tower complex at the Neyveli Power station is of the induced draft type, and is 21 m high. The total number of towers in the complex is 7 and the total number of cells 38. The temperature excess of the cooling tower plume is understood to be about 10 degrees C. The results suggest the possible presence of a localized source which may have been influencing the rainfall of these stations since 1969. Power production at Neyveli increased about twofold after 1969. (Auth)(ND)

<175>

Ground Level Relative Humidity Excess Due to the Operation of the Mechanical Draft Wet Cooling Tower System.
Lee, Jiin L. Table 6.1, Evaluation of Environmental Effects from Evaporative Heat Dissipation Systems at Gulf States Blue Hills Station. Prepared by NUS Corp. for Bechtel Power Corp. Study included in entirety as Appendix B, Blue Hills Station Units 1 & 2 Environmental Report, Gulf States Utilities Co., 1974.

Table presents calculated results of ground level excess relative humidity due to operation of mechanical draft wet cooling tower system at proposed Blue Hills station. Lists ambient conditions and ambient relative humidity, direction of prevailing wind and percentage of excess relative humidity for distances of 1, 3, 5, and 10 km downwind of the site. Table shows the amount of excess humidity in vicinity of cooling towers is expected to be negligible under normal weather conditions in the area. Based on NUS model.

<176>

Number of Hours in Each Direction that Ambient Relative Humidity Was Increased by Given Amounts for Several Distances.
Table 5.1-1, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 4 pp.

Table gives computer model calculations of the increase in relative humidity due to the operation of mechanical draft cooling towers at Sundesert Nuclear Plant, Riverside County, CA. Data are presented as the number of hours during which the relative humidity was increased by various amounts, for several distances in each direction from the plant site.

<177>

Estimated Average Relative Humidity Increase Within 5 and 50 Miles.
Figures 5.1-3 & 5.1-4, Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 2 pp.

Figures illustrate computer predicted average increases in relative humidity at distances of 5 and 50 mi from Sundesert Nuclear Plant, Riverside County, CA, due to cooling tower operation.

<178>

Mathematical Model for Calculating Visible Plume Effects, Ground Fog Potential, and Relative Humidity Increase.
Appendix L, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 62 pp.

Appendix presents mathematical models used to calculate cooling tower visible plume effects, ground fog potential, relative humidity increase, and salt distribution from cooling towers at proposed Sundesert Nuclear Plant, Riverside County, CA. First section discusses modifications of the Halitsky (1966) transverse jet dispersion model in order to apply the model to calculate condensible water vapors from cooling towers. The model was intended to be used for calculating: 1) geometry and length of the visible and invisible plume; 2) amount of increased shadowing under the visible plume; 3) extent of ground fogging, and 4) increases in relative ground-level humidity. Second section gives the mathematical models, equations, and computer programs used to predict average salt deposition rates as a function of distance and direction from the cooling tower. Also included is the specific information used for evaluating cooling tower impact at the Sundesert site, including meteorological data and cooling tower operating characteristics. Includes numerous figures and tables.

<179>

(Annual Occurrences of Visible Plume, Ground Fog, and Shadowing by Cooling Towers, at 35% Capacity.)
Tables 3.3-9 Through 3.3-11 & 3.3-13, Edgewater Generating Station Unit 5 Environmental Report. Prepared by Wisconsin Power & Light Co., May 1976. 3 pp.

Tables list annual projections of visible plume occurrence, ground fog, and duration of shadowing from construction and operation of the cooling tower at the proposed 400-MW Edgewater Unit 5 plant, in Sheyboygan County, WI. The projections are for a 35% capacity factor, which will be normal operation. Parameters include distance from the plant, annual frequency, percentage occurrence, and incremental distance from the cooling tower for shadowing by plumes.

<180>

(Examination of Atmospheric Effects Other than Those Due to Salt Deposition at Chalk Point Generating Station Units 3 and 4.)
Chapter VII, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 8 pp.

Chapter examines potential atmospheric effects of operating Chalk Point Generating Station Units 3 and 4, Prince Georges County, MD, other than those due to salt desposition from the towers and stacks. Effects considered are enhancement of ground-level fog, icing, precipitation, and flight hazards to aircraft. Current literature regarding these topics is summarized, and a mathematical model used for analysis is described. Chapter contains 4 tables and references.

<181>

Occurrence of Fog or Ice, Length of Visible Plume and Extent of Ground Fog for Various Stability Classes.
Westinghouse Environmental Systems Dept. Table 2.6-34, Colstrip Generation and Transmission Project Envionmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 1 p.

Table provides data on expected occurrence of fogging or icing, visible plume, and ground fog resulting from operation of cooling towers at Colstrip Generation and Transmission Project, Rosebud County, MT. The following data are provided for stability classes A-F: 1) number of hours of fogging or icing; 2) mean length of visible plume; 3) extent of start point and 4) ground fog end point.

<182>

Cooling Tower Plume Analysis Units 1 & 2 Charleston Bottoms Generating Station.
Dames & Moore Appendix A-2, Environmental Analysis Spurlock Station Unit 2, Prepared by Stanley Consultants, Inc. for East Kentucky Power Coop., July 1975. 49 pp.

Appendix analyzes the plume behavior of each of 2 alternatives for cooling towers at Charleston Bottoms Generating Station (currently known as Spurlock Station), Maysville, KY. Alternatives include: 1) a conventional mechanical draft tower for the first unit, in conjunction with a similar tower for the second unit and 2) the same conventional Unit 1 tower with a round mechanical tower for Unit 2. Plume behavior investigated includes possible fogging and icing due to cooling tower emissions. A computer model is used to generate anticipated frequency distributions of cooling tower plume height, plume length, ground fogging and icing based on 3 years of meteorological observations. Includes 30 tables and 6 figures.

<183>

Cooling Tower Impact at Lake City for Lake City Station Unit 1.
Hosler, C. L., Pennsylvania State Univ. Appendix E, Final Environmental Statement Lake City Station - Unit 1, Prepared by U.S. Army Engineer District, Buffalo, NY . Pennsylvania Elec. Co., Sept. 1973. 6 pp.

Appendix discusses potential impacts of cooling towers at Lake City Station, Erie County, PA, on the local environment. The potential for fog production downwind, effects upon local weather including lake storms in fall and winter, and icing in winter were investigated using weather data from Cleveland and Buffalo. Included is a discussion of the calculation of plume rise, necessary to assess unfavorable environmental impacts. Cooling towers at Lake City are 8-cell mechanical draft. Tables give observations of cooling tower upon plume, and average number of hours of saturation deficit.

<184>

Meteorological Effects of Cooling Towers at SMUD Site.
Smith, T.B.; Mirabella, V.A., Meteorology Research, Inc., Appendix 3C, Rancho Seco Nuclear Generating Station Unit No. 1 Environmental Report, Sacramento Municipal Utility District, Jan. 1971. 40 pp.

Report describes the possible effects of hyperbolic cooling towers on the local environment at the Rancho Seco power station in Sacramento County, CA. The study is designed to examine the possible effect of cooling towers on diffusion from the plant vents and the effects of large quantities of water released to the atmosphere under normal cooling tower operations. Diffusion effects were investigated with a wind tunnel model of the towers-reactor building complex. The possible effects of water discharged into the environment by the cooling tower plumes were studied through calculations using the available plume rise models. Observations from these studies provided a general understanding of the effects of the cooling towers and permitted the design of a field measurement program to verify the tunnel observations under realistic atmospheric conditions. This field program was carried out from Aug. 24 - Sept. 6, 1970, at the Paradise Steam Plant of the Tennessee Valley Authority at Greenville, KY. Results of the field program were analyzed, compared with the tunnel studies, and used with previously published data to prepare this report. Report includes 19 figures, 3 tables, and 5 references.

<185>

Kaiseraugst Nuclear Power Station: Meteorological Effects of the Cooling Towers.
Schweizerische Bauzeitung 93(37):583
1975
Kaiseraugst Nuclear Power Station

Considerations of water conservation persuaded the German Government in 1971 not to allow the use of the Aar and Rhine for direct cooling of nuclear power stations. The criticism is often made that the Kaiseraugst cooling towers were built without full consideration of the resulting meteorological effects. The criticism is considered unjustified because the Federal Cooling Tower Commission considered all the relevant aspects before making its recommendations in 1972. Test results and other considerations showed that the effects of the

Kaiseraugst cooling towers on meteorological and climatic conditions was indeed minimal. Details are given.

<186>

Impact of a Hanford Nuclear Energy Center on Ground Level Fog and Humidity.
BNWL-2058, 100 pp.
1977
Ramsdell, J.V.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Energy Research and Development Administration

The results of a study of the atmospheric impacts of a Hanford Nuclear Energy Center (HNEC) using evaporative cooling alternatives are described. Specific cooling systems considered include once-through river cooling, cooling ponds, cooling towers, helper cooling ponds and towers, and hybrid wet/dry cooling towers. The specific impacts evaluated were increases in fog and relative humidity. It was concluded that the fogging impact will vary according to the cooling system choice: minimum impact using a combination of cooling towers and once-through cooling; and maximum impact using cooling ponds. The positions of the 4 reactor clusters within the Reservation would only have a secondary effect on the fogging impact. The number of hours of fog in the Tri-Cities could be increased by almost 300 for a 40 reactor HNEC if conventional, low-level evaporative cooling systems are used. The number of hours of fog on the Reservation could increase by almost 600. The moisture releases from an HNEC would increase the density of naturally occurring fog. A computerized model is discussed that considers many physically important considerations in estimating the increased frequency of fog. (ND)

ATMOSPHERIC EFFECTS - OTHER CLOSED CYCLE SYSTEMS

<187>

Analysis of Fogging and Icing Resulting from Operation of the Sooner Generating Station Units No. 1 and No. 2.
Appendix 3.2.4.2-1, Sooner Generating Station Units No. 1 and No. 2 Environmental Assessment Report. Prepared by Benham-Blair & Affiliates, Inc. for Oklahoma Gas & Elec. Co., nd. 24 pp.

Appendix presents an analysis of the expected fogging and icing conditions resulting from the proposed Sooner Generating Station cooling pond. The Sooner plant, located in Pawnee and Noble Counties, OK, consists of two 515-MW fossil fueled units utilizing a cooling pond. The enhancement of natural fog and ice and the initiation of fog and ice were predicted under worst case conditions using an empirical model. Taking into account pond surface water temperatures, plant load factors and meteorological factors such as wind direction, the maximum expected occurrences of initiated fog, ice, and enhanced natural fog were determined for normal discharge temperatures and 1965 meteorological data, maximum discharge temperatures and 1965 data, normal discharge temperatures and 1974 data, and maximum discharge temperatures and 1974 data. The study indicates that state Highway 15 could have up to 4 hrs of initiated fog, 1 hr of ice, and enhanced natural fog as many as 10 hrs per year. The effect on U.S. Rte 177 would be less.

<188>

Fog and Plumes from Power Plant Cooling Systems in the Tri-Cities - Saginaw Bay Area.
Appendix 5.1C, Environmental Report, Operating License Stage, Midland Plant-Units 1 & 2, Vol. 2. Prepared by Portman, D.J. and Weber, M.R., Consumers Power Co., June 8, 1975. 14 pp.

Appendix presents predictions of the extent to which the Midland station Unit 1 and 2, Midland County, MI, will create and/or enhance fog conditions in the surrounding area. Production of fog over the 880-acre cooling lake was estimated by an MIT model assuming a two-dimensional, stratified simulation dividing the lake into 5 heat regions. An estimate of fog occurrence frequency downwind from the plant was provided by a Gaussian diffusion model with multiple area sources. The number of hours per day during which the plant would create its own fog and the hours per day in which naturally occurring fog would be enhanced are estimated. Plans for field monitoring of fog are also included. Report includes 9 figures, 2 tables, and references.

<189>

Precipitation in the Wake of Cooling Towers.
Atmospheric Environment 5:751-765
1971
Overcamp, T.J.; Hoult, D.P.
Massachusetts Institute of Technology, Fluid Mechanics Laboratory,
Department of Mechanical Engineering, Cambridge, MA

A model is proposed for determining the condition under which precipitation can occur from a natural draft cooling tower. Because the time scale for forming raindrops is large compared to the average residence time of droplets in the plume, there is no precipitation unless the wind forces the plume to mix with the aerodynamic wake of the tower and brings it to the ground. When this occurs, the small fog droplets in the plume will diffuse to the ground causing a light precipitation. A simple theory gives the heat transfer and the flux of water vapor emitted by the cooling tower. Equilibrium thermodynamics of mixing processes are used to calculate how much water vapor condenses as the plume is diluted with the surrounding air. Scaled experiments in a towing tank defined, in dimensionless variables, the conditions under which the plume will interact with the wake and strike the ground. A turbulent diffusion model combined with the thermodynamics of mixing is used to estimate the precipitation. These calculations showed that precipitation can be a tenth of a centimeter per hour when the temperature is as cold as -10 C. They also show that precipitation depends strongly on the relative humidity at warmer temperatures. (Auth)

<190>

Atmospheric Effects from Waste Heat Dissipation at Power Plant Cooling Lakes - Second Annual Report.
Exhibit C, Cooling Lake Management: Thermal and Related Research Review, Clinton Power Plant - Second Annual Report. Prepared by Huff, F.A. and Vogel, J.L., Illinois State Water Survey for Illinois Power Co., Aug. 1977. 17 pp.

Report summarizes results of a second year of research on atmospheric effects of cooling lakes. Major emphasis of research has been data procurement, data reduction, and preliminary analytical results of fogging and icing studies. Methodology and instrumentation modifications made at the primary research site, Baldwin Lake (used for cooling Baldwin Power Plant, Randolph County, IL), are reviewed and results are presented. Preliminary comparisons of Baldwin data with Dresden Lake data (used for cooling the Dresden Nuclear Power Station, Grundy County, IL) are also presented. Report contains 5 figures, 1 table, and references.

<191>

Estimated Number of Hours Per Year of Steam Fog by Wind Direction.
Table 5.1-4, Boardman Nuclear Plant Environmental Report, Portland General Elec. Co., Feb. 1977. 1 p.

Table shows annual estimated hours of steam fogging induced by the cooling lake of the proposed Boardman Nuclear Plant, Morrow County, OR. Calculations are made for air temperature above and below 32 degrees F and at various wind directions toward and away from the plant.

<192>

Estimated Number of Hours Per Year of Steam Fog by Wind Direction.
Table 3.2-12, Environmental Analysis-Proposed Participation in Portland General Electric Company's Boardman Coal Plant, Pacific Northwest Generating Co., Oct. 1976. 1 p.

Table gives the estimated number of hours of steam fog rising from the cooling lake per year for each wind direction during operation of the proposed Boardman power station in Morrow County, OR. Data was computed from values identified in the fog index distribution in Tables 3.2-9 and 3.2-10 (#11884). Values are shown for air temperature above and below 32 degrees F.

<193>

Cooling Pond Steam Fog.
Journal Air Pollution Control Association 24:860-864
1974
Currier, E.L.; Knox, J.B.; Crawford, T.V.
Bechtel Power Corporation, San Francisco, CA
Consumers Power Company

A study was made to determine atmospheric and pond surface conditions required for steam fog to occur from power plant cooling ponds, to define the dimensions of the fog, and to collect data on deposition of ice. Data, collected principally at the Four-Corners Plant over a three-year period, included water surface temperature, ambient meteorological conditions and occurrence and magnitude of steam fog and ice deposition. With strong winds, the fog extended onshore without lifting. With light winds, the fog extended some distance onshore but then lifted to form stratus. With almost calm winds, the steam fog li. .d over the pond and drifted downwind as stratus. Steam fog was observed in winds to 28 mph, air-water temperature differences from 21.5 degrees to 68 F and in atmospheric stability categories C, D, E, and F. A fog index number was defined and used for data interpretation. The probability of occurrence of steam fog as a function of the fog index number varied from 0.04 for an index number less than 10 to 1.00 for an index number greater than 90. From the data, if fog occurred, its extent along the ground was equal to or greater than 100 feet 80% of the time, equal to or greater than 500 feet 35% of the time, equal to or greater than 5000 feet 12% of the time. If stratus occurred its extent above ground was equal to or greater than 1 mile 91% of the time, equal to or greater than 5 miles 55% of the time and equal to or greater than 10 miles 36% of the time. Measurements showed that steam fog droplet sizes predominate in the 10 micron diameter size. Values of liquid water content up to 0.20 g/m(E+3) were reported. Ice accretion data show build-up rates from 0.23 to 13 mm/hr of time. (Auth)(ND)

<194>

Winter Field Program at the Dresden Cooling Pond.
Radiological and Environmental Research Division Annual Report, Atmospheric Physics, January-December 1976, (p. 108-113), 188 pp.; ANL 76-88, Part 4.
1977
Everett, R.G.; Zerbe, G.A.
Argonne National Laboratory, Argonne, IL

A winter field program at the cooling ponds of the Dresden nuclear power plant began in November 1976. The program consists of gathering data, including a description of the fog or stratus conditions over the cooling pond complex J to aid in model testing. Fog covered pond 1 to a depth of 2-20 m or more almost every day. Rim icing occurred over the downwind area frequently. Vertical plumes of heights up to several hundred meters were commonly observed. At times stratocumulus clouds formed from the larger plumes. On two occasions, thermal vortices were observed. (ND)

<195>

A Study of Cooling Pond Fog Generation.
Air Pollution Control Association 71st Annual Meeting, Proceedings of a Symposium, Houston, TX, June 25-30, 1978, 13 pp.
1978
Leahey, D.M.; Davies, M.J.E.; Panek, L.A.
Western Research and Development, Calgary, Alberta, Canada
Calgary Power, LTD, Calgary, Alberta, Canada

A detailed meteorological program was initiated at Calgary Power Ltd.'s Sundance cooling pond site in mid-January 1977 and was continued until mid-April 1977. The purpose of the study was to evaluate the frequency with which fog might be expected to occur, the maximum distance over which the fog might create a visibility hazard and the speed with which the fog might be expected to dissipate. A time-lapse camera was used to obtain a continuous observational record related to fog occurrence. Associated information was also collected concerning wind, potential temperature gradients, atmospheric turbulence levels, and moisture deficits for purposes of testing a fog plume model. The model is of a simple advective type which incorporates heat and moisture fluxes. All parameters have a readily recognizable physical meaning. There are no adjustable factors which may be used to 'tune' the model. Evaluations of the model showed that it correctly predicted the presence or absence of fog about 88 percent of the time. It also correctly predicted the manner in which fog densities vary with wind speed, atmospheric stability and moisture deficit. Applications of the model showed that during extreme meteorological conditions, fog from the proposed cooling pond may adversely affect visibility at downwind distances of up to 2 km. (Auth)

<196>

Spray Cooling Fights Fog Best, Says Detroit Edison.
Electric Light and Power, E/G Edition 51(19):32-34
1973
Hoffman, D.P
Detroit Edison

Detroit Edison will install closed-cycle, spray-canal cooling systems at the Greenwood Energy Center. The costs of the alternative cooling systems evaluated were about equal, so the decision was based on environmental considerations. A test program was performed on the system from fall 1970 to June 1972. The test was run in the condenser discharge canal of the Enrico Fermi I plant. From the thermal performance of the single spray nozzle, a spray system computer program was developed to predict the entire canal's cooling capacity for any atmospheric condition. A model for calculating occurrences of low visibilities due to spray canal fog was also developed. Additions of heat and water from system operation is not expected to cause adverse environmental effects. Reduced visibility, drift deposition, and icing events depend upon weather conditions and the rate of total plant heat rejection, and will be intermittent, decreasing with distance from the spray canal. Significant drift is unlikely to occur at distances greater than 600 feet from the canal and total volume of drift should not exceed 0.01% of the sprayed water. (ND)

<197>

(Fogging Occurrence.)
R.W. Beck and Associates, Denver, CO. In: Environmental Analysis Merom Generating Station, Prepared for Hoosier Energy Div. of Indiana Statewide R.E.C. Inc., Sept. 1976. pp. 4-19. Hoosier Energy Div. of Indiana Statewide R.E.C. Inc.

Tables indicate calculated fogging occurrence at the edge of the cooling lake at the proposed Merom Generating Station (two 490-MW units), Sullivan County, IN, for each of the 4 seasons. Occurrences are calculated for the tri-variate distribution of saturation deficit, wind speed, and stability class. Fogging was assumed to occur in each category when the water vapor increased at average wind speed, exceeded the average saturation deficit, and for low wind speed situations the source term was reduced accordingly.

ATMOSPHERIC EFFECTS - ABATEMENT TECHNOLOGY

<198>

Fog Formation and Fog Elimination.
IAEA-SM-187/6; Environmental Effects of Cooling Systems at Nuclear Power Plants, Proceedings of a Symposium, Oslo, August 26-30, 1974. International Atomic Energy Agency, Vienna, (pp. 75-84), 830 pp.
1975
Berliner, P.
Gesellschaft fur Kemforschung, Karlsruhe, Germany

Thermodynamic processes controlling fog formation and elimination from cooling towers are discussed. Psychrometric charts are used to illustrate the discussion. Numerical solutions are described to evaluate the economics of the theorem. The numerical thermodynamic conclusion demonstrates that a small amount of warm dry air is sufficient to prevent any fog in the vicinity of common cooling towers. (ND)

<199>

How to Prevent Cooling Tower Fog.
Hydrocarbon Processing 55(12):97-100
1976
Campbell, J.C.
Lilie-Hoffman Cooling Towers, Inc., St. Louis, MO

One of the most practical means of preventing cooling tower fog is the addition of heat to the exhaust air, thus increasing its capacity to hold water vapor. The most promising methods are finned-tube exchanges and gas burners. Design specifications and examples for both methods are provided. (ND)

<200>

Reducing Cooling Tower Icing Potential.
Electric Light and Power 56(10):56-57
1978
Doran, W.G.; Rosenquist, W.A.
Sargent and Lundy, Chicago, IL

Some of the problems associated with icing conditions on cooling towers are described and suggestions to minimize icing are provided. The five areas with a high freezing potential are the cold water basin, both the exterior and interior surfaces of the tower, areas vulnerable to ice that thaws and falls, and nearby structures. The advantages of mechanical draft towers, besides low initial cost, includes flexible water and air control. After a tower design is selected, a number of guidelines are recommended which are based on a thorough knowledge of both the tower and site characteristics. (ND)

<201>

Elimination of Cooling Tower Fog from a Highway.
Journal Air Pollution Control Association 12(8):379-383
1962
Hall, W.A.
Atlantic Refining Company, Philadelphia, PA

The results of a study of means to eliminate cooling tower fog from a highway are reported. Nine alternatives were considered including moving the tower, distributing the cooling load, diluting the air from the stacks, increasing stack height, and heating the stack effluent. The final solution chosen was to install six gas burners in a stack extension on each of two cells of the eight-cell tower. The burners have been lit on nine occasions and have satisfactorily kept fog from the highway. (ND)

<202>

Control of Cooling Tower Mist.
Cooling Tower Institute Semi-Annual Meeting, Proceedings of a Symposium, Snowmass-at-Aspen, CO, June 22-24, 1970, TP-87A, 6 pp.
1970
Maurer, R.H.
Celanese Chemical Company

A study was conducted to determine and implement a solution to the visibility problem associated with cooling tower emissions. Of the various possible methods of controlling the mist emissions, an exhaust reheat method was selected as the best alternative. Tests showed it was best to install the burners on the fan stacks down wind of the idle fans. The on-stream requirement of the equipment is low, making the operating costs reasonable. (ND)

<203>

Suppression of Ice Fog from Cooling Ponds.
CRREL Report 76-43, 78 pp.
1976
McFadden, T.T.
Cold Regions Research and Engineering Laboratory, Hanover, NH
U.S. Army

Ice fog generated at the Eielson AFB power plant cooling pond contributes heavily to the total ice fog problem on the base. Several methods for ice fog suppression were studied and two techniques were tested experimentally. Experiments were also conducted to determine the magnitude of the various modes of heat transfer within the pond's microclimate. Values of evaporative and radiative heat loss during ice fog are presented. Ice cover is shown to be an effective ice fog suppression technique. Monomolecular films are also shown to be effective and offer some unique advantages, such as ease of application and low overall cost. The heat normally lost to evaporation must be dissipated by other means during suppression. With the ice cover technique this is accomplished by melting the ice cover. During suppression with monomolecular films, the heat must be dissipated by increasing radiative and convective losses. The simplicity of application of monomolecular films, along with their lower cost, combine to make this technique attractive; however, the lower pond temperatures and increased suppression effectiveness weigh heavily in favor of the ice cover technique. More exhaustive testing will provide a better understanding of the problems involved in using the ice cover method of suppression. (Auth)

<204>

Cooling Tower Fog Plumes, Characteristics and Control.

8 pp.
1975
Reisman, J.I.; Ovard, J.C.
Ecodyne Cooling Products Division, Santa Rosa, CA

The fog potential for mechanical draft cooling towers is discussed. With specific emphasis on methods of controlling mechanical draft cooling tower fog plumes. As a first step, the formation and characteristics of cooling tower fog, and mechanical draft cooling tower fog plume behavior are outlined. Second, the significant meteorological variables and the periods when combined meteorological effects are most likely to result in extended cooling tower fogging situations are discussed. Finally, the Ecodyne wet/dry Foglimitor System is described. This system is a wet cooling tower and finned tube heat exchanger (dry cooling) in a combined unit which is specifically designed to eliminate fogging problems while maintaining maximum operational flexibility consistent with efficient plant operation. (ND)

ATMOSPHERIC EFFECTS - ANALYTICAL METHODS AND MODELS

<205>

Meteorological Influences of Atmospheric Cooling Systems as Projected in Switzerland.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 239-264), 638 pp.
1975
Junod, A.; Hopkirk, R.J.; Schneiter, D.; Haschke, D.
Swiss Meteorological Institute, Air Pollution Service, Payerne,
Switzerland
Electro-Watt Engineering Services Ltd., Zurich, Switzerland
Swiss Federal Institute for Reactor Research, Wurenlingen, Switzerland

Numerical-model studies of the meteorological effects of large heat discharges into the atmosphere from evaporative natural draft cooling towers show that the main impact is the persistence of the visible condensed water plumes. There are also slight local reductions in the intensity of solar radiation reaching the ground and, under special conditions, increases in precipitation level downwind of cooling towers. Successful verification of the conceptual model used for the Swiss studies, with some adjustments for special conditions, was achieved following field tests on a 110-m-high natural draft cooling tower in the Federal Republic of Germany. Some details of this model and of the test campaign are presented as well as some indications as to the possibilities available from use of a hydrodynamic model of turbulent flow. (Auth)

<206>

Critical Review of Hydrologic Modeling on Atmospheric Heat Dissipation.
BNWL-2166
1977
Onishi, Y.; Brown, S.M.
Battelle Pacific Northwest Laboratories, Richland, WA

The useful roles of hydraulic modeling in understanding the prediction of atmospheric effects of heat dissipation systems and the state-of-the-art of hydraulic modeling of atmospheric phenomena are assessed. Potentially useful hydraulic modeling facilities both in the United States and abroad are inventoried. Hydraulic model studies to assist the assessment of atmospheric effects of nuclear energy centers are evaluated. (ND)

<207>

ORFAD, A Computer Program to Estimate Fog and Drift from Wet Cooling Towers.
ORNL/TM-4568, 35 pp.
1975
Wilson, J.V.
Oak Ridge National Laboratory, Reactor Division, Oak Ridge, TN

A method for estimating the number of hours when fog and ice will result from wet cooling tower operation and the amount of dissolved solids that will be deposited at different directions and distances from such towers is described. A computer program using this method is described, and instructions for preparing the data for the program and using it are given. The program uses hourly weather data from tapes. It calculates appropriate values of plume rise and dispersion for the weather conditions, thence calculates vapor density where the plume reached the ground, and calculates particle deposition rates and fogging from this vapor density. (Auth)

<208>

Simulation of Spray Canal Cooling for Power Plants-Performance and Environmental Effects.
American Society of Mechanical Engineers Winter Annual Meeting, Proceedings of a Symposium, New York City, NY, December 5, 1976; ASME Paper No. 76-WA/HT-28, 6 pp.
1976
Arndt, C.R.; Barry, R.E.
Detroit Edison, Engineering Research Department, Detroit, MI

A computer simulation has been developed to predict the thermal performance and environmental effect of powered spray modules positioned in a canal to cool power plant condenser discharge water. The simulation takes into account the effects of air and water temperature, wind speed and direction, atmospheric stability and lapse rate, relative humidity spray module configuration and other important variables. The model is capable of predicting local water and air temperatures and the production and concentration of downwind fog for up to five separate canals located on one site. The underlying assumptions leading to the development of the model are fully explained and an example is presented showing its application. A number of conclusions are drawn which are applicable to the design of spray module cooling systems. (Auth)(ND)

<209>

The Prediction of Fog Over Cooling Ponds.
Journal Air Pollution Control Association 27(2):140-142
1977
Hicks, B.B.
Argonne National Laboratory, Argonne, IL
U.S. Energy Research and Development Administration

A revised and apparently improved index for the prediction of fog over cooling ponds was developed from physical arguments. The relevance of the new parameter was tested using the data of Currier et al. The Fog Excess Water Index (FEWI) was derived from simplistic considerations of the humidity field in the vicinity of a cooling pond. The new index seems to be a better measure of cooling pond fog susceptibility than that of Currier et al.; it also has the benefit of being based on a simple physical model. (ND)

<210>

The Generation of Steam Fog Over Cooling Ponds.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical

Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 75-78), 120 pp.
1978
Hicks, B.B.
Argonne National Laboratory, Radiological and Environmental Research
Division, Argonne, IL
U.S. Department of Energy

Fog occurs over cooling ponds in conditions typified by large water - air temperature differences and correspondingly great local atmospheric instability. The associated strong vertical mixing can be taken to result in local supersaturation whenever the vapor pressure of the mixed air exceeds the saturated vapor pressure at the temperature of mixed air. A Fog Excess Water Index, based on this conceptual model, has been tested against data obtained in several recent field programs (at the Dresden Power Plant) and appears to give an improved capability for the prediction of steam fog. The true temperature of the water surface is a critical consideration; but there is little apparent influence of wind speed. Stability regimes characteristic of a cooling pond environment are substantially different from those normally encountered over land. Consequently, downwind fog predictions made by the use of dispersion-type models (such as are routinely used in air pollution studies) should be considered with considerable caution. (Auth)

<211>

New Cooling Pond Fog Index.
Radiological and Environmental Research Division Annual Report, Atmospheric Physics, January-December 1976, (p. 104-107), 188 pp.; ANL-76-88, Part 4.
1977
Hicks, B.B.
Argonne National Laboratory, Argonne, IL
U.S. Energy Research and Development Administration

A method to predict the tendency for steam fog to occur above industrial cooling ponds was developed. The hypothesis upon which the Fog Excess Water Index (FEWI) concept has been based remain to be tested. However, the relevance of the index to cooling pond fog studies has been tested using the extensive data set reported by Currier et. al. (1974) for the Four Corners and Coffeen cooling ponds. Significant improvements over the Fog Index Number method were noted from the use of the FEWI. (ND)

<212>

A Dynamic Plume Model for the Prediction of Atmospheric Effects Associated with Cooling Tower Operation.
Air Pollution Control Association 68th Annual Meeting,
Rao, K.S.; Lague, J.S.; Egan, B.A.; Chu, Y.H.
Environmental Research and Technology, Concord, MA
Wisconsin Electric and Power Company, Milwaukee, WI

A numerical method for predicting the convective rise of cumulus clouds in a quiescent atmosphere has been adapted to model the behavior of a buoyant moist plume released at high vertical velocity into a crosswind. The model has been successfully applied to assess the atmospheric effects (ground-level icing, fogging, and length of visible plume) associated with a number of cooling tower designs. A physically-realistic procedure for treating the merging of multiple plumes has been incorporated for applications to mechanical draft towers. The computational scheme is based on numerical methods for obtaining simultaneous solutions to a system of differential equations expressing conservation of mass, total moisture, momentum, and entropy, as well as a series of equations for handling water phase conversions. Assuming 'top-hat' similarity distribution of properties, the rise, growth rate, velocity, temperature, and liquid mixing-ratio of the plume are calculated at various downwind distances. Vertical profiles of atmospheric temperature, wind, and specific humidity may be used as inputs where data from meteorological towers are available. Appropriate meteorological statistics may be incorporated to predict frequencies of tower-induced fogging and icing as well as visible plume lengths. (Auth)(ND)

<213>

Meteorological Effects of the Mechanical Draft Cooling Towers of the Oak Ridge Gaseous Diffusion Plant.
ATDL Contribution File No. 89, 23 pp.; CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, Proceedings of a Symposium, S.R. Hanna and J. Pell (Eds), College Park, MD, March 4-6, 1974. Technical Information Center, Oak Ridge, TN; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1974 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 55-70), 250 pp.; ATDL-75/17
1974
Hanna, S.R.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Atomic Energy Commission

The mechanical draft cooling towers at the Oak Ridge Gaseous Diffusion Plant dissipate about 2000 MW of heat. Downwash occurs about 40% of the time, when wind speeds exceed about 3 m/s. An elevated cloud forms about 10% of the time. The length of the visible plume, which is typically 100 or 200 m, is satisfactorily modelled if it is assumed that the plumes from all the cells in a cooling tower bank combine. The calculation of fog concentration is complicated by the fact that the moisture is not inert but is taking part in the energy exchanges of a thermodynamic system. Calculations of drift deposition agree fairly well with observations. (AUTH)

<214>

A Review of Potential Biological Impacts of Cooling Tower Salt Drift.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (p. I-143), 90 pp.
1978
Talbot, J.J.
United Engineers and Constructors, Inc.

A literature review has been performed on salt drift generated by the operation of closed cycle cooling systems from electric power generating stations. Emphasis is placed on the interpretation of experimentally determined salt impacts extrapolated to theoretical predictions of salt concentrations from cooling towers, since there are, at the most, two or three closed-cycle cooling systems where adverse impacts have been addressed. Threshold concentrations at which various plant species would be harmfully affected by drift deposition and distances from the cooling tower at which these levels are attained or exceeded are discussed. The existing field data from one operational cooling tower in the U.S. indicates that acute salt drift effects on vegetation occur in the immediate environs of the cooling tower. Chronic effects of long-term operation of cooling towers are not known. The extrapolation of experimental dose-response data on salt damage to natural situations of operating cooling towers should proceed cautiously because salt deposition on vegetation in laboratory situations may not be representative of cooling tower drift under real operational conditions and because laboratory deposition rates are generally much higher than measured drift rates in the field. (Auth)

<215>

Chalk Point Cooling Tower Project: A Selected and Annotated Bibliography on Interactions Between Vegetation and Saline Aerosols, Sulfur Dioxide and Ozone.
PPSP-CPCTP-21, WRRC Special Report No. 6, 29 pp.
1977
Curtis, C.R.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The scientific literature concerning saline aerosols, SO2, and O3, and their effects on botanical and agronomic plant species are listed. The collection is alphabetized by author, annotated, and contains over 100 references on various subjects related to saline aerosols, mechanisms of ion penetration into foliage, salt tolerance of plant species, analysis techniques, SO2 and O3 studies, and baseline or naturally occurring levels of elements, especially Na+ and Cl-, in vegetation. This bibliography was not intended to be a complete and exhaustive survey of all the subject areas, but, rather, it was designed for the purpose of creating a convenient reference data base for assessment of cooling tower drift effects on plant species. (ND)

<216>

Effects of Evaporative Salt Water Cooling Towers on Salt Drift and Salt Deposition on Surrounding Soils.
Journal Environmental Quality 7(2):293-298
1978
Wiedenfeld, R.P.; Hossner, L.R.; McWilliams, E.L.
Texas A and M University, Department of Soil and Crop Science, College
Station, TX
Texas A and M University, Department of Horticulture Science, College
Station, TX
Houston Lighting and Power Company

Five saltwater cooling towers recently constructed near Galveston Bay, Texas, have been shown to contribute to salt deposition in the surrounding area. Levels as high as 1,200 kg/ha per year of total salt were encountered within 100 m of the towers, but decreased in a logrithmic fashion with distance to less than 300 kg/ha per year at 434 m with only 16% attributable to the cooling towers. The remaining deposition was caused by natural sea spray which varied widely but averaged about 250 kg/ha per year in the study area. Changes in composition of airborne salts with distance from the cooling towers were noted, primarily as a narrowing of the Na/Ca ratio. Salinity levels in the soil were in equilibrium with naturally deposited salts. Enhanced salt deposition levels due to the cooling towers initially caused only slight effects in the soils closest to the towers, but may eventually lead to both salinization and solonization in the surrounding vicinity. (Auth)

<217>

Effects of Saltwater Cooling Tower Drift on Water Bodies and Soil.
Water, Air, and Soil Pollution 2:457-471
1973
Roffman, A.; Roffman, H.K.
Westinghouse Electric Corporation, Westinghouse Environmental Systems
Department, Monroeville, PA
U.S. Atomic Energy Commission, Division of Reactor Development and
Technology

Detailed calculations of possible incremental increase in the salinity of soil, irrigation water and bodies of fresh water due to the operation of saltwater cooling towers are discussed. The calculations make use of water balance equations and empirical relations to determine the soil salinity. Salt deposition levels from a typical 1000 MWe natural and mechanical draft cooling towers with a water circulation rate of 31.5 m(E+3)/s and drift rate of 0.002% of the total circulating water were calculated using current available deposition models. The results obtained from these calculations indicate that the incremental effects of saltwater cooling towers upon the surrounding soil and water are generally minimal, if the drift rate is controlled by appropriate eliminators. Some extreme cases may develop under severe weather conditions, but these will be infrequent and will represent a small fraction of the total operating time. (Auth)

<218>

Effect of Cooling Tower Vapours on Agriculture in the Environment of Power Plants.
Energiewirtschaftliche Tagesfragen 26(7):363-366
1976
Seemann, J.

The effect of cooling tower vapors are most evident with respect to solar radiation according to recent investigations, and this is mainly in the immediate vicinity of the power plant. The influence on photosynthesis should be hardly detectable even in this limited area around the power plant. The effect on the air temperature is minimal, and the influence on the relative moisture is so small that it is within the margin of measuring error, with the exception of the few cases in which the vapors are pressed down to the ground. One need not reckon with an increased fungoid growth and bad drying conditions. Rainfall could be additionally increased if the weather situation is likely to rain or if it is raining anyway. Regarding fog frequency, one may assume that there might be a certain increase in fog. So far no cases are known in which fog would occur where there is no general tendency for fog formation. (Auth)(ND)

<219>

The Effect of NaCl on Soil Microbial Respiration and Growth of Four Fungi in Axenic Culture.
Northeast American Society of Agronomy Meeting, Proceedings of a Symposium, Guelph, Ontario, July 16-18, 1975
1975
McCormick, R.W.; Wolf, D.C.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The effect of NaCl on microbial respiration was determined for an alfalfa meal amended (0.5%) Sassafras soil moistened to 60% of the water holding capacity. After 14 weeks of incubation, NaCl rates of 0, 0.25, 0.50, 1.0, 2.5 and 5% reduced CO2 evolution by 0, 22, 25, 30, 40, and 73%, respectively. Nitrification was inhibited by NaCl levels equal to or greater than 0.5%. In another experiment, fungi were grown in a liquid medium with NaCl added at rates of 0, 5, 10, 15, and 30% for ASPERGILLUS FLAVUS and PENICILLIUM FREQUENTANS and 0, 2, 5, 10, and 15% for PHYCOMYCES BLAKESLEEANUS and MUCOR MUCEDO. The fungi were harvested at two week intervals for a period of eight weeks and growth determined on a dry weight basis. For P. FREQUENTANS, biomass was at its maximum, and approximately the same for both the 0 and 5% NaCl levels at the end of 2 weeks. A. FLAVUS followed the same trend as P. FREQUENTANS except maximum biomass production was two weeks later at all salt levels. P. BLAKESLEEANUS obtained its maximum biomass at the end of the 4th week for the 0, 2, and 5% NaCl levels with the biomass decreasing with increasing NaCl levels. M. MUCEDO obtained maximum biomass at the 15% NaCl level after 8 weeks. (Auth)

<220>

Studies on the Effects of Saline Aerosols of Cooling Tower Origin on Plants.
Journal Air Pollution Control Association 27(4):319-324
1977
McCune, D.C.; Silberman, D.H.; Mandl, R.H.; Weinstein, L.H.;
Freudenthal, P.C.; Giardina, P.A.
Boyce Thompson Institute for Plant Research, Yonkers, NY
Consolidated Edison Company of New York, Inc.

A research program was undertaken to develop information that could be used to estimate the risk of adverse effects of saline cooling tower drift on native and cultivated flora in the Indian Point, New York area. Eleven species of woody plants were exposed at 85% relative humidity to a saline mist with 95% of the particles between 50 and 150 um in diameter. Three biological factors--stage of development, species, and phenotype--determined the susceptibility of plants to saline aerosols when the occurrence of any lesion on the foliage was used as a measure of response. The effects of stage of development on the incidence and severity of foliar lesions depended upon the kind of plant. In deciduous woody species, the youngest leaves were most susceptible, but in conifers, the year-old needles were most susceptible. Canadian hemlock was the most susceptible species and witch hazel was the least susceptible. Median effective doses for these two species, although undetermined, could be more than 100-fold different (less than 2.4, the lowest used, and greater than 264 ug Cl/cm(E+2), respectively). Other species, ranked in decreasing order of susceptibility were: white ash, white flowering dogwood, forsythia, chestnut oak, silk tree, black locust, red maple, eastern white pine, and golden rain tree. Phenotypic variation within a species was not so great--within a 10 to 20-fold increase in dose the incidence of injury went from 0 to 100%. Exposures with bush bean showed that the relative humidity (RH) during or after the exposure period affected the incidence of saline induced foliar injury. A change from 50 to 85% RH doubled the effectiveness of the saline mist. It was also found that compared to particles between 50 and 150 um in diameter, an increase in the fraction of particles above 150 um increased the toxicity of the mist. (Auth)

<221>

Effects of Simulated Saline Cooling Tower Drift on Woody Species.
M.S. Thesis, 81 pp.
1977
Francis, B.A.
University of Maryland, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Cooling tower drift effects on woody vegetation were studied as a part of a larger project to evaluate cooling tower effects on the environment. To simulate drift for a field study, cooling tower basin water was sprayed thirty separate times during a 46 day period in 1975 on Virginia pine, PINUS VIRGINIANA Mill.; flowering dogwood, CORNUS FLORIDA L.; tulip tree, LIRIODENDRON TULIPIFERA L.; and California privet, LIGUSTRUM OVALIFOLIUM Hassk. Norway spruce, PICEA ABIES (L.) Karst., and white ash, FRAXINUS AMERICANA L., were added in 1976 and all trees were sprayed 43 times during a 59 day period. Only dogwood leaves showed significant injury. After spraying terminated, dogwood leaves were rated for injury and samples of dogwood and ash leaves were taken for ion analyses. Marginal necrosis of dogwood leaves was associated with increased spray, salt concentration of the spray, and concentration of Cl- in the leaves. Cl- concentration ranged from 3145 to 9000 ug per g dry weight for mild and severe injury, respectively. No clear association was found between injury of dogwood leaves and Na+, K+, or Ca+ concentrations in the leaves. Ash leaves accumulated up to 2749 ug Cl- per g dry weight without injury. Absence of injury on other species was probably due to the ability of their leaves to exclude, or reduce absorption of, toxic concentrations of the ions supplied. (Auth)(ND)

<222>

Effects of Simulated Cooling Tower Drift on Dogwood Foliage.
American Phytopathological Society Annual Potomac Division Meeting, Proceedings of a Symposium, Newark, DE, March 17-19, 1976; Proceedings American Phytopathological Society 3:324-325
1976
Francis, B.A.; Curtis, C.R.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Cooling towers of power plants are used to dissipate waste heat into the atmosphere. If saline water is used for cooling, a saline aerosol known as drift is released into the atmosphere. Drift effects on vegetation are unknown. To simulate drift for a field study, cooling tower basin water was sprayed on dogwood (CORNUS FLORIDA L.) five times a week for six weeks. After six weeks affected leaves in each treatment were rated and placed in one of four injury classes. Foliar Cl- was also determined. Foliage from all treatments (1.77, 3.53, 5.30, and 7.06 Kg total salts/ha/wk) except controls exhibited symptoms. The average foliar Cl- concentration in the lowest treatment, the tap water control, and a no spray control was 3701, 1265 and 867 ug Cl- per g dry wt, respectively. This experiment, conducted under field conditions, indicated dogwood foliage may be susceptible to simulated drift when applied at 1.77 Kg total salts/ha/wk or higher. (Auth)

<223>

Impact of Saline Mists on Woody Plants.
Proceedings American Phytopathological Society 3:228
1976
Feder, W.A.
University of Massachusetts, Suburban Experiment Station, Waltham, MA

Saline mists generated by the use of saline water from a power plant spray cooling canal deposited salt at rates ranging from 0.02gm/m(E+2)/day to 1.05gm/m(E+2)/day. Deposition was correlated with wind speed, wind direction, distance from the source and salinity of canal water. Dormant terminal buds of apple, wild pear, and VIBURNUM were killed one mile from the canal. VIBURNUM, American elm, and wild pear developed brown necrotic spots under the bark on the canal side of the twigs. From late May to early September leaves of several woody species showed slight marginal discoloration, marginal burning, total leaf burning, and leaf drop. Maple petioles were flattened and enlarged. Scarlet oak 6 miles downwind of source showed slight marginal leaf burn in upper branches. Norway maples one-half mile downwind lost three sets of leaves on the side of the trees toward the canal. Leafing out was delayed for up to two weeks in hickory. Field trees sprayed with artifically produced salt mists made with canal water developed symptoms identical to those on trees exposed to salt mists from the canal itself. Tolerance to salt injury from highest to lowest was as follows: hickory, grape, elm, birch, black locust, hopwood, sugar maple, Japanese red maple, ash, dogwood, white oak, buckthorn, cherry, basswood, black oak, Virginia creeper. (Auth)

<224>

Salt Tolerance of Trees and Shrubs.
Tables 6.3-1 Through 6.3-4, Ocean-Sited Plants - Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 8 pp.

Tables list salt sensitivity and tolerance of tree species and ornamental plants. Table 6.3-1 summarizes data relating to sensitivity of roadside trees and shrubs to aerial drift of deicing salt; Table 6.3-2 presents results from a literature survey regarding relative salt tolerance of trees. Table 6.3-3 summarizes studies determining chloride levels corresponding with plant injury, and Table 6.3-4 indicates relative observed salt burn on ornamental plants in the vicinity of the P.H. Robinson Station.

<225>

Dogwood as a Bioindicator Species for Saline Drift.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. 65-77), 462 pp.
1978
Curtis, C.R.; Francis, B.A.; Lauver, T.L.
University of Delaware, Department of Plant Science, Newark, DE
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Vegetation has served as a useful bioindicator for a number of air pollutants. To date, no indicator species have been developed specifically for detection and monitoring of saline cooling tower drift under field conditions. The results of three years of field tests on dogwood (CORNUS FLORIDA L.) which appears to be a species especially well-suited as a bioindicator for saline drift are summarized. Dogwood is a widespread native tree of Maryland forests typically growing along the edge of woodlands. The foliage accumulates Cl- steadily under field conditions and there is a point at which leaf injury occurs with respect to leaf Cl-. Leaf Cl- is associated with the severity of leaf injury, the total number of leaves injured on small trees, and the numbers of simulated saline drift depositions. Similar symptoms develop when leaves are sprayed with either saline cooling tower basin water or NaCl solution. These properties suggest that dogwood may be an excellent candidate for a salt drift bioindicator species. (Auth)

<226>

Preliminary Results of the Effects of Saline Aerosols, Sulfur Dioxide or Saline-Acid Aerosols on Selected Ornamental Woody Species.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 131-139), 462 pp.
1978
Hosokawa, G.; Lauver, T.L.; Curtis, C.R.; Patterson, G.W.
University of Maryland, Department of Botany, College Park, MD
University of Delaware, Department of Plant Science, Newark, DE
Maryland Department of Natural Resources, Power Plant Siting Program

Preliminary experiments were conducted to study the symptoms resulting from treatment of dogwood (CORNUS FLORIDA), bush honeysuckle (LONICERA TARTARICA), and flowering crabapple (PYRUS sp.) with either acute levels of sulfur dioxide or NaCl aerosols, or a combination of these. Sulfur dioxide-induced symptoms developed on dogwoods treated for 3 or 6 hours, and flowering crabapples treated for 2, 4, or 6 hours with 5 ppm (13,166 ug/m(E+3)) sulfur dioxide. Saline aerosol-induced symptoms appeared only on the flowering crabapples after the third exposure (6 hours/exposure) with 20,000 ppm (0.02 g/cm(E+3)) NaCl. In general, sulfur dioxide-induced symptoms occurred earlier on older leaves than on younger leaves. The saline aerosol-induced symptom developed first (2 days after treatment) and the sulfur dioxide-induced symptom 4 or 5 days after treatment. Flowering crabapples were treated with saline-acid aerosols (5 ppm SO2:10,000 ppm NaCl) and symptoms observed. A limited leaf tip necrosis developed on the 3 and 4 hour treated trees. Very small stipples were observed on the leaves of flowering crabapple exposed 6 or 8 hours. In addition to stippling, a marginal necrosis and general chlorosis developed on some of the leaves fumigated for 8 hours. The stipples, previously not observed with either SO2 or saline aerosol treatments, were 1 mm or less in diameter, with a central necrotic lesion surrounded by a chlorotic halo. In general, marginal necrosis appeared earlier than chlorosis, and some leaves exhibited neither necrosis nor chlorosis, but stipples. (Auth)(ND)

<227>

Power Plant Effects.
Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1976, S.I. Auerbach, et al., Part 2, (p. 174-186), ORNL-5257, 310 pp.; ESD No. 1102, 310 pp.
1977
Coutant, C.C., et al.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

A study of the interception and retention of simulated cooling tower drift on vegetation was performed. A portable drift simulator was designed and fabricated to generate a spectrum of droplets representative of drift diameters expected at the stack discharges of cooling towers using current state-of-the-art drift eliminator designs. Radio-labelled sodium chromate was added to the liquid to simulate the chromate in the recirculating cooling water of the Oak Ridge Gaseous Diffusion Plant cooling towers. Species with high ratios of leaf surface area to soil surface area (LAI) have greater interception efficiencies than species with little foliage area. For example, yellow poplar and loblolly seedlings, with area indices of 2 and 3, intercepted 72 and 64% of the deposition flux respectively, whereas fescue grass, with an area index of 1, intercepted 24%. The higher contamination of yellow poplar leaves was likely a function of the orientation of foliage perpendicular to the deposition path rather than leaf area or biomass within the receptor area. From 60 to 75% of the initial contaminant was lost during the first three days by wind scavenging of dew droplets from the foliage. The remaining fraction was lost at a much slower rate, with only 10% remaining on yellow poplars at 27 days as compared to the same amount on fescue at 63 days. At 43 days, 99% of the initial contaminant present was lost from the pine seedlings. It is assumed that stable chromium and radio-labelled chromium behave similarly in vegetation. Consequently, these data are valuable adjuncts for understanding the fate of chromate drift from the ORGDP cooling towers and provide parameters needed for current deposition models to predict the concentrations of drift chemicals in vegetation. (ND)

<228>

Effects of Simulated Salt Drift on Corn and Soybeans Using Brackish Water from the Cooling Towers at Chalk Point.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 3, PPSP-CPCTP-23, WRRC Special Report No. 11, (p. 71-77), 98 pp.
1978
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

During the third year's experiments designed to simulate the action of cooling tower drift on corn and soybeans, applications of salt up to 3.6 kg/ha/week failed to induce a statistically significant reduction in yields for corn and soybeans. However, both corn and soybean plants were exhibiting significant increases in sodium and chloride by the second sampling date. The dry conditions during June and July may have contributed to reduced salt uptake during the early phases of plant growth, especially for soybeans. Extensive leaf damage from salt deposition was found at 2.4 and 3.6 kg/ha/wk treatments in both crops. The lower leaves of the soybeans were most affected by the salts as opposed to the upper leaves on the corn. The trend for reduced yields at high salt applications in corn is consistent with previous observations and can best be explained by reduced photosynthetic activity in the upper leaves due to salt injury. The lower leaves on the soybeans exhibited the most injury but the lower leaves are not closely associated with carbohydrate supply to the pods. The photosynthetic activity of leaves on both crops will be a major focal point in future investigations concerning salt injury to crops. (N)

<229>

Response of Corn and Soybeans to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 3, PPSP-CPCTP-23, WRRC Special Report No. 11, (p. 78-84), 98 pp.
1978
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The results from the two studies of corn and soybeans were grown on soil treated with NaCl and exposed to simulated salt drift over eight weeks of the 1977 growing season are summarized. Corn and soybean plants exposed to the combination of soil applied NaCl and foliar applied salts using water from the operating cooling tower at Chalk Point exhibited greater response to the foliar than the soil applied salts. Therefore, with these two crops, there should be little concern for the potential buildup of salts in the soils affecting the plants. However, both crop species exhibited significant changes in their nutrient contents as a consequence of the foliar applied salts. The corn appeared to exhibit the greatest affects of foliar salts on yields with 2.4 kg/ha/wk causing a significant yield reduction. Although non-significant, the yields for soybeans were lower at the higher foliar salt treatment suggesting that the extensive vegetative damage observed earlier in the growth of the plants may have had some lasting affects.

<230>

Response of Corn and Soybeans to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 2, PPSP-CPCTP-19, WRRC Special Report No. 8, (p. 105-112), 131 pp.; Crops and Soils Research 10
1977
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The initial results from two studies of corn and soybeans grown on soil treated with NaCl and exposed to simulated salt drift over eight weeks of the growing season in 1976 are presented. Young corn plants appeared more sensitive to soil applied NaCl than to the foliar spray. Young soybeans appeared more sensitive to foliar applied salts than to soil applied NaCl. The corn plants appeared to increase and the soybeans appeared to decrease in sensitivity to foliar applied salt. Yields of corn were significantly reduced by the foliar applied salt but not by the soil applied NaCl up to 110 kg/ha. Soybean yields tended to be lower following foliar salt additions but the results were not significant. No significant interactions between soil vs. foliar salts were observed on either crop species. (ND)

<231>

Effects of Simulated Salt Drift on Corn and Soybeans Using Brackish Water from Cooling Towers at Chalk Point.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 2, PPSP-CPCTP-19, WRRC Special Report No. 8, (p. 91-96) 131 pp.; Crops and Soils Research 10
1977
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The second year results from a study simulating salt drift using cooling tower water on corn and soybeans are discussed. Both species showed significant increases in sodium and chloride contents with increased rates of spray yet no appreciable affects on other plant nutrients. No visual damage was observed during the study. The yields of both crop species were not significantly changed by treatments suggesting that both crop species may be able to grow within an environment near a cooling tower having brackish water and withstand drift rates as high as 51.1 l/ha/day with water containing 20,000 ppm salinity. (ND)

<232>

Effects of Salt Sprays on the Yield and Nutrient Balance of Corn and Soybeans.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 379-392), 638 pp.
1975
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

In an effort to simulate the effects of salt spray from cooling towers on corn and soybean crops, plots of each crop were subjected to applications of salt spray of 0, 1.82, 3.64, 7.28, or 14.56 kg/ha week for eight weeks. For 1.82 and 3.64 kg/ha week treatments, nozzles were used which delivered 3.92M NaCl solution at a rate of

1.25 ml/sec and a pressure of 2.81 kg/cm(E+2). The concentrated NaCl solutions were employed to attain mist droplets approaching maximum salt saturation. Extensive leaf damage was induced by the 7.28 and 14.56 kg/ha week treatments in both crops. On the soybean plants the younger vegetation was more sensitive than older leaves. The opposite was observed for the corn plants. The high salt treatments appeared to stunt the young soybean plants to a larger degree than the young corn plants. The soybean plants appeared to recover from the initial acute effects of salt treatments as the plants matured. Vegetative damage to the corn plants was progressive with both the quantity of salt applied and with time. The metabolic index, a measure of the balance of nutrients in the tissue, was significantly decreased by the salt-spray treatments in both crops. The yields of both crops were significantly reduced by the salt-spray treatments. Compared to controls, soybean and corn yields were reduced by 18 and 39%, respectively, by the maximum salt treatments. Sodium levels in the soils were significantly increased by the treatments. (Auth)

<233>

The Influence of Simulated Salt Drift on Yields and Leaf Elemental Composition of Corn and Soybeans.
Northeast American Society of Agronomy Meeting, Proceedings of a Symposium, Guelph, Ontario, July 16-18, 1975
1975
Armbruster, J.A.; Mulchi, C.L.
University of Maryland, College Park, MD

Salt spray as NaCl was applied to corn and soybeans in 1973 and 1974 to simulate the effects of cooling tower salt drift on these crops. In the 1973 studies with salt spray rates applied at 0, 1.82, 3.64, 7.28 and 14.56 kg/ ha for 8 weeks, significant yield reductions were noted for both corn and soybeans at rates above 3.64 kg/ha/wk. In 1974 with salt spray applied daily equaling rates of 0, 5.6, 11.2, 16.8 and 22.4 kg/ha for 8 weeks, significant yield reductions were observed for soybeans and corn at rates higher than 11.2 and 5.6 kg/ha/wk, respectively. In addition, applications of 11.2 and 22.4 kg/ha/wk in 1974 to corn during tasseling caused significant yield reduction at the higher rate only. In general, young soybean plants or new vegetation was more sensitive to salt spray than mature tissue or older plants, but a reverse of this trend was observed for corn. Early season humid and wet conditions in 1974 enhanced the salt damage on both crops. Metabolic index values for leaf tissues, calculated as a ratio of the percent Ca + Mg + K + P to the percent Na + Cl, were significantly reduced by salt treatments in all studies and is being considered as a research tool for monitoring salt drift from operating cooling towers. (Auth)

<234>

Effects of Simulated Salt Drift on Maryland Tobacco Using Brackish Water From Cooling Towers at Chalk Point.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 3, PPSP-CPCTP-23, WRRC Special Report No. 11, (p. 55-62), 98 pp.
1978
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The results from the third year's study involving the affects of brackish water on tobacco are reported. The plants were grown under severe moisture stress except for the last two weeks prior to harvest. The low soil moisture levels may have caused certain inconsistencies in the results, especially in leaf nutrient contents. The low soil moisture may have also affected the response of the tobacco regarding changes in agronomic, chemical and physical properties of the cured tobacco due to applications of brackish water. (ND)

<235>

Response of Maryland Tobacco to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 3, PPSP-CPCTP-23, WRRC Special Report No. 11, (p. 63-70), 98 pp.
1978
Mulchi, C.L.; Armbruster, J.A.
University of Maryland, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The second year's results from a study of tobacco grown on soils treated with NaCl and exposed to simulated salt drift over eight weeks of the growing season are summarized. The absence of normal rainfall amounts and distribution at the Tobacco Experimental Farm during the summer of 1977 most probably contributed to the very dramatic effects of salts from both soil and foliar applied sources on the chemical contents and burning qualities of the tobacco. The low rainfall amounts would induce higher chloride uptake through reduced leaching from the soil and allowing a buildup of foliar applied salts on the leaves. The burning qualities of the tobacco were reduced by the application of only 28 kg/ha NaCl to the soil or 2.4 kg/ha/wk of foliar applied salt. (ND)

<236>

Effects of Simulated Salt Drift on Maryland Tobacco Using Brackish Water from Cooling Towers at Chalk Point.
Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 2, PPSP-CPCTP-19, WRRC Special Report No. 8, (p. 83-90), 131 pp.; Crops and Soils Research 10
1977
Mulchi, C.L.; Newcomb, W.W.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The second year results are presented for a study of tobacco response to simulated salt drift using brackish water from the Chalk Point cooling towers in amounts within the projected range of emissions. Chemical analysis of young tobacco showed significant increases in sodium and chloride contents and a reduction in the metabolic index with increased rate of salt spray. At flowering, there were trends for increased potassium, calcium and magnesium and also significantly higher sodium and chloride contents. Yields were significantly increased by the salt spray treatments but quality was lowered at the highest treatment rate. Overall, tobacco showed beneficial affects of the treatments up to 34.2 l/ha/day. The levels of chloride attained in the green and cured tobacco from the highest treatment was within the normal range for tobacco grown throughout the tobacco producing region in Maryland. (ND)

<237>

Influence of Nitrogen Sources on the Response of Maryland Tobacco to Chloride Fertilization.

Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 2, PPSP-CPCTP-19, WRRC Special Report No. 8, (p. 113-117), 131 pp.; Crops and Soils Research 10

1977

Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The second year results from a study involving the combination of soil chloride and nitrogen sources on Maryland tobacco are presented. Tobacco plants were exposed to increasing levels of chloride as CaCl(2) applied to the soil and to three sources of nitrogen (NH4)2SO4, NH4NO3 and CA(NO3)2 to determine if the source of nitrogen affected the plants response to chloride. Information on agronomic, chemical and physical properties of cured tobacco were obtained. Lower prices, value and alkaloid levels were observed with (NH4)2SO4 treatments. The quality of the tobacco was substantially reduced with increased soil chloride and prices; value and burn tended to be lower at the highest chloride level. Ca(NO3)2 significantly reduced the potassium and magnesium contents and increased calcium contents in the leaves. The chloride content in the leaves was significantly increased and metabolic index reduced with increased soil chloride levels. Calcium nitrate treatments significantly reduced the potassium and magnesium contents but increased the calcium contents in the cured tobacco samples. The metabolic index (ratio of P + K + Ca + Mg/Ma + Cl) was significantly reduced by the increase in soil chloride. The phosphorus content appeared not to be affected by treatments. (ND)

<238>

Response of Maryland Tobacco to NaCl Applied to Soil Combined with Simulated Salt Drift Using Brackish Water from Cooling Towers.

Chalk Point Cooling Tower Project Cooling Tower Effects on Crops and Soils, C.L. Mulchi, et. al., Post Operational Report No. 2, PPSP-CPCTP-19, WRRC Special Report No. 8, (p. 97-105), 131 pp.; Crops and Soils Research 10

1977

Mulchi, C.L.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The initial results from a study of tobacco grown on soils treated with NaCl and exposed to simulated salt drift over eight weeks of the growing season are discussed. Maryland tobacco was grown on plots treated with NaCl at rates of 0, 13. 7, 27.5 55 and 100 kg/ha at preplant then sprayed five days per week for eight weeks with cooling tower water containing 20,000 ppm salinity at rates equal to 0, 34.2 and 68.6 l/ha/day. Green leaf samples taken after three weeks of spraying showed lower calcium and magnesium contents and increased sodium levels in the tissue attributable to the spray treatments. The soil applied NaCl increased the chloride levels in the tissue and reduced the metabolic index for the tissue. However, after six weeks of spraying, the spray treatments significantly increased the phosphorous, magnesium, sodium and chloride in the leaves and higher potassium and calcium levels were in evidence. The soil applied NaCl generally increased yield and value of tobacco up to 27.5 kg/ha. The 68.4 l/ha/day foliar treatment reduced the price, quality and burn of the tobacco. In general, the plants appeared more responsive to the foliar applied salts than the soil applied NaCl. The 68.4 l/ha/day foliar treatment was as damaging as 110 kg/ha of NaCl applied to the soil prior to planting of the tobacco.

<239>

Effects of Cooling Tower Fallout on Soybeans.

Beltsville Agricultural Research Center Research Review, Proceedings of the U.S. Department of Agriculture, College Park, MD, March 25-26, 1975

1975

Mulchi, C.L.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The environmental effects of cooling towers using river water containing substantial quantities of soluble salts are under investigation at PEPCO's electric generating station at Chalk Point, MD., located on the Patuxent River. Of primary interest are the effects of salt drift from the towers on the production of agricultural crops, soils and native species. The research and monitoring program consists of a network of 12 research sites located at 1.6, 4.8, 9.6 kilometer radii and N, E, S, and W directions, respectively. Soybeans are among the six major crops under investigation. Data on vegetative element composition at two stages of growth and yields are obtained annually. Also, changes in the nutrient status of the soils are determined each year. Thus far, two years of pre-operation data has been obtained which will serve as baseline information. The first year of post operation will be 1975 for the towers. Soybean plants were subjected to salt-spray applications on a weekly basis in 1973 and daily basis in 1974 in studies conducted at the Tobacco Experimental Farm near Upper Marlboro, MD. Treatments in 1973 consist of 0,1.82, 3.64, 7.28 and 14.56 kg/ha/wk of NaCl applied for eight weeks. In 1974, the treatments were the application of 0, 5.6, 11.2, 16.8, and 22.4 kg/ ha/wk of NaCl for eight weeks. Significant yield reductions were observed at 7.28 kg/ha/wk rate in 1973 and 11.2 kg/ha/wk rate in 1974. In 1973, the nutrient balance (metabolic index) in the tissue decreased from 32.1 for the control plots to 3.2 at the highest spray treatment. Also, in 1973 the Na and Cl levels in the soil were significantly increased by the spray treatments.

<240>

Sensitivity of Tobacco to Chromium from Cooling Tower Drift.
Tennessee Academy of Science Spring Collegiate Meeting, Proceedings of a Symposium, Harriman, TN; Journal Tennessee Academy Science 49(4):143
1974
Dreyer, P.
Tennessee Wesleyan College, Athens, TN

Tobacco plants were used to assess the impact of airborne contaminants, mainly chromium, on vegetation. A total of forty potted plants were placed at 15, 300, 600 and 1400 (control) meters from cooling towers. Four plants were harvested in one week intervals for a total of 8 weeks and were examined for total plant biomass, leaf biomass, leaf area, and general vigor estimates. The parameters were correlated with concentrations of chromium to evaluate increased trace elements (in this case chromium) through airborne contamination to vegetation as the result of cooling tower operation. (ND)

<241>

Modeling Botanical Injury from Saline Cooling Tower Drift.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9(Supplement); PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. 32-41), 90 pp.
1978
Fruedenthal, P.C.; Beals, G.A.
Consolidated Edison Company of New York, Inc.

A methodology has been developed to estimate the potential for injury to salt-sensitive flora from saline cooling tower drift fallout. This technique is based on greenhouse saline aerosol toxicity experiments, meteorological dispersion modeling, and drought probability analysis. Eleven woody plant species characteristic of Northern deciduous hardwood forests were exposed in an environmental controlled chamber to saline aerosols. Hemlock, flowering dogwood, and white ash were found to be sensitive to a NaCl deposit exceeding 40 kg/km(E+2) in the absence of rainfall, but other species were found to be relatively insensitive. Applying the described methodology to a proposed 150 m high natural draft cooling tower using brackish water makeup and servicing a 1000 MW nuclear plant, the model predicts injury to potentially sensitive flora within a 3.5 km area during nearly half of all years in which the tower would operate. (Auth)

<242>

Interception and Retention of Cooling Tower Drift on Vegetation.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January 19-22, 1976, 28 pp.; ESD No. 872, 28 pp.
1976
Taylor, F.G. Jr.; Gray, D.D.; Parr, P.D.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN
U.S. Energy Research and Development Administration

The reliability of a rather simple drift deposition code (ORFAD) developed at Oak Ridge National Laboratory was tested and analyzed using ecological data on drift effects on vegetation from the environs of the Oak Ridge Gaseous Diffusion Plant. A series of field experiments was conducted to determine both interception and retention of simulated drift by plants. These measurements were combined with model estimates of average annual deposition of drift to obtain predicted concentrations of trace elements in vegetation. Predicted concentrations of drift in foliage were compared to measured concentrations in fescue grass as a preliminary test case. The test case is an example of an attempt to validate a specific deposition model (ORFAD) using biological data.

<243>

Environmental Sciences Division Annual Report for Period Ending September 30, 1975 Ecosystem Analysis
S.I. Auerbach, et al., Part 3, (p. 47-65), ORNL-5193, 265 pp.; ESD No. 914, 265 pp.
1976
Harris, W.F., et al.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

Surface contamination by the airborne cooling tower drift and subsequent ingestion and inhalation of the contaminants are potential pathways for incorporation of trace quantities of chromium into food chains. Cotton rats were live-trapped in a fescue field adjacent to large, mechanical draft cooling towers. A ten-fold increase in chromium concentration in hair and pelt between treatment and control animals indicated that the increased concentrations were derived from direct deposition or physical transfer from plant surfaces during feeding activities. Elemental analysis by organs or tissue further suggested little increase in chromium through ingestion or inhalation. The significance of chronic exposure by ingestion of drift-contaminated food was determined by feeding twenty adult animals fescue grass labeled with isotopic chromium in a chemical form similar to the form maintained in the recirculating cooling waters. The results showed a low assimilation (0.8%) and rapid initial loss of the hexavalent chromium which suggests the nonessential nature of the element in cotton rats. The retention data also confirm the lack of any significant bioaccumulation as depicted in stable analyses, and further suggest the reduced possibility of a toxic effect through ingestion of drift-contaminated vegetation or inhalation of drift-contaminated air. Extrapolations from small mammals to man are briefly mentioned. (ND)

<244>

Bacterial Aerosols from Cooling Towers.
Journal Water Pollution Control Federation 50:2362-2369
1978
Adams, A.P.; Garbett, M.; Rees, H.B.; Lewis, B.G.
U.S. Army, Dugway, UT
Argonne National Laboratory, Argonne, IL

Cooling towers supplied with makeup water from polluted sources have been suspected of aerosolizing large numbers of enteric organisms that may present a hazard to exposed individuals. This study was conducted with cooling towers of the Burbank (CA) Municipal electrical generating wastewater treatment plant. Bacterial counts were made of cooling tower basin water and of the air leaving the cooling tower vents. Differential and selective enrichment media were used to detect the major groups of microbes. Chlorine dioxide suppressed the number of bacteria in the water so drastically that the number of bacteria leaving the tower vents was deemed insufficient to cause public health concern. Gaseous chlorine was considerably less effective than chlorine dioxide in reducing bacterial counts. (Auth)

<245>

On the Question of Airborne Transmission of Pathogenic Organisms in Cooling Tower Drift.
Cooling Tower Institute Annual Meeting, Proceedings of a
Lewis, B.G.
Argonne National Laboratory, Environmental Statement Project, Argonne,
IL
U.S. Atomic Energy Commission

The siting of cooling towers on sewage-polluted waters and the probable widespread use in the future of treated sewage effluent as makeup has raised the question of dispersal of pathogenic organisms in cooling tower drift. Information pertinent to the question, e.g., the occurrence of pathogenic organisms, the factors that affect their survival in water and air, and the relation to public health is discussed. Some approaches to the problem are also presented. It is concluded that some pathogenic organisms can probably survive entrainment in cooling tower drift and be dispersed over areas outside a cooling tower site. Only a fraction of the individuals ingesting viable particles will develop a disease. These fractions will range from 0 to 100% depending on the organism ingested and the susceptibility and conditions of the ingestor. No such problems have been found to occur in England, where many cooling towers are situated on highly polluted rivers. Areas of research are recommended. (ND)

<246>

Estimation of Downwind Viable Airborne Microbes from a Wet Cooling Tower-Including Settling.
Microbial Ecology 4:67-79
1977
Peterson, E.W.; Lighthart, B.
U.S. Environmental Protection Agency, Corvallis
Environmental Research
Laboratory, Ecological Effects Research Division,
Terrestrial Ecology
Branch, Corvallis, OR

In recent years, reuse of municipal waste water as the coolant in drift-producing cooling towers at electrical generating plants has become increasingly common. A hueristic model is presented that can be used to estimate the concentrations of viable airborne microbes in the drift from a wet cooling tower given the concentration of microbes in the cooling tower. The purpose of this presentation is to allow an understanding of the factors affecting airborne concentration and a crude estimate of ground-level concentrations of airborne microorganisms. Concentrations are calculated using a standard meteorological method, the Gaussian dispersion model, in which terms have been included for droplet settling and microbial death rate. Despite the limitations on the validity of the microbial concentrations estimated by this model, if one carefully assesses the specific situation, the predictions can yield insight into problems that could occur. (Auth)(ND)

<247>

Notes for Discussion Legionnaire's Disease Bacteria in Cooling Towers.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January 29, 1979, 4 pp.
1979
Tonkyn, R.G.
The Mogule Corporation, Chagrin Falls, OH

Occurrences of Legionnaire's Disease have been demonstrated in buildings that have evaporative condensors or cooling towers as part of their air conditioning systems and the disease has been observed in buildings and in other circumstances unrelated to air conditioning as well. Recommendations from the Center for Disease Control are attached which recommend that cooling towers should be treated with chemicals that have been tested and shown to be effective in preventing slime, corrosion, algae and high populations of bacteria as a prudent measure. A water treatment industry-wide position to assist the Center for Disease Control in order to eradicate this disease is recommended. (ND)

<248>

An Ecological Study of the Susquehanna River in the Vicinity of the Three Mile Island Nuclear Station Annual Report for 1976.
231 pp.
1977
Nardacci, G.A.
Ichthyological Associates, Inc., Etters, PA
Metropolitan Edison Company

This is the third annual post operational report on the ecology of the vicinity of the Three Mile Island Nuclear Station (TMINS) covering the period from January through December 1976. Study topics include fish, macroinvertebrates, ambient water quality, thermal plume mapping, and effects on natural draft cooling tower salt drift on agricultural crops and natural vegetation. Plant pathology transects were examined from April through October 1976. No differences were noted in flowering time or appearance of the 219 taxa observed with respect to the location of possible salt drift. Plant parasitic diseases were found on four agricultural crops and 21 taxa of natural vegetation, and insect damage was noted on nine taxa. None of the damage caused significant defoliation and no pattern was observed with respect to the operation of the cooling towers at TMINS. Two forests and four fields were surveyed late August through mid-October 1976; results were statistically compared with those obtained in 1973 and 1975. There were few changes in the overstory and understory in the forests. Some of the statistically significant changes in groundcover in forests and fields were related to natural or human disturbance; others were normal in the course of secondary succession. No pattern of change was found that was attributed to the operation of the cooling towers at TMINS. (ND)

<249>

1977 Monitoring of Cooling Tower Operational Effects on Vegetation in the Vicinity of the Three Mile Island Nuclear Station.
Prepared by NUS Corp. for GPU Service Corp., April 1978. 26 pp.

Report summarizes the effects of cooling tower drift on vegetation in the vicinity of the Three Mile Island Nuclear Station located on the Susquehanna River in Dauphin County, PA. Field monitoring was conducted during the fall of 1977 encompassing a 2-mile radius of the nuclear station. Vegetation stress was assessed, in accordance with the NRC Technical Specifications, (presented in appendix), by means of aerial photography, photo interpretation, ground truth observations, and comparison with preoperational baseline conditions. Tables show the relative abundances of the observed plant species in the area. Aerial photographic maps are also provided.

<250>

(Distribution of Vegetation and Vegetational Stress, Three Mile Island and Vicinity 1977.)
Figures 4 & 5, 1977 Monitoring Cooling Tower Operational Effects on Vegetation in the Vicinity of the Three Mile Island Nuclear Station. Prepared by NUS Corp. for GPU Service Corp., April 1978. 2 pp.

Maps show the vegetation in the vicinity of the Three Mile Island Nuclear Station, located on the Susquehanna River in Dauphin County, PA. A field and aerial monitoring survey was preferred at this station to determine the extent of vegetation damage due to the station's cooling tower drift. Types of damage to trees are listed, showing those which are attributable to plant operation and those occurring naturally.

<251>

Effects of Cooling Tower Salt Drift on Agricultural Crops and Natural Vegetation.
Section 11.0, An Ecological Study of the Susquehanna River in the Vicinity of the Three Mile Island Nuclear Station: Annual Report for 1977. Prepared by Ichthyological Associates, Inc. for Metropolitan Edison Co., April 1978. 12 pp.

Object of the investigation was to observe and record changes in the incidence of vegetation pathogens or insect damage on agricultural crops and natural vegetation attributable to salt drift from the cooling towers of the Three Mile Island Station, Unit I, Dauphin County, PA. Plant pathology transects established in earlier studies were examined monthly from April-October 1977. Visual examinations of crops and other vegetation were conducted; a list of all plants in flower was kept to determine differences in flowering time or appearance of flowers, and all plant diseases or significant damages due to insects were recorded. Section contains 4 tables, 1 figure, and references.

<252>

An Ecological Study of the Susquehanna River in the Vicinity of the Three Mile Island Nuclear Station.
395 pp.
1976
Potter, W.A. (Ed.)
Ichthyological Associates, Inc., Etters, PA
Metropolitan Edison Company, Reading, PA

This is the second annual postoperational report on the ecology of the York Haven Pond of the Susquehanna River in the vicinity of Three Mile Island Nuclear Station. Sections include: impingement of fishes; entrainment of plankton, fish, and macroinvertebrates; ambient water quality; bird impaction on cooling towers; and effects of cooling tower salt drift on agricultural crops and natural vegetation. Observations of the incidence of plant pathogens or insect damage on natural vegetation and agricultural crops and changes in vegetation composition attributed to salt drift from the cooling towers were made. Twelve species of Pteridophytes and 216 species of flowering plants were observed. A pattern among plant diseases was not noted. Changes in vegetation composition were attributed to successional trends. No significant impacts from cooling tower salt drift were detected. (ND)

<253>

An Evaluation of Environmental Data Relating to Selected Nuclear Power Plant Sites: The Three Mile Island Nuclear Station Site.
ANL/EIS-4, 8 pp.
1976
Pentecost, E.D.; Murarka, I.P.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
U.S. Nuclear Regulatory Commimssion

Environmental monitoring data for the years 1973 and 1974 pertaining to the Three Mile Island Nuclear Station Unit 1, which began operation in early 1974, were analyzed by the most practical qualitative and quantitative methods. Terrestrial biotic resources were considered for this plant. The effects of the operation of Unit 1 on the local terrestrial organisms were undetectable. However, the data collected included subjective observations for plant pathology resulting from salt deposition, measurements of numbers of stems per plot in 1973 vs. 1974, and ground cover comparisons between years for herbaceous vegetation. The monitoring program lacked the sensitivity needed to detect such changes as foliar absorption of metals or other chemicals present in the cooling tower drift. A soil monitoring program is to be established. Chart-quadrat methods should be employed to monitor the effects of salt drift on perennial woody vegetation. Yearly analysis of leaf chlorophyll content, heavy metals and salts would enhance the detection of subtle effects from cooling tower drift. Study plots should be concentrated along the axis of the major wind direction from the cooling towers. (ND)

<254>

An Evaluation of Environmental Data Relating to Selected Nuclear Power Plant Sites: A Synthesis and Summary with Recommendations.
ANL/EIS-8, 23 pp.
1976
Murarka, I.P.; Policastro, A.J.; Ferrante, J.G.; Daniels, E.W.;
Marmer, G.J.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL

Analysis of the field data gathered during the monitoring programs at seven nuclear power plant sites showed no significant ecological impacts. This conclusion is within the constraints of the quality of available data from these sites. Current monitoring programs are, however, not designed to meet the needs for statistical analysis, and consequently, the monitoring data are often ill-suited for modern statistical procedures. Recommendations are proposed for revising monitoring schemes so that more precise conclusions can be made from fewer field measurements. The effect of salt drift from the Three Mile Island Nuclear Station was extensively studied. Salt drift was not expected to adversely impact local agricultural crops or natural vegetation. Qualitative comparisons of the ground cover for herbaceous vegetation (number of stems per plot, tree-trunk diameter at breast height (dbh), and visible pathological signs on leafy vegetation revealed no detectable impacts of the cooling tower salt drift on the surrounding vegetation. The long term impact on a local scale could be measured only if the edaphic and vegetation tissues are monitored for changes in chemical composition. Measuring tree-trunk dbh was found to be insensitive to determining salt drift effects. (ND)

<255>

Evaluation of Cooling Tower Ecological Effects - An Approach and Case History.
American Nuclear Society 21st Annual Meeting,
Proceedings of a Symposium, New Orleans, LA, June 12, 1975, 8 pp.; Transactions American Nuclear Society 21:90
1975
Mudge, J.E.; Firth, R.W.
Metropolitan Edison Company, Reading, PA
Woodward-Clyde Consultants, Clifton, NJ

Results of the cooling tower environmental monitoring program for the Three Mile Island Station are described. The effect of salt drift from cooling towers was evaluated for a 2.5 mile radius of the station, with the major effort contained within a one mile radius. Ambient levels of drift minerals in soils and selected vegetation were measured during preoperation. If suspected drift-related effects are detected during operational monitoring, soil and vegetation samples will be analyzed for drift mineral concentrations. Results of injury- and succession-related monitoring indicate that no measurable effects on vegetation have occurred since operation began. (ND)

<256>

Three Mile Island Nuclear Station, Unit 1 - Terrestrial Survey, Semiannual Report for 1974.
(p. 4-1 - 4-51)
1975
Woodward-Clyde Consultants
Metropolitan Edison Company

The results of the 1974 terrestrial survey of environmental impacts are reported. Sections include: bird impaction on cooling towers, effects of salt drift on crops and natural vegetation, and vegetation analysis. Operational sampling (June 5-Nov. 30, 1974) results indicate that salt drift from natural draft cooling towers at Three Mile Island Nuclear Station Unit 1 did not have a detectable effect on natural vegetation and crops in the study areas. Plant pathology observations failed to show any evidence of salt stress or injury. Sampling of natural vegetation showed no changes in plant communities which were not due to normal successional trends. (ND)

<257>

Three Mile Island Nuclear Station Units 1 and 2 Terrestrial Environmental Studies, Preoperational Survey Final Report.
73-027, 2 Vols.
1974
Woodward-Envicon, Inc., Clifton, NJ
General Public Utilities Service Corporation
Metropolitan Edison Company

This report contains the tables of preoperational results and field procedures manual concerning the terrestrial environmental studies of the Three Mile Island Nuclear Station. Volume 1 contains the text and figures for the study. Drift impact to area soils and vegetation is not expected to be detrimental, due to adequate rainfall and good soil permeability. Salt sensitive vegetation in the area include tobacco, beech, red pine, and white pine. Impacts would be either to the quality of tobacco and/or foliar necrosis or chlorosis of sensitive vegetation. (ND)

<258>

Results of Ambient Vegetation Mineral Analysis, June 1974.
Attachment 2, 10 pp.
1974
Woodward-Envicon, Inc., Clifton, NJ
Metropolitan Edison Company, Reading, PA

The results of ambient vegetation minerals analysis for June 24-26, 1974 in the vicinity of the Three Mile Island Nuclear Station Unit 1 which began operating on June 5, 1974, are presented. Concentrations of sulfur or chloride higher than levels reported as normal in the literature occurred at some sampling locations for some of the vegetation. However, the vegetation at these sampling locations showed no visible evidence of plant injury such as chlorosis, necrosis or stunting. Copper concentrations were within the normal ranges as reported in the literature. The lack of injury indicates that these mineral concentrations were not at damaging levels. (ND)

<259>

Cooling Tower and Steam Plant Plume Mergence at the Watts Bar Site.
Prepared by Knudson, D.A. for Tennessee Valley Authority, July 1979. 51 pp.

Report documents an investigation of the terrestrial impacts resulting from the mergence of plumes from the Watts Bar Steam Plant and the cooling towers at the Watts Bar Nuclear Plant, Rhea County, TN, to determine the need for continuation of existing terrestrial surveillance and control commitments. Effects considered include increased sulfate production and resulting production of acid aerosols, acid mist (drift), and acid fly ash. Also described are the existing meteorology, monitoring equipment at the site, plume and drift behavior, and mergence of the plumes. The 5 appendices include references, a description of drift and vapor models, the plume rise calculational method, design and operational data of the 2 plants, and pertinent regulatory data. Document contains 1 figure and 12 tables.

<260>

(Vegetation Survey.)
Section 3.1.2.b.2, Supplement to 1978 Annual Environmental Operating Report, Davis-Besse Nuclear Power Station Unit No. 1, for NUS Corp., Toledo Edison Co., Dec. 1978. 7 pp.

Report presents results of vegetation surveys conducted in the vicinity of Davis-Besse Nuclear Power Station, Ottawa County, OH. Aerial color infrared photography and ground reconnaissance were employed to assess the condition and distribution of vegetation and to identify any major stress on flora on and around the plant site. Approximately two- thirds of the land surface within 2 mi of the cooling tower is covered by vegetation. Section contains 1 figure.

<261>

Report on the Terrestrial Effects of Salt-Fallout from Thermal Cooling Systems.
Prepared by NUS Corp. for Public Service Co. of New Hampshire, Oct. 1972. 44 pp.

Report investigates environmental effects of alternative cooling systems for the proposed Seabrook Nuclear Generating Station, in Rockingham County, NH. The proposed cooling system is once-through utilizing Atlantic Ocean water. The 3 alternatives are mechanical draft cooling tower, natural draft cooling tower, and spray canal. Physiological effects of salt deposition on vegetation, from foliage discoloration to death, are discussed. The terrestrial ecology of the site is discussed, with listings and descriptions of the local flora and fauna. To predict the effects of the increased salt-fallout from each type of cooling system, a composite tolerance rating of 54 species of vegetation was compiled. Species were classified according to their salt tolerance: salt tolerant, somewhat intolerant, and very intolerant. Salt deposition rates for each alternative are predicted, with the spray canal having the higher rate in the immediate area, and mechanical draft and natural draft cooling towers depositing salt at greater distances. Report includes 7 tables, 3 figures, and references.

<262>

Measurement and Effects of Drift from an Evaporative Cooling System on Surrounding Vegetation.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 1-17), 90 pp.
1978
Feder, W.A.
University of Massachusetts, Suburban Experiment Station, Waltham, MA
New England Power Company
Federal Hatch Funds

The effects on vegetation of saline mists derived from a spray cooling canal and a method for comparing ambient salt concentrations with vegetation injury are described. A closed cycle, spray cooling canal became operative in 1974 at the New England Power Company's Brayton Point Station, Somerset, Massachusetts. The 2-mile canal was designed to handle 260,000 gpm, 2.3 billion BTU's per hour, with a design 18 degrees F cooling range, and a blowdown of 6,000 gpm to remove salts and other dissolved solids. The site is located between the mouths of the Taunton and Lee rivers at Mt. Hope Bay. Water salinity of the river is about 14,000 ppm. The canal is upwind of residential areas with a mixed population of indigenous and exotic trees and shrubs. The canal produced a salt spray plume carried aloft by warm air which was carried downwind and deposited at locations depending upon wind direction and speed. Impact with vegetation caused injury, including marginal leaf burning, twig and bud destruction and, sometimes, complete killing of trees and shrubs. Some tree species also showed delayed foliar and floral development. Injury severity was inversely related to distance from the canal and injury was most apparent N. and NE. of the canal. Salt injury was detectable four miles downwind of the canal but was severe within a radius of 1,000 m during 1975. Salt deposition was first measured with Pyrex water-filled pans. This method was abandoned because of unreliability, and a simple nylon rope collector was substituted. Ropes were hung at selected sites and collected at weekly intervals. Salt was quantitatively recovered from the ropes by soaking with distilled water and measured as Cl- ion with a specific ion electrode. Salt deposition was clearly distance and wind dependent. Cumulative salt loads for 8 selected sites were measured weekly during 1976 and 1977, and correlated with vegetation injury. Reduction of canal water salinity by the addition of fresh water, coupled with a reduction in the number of spray modules used, resulted in markedly less vegetation injury in 1977 compared with 1975 and 1976. Control of canal water salinity and proper spray management has reduced the environmental impact of the spray cooling canal so that the impact off-site is essentially the same as background from Mt. Hope Bay. (Auth)(ND)

<263>

Ecological Effects of Aerosol Drift from a Saltwater Cooling System.
EPA-600/3-76-078, 101 pp.; PB-258 831, 101 pp.
1976
Hindawi, I.J.; Raniere, L.C.; Rea, J.A.
Corvallis Environmental Research Laboratory, Terrestrial Ecology
Branch, Corvallis, OR
U.S. Environmental Protection Agency, Environmental Research
Laboratory, Corvallis, OR

The local terrestrial effects of salt aerosol drift from powered spray modules and a mechanical draft cooling tower at Turkey Point, Florida were evaluated through field and controlled exposure studies. Indigenous vegetation, soil and fresh water were sampled over a year-long period to acquire pre-activation baseline data and to provide for the assessment of possible environmental impact of salt aerosol loading from the test cooling devices. No measurable effects attributable to salt aerosol emissions from test cooling devices were detected on indigenous plants, soil, or fresh water sampled during or following operation of the test cooling tower/spray modules. Cultivar plants were sited at varying distances to identify and characterize the influence of sea salt aerosol drift from the test cooling devices. The introduced cultivar plants showed visible foliar injury and elevated salt concentrations, correlated to the combined influences of cooling device and east wind drift exposure, only at the exposure site closest (215 m) to the cooling tower/spray modules. Full-term growth effects and salt aerosol tolerance levels of a cultivar plant, bush bean, were examined by controlled exposure to a simulated sea-salt aerosol at concentrations representative of the Turkey Point test site. The trace injury threshold of the bush bean trifoliate leaf was at a salt aerosol concentration of 5 ug/m(E+3) for 100 hours cumulative exposure over a four week period, while pod productivity was reduced at salt aerosol concentrations of 25 ug/m(E+3) and 75 ug/m(E+3) at the environmental conditions of the exposure study. (Auth)

<264>

Environmental Effects of Salt Water Cooling Towers: Potential Effects of Salt Drift on Vegetation.
45 pp.
1971
Moser, B.C.; Swain, R.L.
Rutgers University, Department of Horticulture and Forestry, New
Brunswick, NJ
Jersey Central Power and Light Company, Morristown, NJ

The potential effects of the salt drift from the Forked River Nuclear Power Station on area vegetation were evaluated by reviewing the available literature on salt aerosol (marine and road salt) impacts. Area vegetation was surveyed to determine which plant species would be subjected to salt drift effects. Greenhouse and field studies of vegetation response to sea salt mists were undertaken to evaluate the relationship between duration of salt mist exposure and the extent of plant injury. Sensitivity to airborne sea salt injury varied between species and among individual plants within species, with deciduous plants more sensitive than evergreens. Thus, plant injury in the Forked River area would be highest in vegetation types which are made up of QUERCUS sp., VACCINIUM sp., NYSSA SYLVATICA, and similar deciduous species. An increase in average airborne salt levels in the area from 2.5 to 12.5 ug/m(E+3) should have no significant immediate effect on the appearance or growth of the major types of vegetation. Detrimental long term effects from increased airborne salt levels may include a gradual decline in vigor in some species. Several day averages of 30 ug/m(E+3) coupled with several hours of 100 ug/m(E+3) salt levels might produce foliar injury to sensitive species. Increased soil salt levels should have no significant effect on the major vegetation types in the area. However, the combination of increased chloride absorption from the soil and that absorbed by the foliage could contribute to any long term detrimental effects which might arise. (ND)

<265>

Compositional, Structural and Chemical Changes to Forest Vegetation from Fresh Water Wet Cooling Tower Drift.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 19-38), 462 pp.
1978
Rochow, J.J.
Consumers Power Company, Jackson, MI

A five year study to assess the impact of wet mechanical draft cooling towers on forest communities was conducted at the Palisades Nuclear Plant. Sampling plots located at various distances from the cooling towers were sampled for plant species compositional and structural analysis. Leaf tissue and soil samples were collected for chemical analysis. Areas within 90 m of the cooling towers have suffered severe compositional and structural changes as a result of ice and chemically induced damage. Calculation of diversity indices show that there has been a reduction in species diversity within 60 m of the cooling towers. Calcium, sodium and sulfur loadings for plant tissue show significant ($P=0.05$) increases within 60 m, and in some cases up to 85 m, of the cooling towers. Leaching of soil bases appear not to have increased by an increased deposition of anions. (Auth)

<266>

Measurements and Vegetational Impact of Chemical Drift from Mechanical Draft Cooling Towers.
Environmental Science and Technology 12(13):1379-1383
1978
Rochow, J.J.
Consumers Power Company, Department of Environmental Sciences,
Jackson, MI

Collection and analyses of precipitation prior to and after cooling tower operation at the Palisades Plant in southwestern Michigan resulted in high deposition rates of sulfate and calcium up to 92 m from the towers. Sulfate deposition rates during operation averaged up to 9.0 g/m(E+2)/month in areas within 50 m of the cooling towers and decreased to 0.61 g/m(E+2) /month between 700 and 1609 m. Calcium deposition rates during operation averaged up to 4.5 g/m(E+2)/month in areas within 50 m of the cooling towers and decreased to 0.57 g/m(E+2)/month between 700 m and 1609 m. The high sulfate deposition rates were assumed to be responsible for severe vegetation damage within 92 m of the cooling towers. Examination of chloride deposition rates showed that most affected areas did not receive sufficient amounts to cause vegetation damage. Sulfate and calcium deposition rates were fitted to a multiple regression equation using several independent variables. Plotted regression lines showed that 64% of the sulfate and 47% of the calcium fell out within the first 92 m. Additional studies are now in progress to specifically identify the chemical(s) that is(are) responsible for the vegetation damage. (Auth)(ND)

<267>

Report of the Mammals and Herptiles Occurring near the Palisades Power Generating Facility, Van Buren County, Michigan, June, 1976.
Prepared by Houtcooper, W.C., Aquinas College for Consumers Power Co., 1976. 16 pp.

Report assesses the effects of mechanical draft cooling towers at the Palisades nuclear plant, Van Buren County, MI, on local populations of herptiles and small mammals. Species inventories relationships, food habits, population estimates, reproductive aspects of small mammals, and the presence of invertebrates as a possible food source for the mammals. Field survey methodology is described and results and discussion for each species are presented. The only mammal collected was the white-footed deermouse; herptiles were represented by red-backed salamanders, a toad, and a black racer snake. Collembola accounted for 44% of the invertebrates collected. Report includes 1 figure, 4 tables, and references.

<268>

Effects of Aerosol Drift Produced by a Cooling Tower at the Indian Point Generating Station on Native and Cultivated Flora in the Area.
Boyce Thompson Institute, Environmental Biology Program, Aug. 1974. Included as Appendix E in Economic & Environmental Impacts of Alternative Closed-Cycle Cooling System for Indian Point Unit No. 2, Consolidated Edison Co. of NY, Dec. 1974. 81 pp.

Appendix gives purpose, methodology, and results of experiments performed to determine adverse effects to Indian Point area flora posed by saline mist and salt deposition from cooling tower drift. Effects on 12 coniferous and deciduous woody species were investigated. Drift particle size and ambient relative humidity were 2 significant controlled variables. Appendix includes 16 tables, 30 figures, and 10 references.

<269>

Terrestrial Radionuclide Cycling and Effects.
Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1973, S.I. Auerbach, et al., Part 3, (p. 46-60), ORNL-4935, 175 pp.; ESD No. 570, 175 pp.
1974
Dahlman, R.C., et al.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

Cooling tower effects research has focused on (1) accumulation of chromium in plants and soil in the environs of mechanical draft towers (Oak Ridge Gaseous Diffusion Plant), (2) effects of salt (NaCl) on vegetation following applications of simulated brackish water to five species, and (3) response of tobacco to chromium in drift from a mechanical draft tower (ORGDP). The data show chromium accumulation from 17 years of drift deposition, but only negligible increases of zinc over background levels were found. Concentrations of chromium in vegetation were highest adjacent to the cooling tower, decreasing exponentially with distance. Maximum concentrations 15 m from the towers ranged from 339 to 644 ug/g for grass and litter respectively. Chromium levels in litter were a factor of 2 above those of grasses and forbs. Five species were tested for response to NaCl applications: yellow poplar, redbud, red oak, white oak, and soybeans. Redbud and soybean exposed to cumulative salt applications equivalent to 1.22 x 10(E+4) kg/km(E+2)/month showed continued enhancement of photosynthesis. Visual examination revealed chlorosis and yellowing in older foliage of red oak, white oak and soybean. Severe tip burn and browning of up to 50% emergent foliage occurred in yellow poplar. Cumulative applications equivalent to 1.03 x 10(E+5) kg/km(E+2)/month resulted severe tip burn, yellowing, and browning in all species and extensive defoliation in yellow poplar. Tobacco was exposed to drift from the ORGDP cooling towers to assess the effect of aerosols containing chromium on plant growth. Leaf size proved to be the most sensitive parameter for assessing the effects on growth, i.e., a 75% reduction in leaf size was found at distances of 15 to 200 m from the tower compared to plants located at distances of 600 and 1400 m. The chromium concentration of plants 15 m from the towers was approximately 30 times background concentration. The leaf size effects were manifested at chromium concentrations less than 10 ppm in foliage. Tobacco appears to be one of the most sensitive plants to trace concentrations of chromium. (ND)

<270>

Sensitivity of Tobacco to Chromium from Mechanical Draft Cooling Tower Drift.
Atmospheric Environment 10:421-423
1976
Parr, P.D.; Taylor, F.G. Jr.; Beauchamp, J.J.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN
Oak Ridge National Laboratory, Computer Sciences Division, Oak Ridge,
TN
U.S. Energy Research and Development Administration

The effect of chromium from cooling tower drift on vegetation was assessed at the Oak Ridge Gaseous Diffusion Plant using Kentucky Burley 21 tobacco plants (NICOTIANA TOBACUM) which is noted for its sensitivity to chromium. Potted tobacco plants were placed along the axis of the most frequent wind direction at 15, 200, 600, and 1400 m from the cooling towers. Plants were harvested at one-week intervals for seven weeks from each distance and assessed for total plant biomass, leaf biomass, leaf area, general vigor determinations and chromium concentrations. There was an inverse relationship between foliar chromium concentrations and distance from the towers. Associated with high chromium concentration was a 75 percent inhibition of leaf growth. (Auth)

<271>

Environmental Effects of Chromium and Zinc in Cooling-Water Drift.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 408-426), 638 pp.
1975
Taylor, F.G. Jr.; Mann, L.K.; Dahlman, R.C.; Miller, R.L.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN
Oak Ridge National Laboratory, Computer Sciences Division, Oak Ridge,
TN
U.S. Atomic Energy Commission

An inventory of plant and soil materials in the environs of the Oak Ridge Gaseous Diffusion Plant has provided quantitative evidence for transfer of chromium and zinc to vegetation from cooling tower operation. As expected from atmospheric dispersion models, chromium and zinc concentrations in vegetation were highest adjacent to the tower and decreased exponentially with increasing distance from the source. Concentrations of chromium in foliage ranged from several orders of magnitude above background levels to near background at 1 mile (1609 m) from the tower. Background levels of chromium and zinc were determined from samples collected on sites remote from drift. Potted plants placed downwind from the plume accumulated chromium, reaching equilibrium and attaining maximum concentrations after 4 to 6 weeks of exposure. Vegetation analyses along a horizontal gradient suggested that the equilibrium concentration in foliage and litter remained relatively constant, provided that additions of treatment chemicals to makeup water and drift emission rates remained unchanged. Distribution coefficients (Kd) for hexavalent chromium added in solution to soils showed that little chromium was adsorbed. Values for zinc indicated that the soil acts as a reservoir for the small quantities derived from drift, and accumulation was likely obscured by the natural variability within several soil types or airborne and rain-scavenged materials containing zinc from sources other than the cooling towers. (Auth)

<272>

Distribution of Chromium in Vegetation and Small Mammals Adjacent to Cooling Towers.
Journal Tennessee Academy Science 53(3):87-91
1978
Taylor, F.G. Jr.; Parr, P.D.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

Surface contamination of vegetation by aerosol pollutants and subsequent ingestion by grazing vertebrates is a pathway for incorporation of toxic elements into food chains. Small mammals (herbivores) were live-trapped in a fescue-dominated field adjacent to large, mechanical draft cooling towers (at the ERDA uranium enrichment facility at Oak Ridge) comparable to those utilized by power generation facilities. Cooling waters of the towers contain a chromate, zinc-phosphate compound to inhibit corrosion and fouling within the cooling system. A fraction of the cooling water becomes entrained within the exit air flow and is deposited as drift on the landscape. Resident mammals are subjected to increased chromium exposures both through ingestion and through inhalation pathways. Results showed that concentrations in vegetation ranged from 342 to 15 ppm at 15 and 130 meters downwind. Chromium distribution in mammals adjacent to the cooling towers was compared by organ analyses to corresponding organs and tissues of mammals collected remote from the drift. Concentrations of chromium in pelt, hair, and bone of animals trapped near the cooling towers were significantly higher ($P<0.01$) than concentrations in tissues from control animals. Air concentrations of chromium had previously been determined to be relatively constant at 50 ng/m(E+3) within 200m of the tower (Alkezweeny et al., 1975), and thus provided a potential pathway for increased chromium levels through inhalation. The fate of ingested chromium-contaminated vegetation and possible incorporation by body tissues was determined from a feeding experiment using radiolabelled chromium. (Auth)

<273>

Interception and Retention of Simulated Cooling Tower Drift by Vegetation.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 39-48), 90 pp.
1978
Taylor, F.G. Jr.; Parr, P.D.; Ball, F.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN
Oak Ridge National Laboratory, Analytical Chemistry Division, Oak
Ridge, TN
U.S. Department of Energy

A key issue concerning environmental impacts from cooling tower operation is the interception of drift by vegetation and the efficiency of plants in retaining the residue scavenged from the atmosphere. Chromated drift water, typical of the cooling towers of the Department of Energy's uranium enrichment facilities at Oak Ridge, Tennessee, was prepared using radiolabelled chromium. A portable aerosol generator was used to produce a spectrum of droplets with diameters (100-1300u) characteristic of cooling towers using state-of-the-art drift eliminators. Efficiency of interception by foliage varied according to leaf morphology with yellow poplar seedlings intercepting 72% of the deposition mass in contrast to 45% by loblolly pine and 24% by fescue grass. Retention patterns of intercepted deposition consisted of a short-time component (0-3 days) and a long-time component (3-63 days). Retention times, estimated from the regression equation of the long component, indicated that drift contamination from any deposition event may persist from between 8 and 12 weeks. In field situations adjacent to cooling towers, the average annual concentration of drift on vegetation at any distance remains relatively constant, with losses from weathering being compensated by chronic deposition. (Auth)

<274>

Cooling Systems.
Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1977, S.I. Auerbach, et al., Part 1, (p. 18-27), ORNL-5365, 240 pp.; ESD No. 1145, 240 pp.
1978
Coutant, C.C., et al.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

The potential for chromium concentration in the Little Bayou Creek at the Paducah Gaseous Diffusion Plant to exceed NPDES limits either by direct deposition of drift water or from the transport of drift derived chromium by soil moisture flow was studied. Test results indicated that the concentration in soil water (shallow wells) at 60 and 200 m from the tower was greater than the concentration at the hardpan. The concentration at 60 m (0.112 ppb) was significantly different from the concentrations at all other distances, while the concentrations at 200, 950, and 1260 were different from the 410 m distance. The concentration at 60 m was several orders of magnitude lower than the NPDES limit of 0.05 ppm. It was concluded that the transport of drift-derived chromium in soil water was not a significant pathway for introducing the regulated substance into the stream. Elevated stream concentrations in the absence of tower blowdown suggest that direct deposition of drift water is a major concern. (ND)

<275>

Cooling Tower Drift Studies at the Paducah, Kentucky Gaseous Diffusion Plant.
ORNL/TM-6131, 39 pp.; ESD No. 1275, 39 pp.
1978
Taylor, F.G. Jr.; Hanna, S.R.; Parr, P.D.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

The transfer and fate of chromium from cooling tower drift to terrestrial ecosystems were quantified at the uranium enrichment facility at Paducah, Kentucky. Chromium concentrations in plant materials (fescue grass) decreased with increasing distance from the cooling tower, ranging from 251 plus or minus 19 ppm at 15 meters to 0.52 plus or minus 0.07 ppm at 1500 meters. The site of drift contamination, size characteristics and elemental content of drift particles were determined using a scanning electron microscope with energy dispersive x-ray analysis capabilities. Results indicate that elemental content in drift water (mineral residue) may not be equivalent to the content in the recirculating cooling water of the tower. This hypothesis is contrary to basic assumptions in calculating drift emissions. A laboratory study simulating throughfall from 1 to 6 inches of rain suggested that there are more exchange sites associated with litter than live foliage. Leachate from each one inch throughfall simulant removed 3% of the drift mass from litter compared to 7 to 9% from live foliage. Results suggest that differences in retention are related to chemical properties of the drift rather than physical lodging of the particle residue. To determine the potential for movement of drift-derived chromium to surface streams, soil-water samplers (wells) were placed along a distance gradient to Little Bayou Creek. Samples from two depths following rainstorms revealed the absence of vertical or horizontal movement with maximum concentrations of 0.13 ppb at 50 meters from the tower. Preliminary model estimates of drift deposition are compared to deposition measurements. Isopleths of the predicted deposition are useful to identify areas of maximum drift transport in the environs of the gaseous diffusion plant. (Auth)

<276>

Chalk Point Cooling Tower Project: Cooling Tower Effects on Crops and Soils, Post Operational Report No. 3.
PPSP-CPCTP-23, WRRC Special Report No. 11, 98 pp.
1978
Mulchi, C.L.; Wolf, D.C.; Armbruster, J.A.

University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Information obtained from dust collectors, crop species and soils during the period April 1977 to May 1978 which represents the third year of studies following initiation of cooling tower operation at Chalk Point, Maryland is presented. Results from previous years, which included two years of preoperation and two years of post operation information, were compared with the present information. The dust fall data continued to show particulate deposition rates below preoperational levels. Sodium and chloride deposition rates were variable, but generally below baseline levels. Rainfall salinity increased over previously reported levels, but may have been due to reduced rainfall. Soil studies showed no significant accumulation of sodium, chloride or other ions in salt drift. Crop yields showed no reductions which could be associated with salt deposition. Tissue chloride levels were higher than baseline values for corn and tobacco, but below levels noted for the 1976 growing season. Metabolic index values were also lower than baseline for corn and tobacco which suggest that the plants are responding to the values are within the range for healthy plants. Soybean information appears to be very similar to 1973-74 values. Tall fescue continues to accumulate quantities of chloride and has risen each year of operation, however, these increases have not been centered near the towers. Section B contains five papers describing the results of simulation studies; each have been input separately. (ND)

<277>

Chalk Point Cooling Tower Project: Cooling Tower Effects on Crops and Soils, Post Operational Report No. 2.
PPSP-CPCTP-19, WRRC Special Report No. 8, 131 pp.
1977
Mulchi, C.L.; Wolf, D.C.; Foss, J.E.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The results of the May 1976 - April 1977 studies at the Chalk Point cooling towers are presented. Information on dust collectors, (particulates, sodium and chloride), rainfall, crop species and soils during the second year of cooling tower operation is included. Comparisons of post operational results with results obtained during the preoperational period are included. Dustfall particulate deposition appeared below the rates observed previously, however, there was an increase of sulfur dioxide levels. There was no further increase in rainfall acidity compared to previous observations. Rainfall salinity measurements showed a general increase over previous operations. Soil chemical analyses for 1976 exhibited a trend for increased extractable sodium and electrical conductivity but the trend was reversed for 1977 sodium results. Tobacco and soybeans revealed significantly higher leaf chloride levels, however, with no apparent adverse affects due to salt deposition. The metabolic index appears to be a better tool for assessing salt deposition than either sodium or chloride alone. (ND)

<278>

Chalk Point Cooling Tower Project: Cooling Tower Effects on Crops and Soils, Post Operational Report No. 1.
PPSP-CPCTP-13, WRRC Special Report No. 3, Vol. 1 of 2, 53 pp.
1976
Mulchi, C.L.; Wolf, D.C.; Foss, J.E.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The results of the May 1975 - April 1976 studies at the Chalk Point cooling towers are presented. Information on ambient dustfall sodium, chloride and water insoluble particulate matter contents for twelve months following the initiation of tower operation is summarized, and post operational information and preoperational chemical characteristics for crop species and soils in the area are compared. The results do not show any alarming increases in salts either in the dustfall collectors, rainfall collectors, soil or plant samples from the first year. However, it can not be concluded that the Unit No. 3 cooling tower will not cause any long range effects on the environment from the first year of information. The tower was not in operation for extended periods of time and operated at less than maximum capacity for long periods. Additional studies are planned. (ND)

<279>

Chalk Point Cooling Tower Project: Cooling Tower Effects on Crops and Soils, Post Operational Report No. 1.
PPSP-CPCTP-13, WRRC Special Report No. 3, Vol. 2 of 2, 31 pp.
1976
Mulchi, C.L.; Wolf, D.C.; Foss, J.E.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Studies concerning the effects of saline aerosol drift on crop species and soils were undertaken to support research on cooling tower effects at Chalk Point. The areas discussed include (1) effects of simulated drift on Maryland tobacco, corn and soybeans using brackish water from the Chalk Point cooling towers, (2) influence of nitrogen sources on the response of Maryland tobacco to chloride fertilization, (3) movement of NaCl through the soil, and (4) respiration rate of soil amended with salt-sprayed soybean residue. Tobacco showed beneficial effects from the spray treatments; exhibiting higher yields, improved value, and increased filling capacity. There were significant increases in sodium and chloride in the plant tissue. The effects of cooling tower water spray on yields of corn and soybeans were nonsignificant at the 95% probability level, however, yields tended to be reduced with increased spray treatments. Trends for increased tobacco yields and value were found with increased chloride and for nitrate nitrogen. Tobacco leaf burn was negatively correlated with chloride levels in tissue and positively correlated with the metabolic index or nutrient balance. With normal rainfall to move NaCl through the soil, it would appear that Na could accumulate in the soil as a result of salt deposition at the rate of 20 g/m(E+2)/month from the cooling tower. (ND)

<280>

Cooling Tower Effects on Crops and Soils: Preoperational Report April 1973 - April 1975.
PPSP-CPCTP-6, WRRC Special Report No. 1, Vol. 1, 108 pp.; PB-284 076, 108 pp.
1976
Mulchi, C.L.; Wolf, D.C.; Foss, J.E.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Agronomic and soils studies completed during the period April 1973 - April 1975 which preceded the initiation of cooling tower operations at Chalk Point, Maryland are summarized. Information is presented for ambient dustfall sodium, chloride and water insoluble particulate matter contents; baseline chemical characteristics for crop species and soils in the area; and salt drift effects on plants and soils. The levels of salts over the area were rather uniform with no major distances or directions being favored. Rainfall washout could account for most of the sodium and chloride found in the dustfall collectors leaving very little to dry deposition. Agronomic information on tobacco includes yields, average price, value and quality index. Chemical and physical characteristics of cured tobacco appeared within normal limits. The nutrient data from the various agricultural species (tobacco, corn, soybeans, wheat, oats, barley, and tall fescue) indicate a broad range in chemical composition among the group of species as a whole but remarkable uniformity across locations for each individual species. Crops such as tobacco and soybean showed low baseline accumulations for sodium and chloride (Cl); corn, wheat, oats and barley had moderate Cl contents; and tall fescue appeared to accumulate Cl in substantial quantities. The species with the shortest growing periods for plant maturity had the lowest Cl accumulations. Warm season plants (tobacco and soybeans) have the capacity to rapidly absorb Cl from foliar deposition. The metabolic index values for tobacco, soybeans and corn should prove to be a sensitive indicator for salt accumulation. The moderate to low index values for the small grains and tall fescue may not be as sensitive an indicator as with the row crops. (ND)

<281>

Cooling Tower Effects on Crops and Soils: Preoperational Report Appendix 1972-1975.
PPSP-CPCTP-6, WRRC Special Report No. 1, Vol. 2., 97 pp.; PB-284 075, 97 pp.
1976
Mulchi, C.L.; Wolf, D.C.; Foss, J.E.; Armbruster, J.A.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

This report contains data collected on a monthly basis over the period April 1973-April 1975 for dustfall particulates, sodium and chloride and sulfur dioxide levels obtained at the Chalk Point Generating Station. Information on rainfall amounts, acidity and salinity; soil chemistry, yield and quality of major crops; and chemical analyses of vegetative samples from seven crop species for 1973 and 1974 growing seasons are reported. Also included in this report are summaries of experiments conducted at the Tobacco Experimental Farm near Upper Marlboro, Maryland involving the simulation of salt spray drift on tobacco, corn and soybeans. Crop yields and quality and chemical analyses of vegetative samples are reported. (ND)

<282>

The Influence of Fallout from Chalk Point Electrical Generating Station Cooling Tower on Surrounding Terrestrial Vegetation and Soils.
Chalk Point Cooling Tower Study, R.L. Green, (p. 23-31), 42 pp.
1973
Bezdicek, D.F.; Mulchi, C.L.; Armbruster, J.A.; Foss, J.E.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The objectives of the agronomy studies at the Chalk Point Electrical Generating Station Cooling Tower are discussed. These include the characterization of the physical and chemical properties of the area soils, monitoring fallout and the level and movement of such materials in soils, evaluation of the possible effects of fallout on the physical, chemical and biological properties of the area soils, and evaluation of the effect of fallout on the quality and productivity of major crops prior to and following the operation of the facility. Study plots were selected according to the recommendations of the meteorology studies. Background monitoring for salt deposition has begun with standard dust-fall apparatus. (ND)

<283>

Changes in Soil Chemical Properties Related to the Use of Brackish Water in a Natural Draft Cooling Tower.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 97-109), 462 pp.
1978
Wolf, D.C.; Foss, J.E.; McCormick, R.W.; McClung, G.; Armbruster, J.A.; Mulchi, C.L.; Kinsey, T.G.
University of Maryland, Department of Agronomy, College Park, MD
University of Maryland, Department of Dairy Science, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Twelve research sites were established to the north, east, south, and west at distances of 1.6, 4.8, and 9.6 km from the Chalk Point Electrical Generating Station. Soil samples were collected during 1973 and 1974 prior to cooling tower operation, and in 1975, 1976, and 1977 during which the tower was in operation. The soils were sampled at depths of 0-15 and 45-60 cm and analyzed for pH, electrical conductivity, organic matter, Kjeldahl-N, and extractable Na, K, Mg, Ca, P, Cl, NH4-N, and NO3-N. A statistical analysis of the data showed that the extractable Na content of the soils was lowest in the south direction during 1975, highest in the north and west during 1976, and lowest in the east direction during 1977. The Na levels in the soil at the 1.6 km distance were significantly higher in the north direction for the three years of cooling tower operation. The electrical conductivity of the soils indicated that the sites located at the three distances were not significantly different during 1975, but the 9.6 km distance was significantly lower than the 1.6 km distance during 1976 and 1977. It was concluded that changes occurred in the chemical properties of the soils in the vicinity of Chalk Point Generating Station during the three years of cooling tower operation. However, the salt content of the soils remained equal to or less than pre-cooling tower operation levels with extractable Na levels and electrical conductivity values of 85% and 83% of the baseline values, respectively. (Auth)

<284>

Movement of NaCl Through Three Soil Profiles and Its Effect on Soil Chemical Properties.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 111-130), 462 pp.
1978
McCormick, R.W.; Wolf, D.C.; McClung, G.; Foss, J.E.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The movement of NaCl through the upper 45 cm of three representative soils in the area which could be affected by the Chalk Point Electrical Generating Station was studied. Three replicate treatments of 0, 10, and 20 g NaCl/m(E+2) were applied to a Sassafras loam, Sassafras sandy loam, and Lakeland loamy sand at three different times. Soil samples were taken at 0-15, 15-30, and 30-45 cm depths at approximately monthly intervals for 13 months and analyzed for exchangeable Na and electrical conductivity. When NaCl was added to the soils at rates of 10 and 20 g/m(E+2), the soluble salt levels as measured by electrical conductivity returned to the level of the control treatments within one month. The Na cation was not leached through the soil profiles as rapidly as the Cl anion. Nine months after the last salt application, the Na content of all soils had returned to that of the control treatment except for the Sassafras sandy loam which contained significantly more Na at all three sampling depths than the control. Under the experimental conditions studied, it would appear that Na could accumulate in the soil as a result of a salt deposition at a rate of 10 g/m(E+2) month. (Auth)

<285>

Deposition of Sodium, Chloride, Particulate Matter and SO2 Near the Chalk Point Generating Station.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 39-50), 462 pp.
1978
Mulchi, C.L.; Wolf, D.C.; Armbruster, J.A.; McClung, G.;
Douglass, L.W.
University of Maryland, Department of Agronomy, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Dustfall sodium, chloride and water insoluble particulate matter deposition rates and SO2 levels were measured on a monthly basis at 12 locations (1.6, 4.8 and 9.6 km distances in N, E, S and W directions) near the Chalk Point generating station, Maryland, over a four-year period beginning May, 1973. Dustfall sodium and chloride deposition rates measured prior to Unit 3 operations averaged 36.5 + or - 12.0 and 67.1 + or - 22.2 mg/m(E+2)-month, respectively, with lower deposition rates occurring during the summer and higher rates occurring during winter and early spring. Linear regression analyses of sodium vs. chloride deposition rates produced slope (b), intercept (a) and correlation coefficient (r) values of 1.83, 1.62 and 0.88, respectively, which suggest that most of the background sodium and chloride were deposited on an equal molar basis. Deposition rates measured after Unit 3 became operational were consistently below the rates measured during the preoperational period. Rainfall sodium and chloride concentrations increased slightly at the 4.8 km locations following Unit 3 operations but the increases were within standard deviation estimates for the preoperational period. These results suggest that the intermittent use of Unit 3 during the initial 24 months of operations did not alter the rates of sodium and chloride deposition in the region 1.6 to 9.6 km distance from the power plant complex. Similar conclusions were made for dustfall particulates and SO2 measurements except elevated SO2 levels were observed for several periods during the harsh winter of 1976-77. (Auth)(ND)

<286>

Response of Field Crops to Salt Drift from a Natural Draft Cooling Tower.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 79-96), 462 pp.
1978
Armbruster, J.A.; Mulchi, C.L.; Douglass, L.W.; Wolf, D.C.
University of Maryland, Department of Agronomy, College Park, MD
University of Maryland, Department of Dairy Science, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

A monitoring network of twelve research sites was established at distances of 1.6, 4.8 and 9.6 km in the north, east, south, and west directions from the Chalk Point, Maryland, Electrical Generating Station. Crops planted at each site were corn (ZEA MAYS L.), soybeans (GLYCINE MAX L. Merr.), and tobacco (NICOTIANA TOBACCUM L.). Plant tissue samples and grain yields were collected from corn and soybeans during 1973 and 1974 prior to cooling tower operation, and in 1975, 1976, and 1977 during which the tower was in operation. Tissue samples and yields were collected from tobacco during 1973-1976. Plant tissue samples were analyzed for P, K, Ca, Mg, Na, and Cl. Results of two years of baseline (1973-1974) and three years of post operative monitoring (1975-1977) of the effect of salt drift from the cooling tower showed no effect on grain yields of corn and soybeans attributable to salt damage. Two years of post operative monitoring of yields of air-cured tobacco also showed no change from baseline yields. Post operative levels of sodium and chloride in plant tissue of all three crops were statistically equivalent to baseline levels. Plant nutrient balances as measured by a calculated metabolic index value remained unaffected by salt drift. Quality index measurements of commercial usability of air-cured tobacco were not altered during post operational monitoring. (Auth)

<287>

Reduction in Crop Yields Due to Saline Drift Deposition (at the Chalk Point Generating Station Units 3 and 4).
Figure VI-1, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 1 p.

Graph indicates percent reduction in corn and soybean yield vs. salt deposition in kg per hectare-month due to salt deposition from the Chalk Point Generating Station Units 3 and 4, Prince Georges County, MD. Values are based on simulated drift experiments.

<288>

Reduction in Tobacco Burning Time Due to Saline Drift Deposition (at the Chalk Point Generating Station Units 3 and 4).
Figure VI-2, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 1 p.

Graph indicates percent reduction in burning time vs. salt deposition in kg per hectare-month due to salt deposition from the Chalk Point Generating Station Units 3 and 4, Prince Georges County, MD. Figure is based on simulated drift experiments.

<289>

Chalk Point Cooling Tower Project: Native Vegetation Study Final Report FY78.
PPSP-CPCTP-24, WRRC Special Report No. 10; PB-289 163/8SL;
1978
Patterson, G.W.; Curtis, C.R.; Lauver, T.L.; Hosokawa, G.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The research and monitoring accomplishments by the Botany Section of the Chalk Point Cooling Tower Project (CPCTP) during FY 1977-1978 are reported. In addition, Na+ data are reported for June - September 1976, which were not available for the last annual report. The research areas include a foliage sampling program f : sodium and chloride concentrations, field test plots of native trees (primarily dogwood) for Cl- concentrations, simulated drift studies on tobacco, Virginia pine, dogwood, tulip-poplar and privet, and saline-acid aerosol experiments on vegetation. (ND) stipples. (Auth)(ND)

<290>

The Effects of Saline Cooling Tower Drift on Seasonal Variations of Sodium and Chloride Concentrations in Native Perennial Vegetation.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. I 49-63), 462 pp.
1978
Lauver, T.L.; Curtis, C.R.; Patterson, G.W.; Douglass, L.W.
University of Maryland, Department of Botany, College Park, MD
University of Delaware, Department of Plant Science, Newark, DE
University of Maryland, Department of Dairy Science, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The Potomac Electric Power Company (PEPCO) generating station at Chalk Point, Maryland utilizes a (brackish water) natural draft cooling tower in its cooling cycle. A monitoring study was established to evaluate the effects of saline drift on native, perennial vegetation in the vicinity of the Chalk Point power plant. Sampling from a total of 13 naturally-occurring field sites of dogwood (CORNUS FLORIDA), black locust (ROBINIA PSEUDO-ACACIA), Virginia pine (PINUS VIRGINIANA), and sassafras (SASSAFRAS ALBIDUM), was continued from May 1974 through September 1976. Samples were collected monthly, May through September, in any given year. Samples were collected and analyzed prior to the operation of the cooling tower (1974), and also since the tower was in operation (1975-76). Statistical comparisons among the 1974, 1975, and 1976 data indicate some significant increases in ion concentration have occurred in a few sites, but these are small and are not attributable to cooling tower drift. In some instances, site post operational ion concentrations have decreased. Aging, metabolic changes, and/or seasonal changes in rainfall are thought to contribute to the fluctuations in ion concentration. (Auth)(ND)

<291>

Dogwood Leaf Injury Due to Chloride Deposition (at the Chalk Point Generating Station Units 3 and 4).
Figure VI-3, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 1 p.

Graph indicates percent of leaves injured vs. leaf chloride concentrations for dogwoods in the vicinity of the Chalk Point Generating Station, Prince Georges County, MD. Figure is based on simulated drift experiments and field sampling.

<292>

Chalk Point Cooling Tower Project: Field Research on Native Vegetation Final Report FY77.
PPSP-CPCTP-18, WRRC Special Report No. 7, 185 pp.
1977
Curtis, C.R.; Lauver, T.L.; Francis, B.A.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

FY 1976-1977 research and monitoring accomplishments by the Botany section of the Chalk Point Cooling Tower Project are summarized. The time interval for data acquisition for this period overlaped with the FY 1975-1976 report by one month, and all new data reported here were obtained from May 1, 1976 to June 30, 1977. All data obtained after the release of last year's report (PPSP-CPCTP-14) are included in a tabular form and in a graphic summary form in the appendices. The research areas included a foliage sampling program, field test plots, and simulated drift studies. Based on comparisons among the 1974, 1975 and 1976 data, no significant changes in foliar Cl- levels occurred between 1974 and 1975. However, the 1976 field data indicated a significantly higher Cl- level in 3 out of the 12 monitored field sites. Dogwood was far more sensitive to simulated drift deposition than other tree species such as tulip-poplar or Virginia pine. Virginia pine and spruce were resistant to salt spraying and were not good salt injury indicator plants. Tulip-poplar leaves were intermediate in salt sensitivity although bracts encasing the young leaves appeared to be highly sensitive to salt spraying. Further studies are recommended, particularly simulation studies using known concentrations of NaCl to evaluate symptom injury and species sensitivity. (ND)

<293>

Foliar Sodium and Chloride in Trees: Seasonal Variations.
Environmental Pollution 14(1):69-80
1977
Curtis, C.R.; Lauver, T.L.; Francis, B.A.
University of Maryland, Department of Botany, College Park, MD

As a part of project to evaluate the effects of natural draft cooling tower drift on the environment, a systematic sampling program was conducted to determine the naturally-occurring amounts of sodium (Na+) and chloride (Cl-) ions in foliage of Virginia pine (PINUS VIRGINIANA Mill.), black locust (ROBINIA PSEUDO-ACACIA L.), sassafras (SASSAFRAS ALBIDUM (Nutt) Nees) and white flowering dogwood (CORNUS FLORIDA L.). Foliage samples were collected between May 1974 and April 1975 from a total of thirteen native tree sites in southern Maryland near Chalk Point. Each tree site was composed of ten marked trees in which the foliage of each tree was sampled on a monthly basis. The seasonal trends noted for Na+ and Cl- depended upon the tree species and site location. In general, foliar Na+ tended to increase during the growing season in Virginia pine and all deciduous species. Foliar Cl- tended to increase markedly during the growing season, especially in dogwood. A summary of seasonal means, ranges and monthly variations is presented for all sites and species. The importance of these data is discussed in relation to cooling tower drift. (Auth) (ND)

<294>

Chalk Point Cooling Tower Project: Field Research on Native Vegetation.
PPSP-CPCTP-14, WRRC Special Report No. 4, 130 pp.; PB-284 209
1976
Curtis, C.R.; Lauver, T.L.; Francis, B.A.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Research accomplishments and data obtained from May 1975 to June 1976 by the botany section of the Chalk Point Cooling Tower Project are summarized. The areas reported on include the foliage sampling program, chloride concentration in field test slots; simulated drift studies, and ambient oxidant studies using open top field chambers. From a comparison of the 1974 and 1975 field data, it was concluded that no significant changes in foliar levels occurred. Trends were similar for both time periods, and in many cases the Cl- values were nearly the same. No symptoms characteristic of salt injury were found. However, the simulated drift studies conclusively showed that cooling tower basin water applied at high doses as a spray can cause foliar symptoms (marginal necrosis and isolated necrotic areas) on dogwood. From the available evidence, it was concluded that the threshold Cl- level for dogwood leaf injury is near 4000 ppm under field conditions. This is the first report of injury induced by simulated cooling tower drift spraying under field conditions. (ND)

<295>

Cooling Tower Effects on Native Perennial Vegetation: Preoperational Report.
PPSP-CPCTP-7, WRRC Special Report No. 2, Vol. 1 of 2, 51 pp.
1976
Curtis, C.R.; Lauver, T.L.; Francis, B.A.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Results of background (preoperational) and simulation studies on perennial vegetation completed during the period August 1972-April 1975 at Chalk Point, Maryland are described. The two main purposes of the study were to estimate natural foliar salt load in native vegetation and to attempt to recognize the symptoms of drift injury. Test field plots (tree farms) were established in six locations near the power plant for future long-range observation and chemical testing. Results for 1972 indicated that the majority of the chloride concentrations in the leaves of the species studies fell within the ranges of 100 to 500 ppm. Ranges in sodium ion loads for native perennial vegetation for 1974-1975 were: dogwood 41.8 to 70.4 ug/g; Virginia pine (multiple sites) 24.7 to 631.2 ug/g; black locust (multiple sites) 44.8 to 291.0 ug/g; and sassafras (multiple sites) 34.5 to 194.6 ug/g. Ranges in chloride ion loads for native perennial vegetation for 1974-1975 were: dogwood 570.8 to 3817.2

ug/g; Virginia pine (multiple sites) 270.5 to 2765.0 ug/g; black locust (multiple sites) 275.7 to 2606.7 ug/g; and sassafras (multiple sites) 106.8 to 614.6 ug/g. Symptoms of simulated drift injury (test field plots) for dogwood were commonly leaf wrinkling and curling, and occasionally marginal necrosis. Tulip-poplars appeared to be highly resistant to simulated drift; limited necrotic zones appeared only where the leaf was previously injured by insects or mechanical rupture. Tulip-poplar stipule injuries (necrosis) were noted for the three highest drift treatments. Extensive field data are provided in the appendices in Volume 2 of this report. (ND)

<296>

Cooling Tower Effects on Native Perennial Vegetation: Preoperational Report Appendices.
PPSP-CPCTP-7, WRRC Special Report No. 2, Vol. 2 of 2, 204 pp.
1976
Curtis, C.R.; Lauver, T.L.; Francis, B.A.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Data from background (preoperational) studies on perennial vegetation completed during the period August 1972-April 1975 at Chalk Point, Maryland are tabulated. The two main purposes of the study were to estimate the natural foliar salt load in native vegetation and to attempt to recognize the symptoms of drift injury. Volume 1 of this report describes the study methods and overall results. This volume contains tabularized data from the sodium and chloride measurements of native perennial vegetation. (ND)

<297>

Field Research on Vegetation Near the Chalk Point, Maryland Cooling Tower.
Energy Conservation Conference, Proceedings of a Symposium, Las Vegas, Nevada, December 7-9, 1975, 23 pp.
1975
Curtis, C.R.; Lauver, T.L.; Francis, B.A.; Mulchi, C.L.; Douglass, L.W.
University of Maryland, Department of Botany, College Park, MD
University of Maryland, Department of Agronomy, College Park, MD
University of Maryland, Department of Dairy Science, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Approaches taken in the study of potential environmental consequences of cooling tower drift at the Chalk Point Power Plant's natural draft cooling towers are reviewed. The three major research areas involve gathering foliar baseline data, monitoring the field test plot species for symptoms, and performing saline aerosol experiments with simulated drift. Comparison of data among the three research areas should provide a sound basis for evaluation of long-term salt drift effects on the environment. No conclusions were made due to the preliminary nature of the baseline studies. Noticeable symptoms of simulated drift injury include extensive marginal necrosis, stunted growth, and wrinkled leaves on dogwoods. Early symptoms on soybean foliage included interveinal chlorosis, stunted growth, and lesion formation. (ND)

<298>

Seasonal Variations in the Salt Load of Native Dogwood Trees Near Chalk Point, Maryland.
Botanical Society of America 71st Annual Meeting, Proceedings of a Symposium, New Orleans, LA, June 1, 1976
1976
Curtis, C.R.; Lauver, T.L.; Francis, B.A.; Douglass, L.W.
University of Maryland, Department of Botany, College Park, MD
University of Maryland, Department of Dairy Science, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Seasonal variations in naturally occurring levels of sodium (Na^+) and chloride (Cl^-) in foliage of dogwood (CORNUS FLORIDA L.) were determined prior to the operation of a nearby saline aerosol emission source. To help predict the effect of saline aerosols on vegetation in local ecosystems, it is necessary to determine the magnitude of seasonal fluctuations in foliar salt. A native stand of ten dogwood trees was sampled monthly from May 1974 to September 1974. Leaf samples were collected, dried, ground and analyzed for Na^+ and Cl^-. Each sample was independently analyzed three times for Na^+ and Cl^-. The average monthly Na^+ values for the site ranged from 42 ug/g to 70 ug/g with a seasonal average of 54 ug/g. However, the average Cl^- values increased steadily throughout the season and ranged from 571 ug/g in May to 3817 ug/g at the end of the season. In separate experiments to determine the threshold level for foliar salt injury, young trees were planted and sprayed with saline aerosols 5 times a week for 6 weeks. Foliary injury was detected when leaf Cl^- was about 3800 ug/g. These results indicated that dogwood accumulated Cl^-, and natural levels of leaf Cl^- tended to rise during the growing season and reach a maximum just prior to leaf abscission. (Auth)

<299>

Sodium and Chloride Concentrations in Native Vegetation near Chalk Point, Maryland.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 406, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 370-378), 638 pp.
1975
Curtis, C.R.; Gauch, H.G.; Sik, R.
University of Maryland, Department of Botany, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Baseline sodium and chloride data (1972) obtained from leaves of perennial woody species in the Chalk Point area are described. Sodium and chloride concentrations in leaves collected in 1972 of various perennial species of native plants have been determined for the Chalk Point area. These data are regarded as imperative base-line or background data with regard to salt concentrations in native vegetation prior to the operation of the Chalk Point cooling towers. In general, the majority of the chloride concentrations in leaves of species examined so far fall within the range of 100 to 500 ppm. The reasons for variations in chloride concentrations in a given species for various sampling dates and locations are yet to be elucidated. Because of the possible leaching effect of rains, some of the lower values may have resulted from sampling soon after a rain. There were also increases in the sodium concentration in leaves of certain species later in the season. This apparent trend will be examined in samples collected during the coming growing season. (Auth)(ND)

<300>

Possible Effects of Salt Drift on Annual, Perrennial, and Ornamental Species of Plants.

Chalk Point Cooling Tower Study, R.L. Green, (p. 32-42), 42 pp.

1973

Curtis, C.R.; Gauch, H.G.; Sik, R.

University of Maryland, Department of Botany, College Park, MD

Maryland Department of Natural Resources, Power Plant Siting Program

The effects of salt drift on non-agronomic species of plants is being studied by the Botany Department. Baseline studies include vegetation analyses of area species and sodium and chloride concentration determination for area species. Field plots of ornamental and native annual and perennial plants will be examined for relative growth and salt damage. Study methods and tentative results are discussed. About three-fourths of the chloride concentrations in the baseline studies fell within the range of 100-500 ppm. (ND)

AESTHETIC IMPACTS - TOWER VISIBILITY

<301>

Comparative Cooling Tower and Plume Visibility Study.
Energy Impact Associates, Inc. for Massachusetts Energy Facilities Siting Council, Feb. 1979. 34 pp.

Report provides a means for assessing the relative visual impact of alternative cooling tower types at the proposed Montague Nuclear Power Station, Franklin County, MA. Four unretouched photographs illustrate the view of the station from 4 points in the vicinity. Twenty retouched photographs show the same views with circular mechanical draft and natural draft cooling towers with plumes of various heights and lengths. Report includes a map showing the station and the camera vantage points; the methods used in the study, and drawings of the 2 types of cooling towers.

<302>

(Comparison and Typical View of Natural Draft Cooling Towers.)
Figures 6.4-1 & 6.4-2, Ocean-Sited Plants - Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 2 pp.

Figures compare natural cooling tower height to known and typical coastal structures and present a typical view of a coastal power plant with natural draft cooling towers.

<303>

Summary of Visual and Aesthetic Impacts.
Exhibit 97, Appendix E1, Oyster Creek & Forked River Nuclear Generating Stations: 316(a) and (b) Demonstrations. Prepared by Ebasco Services, Inc. for Jersey Central Power & Light Co., Nov. 1977. 1 p.

Visual environmental impacts such as permanent vegetative loss, visible plume, ground fog, and profile impact resulting from proposed alternative cooling water systems at the Oyster Creek nuclear station, Ocean County, NJ, are summarized in this table.

<304>

Visibility of Tower Alternatives.
U.S. Nuclear Regulatory Commission . Table 9.4, Final Environmental Statement Related to Construction of Montague Nuclear Power Station Units 1 & 2, Northeast Nuclear Energy Co., Feb. 1977.

Table indicates the extent to which the alternative cooling towers being considered at the Montague power station in Franklin County, MA, would be visible from ground level within the study area. Values are shown for cooling tower heights of 70, 182, and 565 ft.

<305>

Visual Impact of Proposed and Alternative Cooling Towers.
U.S. Nuclear Regulatory Commission . Appendix K, Final Environmental Statement Related to Construction of Montague Nuclear Power Station Units 1 & 2, Northeast Nuclear Energy Co., Feb. 1977. 57 pp.

Appendix contains the NRC staff's assessment of the visual impacts of the 500, to 570-foot cooling towers at the proposed Montague power station. Visual impacts of 2 alternative cooling tower systems (one 182 ft high, the second 70 ft) are described. As criteria for evaluation of the visual impact, the NRC staff used: 1) visibility (the amount of the tower that was visible from various locations and the percentage of area from which the towers could be seen) and 2) environmental context, which includes the residential, commercial, educational, cultural, recreational, and historic characteristics of the Montague area. Information addressed the presence of the cooling towers from the point of view of a setting to the town of Montague, to the Commonwealth of Massachusetts, and to the Northeast Region. The visibility of the cooling towers from a variety of locations and the varying environmental contexts from which the cooling towers would be viewed are also discussed. Report includes 30 figures.

<306>

Study of Regional Visual Impact Factors of Natural Draft Cooling Tower.
Table 5-2, Eliminate Requirement for Termination of Operation with Once-Through Cooling System, Indian Point Unit 2 Environmental Report, Consolidated Edison Co. of New York, March 1977. 2 pp.

Table presents visual observations of Indian Point power plant and cooling tower from 5 vantage points. The approximate distance of each point from the plant is also given.

AESTHETIC IMPACTS - PLUME VISIBILITY

<307>

The Generation of Visible Plumes by Wet Dry Cooling Towers.
Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, New Orleans, LA, January 28-30, 1974, 16 pp.
1974
Biese, R.J.
Gilbert Associates, Inc.

The immediate psychrometric behavior of the subsaturated vapor/air plumes discharged by induced draft cooling towers employing both evaporative and dry cooling in combination are examined. Plume characteristics such as temperature and relative humidity were traced from the tower stack exit to the point of saturation. This critical point signaled the onset of plume visibility. The plume characteristics were examined via a computerized mathematical model employing simple numerical techniques. The results indicated that for any fixed set of environmental conditions, effects, such as exit velocity, initial temperature, and heat loss by radiation, were small compared to the effect of initial relative humidity. Specific examples are given which indicate plume appearance under conditions which might be expected to induce natural fog. (Auth)(ND)

<308>

Condensation Plume Computations.
Table 5.1-5, Boardman Nuclear Plant Environmental Report, 1 p.
1977
Portland General Elec. Co.

Table shows cooling lake condensation plume computations at the Boardman power station in Morrow County, OR. Parameters are pond surface temperature, ambient air temperatures, estimated average temperature of modified air, relative humidity, wind direction, calculated height of plume top, and calculated plume length. Estimates were made of the moisture evaporated during transit of the reservoir cross-wise and lengthwise by the coldest air recorded and for a more usual situation.

<309>

Estimated Frequency of Occurrence of Visible Plumes from the Natural Draft Cooling Towers.
Figures 5.1-6 Through 5.1-9, 5.1-11, & 5.1-13, Haven Nuclear Plant Units 1 & 2 Environmental Report Construction Permit Stage. Wisconsin Elec. Power Co.; Wisconsin Power & Light Co., and Wisconsin Public Service Corp., Jan. 1978. 6 pp.

Figures delineate percent of time that visible plumes will occur due to operation of the natural draft cooling towers serving the proposed 1,800-MW Haven Nuclear Plant in Sheboygan County, WI. Different wind directions are shown.

<310>

Average Visible Plume Lengths (Miles) by Wind Direction.
Table 5.1.5, Final Environmental Report (Operating License Stage) for Grand Gulf Nuclear Station Units 1 & 2. Prepared by Mississippi Power & Light Co., July 1978. 1 p.

Table presents average estimated visible plume lengths (in miles) from 2 natural-draft cooling towers at Grand Gulf power station in Claiborne County, MS. Values are presented for 16 radial distances during 4 months and are based on twice daily observations. Also shown are the average projected plume lengths for all directions for each cardinal month.

<311>

Average Visible Plume Lengths (Miles) by Wind Direction, Percentage Frequency of Wind Direction, and Average Wind Speed.
Table 5-3, Final Environmental Statement Related to Construction of Grand Gulf Nuclear Station Units 1 & 2. Mississippi Power & Light Co. Prepared by U.S. Atomic Energy Commission, Aug. 1973. 1 p.

Table gives the average plume lengths by wind direction, together with average wind speed and percentage frequency of occurrence of directional winds for the region in the vicinity of the proposed Grand Gulf power station in Claiborne County, MS. Results are based on the combined effects of 2 natural draft cooling towers operating in January, April, July, and October.

<312>

Annual Frequency of Elevated Plumes from Natural Draft Tower, OCNGS.
Table 5.1-8, Oyster Creek and Forked River Nuclear Generating Stations - 316(a) & (b) Demonstration. Prepared by Jersey Central Power & Light Co., Nov. 1977. 1 p.

Table lists the estimated frequencies of elevated visible plumes from the proposed natural draft cooling tower at Oyster Creek Nuclear Generating Station, Ocean County, NJ. Data indicate the number of hours per year plumes will be visible for 16 compass directions from the tower at various plume lengths up to 14,000 ft.

<313>

(Visible Plume Length Cumulative Frequencies and Elevated and Surface Levels.)
Figures 5.1 & 5.2, Final Environmental Statement Related to the Proposed Catawba Nuclear Station Units 1 & 2. Duke Power Co. Prepared by U.S. Atomic Energy Commission, Dec. 1973. 2 pp.

Figures illustrate isolines describing the frequency of occurrence and extent of visible plumes from the proposed Catawba power station in York County, SC, for the period November through May. The applicant has estimated the horizontal excursions of visible cooling tower plumes at Catawba based on plume observation and atmospheric measurements at the Paradise Steam Plant of the Tennessee Valley Authority (natural draft towers) and the applicant's Cliffside Generating Station (mechanical draft towers).

<314>

Number of Occurrences of Visible Tower Plumes of Various Lengths for Sixteen Directions from the Plant.
Table 3.1.4-11, Intermountain Power Project Preliminary Engineering and Feasibility Study, Environmental Assessment. Prepared by Westinghouse Elec. Corp. for Los Angeles Dept. of Water & Power, May 1977. 1 p.
Table lists potential average maximum extents (km) of visible cooling towers plumes for 16 directions from the proposed Intermountain Power Project, Wayne County, UT. Total hours of occurrences are also included.

<315>

Frequency Distribution of Visible Plume Per Affected Direction Sector.
Table 5.1-21, Susquehanna Steam Electric Station, Units 1 & 2, Environmental Report, Operating License Stage. Prepared by Pennsylvania Power & Light Co., May 1978. 1 p.
Table presents frequency distribution data for visible plumes at 21 increasing distances and 16 compass directions from natural draft cooling towers at Susquehanna Steam Electric Station, Luzerne County, PA. Data are from a diffusion model.

<316>

(Occurrence of Visible Plumes.)
Table 4, Applicants' Direct Testimony with Respect to Use of Closed-Cycle Cooling at Seabrook and Analyses of Alternative Sites. Presented before U.S. Nuclear Regulatory Commission, Atomic Safety and Licensing Board, 1977. 1 p.
Table lists direction, approximate distance, and number of hours per year a visible plume from the alternative natural draft cooling tower would pass over 8 locations near the proposed Seabrook nuclear plant, Rockingham County, NH.

<317>

Average Annual Frequency of Visible Cooling Tower Plume Length for the Proposed Trimble County Generating Station.
Figure 6.3.1-1, Draft Environmental Impact Statement Trimble County Generating Station Supporting Report. Louisville Gas & Elec. Co. Prepared by U.S. Environmental Protection Agency, Feb. 1978. 1 p.
Figure shows the average annual frequency (hours) of visible cooling tower plumes by length for the proposed Trimble County Generating Station, Trimble County, KY. Lengths are depicted as radii running from the center of the station to the extent of the plume, and the figure is marked with circles of radii every 0.5 km between 0 and 5.0 km. The plant will utilize 2 natural draft cooling towers.

<318>

(Visible Plume Occurrence.)
Figures 4-9 & 4-10, Power Plant Site Evaluation Report: Dickerson Site. Prepared by Johns Hopkins Univ. for Potomac Elec. Power Co., Maryland Power Plant Siting Program, Jan. 1974. 2 pp.
Figures are maps showing predicted contours of equal frequency of occurrence of visible plumes from mechanical draft cooling towers considered as an alternative cooling system for the proposed expansion of Dickerson Steam Electric Station, Montgomery County, MD. Contours are for daylight hours per season for 2 alternate designs, each assuming an entrainment coefficient of .2. Design I towers would be 70 ft high with 26 cells per unit, while Design II towers would be 38 ft high with 32 cells per unit.

<319>

Potential Hours of Mechanical Draft Tower Plumes.
Table 10.1-4, Fulton Generating Station Units 1 & 2 Environmental Report, Philadelphia Elec. Co., Nov. 1973. 1 p.
Table tabulates 1) predicted number of hours of saturation condition when plume merges with natural fog or low clouds; and 2) number of hours plumes will extend beyond 1 mi. due to operation of mechanical draft cooling towers. Calculations are based on meteorological data collected at Peach Bottom Weather Station No. 2 during the period of January 1968 through June 1970.

<320>

Duration of Visible Plume Occurrence for Natural Draft Wet Cooling Tower System.
Table 10.1-5, Braidwood Station Environmental Report, Commonwealth Edison Co., Aug. 1973. 1 p.
Table lists the calculated number of hours in which the plume from alternative natural draft wet cooling tower is visible when the wind frequency in each of 16 compass directions is taken into account. Values are given for distances from 0.3-30.0 mi. downwind from tower.

<321>

Frequency of Visible Plume Occurrence for Natural Draft Wet Cooling Tower System.
Table 10.1-6, Braidwood Station Environmental Report, Commonwealth Edison Co., Aug. 1973. 1 p.
Table is a composite evaluation of the visible plume occurrence in which the frequency of visible plumes is given as a function of downwind distance due to operation of alternative natural draft wet cooling tower.

<322>

Condensed Water Plume Occurrence from Natural Draft Cooling Towers.
Table 10.1-8, Clinton Power Station Units 1 & 2 Environmental Report, Illinois Power Co., Oct. 1973. 1 p.
Table lists frequency and percentage of time that condensed water plume will occur at distances of 0.3-30.0 mi. from alternative natural draft cooling towers considered for Clinton Power Station.

<323>

Visible Plume from Natural Draft Wet Cooling Tower (Hours per Year).
Figure 10.1-3, Greenwood Energy Center Units 2 & 3 Environmental Report, Detroit Edison Co., Sept. 1973. 1 p.

Figure is a map of Greenwood Energy Center's surrounding area indicating the number of yearly hours of visible plume occurrence due to alternative natural draft wet cooling towers.

<324>

Visible Plume from Mechanical Draft Wet Cooling Towers (Hours per Year).
Figure 10.1-4, Greenwood Energy Center Units 2 & 3 Environmental Report, Detroit Edison Co., Sept. 1973. 1 p.

Figure is a map of Greenwood Energy Center's surrounding area indicating the number of yearly hours of visible plume occurrence due to alternative mechanical draft wet cooling towers.

<325>

Visible Plume from Wet/Dry Cooling Towers.
Figure 10.1-5, Greenwood Energy Center Units 2 & 3 Environmental Report, Detroit Edison Co., Sept. 1973. 1 p.

Figure is a map of Greenwood Energy Center's surrounding area indicating the number of yearly hours of visible plume occurrence due to alternative natural draft wet/dry cooling towers.

<326>

Estimated Frequency of Occurrence of Visible Plumes from the Natural Draft Cooling Towers.
Figures 10.1-2 & 10.1-3 River Bend Station Units 1 & 2 Environmental Report, Gulf States Utilities Co., Sept. 1973. 1 p.

Figures consists of 8 graphs indicating visible plume height above ground level as a function of horizontal distance from natural draft cooling towers at River Bend Station for 16 compass directions.

<327>

Estimated Frequency of Occurrence of Visible Plumes from the Round Mechanical Draft Towers.
Figures 10.1-5 & 10.1-6, River Bend Station Units 1 & 2 Environmental Report, Gulf States Utilities Co., Sept. 1973. 2 pp.

Figures consist of 8 graphs indicating visible plume height above ground level as a function of horizontal distance from alternative round mechanical draft cooling towers at River Bend Station for 16 compass directions.

<328>

Frequency of Visible Plume from Natural Draft Towers, Wet Mechanical Towers, and Wet/Dry Mechanical Draft Towers.
Figures 10.1-6, 10.1-13, & 10.1-20, NEP 1 & 2 Environmental Report, New England Power Co., Sept. 1976. 3 pp.

Figures graph the frequency of visible plume from natural draft, wet mechanical, and wet/dry mechanical draft towers. Individual curves are plotted for wind variance from the east, west, north, and south for each type, and values are expressed in hours per year. Studies were conducted during alternative design analysis for NEP Units 1 and 2, Washington County, RI.

<329>

Expected Plume Length and Frequency of Occurrence for 16 Compass Point Sectors (All Temperatures), Natural Draft Cooling Towers, Bellefonte Nuclear Plant Site.
Figure 2.6-4, Bellefonte Nuclear Plant Units 1 and 2 Final Environmental Statement, Tennessee Valley Authority, May, 1974. 1 p.

Figure shows the probability of cooling tower plume occurrence for various directions and distances from the Bellefonte Nuclear Plant, Jackson County, AL, under all temperature conditions.

<330>

Expected Plume Length and Annual Frequency of Occurrence for 8 Compass Point Sectors, Round Mechanical Draft (Wet) Cooling Towers, Yellow Creek Nuclear Plant.
Figure 5.1-1, Yellow Creek Nuclear Plant Units 1 & 2 Environmental Report, Tennessee Valley Authority, Dec. 1976. 1p.

Figure shows the expected cooling tower plume lengths and estimated frequencies of occurrence for 8 compass point sectors from the Yellow Creek power station in Tishomingo County, MS. This diagram, superimposed on a topographical map of the site area, extends to about 7.5 km from the site.

<331>

10-Year Average Winter, Spring, Summer, and Fall Distribution of Horizontal Plumes, Cincinnati, Ohio.
U.S. Army Engineer District, Huntington, WV. Exhibits 4.2.1.2-1 through 4.2.1.2-4, Killen Electric Generating Station Units 1 and 2, Draft Environmental Impact Statement, Dayton Power & Light Co., July 1976. 4 pp.

Figures are histograms of seasonal frequency illustrating predicted plume length resulting from the proposed operation of natural draft cooling towers at Killen station, Adams County, OH. Distribution of overhead plumes in the station area was predicted by means of a computer analysis of hourly surface meteorological observations recorded from 1948-1957.

<332>

Characteristics of Horizontal Long Plumes, 10-Year Average.
U.S. Army Engineer District, Huntington, WV. Exhibit 4.2.1.2-5, Killen Electric Generating Station Units 1 and 2, Draft Environmental Impact Statement, Dayton Power & Light Co., July 1976. 1 p.

Table summarizes information on visible plumes resulting from the proposed operation of natural draft cooling towers at Killen Electric Generating Station, Adams County, OH. Seasonal data are given for maximum plume length, average plume length during the 10 hr each year with the longest plumes, and frequency of plumes (hours/years). Distribution of plumes was predicted by means of a computer analysis of hourly surface meteorological observations recorded from 1948-1957.

<333>

Frequency Distribution of Visible Plume at Colstrip.
Westinghouse Environmental Systems Dept. Table 2.6-35, Colstrip Generation and Transmission Project Environmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 1 p.

Table gives the calculated frequency distribution of visible plumes in 16 directions, resulting from operation of cooling towers at Colstrip Generation and Transmission Project, Rosebud County, MT. Data is given as the number of hours of visible plume.

<334>

Study of Regional Visual Impact Factors of Natural Draft Cooling Tower.
Table 5-2, Eliminate Requirement for Termination of Operation with Once-Through Cooling System, Indian Point Unit 2 Environmental Report, Consolidated Edison Co. of New York, March 1977. 2 pp.

Table presents visual observations of Indian Point power plant and cooling tower from 5 vantage points. The approximate distance of each point from the plant is also given.

<335>

Estimated Annual Percent Persistence of Elevated Visible Plume Lengths.
Tables 5.1-2 and 5.1-3, WPPSS Nuclear Project No. 2 Environmental Report (Operating License Stage), Washington Public Power Supply System, Mar. 1977. 2 pp.

Tables summarize the annual percent persistence of visible plume length from the operation of a mechanical draft cooling tower at the site of WPPSS No. 2, Benton County, WA. Table 5.1-3 gives this data for conditions in which the ambient air temperature is at freezing point or below. Data are given for various directions and distances from 1-30km from the plant.

<336>

Predicted Visible Plume Widths in Meters as a Function of Month and Downwind Distance.
Table 5.1-5, WPPSS Nuclear Project No. 2 Environmental Report (Operating License Stage), Washington Public Power Supply System, Mar. 1977. 1 p.

Table gives average predicted visible plume widths resulting from operation of mechanical draft cooling towers at WPPSS No. 2, Benton County, WA, as a function of month of the year and downwind distances of 1,000 to 24,000m from the plant.

<337>

Annual Hourly Frequency of Plume Lengths from Natural Draft Tower.
Figure 10.1-12, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.

Figure graphs annual hourly frequency of plume lengths due to operation of proposed natural draft cooling towers considered for WPPSS Nuclear Projects No. 3 and 5.

<338>

The Observed Rise of Visible Plumes from Hyperbolic Natural Draft Cooling Towers.
Atmospheric Environment 10:425-431
1976
Brennan, P.T.; Seymour, D.E.; Butler, M.J.; Kramer, M.L.;
Smith, M.E.; Frankenberg, T.T.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation, Canton, OH

The behavior of natural draft cooling tower plumes and related meteorological variables have been measured from aircraft near three major plants (Amos, Mitchell, Muskingham River) of the American Electric Power System from November 1973 to March 1975. The rise of those plumes which persisted long enough to reach a stablized height depended primarily upon the height of the capping inversion aloft. All such plumes rose to elevations of 425 m or more above grade. No significant relationships between plume rise and wind speed, plant load, or ambient temperature were found. Simple temperature-humidity soundings in the vicinity of the towers would serve as effective predictors of plume rise and persistence. (Auth)(ND)

<339>

Estimated Annual Visible Plume Occurrences.
Figure 5.1-2, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 1 p.

Figure shows an isopleth of the number of hours of visible plume versus downwind distance, for a distance of 2 mi from the source, due to operation of mechanical draft cooling towers at Sundesert Nuclear Plant, Riverside County, CA.

<340>

Average Hours Per Year of Visible Plume for Natural Draft Cooling Towers.
Figure 5.1-3, Erie Nuclear Plant Units 1 & 2 Environmental Report, Ohio Edison Co., May 1977. 1 p.

Figure presents area map superimposed by isohours of predicted annual visible plume from the cooling tower for the proposed Erie Nuclear Plant, Erie County, OH. Visible plume was defined to occur when ambient relative humidity reached 100% and is estimated to range from 560 hours at 1 mi to 160 hour at 4 mi each year.

<341>

Seasonal Occurrence of Upper Level Plumes from Round Mechanical Draft Cooling Tower - Clay Boswell Unit 4.
Table IV-B-3, Clay Boswell Steam Electric Station Unit 4 Environmental Report, Minnesota Power & Light Co., March 1976. 1 p.

Table presents data on the estimated length and occurrence of upper level plumes from the round mechanical draft cooling tower of Clay Boswell Unit 4, a proposed 500-MW plant located in Itasca County, MN, and scheduled for 1980 completion. Based on data from January-December 1955 observations, the expected seasonal frequency of occurrence of 0-500, 500-1,000, 1,000-5,000, 5,000-10,000, and 10,000-15,000-foot long plumes is calculated and the direction of maximum plume frequency, and the length of the longest plume is given.

<342>

Calculated Frequency of Occurrence of Coronado Generating Station Cooling Tower Plume Lengths Greater Than Indicated Value.
Table II-37, Final Environmental Statement - Coronado Project, Owned by Salt River Project . Prepared by Bureau of Reclamation, U.S. Dept. of Interior; Bureau of Land Management, U.S. Dept. of Interior, and U.S. Forest Service, U.S. Dept. of Agriculture, Aug. 1977. 1 p.

Table gives information on visible plumes resulting from operation of mechanical draft cooling towers at the Coronado Project, AZ. Frequency of occurrence of plume lengths from 0 to 10,000 ft is given for the 16 principal directions.

<343>

Arthur Kill Site - Annual and Seasonal Predicted Frequency (Percent) of Visible Plume Occurrence.
Figures 2.4-12 Through 2.4-16, 1980 - 700 MW Fossil Fueled Unit, Application to the New York State Board on Electric Generation Siting and the Environment, Part VI, Power Authority of the State of New York, 1975. 5 pp.

Figures illustrate predicted annual and seasonal frequencies of occurrence of visible plumes resulting from operation of a 400-foot natural draft cooling tower at the proposed 700-MW plant on the Arthur Kill site, NY.

<344>

Investigation of Cooling Tower Plume Behavior.
Cooling Towers, Chemical Engineering Progress Technical Manual, Proceedings of a Symposium, Houston, TX, February, 1970. American Institute of Chemical Engineers, New York City, NY, (p. 83-86), 145 pp.
1970
Blackwell, J.P.; Leavitt, J.M.
Tennessee Valley Authority, Muscle Shoals, AL

General field observations and the methodology and preliminary results and interpretations of cooling tower plumes at the Paradise power plant in Kentucky are presented. Observations were made in about 130 days during the period January-December, 1970. The results showed that there was considerable monthly variation in cooling tower plume lengths. Preliminary evaluation has not revealed significant adverse effects. For January 29 data there was a measurable increase in the temperature and moisture content of the atmosphere downwind of the visible plume with mist being detected both under the visible plume and downwind. (ND)

<345>

Daily Observations of Visible Plume Length at TVA's Paradise Cooling Towers.
Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1976 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 511-522), 627 pp.; ATDL-77/23; ATDL Contribution File No. 76/18, 12 pp.
1977
Hanna, S.R.; Pike, M.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
Oak Ridge Associated Universities, Oak Ridge, TN
U.S. Department of Commerce

Observations of visible plume length taken each morning at TVA's Paradise Steam Plant cooling towers show only a slight correlation with ambient saturation deficit and wind speed, and very little dependence on season or weather type. Average visible plume height and length are 270 m and 360 m, respectively, with standard deviations of 120 m and 380 m. (Auth)

<346>

Visible Plume Abatement with the Wet/Dry Cooling Tower.
Power Engineering 79(3):54-57
1975
Rubin, A.M.; Klanian, P.S.
Franklin Institute Research Laboratories
Westinghouse Electric Corporation

Initial test results of a wet/dry cooling tower study at Cliffside Power Plant documenting different degrees of plume visibility for various modes of operation and ambient conditions are reported. A method to predict analytically the visibility in a plume is also presented. The results show that dense plumes occur when predicted visibility in the plume is less than 25 m. Plumes with visibilities predicted at greater than 100 m will appear as light puffs and should have no environmental impact. Plumes associated with an intermediate visibility range from 50 to 75 m are relatively light. Plume characteristics can be controlled by varying the wet/dry operational mode of the tower, thus minimizing environmental impact. (ND)

<347>

Observation of Cooling Tower Vapor Plumes PEPCO Benning Road Station - 8 Cell Mechanical Draft Tower.
Table 10.1-3, Fulton Generating Station Units 1 & 2 Environmental Report, Philadelphia Elec. Co., Nov. 1973. 1 p.

Table lists actual plume data due to operation of mechanical draft cooling tower at Potomac Electric Power Co.'s Benning Road Station. Data parameters include: 1) dry bulb temperature; 2) relative humidity; 3) wind speed; 4) wind direction angle between tower long axis and wind direction; 5) initial vapor temperature; 6) maximum visible plume height; 7) predicted plume height; and 8) maximum plume length. Data were collected during February and March 1972.

<348>

The Persistence of Plumes from Natural Draught Cooling Towers.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135 pp.; Atmospheric Environment 8(4):407-418 1973
Barber, F.R.; Martin, A.; Shepherd, J.G.; Spurr, G.
Scientific Services Department, Midlands Region, Nottingham, England
Scientific Services Department, North West Region, England
Central Electricity Generating Board, London, England

A photographic record has been made of the cooling tower plumes at the large modern Ratcliffe Power Station, over a period of a full year, together with meteorological and station operating data. The photographs have been examined and the plume lengths assigned to one of three categories (short, medium or persistent). A simple statistical analysis shows that plumes are predominantly short in the summer, but their persistence increases as the winter advances. Atmospheric relative humidity near ground level is an important factor, and may be used to estimate the frequencies of occurrence of different plume categories with good accuracy, or categorize individual plumes correctly on three out of four occasions. An improved formula giving the plume length directly in terms of the tower operating and meteorological conditions has also been developed, and takes some account of the mingling of plumes from adjacent towers. The accuracy of the prediction is almost the same as that of the purely empirical correlation in terms of relative humidity but should be capable of development to a form suitable for general application. (AUTH)

AESTHETIC IMPACTS - NOISE

<349>

(Power Plant Equipment Noise Emissions - Cooling Towers.)
Section 4.4, Electric Power Plant Environmental Noise Guide. Prepared by Bolt, Beranek & Newman, Inc. for Edison Elec. Inst., 1978. 14 pp.

Section outlines procedures for predicting the sound levels of mechanical and natural draft cooling towers at distances from 10 to 500 meters from the source. Noise estimates of induced draft propeller-type cooling towers are calculated through an equation relating fan kilowatts to the overall sound power level in decibels. The equation can be modified to evaluate the total sound pressure at different receiver angles from a series of multiple cooling towers. Natural draft cooling tower sound power levels are estimated through a series of graphs and tables assuming waterflow rate from 380 to 2660 cubic meters per minute. These sound levels were predicted by a series of noise data comparisons from different cooling towers which determined the relationship between sound power level and tower type, size, capacity, and fan-rate or waterflow. Directivity effects, tonal characteristics, temporal characteristics, and source height are considered for each tower type. Section includes 5 tables and 5 figures.

<350>

Noise Prediction Techniques for Siting Large Natural Draft and Mechanical Draft Cooling Towers.
American Power Conference, Proceedings of a Symposium, Chicago, IL; Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January 31, 1977, 9 pp.
1976
Capano, G.A.; Bradley, W.E.
Stone and Webster Engineering Corporation, Boston, MA

Cooling tower noise has been shown to be a significant power plant noise source when compared to property line noise codes. The Dyer and Miller method for predicting mechanical draft tower noise was found to be valid within the limits discussed. Sound level measurements of natural draft towers in the 140,000 to 600,000 gpm range indicate that the natural draft tower noise prediction techniques of Ellis, and Carlson and Teplitzky overpredict levels for large towers; therefore a new prediction method was developed. The new prediction method can be used for evaluating the types of towers and tower locations necessary to meet noise codes or annoyance criteria based on A-weighted or octave band levels. Potential noise control alternatives and their corresponding penalties are discussed. (ND)

<351>

Noise Radiation from Natural-Draft Cooling Towers for Nuclear Power Plants.
ORNL-5070, 27 pp.
1975
Carley, T.G.
Oak Ridge National Laboratory, Energy Division, Oak Ridge, TN
U.S. Nuclear Regulatory Commission
U.S. Energy Research and Development Administration

A procedure for computing the noise levels in the vicinity of natural draft cooling towers is presented. The noise levels are computed in overall and octave band levels with A-weighting and with no weighting. Attenuation of the noise by wave spreading, atmospheric absorption, barrier screening, vegetation, and wind and temperature gradients are included. The procedure is applied to a nuclear power plant served by four cooling towers and to a nuclear energy center with forty cooling towers. (Auth)

<352>

Estimation and Impact of Environmental Noise from Natural Draft Cooling Towers.
Noise Control Engineering 3(1):4-8
1974
Carlson, J.P.; Teplitsky, A.M.
Consolidated Edison Company, Emissions Control Bureau, New York City,
NY

Crossflow and counterflow natural draft cooling towers and the noise emitted to the community for electric utility application are examined. Field measurement results are summarized; a simplified natural draft cooling tower emission scheme is developed; and the impact of noise emission on communities by using current rating schemes is evaluated. Sound emitted by natural draft cooling towers was predictable at distances of 40 ft or more from the basin rim. Noise emissions appeared to be most directly related to water loading. It is concluded that the environmental impact of natural draft cooling tower sound emissions can be minimal when there is adequate distance between the tower and the community to attenuate the cooling tower noise. (ND)

<353>

Cooling Tower Noise Generation and Radiation.
Journal Sound and Vibration 14(2):171-182
1971
Ellis, R.M.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

An investigation has been carried out into the generation of noise by large natural draft cooling towers, and the mechanism of noise radiation from them, based on measurements made at four large power stations. An expression relating the A-weighted acoustic power of a tower to its physical characteristics has been derived. This, together with the discovery that the towers behave as area sources at low frequencies and as arc sources at high frequencies, has enabled a complete prediction method to be proposed. This method was used to estimate the noise from three further cooling towers and gave excellent agreement with the levels which were subsequently measured. (Auth)

<354>

Induced Draft Cooling Tower Noise and Its Control.

CONF-770151; Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January, 1977, 22 pp.
1977
Wang, J.S.
Exxon Research and Engineering Company, Florham Park, NJ

Cooling towers generate noise which is not sufficiently loud to cause in-plant noise problems at grade, but some may have an adverse impact on the adjacent community. Noise data measured at Exxon process plants are correlated into a prediction technique for estimating induced draft cooling tower noise in communities adjacent to a plant. Predictions are given in 'A' weighted decibels (dBA) corresponding to the manner in which regulations are commonly expressed, and in the octave band basis required for design purposes when a noise control measure is found to be necessary. Good agreement was observed between estimated and measured noise levels. The fans and falling water were the major noise sources of induced draft cooling towers. The fan noise was radiated from both the fan stacks and louvered faces and the water noise almost exclusively from the louvered faces. This study showed that the fan noise dominated the water noise at locations distant from the cooling tower and that the noise radiated from the louvered faces dominated that from the fan stacks. This information is useful in selecting a method for cooling tower noise control. If the estimated noise levels should exceed noise criteria, general techniques are given in this paper for controlling cooling tower noise to achieve compliance. (Auth)

<355>

Noise from Cooling Towers of Power Parks.
BNL-20579, 28 pp.
1975
Zakaria, J.; Moore, F.K.
Cornell University, Sibley School of Mechanical and Aerospace
Engineering, Ithaca, NY
Brookhaven National Laboratory, Energy Policy Analysis Group, Upton,
NY
U.S. Nuclear Regulatory Commission

The noise pollution problem from large power parks was theoretically evaluated for both natural and mechanical draft wet towers as the major sources of acoustic power. Noise radiation from single isolated towers, as well as from a dispersed array of towers has been considered for both types of cooling systems. The results showed that acoustic power generation from mechanical draft towers will be much greater. In power parks (48,000 Mw) mechanical draft tower systems will reach 45 DBA at a park radius of 2100 ft. This radius will be about 24,000 ft. for natural draft towers. (ND)

<356>

Predicted Maximum Construction Noise Levels at Closest Residence for Alternate Cooling Systems (dBA).
Table 10-3, Pilgrim Station Environmental Report, Boston Edison Co., Jan. 1974. 1 p.

Table lists the predicted maximum noise levels at closest residence due to construction of the proposed once-through cooling and alternative mechanical draft and natural draft cooling towers for Pilgrim Station in Massachusetts. Locations studied include Priscilla Beach, Manomet, White Horse Beach, Manomet Heights, and Northwest construction site.

<357>

Noise Level dBA-Natural Draft Towers and Wet and Wet/Dry Mechanical Draft Towers.
Figures 10.1-7 & 10.1-14, NEP 1 & 2 Environmental Report, New England Power Co., Sept. 1976. 2 pp.

Figures show the predicted noise levels generated by the operation of natural draft, wet, and wet/dry mechanical draft towers. The sound spreading was assumed to be hemispherical and standard conditions were used for atmosphere attenuation. Studies were conducted during alternative design analysis for NEP Units 1 and 2, Washington County, RI.

<358>

Noise Level Calculations - Browns Ferry Mechanical Draft Cooling Towers.
Appendix V, Browns Ferry Nuclear Plant Units 1, 2, and 3 Final Environmental Statement, Tennessee Valley Authority, Sept. 1972. 4 pp.

Appendix describes noise level calculations for 4 points at a distance of 1,000 ft. from the perimeter of the 6 cooling towers at the Brown Ferry power plant in Limestone County, AL. Information details design parameters, empirical data, and other characteristics of the cooling towers used in the calculations. The report also identifies certain environmental factors that may affect sound pressure level. Two tables are included in the appendix.

<359>

Environmental Noise Impact of Cooling Towers Residential Zones Studied (452 Acres).
Table 5-1, Eliminate Requirement for Termination of Operation with Once-Through Cooling System, Indian Point Unit 2 Environmental Report, Consolidated Edison Co. of New York, March 1977. 1 p.

Table presents residential land areas exposed to average ambient day/night sound levels greater than Ldn=55 dB and the increase estimated to be caused by Unit No. 2 cooling tower operation and construction.

<360>

Sound Emissions Resulting from Construction and Operation of Cooling Towers at Indian Point Unit 3 Nuclear Station.
Appendix C, Economic and Environmental Impacts of Alter- native Closed-Cycle Cooling Systems for Indian Point Unit No. 3. Ostergaard, P.B. and Meyerson, N.L., Ostergaard Associates for Consolidated Edison Co. of N.Y., Inc., May 1975. 35 pp.

Report compares, by means of analytical models, noise of construction and operation of 2 types each of natural draft and mechanical draft cooling towers for the Indian Point nuclear station. Incremental increases in noise over ambient levels, dominated by the Unit 2 facility, are predicted. Municipal regulations, bordering residential areas, and construction traffic are discussed. Report includes 4 tables, 14 figures, and references.

<361>

Sound Emission Impact from Operation and Construction of Cooling Towers at Indian Point Nuclear Station.
Ostergaard, P.B.; Meyerson, N.L. Ostergaard Associates, Sept. 1974. Included as Appendix G in Economic & Environmental Impacts of Alternative Closed-Cycle Cooling System for Indian Point Unit No. 2, Consolidated Edison Co. of NY., Dec. 1974. 103 pp.

Appendix presents results of sound impact study of noise caused by the construction and operation of several types of natural draft and mechanical draft cooling towers at the immediate Indian Point area. Topics include: 1) noise rating methodology and government regulations; 2) site ambient noise climate; 3) additional noise from construction and operation of cooling towers, including tracking noise associated with construction, and 4) impact of noise on the community. There are 36 figures, 18 tables, 17 references, and 6 appendices.

<362>

Mechanisms of Sound Generation in Natural-Draft Wet Cooling Towers and the Prediction of Sound Levels at Radial Distances.
Meyerson, N.L., Ostergaard Associates, Feb. 1974. Included as Appendix H in Economic & Environmental Impacts of Alternative Closed-Cycle Cooling System for Indian Point Unit No. 2, Consolidated Edison Co. of NY., Dec. 1974. 98 pp.

Prediction methods were developed for determining sound level at any distance from both crossflow and counterflow natural draft cooling towers, using references available in acoustical literature and measured sound levels from a number of towers at different sites. The method of predicting the sound level utilizes physical and operational parameters of the towers and the distance from the tower to the observation point. A series of adjustments to the sound level is given for a variety of meteorological conditions and site parameters.

<363>

Unsilenced Sound Power Levels of Major Operational Noise Sources for Unit 1.
Table 5.6-1, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 1 p.

Table lists anticipated sound power levels of major sources of noise from Sundesert nuclear station, Riverside County, CA. Equipment considered includes atmospheric dump or steam generator relief valves and vents, turbine generator, mechanical draft cooling tower bank, main transformers, and ventilation fans.

<364>

(Induced and Forced Draft Fan Sound Power Levels.)
Tables 4.3-3 & 4.3-4, 1980 - 700 MW Fossil Fueled Unit, Application to the New York State Board on Electric Generation Siting and the Environment, Part VI, Power Authority of the State of New York, 1975. 2 pp.

Tables give the estimated unsilenced and silenced sound power levels produced both by forced draft and induced draft fans for the natural draft cooling tower at the proposed Arthur Kill plant on Staten Island, NY.

<365>

Noise Emission Characteristics of Circular Mechanical, Natural, and Fan-Assist Natural Draft Cooling Towers with Silencers.
Proceedings American Power Conference 39:691-701
1977
Capano, G.A.
Stone and Webster Engineering Corporation, Boston, MA

Noise measurements were taken at several plants in West Germany. Inlet noise of all large, wet towers tended to average 85 to 86 dBA. The dominant noise source in each case has been demonstrated to be water noise. Propagation of this noise, with respect to distance, was similar for all sizes of wet-style United States and European cooling towers. Outlet noise emission characteristics of circular mechanical draft, fan-assist, and natural draft towers showed inlet-to-outlet chimney attenuation on the order of 1.5, 3.5, and 15 dB, respectively. The actual directivity of outlet noise emission was not well defined, but there is a potential for outlet noise to be perceived at 3280 to 4920 feet. Berms provide effective reduction of near-field inlet noise (15 dB) for natural draft towers, while application of mineral wool absorptive silencers to natural draft or fan-assist inlets can provide noise attenuation of 10 to 40 dB. Silencers can be selected to control specific emission level from tower outlets as well. Noise control is essentially an exercise in economics. When the cost is justifiable, noise reduction as small as 10 dB and as much as 40 dB can be achieved readily. (ND)

MISCELLANEOUS IMPACTS

<366>

Cooling Tower Impacts on Surrounding Real Estate Values.
Table 5-3, Eliminate Requirement for Termination of Operation with Once-Through Cooling System, Indian Point Unit 2 Environmental Report, 1 p.

Table presents 3 real estate appraisal firms' opinions on the interrelationship between the various negative effects of a natural draft cooling tower and surrounding real estate values.

<367>

Results of the Preoperational Monitoring of Three Mile Island Nuclear Station Unit 2 Cooling Towers for Bird Impaction, Summer and Fall 1974.
Attachment 1, Three Mile Island Nuclear Station, Terrestrial Survey, Semiannual Operating Report. Prepared by Woodward-Envicon, Inc. for Metropolitan Edison Co., Dec. 1974. 3 pp.

Attachment presents data on bird impaction on the natural-draft cooling towers at the Three Mile Island Nuclear Station Unit 2 in Dauphin County, PA. Data were collected as part of a preoperational monitoring program during the periods June 5 to June 30, and Sept. 1 through Nov. 30, 1974. Of 20 dead or injured birds found around the towers, all were songbirds, including 12 kinglets, 6 vireos, a brown creeper, and a warbler. None of the birds are classified as endangered species. Climatic conditions during impacts are mentioned.

<368>

Transmission Facilities Maintenance Due to Salt Drift Deposition and-or Cooling Tower Blow-Thru.
Table 3.0-14, Ocean-Sited Plants - A Survey of Operating Experience with Saltwater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 2 pp.

Table lists transmission facility maintenance necessary due to salt drift deposition and-or cooling tower blow-through at 12 power generating stations with saltwater, closed-cycle cooling systems. Maintenance was primarily concerned with arcing caused by a build-up of salt deposits on lines and insulators.

<369>

Can Salt Water Cooling Tower Drift Cause Insulator Flash-Over?.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 187-214), 462 pp.
1978
Laskowski, S.M.
Pickard, Lowe and Garrick, Inc.

Saltwater cooling tower operation can result in salt drift accumulation on switchyard equipment such as insulators. Under certain conditions and depending on the contamination level on the insulator, salt accumulations lead to the occurrence of insulator flashover. The mathematical model and computer simulations developed to estimate salt accumulation rate on insulators are summarized. A series of parametric studies were made to find how the estimated salt drift accumulations are affected by cooling tower and insulator characteristics and by ambient weather conditions. A comparison was made between computer program estimates and plant experience with insulator contamination and flashovers for two power plants operating with saltwater mechanical draft cooling towers. The comparison suggests that the computer model over-predicts accumulation since the model did not take into account natural removal mechanisms. However, the site with the predicted highest accumulation has indeed experienced flashover. (AUTH) (ND)

PLUME DYNAMICS - GENERAL STUDIES

<370>

Field Investigation of Cooling Tower and Cooling Pond Plumes.
EPA-600/7-78-059, 116 pp.
1978
West, R.E.
University of Colorado, Chemical Engineering Department, Boulder, CO
U.S. Environmental Protection Agency, Office of Research and Development

Measurements were made relating to the behavior of water-vapor plumes from forced-draft cooling towers and from cooling ponds. There were three categories of measurements. (1) Ambient weather data including temperature, humidity, wind speed and wind direction. These measurements were made with standard meteorological equipment. (2) Source data, including the temperature, mixing ratio and flow rate of the air leaving the cooling tower or cooling pond. Cooling tower measurements were made with a traverse rig. Cooling pond source data were estimated using correlations. (3) Water-vapor distribution in the atmosphere in the vicinity of the source, including temperature and mixing ratio of air above the ground at various locations with respect to source. These measurements were made with tethered-balloon-borne radio sondes. Cooling tower measurements were made at the Comanche Station of the Public Service Company of Colorado near Pueblo, Colorado. The Valmont Station of the Public Service Company of Colorado, near Boulder, Colorado was the site of the cooling pond measurements. The results are presented in graphical and tabular form. The reliability of the measured and calculated values is discussed. Cooling tower results are not compared with predictive models. Cooling pond results are compared with some methods of prediction. Significant features of cooling tower and cooling pond plumes are discussed. (Auth)

<371>

A Comparison of Drift Transport Predictions for Various Types of Cooling Systems.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 231-243), 462 pp.
1978
Moore, R.D.; Wheeler, D.E.; Wilber, K.R.
Environmental Systems Corporation, Knoxville, TN

Generally the design and selection of a cooling system for a power plant is based upon an economic optimization related to the plant and its site. Other considerations are discussed which may not be a part of a strict economic evaluation, specifically the variability of drift emission and deposition between various types of cooling systems. Considered in the study were circular mechanical draft, rectangular mechanical draft, natural draft, fan-assisted natural draft, and the 'teapot' mechanical draft cooling towers. Using a drift transport model considered to provide good state-of-the-art capability, it was demonstrated that very significant differences in drift deposition predictions can occur between the various systems. These differences can be very pronounced near the tower at distances less than about 1-5 km but become increasingly small at greater distances. These variations are primarily due to droplet spectrum, tower geometry and design, emission rate, and meteorology. The results presented may be used to gain insight into environmental considerations not found in a strict economic evaluation of a cooling system design and further illustrate that development of state-of-the-art drift predictions is a complex task which can be accomplished only by consideration of many basic and important parameters. (Auth)

<372>

Drift Deposition Rates from Wet Cooling Systems.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 585-597), 638 pp.
1975
Roffman, A.; Grimble, R.E.
Westinghouse Electric Corporation, Westinghouse Environmental Systems Department, Monroeville, PA
Westinghouse Research and Development Laboratories, Pittsburgh, PA

Drift losses from wet cooling systems, such as natural draft wet cooling towers, mechanical draft wet cooling towers, and spray canals or ponds, have raised some environmental concerns in recent years. In contrast to wet-cooling-system fog, the drift droplets contain essentially the same chemicals in the same concentrations as the circulating water and in some cases exceed these levels. A three-dimensional quasi-steady-state diffusion model has been developed to predict drift deposition rates from wet cooling systems. The model accounts for changes in droplet radius due to evaporation and corresponding changes in the chemical concentration of the droplets. Typical atmospheric conditions were accounted for in the calculations of drift deposition rates from the cooling systems under consideration. Temperature and humidity variations have the largest effect on drift droplets discharged from a natural draft cooling tower. Under neutral atmospheric conditions the total reduction in drift deposition rates due to temperature and humidity variations is about 15 to 16% from about 1000 to 8000 m downwind. Results reveal that, for the same cooling capacity and for a given set of meteorological conditions, the drift deposition rate is the highest for spray canals but is largely confined to its immediate vicinity, followed by mechanical draft wet cooling towers and natural draft wet cooling towers. Calculations also indicate the variations in drift deposition rates for the three types of cooling systems as a function of various atmospheric conditions. Drift deposition rates from a mechanical draft cooling tower, with the same atmospheric conditions accounted for, are about 4 to 6% from 100 to 2000 m downwind. Drifts from spray canals experience changes of less than 1%. (Auth)(ND)

<373>

The Effect of Atmospheric Conditions on the Length of Visible Cooling Tower Plumes.
Atmospheric Environment 9:437-445
1975
Wigley, T.M.L.; Slawson, P.R.
University of Waterloo, Department of Mechanical Engineering,
Waterloo, Ontario, Canada
National Research Council, Canada

The governing equations for the initial phase of cooling tower plume behavior are solved numerically to illustrate the quantitative effects of atmospheric temperature, moisture content, stability and moisture gradient on visible plume lengths. Some discussion of the atmospheric turbulence dominated phase of plume behavior is given. Decreasing relative humidity with height and/or stable conditions in the atmosphere are found to lead to decreased plume lengths. The effects are most pronounced at low temperatures and high atmospheric relative humidities. The influence of the entrainment parameter on visible plume length is examined and found to be relatively minor when compared to the influence of atmospheric conditions. The numerical results are compared with a simple graphical solution and the results show considerable disparity. The sensitivity of plume length to changes in atmospheric conditions predicted emphasizes the need for comprehensive full-scale experimental data to test the various theories for cooling tower plume dynamics. (Auth)

<374>

A Comparison of Wet and Dry Bent-Over Plumes.
Journal Applied Meteorology 11(2):335-340
1972
Wigley, T.M.L.; Slawson, P.R.
University of Waterloo, Department of Mechanical Engineering,
Waterloo, Ontario, Canada
National Research Council of Canada, Ontario Hydro Electric Commission
U.S. Atomic Energy Commission

The theory of moist bent-over plume behavior given by Csanady and by Wigley and Slawson is expanded and clarified to illustrate the differences between moist and dry plume behavior under various atmospheric stability conditions associated with linear gradients of temperature and humidity. If plume types are defined according to the behavior of a dry plume in stable, neutral and unstable conditions, then it is found, for example, that a condensed (or 'wet') plume rising in an atmospheric with lapse rate equal to the saturated adiabatic lapse rate will behave as a 'neutral' plume, while a dry plume in the same atmosphere will behave as a 'stable' plume. Also, while the condensed portion of a given plume rises according to one stability criterion, the re-evaporated portion may rise according to another. (Auth)

<375>

Vertical Velocities in Cooling Tower Plumes.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Wat Resources Center, University of Maryland, College Park, MD, (pp. II 51-59), 462 pp.
1978
Pena, J.A.; Chin, T.N.
The Pennsylvania State University, Department of Meteorology,
University Park, PA
U.S. Energy Research and Development Administration

Vertical velocities have been measured in cooling tower plumes. Results are shown for measurements at 40 m above the cooling tower mouth for three different plumes, and for four heights (100, 220, 315 and 450 m) in the same plume. Plume sections with negative vertical velocity appears at all plume levels. Drift drop losses via these downdrafts appears as the main break-away mechanism for these drops. (Auth)

<376>

Secondary Motions in Cooling Tower Plumes.
Appendix B, Report on ATDL Research on Meteorological Effects of Thermal Energy Releases, August 1, 1976-September 31, 1977, S.R. Hanna, K.S. Rao, and R.P. Hosker in: Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 95-104), 320 pp.; ORNL/TM-6248; ATDL Contribution File No. 77/24, 13 pp.
1978
Hanna, S.R.; Pike, M.; Seitter, K.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

Time-lapse photography was used to estimate the speed of the secondary motions in the condensed plumes from a hyperbolic natural draft cooling tower (Paradise Power Plant) and a bank of mechanical draft cooling towers (Oak Ridge Gaseous Diffusion Plant). At a distance of about 30 m from the towers, the median tangential speed is about 2.5 m/s in the downward direction, for ambient wind speeds of 7 to 13 m/s. Secondary motions such as these may influence drift deposition. (Auth)

<377>

Cooling Tower Plume Rise.
Combustion 46(5):30-33
1974
Brown, D.H.; Sneck, H.J.
General Electric Company, Schenectady, NY

Preliminary results of heated dry air plume performance in calm air inversions are presented. Analysis of plume trajectories and experiments on heated air plumes rising in severe inversions in a scale model facility have indicated that large diameter, low velocity tower exit conditions maximize the height to which the plume will rise. Evaluation of crosswind effects and plume condensation with impact on fogging and icing are also considered. (ND)

<378>

The Prediction of the Rise of Cooling Tower Plumes.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135 pp.; Atmospheric Environment 8(4):403-406
1973
Moore, D.J.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

An expression developed from the chimney plume trajectory equation (Moore, 1974) is shown to give a good representation of some limited experimental data on cooling tower plumes at Eggborough. The heat emission term is taken as that from a single tower. Account is also taken of the relatively small temperature difference between the effluent and the ambient air and the low efflux velocity. Interaction between the plumes from adjacent towers and other effects which could alter the sensible heat content of the plumes do not seem to have been important in determining the rise in this investigation. (Auth)

<379>

Discussion of Possible Effects Due to Mixing of Radioactive and Thermal Releases to the Atmosphere from Nuclear Power Plants.
IAEA-SM-197/28; Combined Effects of Radioactive, Chemical and Thermal Releases to the Environment, Proceedings of a Symposium, Stockholm, Sweden, June 2-5, 1975. International Atomic
Hubschmann, W.G.; Nester, K.; Wilhelm, J.G.
Kernforchungszentrum Karlsruhe, Germany

As the number of reactors, stacks and cooling towers at a power plant site increases, mixing of dry radioactive off-gas with a moist cooling tower plume will occur often enough to require study. For the purposes of this paper, it is assumed that a 100 m high stack of a 1000 MW(e) nuclear power plant lines up with a wet cooling tower in the main wind direction. The mechanism of mixing at various wind velocities is discussed. As compared with the dry off-gas plume, two additional mechanisms influencing the radiological effect of the released activity come into play: (a) the activity concentration near the ground is reduced by the strong buoyancy of the moist plume, whereas (b) the wash-out of aerosols by natural precipitation is increased. The radiological effect of noble fission gas release is reduced, but in the case of radioiodine the two effects partly compensate each other. Future reactors intended for large nuclear power plant sites, therefore, should be equipped with an effective iodine retention system. If this is provided, the mixing of the dry and moist plumes helps to decrease further any radiological impact of nuclear power plants to an almost negligible level. (Auth)

<380>

Drop Size Distribution and Evaporative Cooling.
Brennstoff Warme-Kraft 18(3):117-120
1966
Atagunduz, V.G.
Institut for Thermodynamik der Luft-und Raumfahrt, Stuttgart, Germany

The influence of drop size distribution in cooling towers on the attainable average water discharge temperature is examined. Free falling, non-colliding drops are discussed. A method of calculation is indicated for the determination of the drop size distribution along the path of the drop and for the consideration of the mutual influence of drops of different sizes during the cooling process. (Auth)

<381>

Droplet Growth Inside and Outside Cooling Towers-I. The Growth of Droplets Inside Cooling Towers.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135
Foster, P.M.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

Estimates are made of the modification produced by droplet coalescence to the size distribution of carryover droplets rising inside a large, modern cooling tower. The effect this has on the precipitation behavior obtained downwind of the tower is also estimated. It is concluded that its effects are important only at high carryover rates (approximately greater than 0.26 g/m(E+2)/S at eliminator level) when it provides a source of large droplets, resistant to evaporative effects which fall a short distance-downwind (approximately less than 1 km travel). (Auth)

<382>

Droplet Growth Inside and Outside Cooling Towers-II. Calculation of Droplet Fallout from Cooling Tower Plumes.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135
Foster, P.M.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

A simple model of a cooling tower plume is used to estimate the precipitation and growth behavior of carryover droplets which rise within and then subsequently fall from the plume downwind of the cooling towers. Comparison with the measurements made at Ratcliffe-on-Soar Power Station suggests that this process largely accounts for the precipitation behavior which was observed on cold, foggy days before droplet elimination inside the cooling towers was improved. (Auth)

<383>

Droplet Dynamics in Cooling Tower Plumes.
Ph.D. Thesis, 127 pp.
1974
Picklesimer, E.A. Jr.
The University of Tennessee, Knoxville, TN

The paths and ultimate deposition of salt laden drift drops exiting from a cooling tower was studied by analyzing the basic droplet dynamics governing the transport of these droplets. The equation of motion is developed for a liquid drift drop as it is transported through the atmosphere. A term appears in the equation of motion which has not been considered by previous authors. A finite difference technique is used to solve for the velocity and position of the drift drop at any time. Meteorological variables as well as cooling tower variables are considered in calculating the trajectory of the drift drop. A model is developed to account for the effects of dissolved chemicals on droplet evaporation rate. Previous models considered only sodium chloride, whereas the present model is general enough to consider any soluble organic salt. The concepts presented in this paper have been incorporated into a model which predicts chemical deposition from evaporative cooling towers. The results of the model study show better agreement with experimental data than previous models. (AUTH) (ND)

PLUME DYNAMICS - NATURAL DRAFT COOLING TOWERS

<384>

The Production of Airborne Droplets Below Eliminator Level in Natural Draught Cooling Towers.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135
Schriven, R.A.; Morton, V.M.; Newlands, A.G.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

The various sources of airborne droplets with diameters 50-300 um below eliminator level in natural draft cooling towers are discussed. It is suggested that the majority come from the break-up of minute impact jets formed in the very early stages of a splash long before the crown stage is reached. An approximate theory is developed assuming the break-up is caused by Helmholtz instability. This is in agreement with measurements of mass flux variations with droplet diameter (Chilton), static head (Martin and Barber), and droplet fall height. The total upflux of satellites is independent of the size distribution of the spray drops and depends only on the impact speed, the updraft speed and surface tension. It is suggested that most of the satellites produced by a closely spaced pack of the type used at Ratcliffe come from the top rows of splash bars and modifications at this level could significantly reduce droplet burdens. The open type of pack with larger vertical spacings as used at Cottam adds significantly to the production of satellites but most of these are probably removed in passage up through the pack. (Auth)

<385>

Characteristics, Classification and Incidence of Plumes from Large Draft Cooling Towers.
Combustion 43:25-31; Proceedings American Power Conference 33: 535-545
1971
Bierman, G.F.; Kunder, G.A.; Sebald, J.F.; Visbisky, R.F.
Metropolitan Edison Company
Gilbert Associates, Inc.

The potential effects of natural draft cooling tower operation are discussed. Some of the aspects of cooling tower discharges, specifically plumes and drift, are presented. Impacts to vegetation and general ecology should be minimal at drift rates of 0.03 to 0.002 percent of the cooling water circulated, in comparison to natural salt fallout. The salt fallout concentration at ground level is also lessened with the use of natural draft cooling towers because of their generally greater plume penetration characteristics and increased plume dispersion. The plume classification technique developed in conjunction with the Keystone and Three Mile Island studies has been useful in describing plume type, incidence and characteristics. The Keystone studies indicate that there is a reasonable possibility of predicting, from published weather data, the nature and frequency of natural draft cooling tower plumes. Further research is recommended. (ND)

<386>

Results of Measurements of the Droplet Emission by a 130 M High Natural Draft Cooling Tower.
Technische Ueberwachung 15(3):83-87
1974
Bung, W.

A throttle calorimeter was used to measure droplet emissions of a natural draft cooling tower from a 350 MW power plant. The tower's cooling capacity was 450 Gcal/hr and the throughput was 35,000 m(E+3)/hr. The total droplet emission, consisted of droplets carried along from the water distribution and the spraying installations and of droplets developing through post-condensation. The results showed that 90% of the determined droplet concentration came from post-condensation and depended largely on the meteorological conditions. Through installation of a droplet trap, the droplet emission on the ground becomes, at most weather conditions, small. (ND)

<387>

Characteristics, Classification and Incidence of Plumes from Large Natural Draft Cooling Towers.
Bierman, G.F., et al., Metropolitan Edison Co., and Gilbert Associates, Inc., Presented before American Power Conference, April 22, 1971. 20 pp.

Report discusses plume rise characteristics, developments in drift reduction technology, plume classification, and correlation of ground level meteorology and plume behavior with emphasis on natural draft cooling towers. The larger discharge diameter of natural draft cooling towers, compared to mechanical draft towers, results in plumes remaining buoyant longer and rising to higher altitudes, thereby reducing possible adverse effects of fogging and surface icing. Salt deposition at ground level is reduced with the use of natural draft cooling towers for the same reason. Field studies of the plume characteristics and ambient weather conditions at the natural draft cooling tower of the Keystone Power Station, Armstrong County, PA, from January through July 1969 provided criteria for classifying plumes by configuration and length. Resulting categories were characterized by incidence of occurrence. Meteorological conditions were found to influence length, configuration, and behavior of the plumes. Report includes 4 figures and references.

<388>

Annual Average Distribution of Cooling Tower Salt Drift Deposition for the Proposed Trimble County Generating Station.
Figure 6.3.1-2, Draft Environmental Impact Statement Trimble County Generating Station Supporting Report. Louisville Gas & Elec. Co. Prepared by U.S. Environmental Protection Agency, Feb. 1978. 1 p.

Figure estimates annual average distribution of cooling tower salt drift deposition from the proposed Trimble County Generating Station, Trimble County, KY. A model based on the ballistics approach was used to generate the data shown.

<389>

Staff's Predicted Annual Average Drift Deposition and Airborne Salt Concentration Out to 5 Miles.
U.S. Nuclear Regulatory Commission . Figures 5.9 & 5.10, Final Environmental Statement Related to Construction of Montague Nuclear Power Station Units 1 & 2, Northeast Nuclear Energy Co., Feb. 1977. 2 pp.
Figures illustrate the NRC staff's predicted annual average drift deposition and airborne salt concentrations during operation of the proposed Montague power station in Franklin County, MA.

<390>

(Staff's Prediction of Annual Average Salt Deposition Rates and Airborne Salt Concentrations for Natural-Draft Tower B.)
U.S. Nuclear Regulatory Commission . Figures 9.4 and 9.7, Final Environmental Statement Related to Construction of Sterling Power Project Nuclear Unit 1, Rochester Gas & Elec. Corp., et al., June 1976. 2 pp.
Figures illustrate the NRC staff's prediction of annual average salt deposition rates and airborne salt concentration at tower base elevation for a natural draft cooling tower considered during alternative cooling system design studies for the Sterling power project. Values are for 0.5-mile intervals out to 4.5 mi.

<391>

Environmental Effects of Atmospheric Discharges from a Natural Draft Tower at the Sterling Site.
Appendix 2A, The Sterling Power Project Nuclear Unit No. 1, Cooling Tower Evaluation. Prepared by Pickard, Lowe & Garrick.
Appendix provides calculations and results of drift and plume models for a natural draft cooling tower being considered as an alternative cooling system at the proposed 1200-MW Sterling nuclear plant in Cayuga County, NY. Cooling tower feasibility is being studied for the plant, as is the preferred once-through system, to determine the best practicable control technology. The humid plume model used considers the extent of visible plume length, ground shadowing, potential ground fog, icing, and changes in ground level relative humidity. The drift model was used to compute salt deposition rates and airborne concentrations and icing due to drift. Appendix includes 55 figures, 8 tables, 2 sub-appendices, and references.

<392>

Cooling Tower Salts Discharged in Drift.
Table 3.7, Final Environmental Statement Related to Construction of Davis-Besse Nuclear Power Station. Toledo Edison Co. and Cleveland Elec. Illuminating Co. Prepared by U.S. Atomic Energy Commission, March 1973. 1 p.
Table shows the estimated chemical composition of the drift and the weight of solids deposited from the cooling towers during operation of the Davis-Besse power station in Ottawa County, OH. Constituent elements are total dissolved solids, calcium, magnesium, sodium, chloride, nitrate, sulfate, phosphate, silica, and bicarbonate.

<393>

(Maximum Solid (Salt) and Liquid Deposition Rates.)
Tables 5.1-22 & 5.1-23, Susquehanna Steam Electric Station, Units 1 & 2, Environmental Report, Operating License Stage. Prepared by Pennsylvania Power & Light Co., May 1978. 2 pp.
Tables present estimated maximum solid (salt) and liquid deposition rates at 16 distances of .5 to 80 km and 16 compass sectors from natural draft cooling towers at Susquehanna Steam Electric Station, Luzerne County, PA. Data are from a model which assures operation of both units and a maximum dissolved solids concentration of 1640 mg per l.

<394>

Typical Natural Draft Tower Drift Size Distribution.
Table 10.1-3, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.
Table lists 4 droplet sizes from a typical natural draft cooling tower and the percentage of total drift mass that size contributes.

<395>

Annual Salt Deposition from Natural Draft Cooling Tower (lb/acre).
Figure 10.1-13, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.
Figure is a topographical map of site and surrounding area with predicted annual salt deposition due to operation of proposed natural draft cooling tower for WPPSS Nuclear Projects No. 3 and 5.

<396>

Maximum Annual Water and Salt Deposition Rates for any 22 1/2 Sector Alternate 1.
Figure 10.1-2, Fulton Generating Station Units 1 & 2 Environmental Report, Philadelphia Elec. Co., Nov. 1973. 1 p.
Figure is graph of maximum annual water and salt deposition rates as a function of distance from natural draft cooling towers. A table of droplet mass distributions is also included.

<397>

Salt Drift LBS/AC/YR - Natural Draft, Wet Mechanical, and Wet/Dry Mechanical Draft Towers.
Figures 10.1-8, 10.1-15, & 10.1-21, NEP 1 & 2 Environmetnal Report, New England Power Co., Sept. 1976. 3 pp.
Figures show the isopleths of predicted salt deposition rates from natural draft, wet mechanical, and wet/dry mechanical draft towers. Studies were conducted during alternative design analysis for NEP Units 1 and 2,

Washington County, RI. Rates are shown for the immediate vicinity and the surrounding area of the cooling tower complex.

<398>

Average Daily Drift Deposition, January and July.
Figures 5.1-2 & 5.1-3, Yellow Creek Nuclear Plant Units 1 & 2 Environmental Report, Tennessee Valley Authority, Dec. 1976. 2pp.

Figures show solid deposition rates from the round mechanical-draft cooling towers drift for the months of January and July at the Yellow Creek power station in Tishomingo County, MS.

<399>

Chemical Deposition Due to Operation of Pleasants Power Station's Aerodynamic Downwash Natural Draft Towers.
Figure 3.2-3, Environmental Report for Pleasants Power Station Units 1 and 2, Monongahela Power Co.; Potomac Edison Co. and West Penn Power Co., Dec. 1977. 2 pp.

Figures illustrate estimated chemical deposition rates and corresponding ambient concentrations, expected to arise from cooling tower drift at Pleasants Power Station Pleasants County, WV, under the condition of aerodynamic downwash. Downwash occurs when wind speeds exceed approximately 20 mph and the rising plume is caught in the turbulent wake of the structure itself.

<400>

Approximate Composition of Cooling Tower Drift.
U.S. Army Engineer District, Huntington, WV. Table 3.2-2, Pleasants Power Station Units 1 & 2 Final Environmental Impact Statement, Allegheny Power System Inc., Jan. 1975. 1p.

Table analyzes cooling tower drift resulting from operation of Pleasants Power Station, Pleasants County, WV. Data include percentages by weight of various chemicals including calcium, chloride, sodium, sulfate, and other dissolved solids.

<401>

Approximate Composition of Cooling Tower Drift.
Table 3.2-2, Environmental Report for Pleasants Power Station Units 1 and 2, Monongahela Power Co., Potomac Edison Co., and West Penn Power Co., Dec., 1973. 1 p.

Table shows percentage by weight of various chemicals expected to be deposited due to cooling tower drift from proposed Pleasants Power Station, Pleasants County, WV. These include calcium, chloride, sulfate, and other dissolved solids.

<402>

Average Annual and Spring Salt Deposition Rates (lb/Acre/Month), Natural Draft Tower.
U.S. Army Engineer District, Huntington, WV. Exhibits 4.2.1.2-7 and 4.2.1.2-8, Killen Electric Generating Station Units 1 and 2, Draft Environmental Impact Statement, Dayton Power & Light Co., July 1976. 2 pp.

Maps illustrate the predicted distribution of salt deposition expected to result from operation of the natural draft cooling tower at Killen station, Adams County, OH. Distribution was predicted using computer analysis of assumed design and operating characteristics in conjunction with the 10-year (1948-1957) record of hourly meteorological data.

<403>

Maximum Deposition Rates of Principal Ions of Natural Draft Cooling Tower Salts.
U.S. Army Engineer District, Huntington, WV. Exhibit 4.2.5.2-1, Killen Electric Generating Station Units 1 and 2, Draft Environmental Impact Statement, Dayton Power & Light Co., July 1976. 1 p.

Table predicts maximum total natural draft cooling tower salt deposition rates for Killen Electric Generating Station, Adams County, OH, in terms of the individual contributions of ions. Exhibit also shows the contributions of these ions to the soil, via natural precipitation, and losses through harvesting of crops.

<404>

Natural Draft Cooling Tower Annual Salt Deposition, Lbs/Acre/Year.
Ebasco Services, Inc., New York. Table VI-C-6, George Neal Steam Electric Station Neal Unit 4 Environmental Impact Assessment, Iowa Public Service Co., Dec. 1974. 1 p.

Table shows amount of alternative natural draft cooling tower annual salt deposition for Neal Unit 4. Information is given by distance and direction from tower.

<405>

Studies of the Environmental Impact of Evaporative Cooling Tower Plumes.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 41-47), 320 pp.; ORNL/TM-6248;
1978
Thompson, D.W.
The Pennsylvania State University, Department of Meteorology, College
Park, PA
U.S. Department of Energy

Airborne measurements of a variety of the physical characteristics of the plumes from natural draft cooling towers at the Keystone Power Plant were undertaken as a part of the METER Program. Preliminary studies of remote sodar plume probing techniques and the development of simplified dynamical numerical models suitable for use in conducting field measurement programs were also initiated. Airborne measurements made consisted almost entirely of studies of cooling tower and merged cooling tower-stack plume aerosol and chemistry. The PSU Doppler sodar was used for an extended series of remote measurements of the characteristics of plume turbulent temperature and velocity fluctuations. A power plant energy balance model was developed and applied to the Keystone power plant. Specific results are not given, however citations are given which do provide the results. (ND)

<406>

Airborne Measurements of Turbulent Temperature and Velocity Fluctuations in Cooling Tower Plumes.
Atmospheric Turbulence, Diffusion and Air Quality, Proceedings of the Third Symposium, Raleigh, NC, October 19-22, 1976. American Meteorological Society, Boston, MA, (p. 576-580), 600 pp.
1976
Thompson, D.W.; Norman, J.M.; Miller, R.L.
The Pennsylvania State University, Department of Meteorology,
University Park, PA

During the past 18 months the first detailed observations of turbulent temperature and velocity fluctuations in plumes have been completed as a part of a comprehensive series of airborne meteorological, turbulence, drift water, aerosol and air chemistry measurements in cooling tower and merged cooling tower-stack plumes from the Keystone-Connemaugh power plant near Indiana, PA. The time series showed that, at least for cooling towers of the size of those at the Keystone plant, convection was highly variable and entrainment occurred rapidly at all scales up to about half the tower diameter. The observations indicated that due to large variations in the vertical draft velocity and the relative partitioning of energy into sensible and latent heat fluxes, the mean excess temperature rarely exceeds 5 to 6 degrees C at distances of 50 to 100 m from the tower mouth and that within 500 m of the tower mean temperature differences are less than about 0.5 to 0. 75 degrees C. Computations of the frequency distributions of instantaneous plume-mean atmospheric temperature differences showed the limitations of mean values as predictors of plume behavior. (ND)

<407>

Results of Staff Calculations of Salt Drift Deposition, Induced Fogging and Salt Aerosol Concentration from Operation of a Natural Draft Cooling Tower at Arkansas Unit 2.
U.S. Nuclear Regulatory Commission . Appendix F, Final Environmental Statement Related to Operation of Arkansas Nuclear One Unit 2, Arkansas Power & Light Co., June 1977. 8 pp.

Appendix is a series of 9 figures that show the results of the NRC staff's calculations of salt drift deposition, induced fogging and salt aerosol concentrations from operation of a natural draft cooling tower at Arkansas Nuclear One Unit 2. The concentrations of salt in air represent averages over the period indicated for each graph and are given in micrograms per cubic meter. The ORFAD computer program was used for staff calculations. The program utilized NOAA meteorological data from Little Rock, AK.

<408>

Characteristics of Cooling Tower Plumes from Paradise Steam Plant.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. II 31-50), 462 pp.
1978
Coleman, J.H.; Crawford, T.L.
Tennessee Valley Authority, Division of Environmental Planning, Muscle
Shoals, AL

Progress in understanding the effects of heat and moisture released to the atmosphere from cooling towers is hampered by lack of an adequate observational data base. Thus the Tennessee Valley Authority set up a systematic program of routine observations at Paradise Steam Plant in central Kentucky. During a year's time, onsite meteorological personnel made 372 observations during midmorning and early afternoon. The height and length of the visible plume were estimated, and wind speed, temperature, and humidity at tower-top elevation were measured. These data were analyzed graphically and statistically for trends in the relationships between plumes and meteorological factors. Plumes observed during foggy conditions were higher and shorter than typical morning plumes. Morning plumes were longer and slightly higher than afternoon plumes. Plumes were relatively short for both high and low wind speeds; plumes longer than 3 km occurred only with wind speeds between 3 and 9 m/s, and no plumes longer than 1 km were observed for winds stronger than 9 m/s. No plumes longer than 1 km were observed for saturation deficits greater than 2.5 g/kg or for temperatures higher than 22 degrees C. Plumes observed during the winter months were about twice as high and about five times as long as plumes observed during summer months. (Auth)(ND)

<409>

John E. Amos Cooling Tower Flight Program Data December 1974 - March 1975.
118 pp.
1975
Kramer, M.L.; Seymour, D.E.; Butler, M.J.; Kempton, R.N.;
Brennan, P.T.; Conte, J.J.; Thomson, R.G.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation

The John E. Amos Cooling Tower Flight Program data from December 1974 through March 1975 are presented in chronological order. The purpose of the three part study (December 1973-March 1976) is to determine the relation between ambient meteorological conditions and the behavior of visible plumes from natural draft cooling towers. For each flight a cross sectional diagram of the visible cooling tower plume with relative humidity, dry bulb and dew point temperature profiles are included. Following each profile is a photograph of the visible cooling tower as it appeared during the flight. A legend for the cross sectional diagram and a summary of instrumentation used in the program preceeds the data from flight number one. (ND)

<410>

John E. Amos Cooling Tower Flight Program Data December 1975 - March 1976.
107 pp.
1976
Kramer, M.L.; Seymour, D.E.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation

The results of the December 1975-March 1976 airborne measurements programs at the John E. Amos power plant near Charleston, WV are reported. The purpose of the three part (November 1973 - August 1974) study was to determine the relation between ambient meteorological conditions and the behavior of visible plumes from natural draft cooling towers. The data consist of temperature soundings using mercury thermometers, measurements of visible plume length and height, and wind speed and direction. In particular, this series of observations were of the behavior of cooling tower plumes at temperatures less than or equal to 10 degrees F. Data for 17 flight tests are presented in tabular, graphic, and photographic form. Light snow was noted in some of the observations. (ND)

<411>

Observed Cooling Tower Plume Characteristics.
BNWL-SA-5[illegible]01, 27 pp.
1976
Wolf, M.A.
Battelle Pacific Northwest Laboratories, Richland, WA

In-plume measurements with an instrumented Cessna 411 aircraft were made at the Rancho Seco, Trojan, and Centralia power plants. Additional surface-based operations conducted at Rancho Seco included pibal tracking to determine the wind velocity profile, time-exposure photographs of the plume for external plume definition and measurements of sulfate deposition due to the drift of entrained circulating water. Results are summarized for three days' operation at Rancho Seco (February 17, 18, and 20, 1975) and one day (May 13, 1976) at Trojan and Centralia. Measurements were made for temperature, humidity, turbulence, Aitken nuclei and cloud droplet spectra.

<412>

Natural Draft Cooling Tower Plume Behavior at Paradise Steam Plant (Part II).
Prepared by Tennessee Valley Authority, Feb. 1978. 140 pp.
1978
Tennessee Valley Authority

Cooling tower plume field studies conducted at the fossil-fueled Paradise Steam Plant, Muhlenberg County, KY, during January and February 1973, are described in this report. Main objective of this segment of the 2-part study was to provide observations on the trajectory and growth of the visible (condensed) plume from the plant's natural draft cooling towers. Data could be used to verify various models for cooling tower plumes. A secondary objective of the report was to describe and verify a simple vapor plume model described in Part I of the report. Report also contains details, included as appendices, of plant operating conditions, measurements inside and at the base of the cooling towers, and measurements of pertinent ambient air quality parameters. Paradise Steam Plant has 3 units with a total capacity of 2600 MW. Two of the cooling towers are 183 m tall, while the third is 244 m. Document contains 36 figures, 2 tables, 4 appendices, and references.

<413>

Natural-Draft Cooling-Tower Plume Behavior at Paradise Steam Plant.
Waste Heat Management and Utilization Conference, Proceedings of a Symposium, Miami Beach, FL, May 9-11, 1977, 28 pp.
1977
Slawson, P.R.; Coleman, J.H.
University of Waterloo, Waterloo, Ontario, Canada
Tennessee Valley Authority, Muscle Shoals, AL

A field study of natural draft cooling tower plume behavior at Paradise Steam Plant of the Tennessee Valley Authority was conducted during the period January 31 to February 12, 1973. This was the second phase of a two-phase study that began in September 1972. First-phase results were reported in 1976. Details of the experimental technique and measurements of some of the observed time-mean condensed (visible) plumes are presented with corresponding source parameters and ambient air data. The governing equations describing the behavior of a simple one-dimensional moist plume are integrated in closed form using some simplifying assumptions and are also integrated numerically in their more general form to produce the basis for two vapor plume models. Predictions from the closed-form model are compared to observed time-mean plumes. Visible plume centerline trajectories and plume boundaries are reasonably well predicted from measured source and ambient data within the limits of scatter of these data. Predictions of visible plume length are very sensitive to the value of ambient relative humidity used, particularly when the relative humidity is high and ambient temperatures are low. Tower downwash effects that may greatly influence plume trajectory and growth are accounted for by very simple means. In the presence of strong vertical wind shear or an elevated inversion, the numerical integration model predicts plume behavior more accurately than does the closed-form integration model. (Auth)

<414>

Natural Draft Cooling Tower Plume Behavior at Paradise Steam Plant (Part I).
Prepared by Tennessee Valley Authority, Aug. 1975. 153 pp.

A simple one-dimensional plume rise theory for near-neutral atmospheric conditions was used to predict cooling tower plume lengths and excess moisture as functions of distance downwind from power plants utilizing natural draft towers. Field data were collected from the hyperbolic natural draft cooling towers at the Paradise Steam Plant, Muhlenberg County, KY. Report contains a limited theoretical analysis of cooling tower plumes and data from field studies at Paradise from January-March, 1971, and September 1972. Main objectives of the field experiments were to obtain data on the excess moisture in the invisible plume and to estimate lengths of condensed plumes under various atmospheric conditions. Supporting data were obtained on operating conditions for the plant and cooling towers. Major sections of the report include experimental technique and equipment description, theoretical considerations, data analysis, and results and discussion. Field observations produced data on plume moisture, and these results are tabulated and presented as appendices. Another appendix presents derivations of equations used in plume length section. Report contains 27 figures, 3 tables, 3 appendices, and references.

<415>

Investigation of Cooling Tower Plume Behavior.
Colbaugh, W.C.; Blackwell, J.P., and Leavitt, J.M.
In:CEP Technical Manual No. T40, Cooling Towers.
Sponsored by Tennessee Valley Authority, nd. pp. 83-86.

Report summarizes methodology and results from a survey of cooling tower plume observations, correlated with meterological and plant operational information, which began in 1969 at the Paradise Plant, a 3-unit, 2600-MW, fossil-fueled facility in Muhlenberg County, KY. The plant has 3 hyperbolic, natural-draft, wet-counterflow cooling towers. Report covers general field observation program, comprehensive field data acquisition, power plant and cooling tower design and operation, meteorological data acquisition, cooling tower plume characterization, typical daily activities, and preliminary results and interpretation. Vapor plumes were defined as to configuration and behavior resulting from various combinations of emissions and meteorological conditions. Article contains 5 figures and 1 table.

<416>

Documentation - Drift Deposition Assessment - Bellefonte, Hartsville, and Phipps Bend Nuclear Plants.
Prepared by Tennessee Valley Authority, 1978. 14 pp.

Document was submitted to the NRC as supporting evidence for a change requested by TVA in the terrestrial monitoring requirements at 3 nuclear plants presently under construction. The plants are Bellefonte, Jackson County, AL; Hartsville, Smith and Trousdale Counties, TN, and Phipps Bend, Hawkins County, TN. The assessment utilized drift deposition model predictions to project the accumulation of drift-deposited toxic elements in soil and plants. The estimated amounts of drift-deposited solids were compared to the amount of solids deposited by natural precipitation. Document provides plant-specific information on cooling tower design and operation, discussion of the drift deposition model, site-specific meteorological input to the model, and method for computing the accumulation of drift-deposited material in plants and soil. For the latter method, the accumulation of lead near the Hartsville plant was used as an example. Each plant uses counterflow natural draft cooling towers varying from 145 to 164 m in height, with circulating water flows varying from 27,000 to 31,000 liters per second. Similar drift droplet spectrums and mass fractions were used in each case. Meteorological data required for the model are wind direction and speed, dry-bulb temperature, and dewpoint temperature for the period of record. Data for each plant are presented in tabular form. References are provided.

<417>

Cooling Towers and the Environment.
Journal Air Pollution Control Association 26(6):582-584 1976
Kramer, M.L.; Smith, M.E.; Butler, M.J.; Seymour, D.E.; Frankenberg, T.T.
Smith-Singer Meteorologists, Inc., Amityville, NY
American Electric Power Service Corporation, Canton, OH

Measurements of natural draft cooling tower plume behavior, as well as meteorological variables, were obtained from aircraft flights near major (J.E. Amos, Muskingum River and Mitchell) power plants of the American Electric Power System. Persistence of the visible plume to great distances depended essentially on ambient humidity. Atmospheric stability at plume elevation was also important. Cooling tower-induced fog at ground-level was never observed in any of the tests, and aerodynamic downwash of the visible plume was absent also. The cooling towers did cause modification of natural clouds and they occasionally shadowed some local areas from the sun. Merging of the stack and cooling tower plumes was a common occurrence. (AUTH)

PLUME DYNAMICS - MECHANICAL DRAFT COOLING TOWERS

<418>

Typical Mechanical Draft Tower Drift Size Distribution.
Table 10.1-5, WPPSS Nuclear Projects 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.

Table lists 4 droplet sizes from a typical mechanical draft cooling tower and the percentage of total drift mass that size contributes.

<419>

Deposition of Solids from Drift for Mechanical Draft Cooling Towers for the Catawba Station.
Table 5.6, Final Environmental Statement Related to the Proposed Catawba Nuclear Station Units 1 & 2. Duke Power Co. Prepared by U.S. Atomic Energy Commission, Dec. 1973. 1 p.

Table describes the drift expected from mechanical draft cooling towers at the proposed Catawba power station in York County, SC. These values are given for various distances from the plant and were calculated on the assumption that wind frequencies in all directions were equal.

<420>

Drift Deposition Rates.
Westinghouse Environmental Systems Dept. Table 2.6-38, Colstrip Generation and Transmission Project Environmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 1 p.

Table gives calculated drift deposition rates of total dissolved solids resulting from operation of cooling towers at Colstrip Generation and Transmission Project, Rosebud County, MT. Rates were calculated for 4 relevant wind directions, using the joint frequency distribution of wind speed, direction, and stability.

<421>

Estimated Offsite Maximum Values of Short-Term, Near-Ground, Airborne Concentrations (Mg/m3) of Salt.
Table 5.1-3, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 1 p.

Table summarizes maximum offsite short-term, near-ground, airborne salt concentrations resulting from operation of mechanical draft cooling towers at Sundesert Nuclear Plant, Riverside County, CA. Hours of persistence of wind direction, distance to peak, and airborne concentrations are given for each month of the year.

<422>

Drift Deposition and Salt Concentration in Air from Cooling Towers.
Figures 4.1-1 and 4.1-2, Portsmouth Gaseous Diffusion Plant Site Final Environmental Impact Statement, U.S. Energy Research and Development Administration, May 1977. 2 pp.

Figures illustrate results of a computer model used to calculate drift and salt concentrations in the air, resulting from operation of mechanical draft cooling towers at Portsmouth Gaseous Diffusion Plant, Pike County, OH. Drift and salt concentrations are plotted as a function of distance from the cooling towers for radii of up to 4 mi.

<423>

Measured Chromium Distributions Resulting from Cooling Tower Drift.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 558-572), 638 pp.
1975
Alkezweeny, A.J.; Glover, D.W.; Lee, R.N.; Sloot, J.W.; Wolf, M.A.
Battelle Pacific Northwest Laboratories, Richland, WA

Measurements were made at the Oak Ridge Gaseous Diffusion Plant to determine air concentrations and surface deposition rates of chromium dissolved in drift droplets originating in a mechanical draft cooling tower. The circulation rate of chromium in the tower during these measurements ranged between 47 and 76 kg/hr. Observed chromium fluxes that were about 1 mg/m(E+2)/hr at a distance of 30 m from the tower decreased by approximately two orders of magnitude within 1 km. Air concentrations of chromium were fairly constant at about 50 mg/m(E+3) within 200 m of the tower and decreased by less than an order of magnitude out to 1 km. A simplified drift model provided deposition flux estimates within an order of magnitude of observed values. (Auth)

<424>

Estimates of Salt Deposition Rates and Concentrations.
Figures 5.3 & 5.4, Final Site Environmental Statement Related to the Determination of the Suitability of Site G for Eventual Construction of the Blue Hills Station Unit Nos. 1 & 2. Gulf States Utilities Co. Prepared by U.S. Nuclear Regulatory Commission, July 1978. 2 pp.

Radial distributions of ambient salt concentrations and deposition rates resulting from mechanical draft cooling tower plumes at the proposed Blue Hills Station Units 1 and 2, Newton County, TX, are shown in these figures. Estimates were based on meteorological data recorded from January 1964 to December 1973.

<425>

Maximum Offsite Predicted Ground Deposition of Salt Due to Palo Verde Nuclear Generating Station Cooling Towers.
Table 10.2-2, Environmental Report Construction Permit Stage Palo Verde Nuclear Generating Station Units 4 & 5. Prepared by Arizona Public Service Co., Sept. 1978. 1 p.

Table compares predicted ground salt deposition from cooling towers for 4 alternative plant makeup water sources considered for the proposed Palo Verde Nuclear Generating Station Units 4 and 5, Maricopa County, AZ. Alternatives for the cooling tower makeup include various combinations of groundwater, Phoenix wastewater effluent, and irrigation drainage water. Deposit projections are based on NUS isopleth data. Estimates are given for dry deposition, drift droplets, total deposition, and mean annual airborne concentrations.

<426>

Salt Deposition Rates Resulting from Cooling Tower Drift.
Table 39, Final Environmental Impact Statement Weston Generating Unit 3. Prepared by Wisconsin Public Service Corp., U.S. Army Engineer Dist., St. Paul, Oct. 1978. 1 p.

Table summarizes expected salt deposition rates, by direction and distance, resulting from cooling tower drift from the Weston Generating Unit 3 cooling tower in Marathon County, WI. The maximum rate of 2.2 pounds per acre per year occurs 1.5 mi ESE of the tower. Data are based on a drift model utilizing a ballistics method approach.

<427>

Annual Salt Deposition from Mechanical Draft Cooling Towers (lb/acre).
Figure 10.1-15, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.

Figure is a topographical map of site and surrounding area with pre dicted annual salt deposition due to operation of alternative rectangular mechanical draft cooling towers for WPPSS Nuclear Projects No. 3 and 5.

<428>

Salt Deposition Patterns Out to 0.5 and 6.9 Miles.
Figures 5.1-11 and 5.1-12, WPPSS Nuclear Project No. 2 Environmental Report (Operating License Stage), Washington Public Power Supply System, Mar. 1977. 2 pp.

Figures show estimated patterns of salt deposition on the surrounding region, resulting from cooling tower operation at WPPSS No. 2, Benton County, WA. Calculations were made using the wind direction frequency data from an onsite meteorological tower.

<429>

Salt Drift Pattern - Round Mechanical Draft Cooling Towers.
Figure 10.1-7, River Bend Station Units 1 & 2 Environmental Report, Gulf States Utilities Co., Sept. 1973. 1 p.

Topographical map of River Bend Station site indicates predicted isopleths of salt deposition rates due to operation of alternative round mechanical draft cooling towers.

<430>

Round Mechanical Draft Cooling Tower Annual Salt Deposition, Lbs/Acre/Year.
Ebasco Services, Inc., New York. Table VI-C-8, George Neal Steam Electric Station Neal Unit 4 Environmental Impact Assessment, Iowa Public Service Co., Dec. 1974. 1 p.

Table shows amount of alternative round mechanical draft cooling tower annual salt deposition for Neal Unit 4. Information is given by distance and direction from tower.

<431>

Mechanical Draft Cooling Tower Field Study.
Appendix B, Power Plant Site Evaluation Report: Dickerson Site. Prepared by Johns Hopkins Univ. for Potomac Elec. Power Co., Maryland Power Plant Siting Program, Jan. 1974. 7 pp.

Appendix describes study of cooling tower visible plume behavior at the mechanical draft cooling tower serving the 289-MW No. 16 Generating Unit at the Benning Road Power Station, Washington, D.C. Data recorded during the study included power load, heat exchanger water temperature, makeup water and blowdown water volumes, exit volume, mean temperature, mean relative humidity, surface temperature, humidity, wind direction and wind speed, and plume height, length, and width. Instruments used in the experiment are described. Appendix contains 3 tables and 3 figures.

<432>

Salt Deposition from Unit 3 Mechanical Draft Cooling Tower - Spring Season and Annual Rate.
Figures III-E-19 and III-E-20, Clay Boswell Steam Electric Station Unit 4 Environmental Report, Minnesota Power & Light Co., March 1976. 2 pp.

Figures diagram the amount of salt deposited by the Clay Boswell Unit 3 mechanical draft cooling tower. The plant, located in Itasca County, MN, is comprised of 3 coal-fired units with a capacity of 500 MW. From values averaged over a period from 1955 to 1965, profiles are constructed for 1, 2, 5, and 10 pounds of salt deposited per acre per year and for 15, 35, and 65 pounds of salt deposited per acre per month.

<433>

Deposition of Specific Ions from Unit 3 and Unit 4 Cooling Tower Drift.
Table IV-B-4, Clay Boswell Steam Electric Station Unit 4 Environmental Report, Minnesota Power & Light Co., March 1976. 1 p.

Table presents data on the expected ion levels in Clay Boswell Units 3 and 4 cooling tower blowdown water and, based on these levels, the deposition of ions from cooling tower drift is calculated. Clay Boswell, a 500-MW plant located in Itasca County, MN, has 3 operating units, with Unit 4 due to be completed in 1980. Chloride, calcium, and magnesium levels are listed as percent of the total dissolved solids in the blowdown waters, and the maximum spring season deposition rate of ions from the Unit 3 cooling tower and the Unit 4 rectangular mechanical draft cooling tower is described for on-site and off-site locations.

<434>

Calculated CGS Salt Deposition Rates.
Table II-40, Final Environmental Statement - Coronado Project, Owned by Salt River Project . Prepared by Bureau of Reclamation, U.S. Dept. of Interior; Bureau of Land Management, U.S. Dept. of Interior, and U.S. Forest Service, U.S. Dept. of Agriculture, Aug. 1977. 1 p.

Table gives data on predicted salt deposition rates resulting from cooling tower drift associated with operation of the Coronado Project, AZ. Rates are given for the 16 principal directions and for distances ranging from 1.5 to 5 km.

<435>

Estimated Maximum Offsite Monthly and Annual Average Dry Deposition Rates (kg/km2 - month) and Near-Ground Airborne Concentrations of Salt.
Table 5.1-2, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 1 p.

Table gives computer model calculations of salt deposition due to drift from operation of mechanical draft cooling towers at Sundesert Nuclear Plant, Riverside County, CA. Included are salt deposition rates and airborne salt concentrations at peak distance and 10 mi downwind of the plant using meteorological data for months of June 1975 - May 1976.

<436>

Predicted Average Near-Ground Airborne Salt Concentrations and Salt Deposition Rates.
Figures 5.1-5 Through 5.1-16, Sundesert Nuclear Plant Units 1 and 2 Environmental Report, San Diego Gas & Elec. Co., Project Manager, Nov. 1976. 12 pp.

Figures illustrate predicted isopheths of monthly, annual, and short-term average salt deposition rates on the ground, and near-ground airborne concentrations of salt as a function of distance and direction from Sundesert station's mechanical draft cooling tower, Riverside County, CA. Data are given for July and December meteorological conditions as well as annual averages.

<437>

Ecological Analyses and Applications.
Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1977, S.I. Auerbach et al., Part 1, (p. 1-17), ORNL-5365, 240 pp.; ESD No. 1145, 240 pp.
1978
Kroodsma, R.L., et al.
Oak Ridge National Laboratory, Environmental Sciences Division, Oak
Ridge, TN

Drift deposition for the proposed mechanical draft cooling towers (Sundesert Nuclear Plant, Blythe, CA) using irrigation waste water were estimated using the ORFAD computer model. Calculated impaction values were below literature values for damage to crops grown in the area and no impact was anticipated. With respect to native desert shrubs (creosote bush and burro bush) and the low rainfall, salt deposition for soils could reach critical levels over the 40-year life of the plant. Alternative cooling tower specification investigations were recommended. (ND)

PLUME DYNAMICS - BRACKISH AND SALTWATER COOLING TOWERS

<438>

Determination of Drift Deposition Rates and Size Spectra from a Brackish Water Natural Draft Cooling Tower.
M.S. Thesis, 120 pp.
1975
Pringle, W.J.B.
University of Maryland, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Brackish waters used in conjunction with cooling towers are of environmental concern because of the potential detrimental effects of salt deposition on the surrounding area from the drift. As a result, an empirical study of saltwater drift deposition from a brackish water natural draft cooling tower was conducted using an automatic drift sampler. This apparatus was used in conjunction with salt and water sensitive filter papers. The size distribution and total amount of drift deposited on an area was determined from the characteristic stains that impinged drift left on these filter papers. Using this technique, ground level drift deposition rates and size spectra were determined for various distances downwind under different meteorological conditions. Meteorological measurements of ambient temperature, relative humidity, wind speed and direction, were conducted. The meteorological data and collected drift size spectra data from a series of experiments are presented. In addition a comparison is made between the measured values and the predicted values determined by the drift deposition model of Israel and Overcamp (1974) for each of the experiments. It is shown that the sampling technique works well under field conditions. The comparison of actual to predicted values of drift deposited, in specific size groups, indicates that the model tends to overpredict the drift droplet deposition rate. This might be largely due to the fact that no actual data are available, as yet, on the drift emission rate of the tower, the emitted drift size spectrum, or the necessary parameters that are needed to calculate the buoyancy flux. (Auth)(ND)

<439>

Determination of Salt Deposition Rates from Drift from Evaporative Cooling Towers.
Journal Engineering Power (Transactions ASME) 96(3): 283-291; American Society Mechanical Engineers, Paper No. 74-PWR-C
1974
Hosler, C.L.; Pena, J.A.; Pena, R.
The Pennsylvania State University, Department of Meteorology,
University Park, PA

A method for estimating the deposition rate of the salt ejected in drift drops from a cooling tower in which saltwater is circulated is described. The surface over which the salt will be distributed depends upon the wind speed, the maximum height the drops can reach, and thc drop fall velocities. The drop fall velocity changes because of the evaporation in the air outside of the plume. The rate and extent of the evaporation is a function of the drop size, salt concentration, and ambient relative humidity. Three degrees of evaporation have been considered: (1) no evaporation; (2) evaporation to saturated solution and (3) evaporation to dry salt particles. For each degree of evaporation a graph was constructed that permits determination of the distance from the tower at which the salt contained in given drop size will fall. To use these graphs, the salt concentration, wind speed, and the maximum height a drop can reach must be known. The choice of the graph to be used for a particular case is made on the basis of humidity data for the site and the drift drop size. Corrections to compensate for the errors introduced by some of the assumptions are presented. (Auth)

<440>

Drift Losses from Saltwater Cooling Towers - Some Atmospheric Considerations.
American Geophysical Union 54th Annual Meeting, Proceedings of a Symposium, Washington, DC, April 16-20, 1973; Transactions American Geophysical Union 54:284;
1973
Roffman, A.
Westinghouse Electric Corporation, Environmental Systems Department,
Pittsburgh, PA
U.S. Atomic Energy Commission

The important saltwater cooling tower parameters influencing the degree of environmental impact are drift rate, droplet size distribution, atmospheric transport characteristics and climatological conditions. A saltwater cooling tower study conducted for the AEC includes among other subjects the state-of-the-art of meteorological measurements and prediction methods associated with saltwater cooling towers. Eight different methods for measuring drift from cooling towers are being used by various investigators. The drift rate measured at various cooling towers is between 0.002 to 0.003 % of the circulating water flow in the towers. Very few tests have been conducted to compare the different techniques. Drift deposition rates are estimated by using different approaches such as the Gaussian dispersion equation with the appropriate fall velocities, estimation of the droplets trajectories and the conservation of mass equation. The range of variation between the predicted salt deposition rates may reach a factor of + 10 for the same initial conditions. Few field measurements of drift deposition rate from saltwater cooling towers have been conducted. The findings associated with drift and its deposition rates, measurements and prediction techniques, including results obtained in this study from drift rate measurements at a saltwater cooling tower are discussed. (Auth)

<441>

(Summary of Drift and Blow-Through Problems at Facilities with Saltwater Closed-Cycle Cooling Systems.)
Tables 3.0-11 Through 3.0-13, Ocean-Sited Plants - A Survey of Operating Experience with Saltwater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 4 pp.

Tables summarize drift and blow-through problems reported at 35 worldwide facilities which use saltwater, closed-cycle cooling systems. These facilities include coastal and inland power generating stations and processing plants. Problems encountered include on-site property effects, off-site property effects, and transmission system arcing and station outage.

<442>

(Typical Seawater Cooling Tower Particulate Emissions Compared to State and Federal Air Quality Regulations.)
Tables 6.5-2 Through 6.5-4, Ocean-Sited Plants - Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 3 pp.

Tables compare typical seawater cooling tower drift emissions to state and federal air quality regulations. An estimate of the maximum sizes of fossil and nuclear power plants with seawater closed-cycle cooling systems which would meet 30 lb per hr particulate emission standards is also presented. Data include typical circulating water flow per hour, concentration factor, total drift emission, drift emission per tower, and typical regulations.

<443>

(Ground Level Salt Drift Deposition and Airborne Particulate Concentrations - Natural and Mechanical Draft Cooling Towers.)
Tables 6.2-1 & 6.2-2, Ocean-Sited Plants - Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 7 pp.

Tables list predicted values of yearly and monthly salt drift ground level deposition and airborne particulate concentrations at distances from 500 to 25,000 ft from natural and mechanical draft seawater cooling towers. Models assume circulating water salinity of 70,000 ppm.

<444>

(Droplet Size Distribution - Natural and Mechanical Draft Cooling Towers.)
Figures 6.2-1 & 6.2-2, Ocean-Sited Plants - Engineering, Environmental and Economic Aspects of Seawater Closed-Cycle Cooling Systems - I. Prepared by Stone & Webster Engineering Corp. for Utility Water Act Group, June 1978. 2 pp.

Figures are graphic presentations of water droplet size distribution from mechanical and natural draft cooling towers. Mass versus diameter are compared from data collected at 16 sites.

<445>

Performance Testing of a Salt Water Natural Draft Cooling Tower.
12 pp.
Monjoie, M., Sobel, N.
Hamon Sobelco, S.A.
Research-Cottrell, Inc.

The B.L. England Station, Unit 3, uses a natural draft cooling tower circulating sea water, the first in the United States. Testing the tower, proving that it met its guaranteed thermal performance and drift rate in actual service presented special engineering problems for its designer and builder, Research-Cottrell/Hamon. The thermal design was unusual in that the effect of salinity on water properties, predominantly vapor pressure, had to be compensated for, and the unusually low, 0.002% specified drift level required an entirely new approach to performance testing. It should be emphasized, however, that the results of these tests should not be considered alone in determining the extent of cooling tower drift limitation but in conjunction with previous experience and tests results. Decisions must be made on a site-by-site basis; and in many cases such extreme drift limitation may not, in fact, be economically or ecologically justifiable. (ND)

<446>

Testing a Saltwater Cooling Tower.
Power 120(12):42-43
1976
Monjoie, M.; Sobel, N.
Hamon Sobelco, S.A.
Research-Cottrell, Inc.

Thermal tests instrumentation, procedures, and test data as well as drift measurement results for the B.L. England's saltwater natural draft cooling tower are given. The results show that the tower operates within the design for thermal performance. Drift measurements were well below the 0.002% guaranteed level, demonstrating that the cooling tower met environmental criteria. The results of these tests should not be considered alone in determining the extent of tower drift, but rather in conjunction with previous experience and test results. Decisions must be made on a site-by-site basis, in many cases, extreme drift limitation may not, in fact, be economically or ecologically justified. (ND)

<447>

Effect of Mechanical Cooling Devices on Ambient Salt Concentration.
EPA-600/3-76-034, 133 pp.; ADAPT-75-8; PB-256 679
1976
Hunter, H.E.
ADAPT Service Corporation, Reading, MA
U.S. Environmental Protection Agency, Environmental Research
Laboratory, Corvallis, OR

The purpose of this study was to analyze the airborne salt concentration data collected during the demonstration of saltwater mechanical cooling devices at Turkey Point power plant. The data was devided into three classes: (1) background salt concentration, (2) cooling tower plus background salt concentration; and (3) powered spray modules plus background salt concentration. The primary results of the study were: (1) the operation of the cooling tower at the Turkey Point power plant did not increase the background salt concentration by a measurable amount, and (2) the effect of operating the spray modules probably increased the background salt concentration at Station 7 by approximately 50% and did not increase it by a measurable amount at any other station. The conclusions are based on the results of statistical summaries of the difference between the concentration measured with the device operating and the expected background concentration made at each station and pooled over all stations. The average difference between the measured concentration with the cooling tower operating and the expected background concentration was the order of 2 x 10(E+3) ug/m(E+3) with a standard deviation of 4.8 ug/m(E+3). Algorithms were developed to calculate the background concentration at each station as a function of the environment, and included as Appendix D. The advantages and a detailed description of the ADAPT approach for performing the regression analyses for the study are given in Appendix A. (ND)

<448>

Test Program on Environmental Effects of Saltwater Mechanical Cooling Devices.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 501-508), 638 pp.
1975
Henderson, C.D.; Dowdell, S.H.
Florida Power and Light Company, Miami, FL
The Environmental Protection Agency and Florida Power and Light Company are cooperating in a test program to determine drift characteristics and salt deposition on adjacent terrain from natural causes and from a full-size, single-cell, mechanical-induced-draft, wet cooling tower using saltwater at a coastal site in subtropical United States. The program also includes similar tests on powered spray modules and an evaluation of the material performance of the cooling devices in this environment. The 13-month data-acquisition program was begun in August 1973. Results of the test program should be available in late 1974. (Auth)(ND)

<449>

Salt Water Condenser Cooling: Measurements of Salt Water Drift from a Mechanical-Draft Wet Cooling Tower and Spray Modules, and Operating Experience with Cooling Tower Materials.
Proceedings American Power Conference 38:740-755
1976
Schrecker, G.O.; Henderson, C.D.
Environmental Systems Corporation, Knoxville, TN
Florida Power and Light Company, Miami, FL
The results of drift tests on saltwater mechanical draft cooling towers and spray modules for saltwater cooling canals for Florida Power and Light Company's Turkey Point Power Plant are reported. The results of an additional and on-going study by FP&L which evaluates the performance of the cooling tower materials in the saltwater environment are also presented. The drift test on the mechanical draft saltwater cooling tower which is equipped with state-of-the-art drift eliminators showed a test-averaged salt emission fraction of 0.00084 percent of the salt circulating as solute in the basin water. The drift emission fraction was 0.00034 percent of the circulating cooling water and its mass median diameter 125 um. The operating experience accumulated between early 1974 and to date indicated that the choice of materials for this saltwater cooling tower was generally very good. The spray module test showed as expected that, other factors being equal, the drift decreased with increasing distance from the modules and with increasing height above the water line. The test showed a strong dependence of the drift data on the wind vector. Therefore, if the salt emission fraction of the spray modules is to be determined, simultaneous drift data acquisition by a network of sensors would be recommended. (ND)

<450>

Drift Data Acquired on Mechanical Salt Water Cooling Devices.
EPA-650/2-75-060, 532 pp.; PB-246 800, 532 pp.
1975
Schrecker, G.O.; Webb, R.O.; Rutherford, D.A.; Shofner, F.M.
Environmental Systems Corporation, Knoxville, TN
U.S. Environmental Protection Agency, Office of Research and
Development, Research Triangle Park, NC
This report contains data on the drift emission from a single cell mechanical draft cooling tower and two spray modules at the Turkey Point generating station, and measurements of airborne salt loadings in the vicinity of these cooling tower devices up to a distance of about 2 km. The airborne salt loadings were measured before the cooling devices became operational and later during the operation of either the cooling tower or the two spray modules. The tests were performed at Florida Power and Light Company's Turkey Point Electric power generating plant. Drift measurements were conducted on both cooling devices during the winter test phase (January 21-March 31, 1974) and again on the cooling tower during the summer test phase (July 16-24, 1974). Cooling tower drift data were acquired along five fan stack exit diameter traverses, with 12 to 16 data points per traverse. Each data point was usually comprised of a drift droplet size spectrum, sodium and magnesium mass fluxes, air updraft velocity, exhaust air temperature, and tower operational and meteorological data. The range of measured droplet diameters was 10 to 2240 um, with 85% between 10 to 600 um. The spray module tests yielded drift emission data, i.e. the drift droplet size spectrum and mineral mass flux, together with meteorological data, at selected points in space downwind of the spray modules. The range of measured droplet diameters was between 10 um and, on the average, 300 um. The upper limit varied between 200 and 500 um, primarily due to wind speed and distance from the spray modules. Ambient airborne salt loadings were measured during the period of August 24, 1973 to January 11, 1974, by means of a network of six sampling stations. Between January 31 and July 24, 1974 airborne salt loadings were measured during the operation of either the cooling tower or the two spray modules. No conclusions are presented. (ND)

<451>

Separation of Chalk Point Drift Sources Using a Fluorescent Dye.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 83-104), 462 pp.
1978

Meyer, J.H.; Stanbro, W.D.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

A water soluble fluorescent dye (Rhodamine WT) was used as a tracer in studies to separate cooling tower and stack drift deposition. Organization, instrumentation, and proof-of-principle testing of the dye experiment are discussed. Sampling arrays consisting of both funnel and filter paper droplet receptors were used along 30 degree arcs at 0.5 Km and 1.0 Km radii downstream of the cooling tower. The dye tracer experiment and the results are discussed. Total deposition data for both the 0.5 Km and 1.0 Km sampling arrays are available. Deposition drop size distributions are available at this time only for the plume centerline sampling stations at 0.5 km and 1. 0 km. Deposition data obtained have allowed positive identification and quantification of salt drift from both cooling tower and stack. The experiment has shown the value of using sampling arrays along fixed arcs and distances rather than isolated sampling along plume centerline. It has also provided a data base for model validation and impact assessment. (Auth)(ND)

<452>

Chalk Point Cooling Tower Project: Report Cooling Tower Drift Dye Tracer Experimental Plan.
JHU-CP-3, 40 pp.
1977
Meyer, J.H.; Stanbro, W.D.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The experimental design of the Chalk Point Cooling Tower Dye Drift Experiment is described. The test is designed to differentiate between cooling tower and stack drift. The cooling tower circulating water is to be tagged with a water soluble flourescent dye (Rhodamine WT) so that the downwind cooling tower drift can be identified and quantified. The Applied Physics Laboratory (APL) has the responsibility of coordinating the experiment and forecasting the specific meteorological conditions which are conducive to a successful experiment. APL will also be responsible for collecting field deposition data and analysis, dye charging of the basin water, real time monitoring of the dye concentration and on site meteorology. PEPCO will be responsible for power plant operations and all associated engineering data as well as special equipment needed during characterization of the cooling tower. Environmental Systems Corporation will be responsible for characterization of the cooling tower and certain field measurements during the experiment. The test has been tentatively rescheduled for May, 1977. The Proof of Principle Tests (Appendix I) and an environmental impact statement (Appendix II) for the test are included in the report. (ND)

<453>

Drift Management in the Chalk Point Cooling Tower.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 128-146), 538 pp.
1975
Holmberg, J.D.
Marley Company, Engineering Division, Mission, KS

The crossflow natural draft cooling tower at Chalk Point is the product of several aspects of concern for the environment. Of these concerns, that for the potential detrimental effects of salt deposition from cooling tower drift was an important consideration in the tower selection and details and proportions of the design. The effects of basic principles of water and air handling and of particle transport on the drift characteristics of the tower are discussed. Adaptation of these principles during a four year development program is presented. Reduction of the salt deposition rate as affected by the resulting improved drift-drop-size distribution is illustrated. (Auth)

<454>

Estimates of Salt Loading by Unit No. 3 Cooling Tower, (Chalk Point Generating Station).
Chapter 4, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 16 pp.

Document uses a saline drift model and a large meteorological data base to estimate the magnitude of salt loading by the 400-foot, natural draft cooling tower at Chalk Point Generating Station Unit 3, Prince Georges County, MD, on the local area. Document gives sources for the development of the data base, discusses the content of the data base, and describes the processing of data into the input parameters required by the model. Chapter also discusses tuning of a plume behavior submodel to seasonal plume data, scaling of exit velocity and temperature, drift rate and distribution of droplet sizes, circulating water salinity, and evaporation of drift droplets. The results of the model predictions are presented, including total salt emitted and deposited annually within 10 km of the tower, seasonal salt loading for various distances and directions from the tower, location of maximum deposition, and annual, seasonal, and worst month isopleths of salt loading. Chapter contains 14 figures, 10 tables, and references.

<455>

(Isopleths of Salt Loading to the Area Surrounding the Chalk Point Unit No. 3 Cooling Tower.)
Figures IV-4 Through IV-9, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 6 pp.

Figures show 3, 2, 1, and 0.5 kg per hectare-month isopleths of salt deposition in the area surrounding the Unit 3 cooling tower at Chalk Point Generating Station, Prince Georges County, MD, which uses saline cooling water. Separate isopleths presenting the estimated annual salt loading are shown for winter, spring, summer, and fall months, and also for August (worst month).

<456>

Impact of Salt Loading (by the Chalk Point Generating Station Units 3 and 4).
Chapter 6, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 15 pp.

Chapter evaluates the impacts of salt drift at the Chalk Point Generating Station, Prince Georges County, MD, for 3 cases: 1) the Unit 3 cooling tower; 2) the Unit 3 cooling tower plus stack, and 3) the operational Unit 3 and an identical planned Unit 4 with cooling towers and stacks. Total salt loading is estimated and maximum salt deposition rates for onsite and offsite locations are tabulated. Based on field surveys and controlled experiments, impacts on soils, crops, and native vegetation are evaluated, including reduction in crop yields and tobacco burning time due to saline drift deposition, dogwood leaf injury due to chloride deposition, and the effect of salt spray on dogwood. Chapter also contains an assessment of damage to man-made structures. Four figures, 6 tables, and references are included.

<457>

Maximum of the Average On-Site Salt Deposition Rate (at the Chalk Point Generating Station Units 3 and 4).
Table VI-1, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 1 p.

Table presents seasonal and annual maxima of average onsite salt deposition rates at the Chalk Point Generating Station, Prince Georges County, MD, for 3 different cases: 1) Unit 3 cooling tower; 2) Unit 3 cooling tower plus stack, and 3) Unit 3 (operational) and an identical planned Unit 4 with cooling towers and stacks. Location of the cooling towers and stacks is considered to be a single point and values are given for various distances and directions from that point.

<458>

Maximum of the Average Off-Site Salt Deposition Rate (from Chalk Point Generating Station).
Table VI-2, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 1 p.

Table presents seasonal and annual maxima of average offsite salt deposition rates around the Chalk Point Generating Station, Prince Georges County, MD, for 3 different cases: 1) Unit 3 cooling tower; 2) Unit 3 cooling tower plus stack, and 3) Unit 3 (operational) and an identical planned Unit 4 with cooling towers and stacks. Location of the cooling towers and stacks is considered to be a single point and values are given for various distances and directions from that point.

<459>

Tables of Salt Loading Estimates for (Chalk Point Generating Station) Unit No. 3 Cooling Tower.
Appendix A, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 35 pp.

Appendix contains tables estimating salt loading to the area surrounding the 400-foot, natural draft cooling tower at Chalk Point Generating Station Unit 3, Prince Georges County, MD. Predictions were obtained by using a saline drift model and a meteorological data base. Monthly and seasonal salt loading are predicted in kilograms per hectare-month for various distances and wind directions from the tower at a plant load of 500 MW for 15 and 24 hrs per day. Appendix contains 34 tables.

<460>

Variations in the Chalk Point Cooling Tower Effluent Parameters and Their Effects on Drift Transport.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9(Supplement); PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. 42-53), 90 pp.
1978
Webb, R.O.; Wheeler, D.E.; Moore, R.D.
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program

Values of drift effluent parameters measured near the exit plane of the Chalk Point Unit #3 cooling tower over the past two years have exhibited a wide range of variation. Some aspects of the variations measured in updraft air speed, updraft air temperature, liquid drift emission and drift droplet size spectra, are discussed as obtained from the Summer Seasonal Test data acquired in the Chalk Point tower in June 1976. The variations in drift effluent were used as imput to a drift transport model and calculations were performed to determine how these variations affected downwind values of drift deposition at ground-level. Results of the calculations show the sensitivity of the model predictions to realistic variations in the effluent parameters. Results of variation in horizontal wind speed and ambient temperature were also determined. Variations in the drift droplet mass emission spectrum were found to have the greatest effect on deposition when compared with updraft air temperature and updraft air speed. Variations in horizontal wind speed were found to affect downwind deposition to a greater degree than comparable changes in tower updraft air speed. Variations in ambient temperature resulted in effects on downwind deposition comparable to those resulting from updraft air temperature variations. (Auth)

<461>

Airborne Monitoring of Cooling Tower Effluents.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978,

R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 167-186), 462 pp.
1978
Woffinden, G.J.
Meteorology Research, Inc., Altadena, CA

Chalk Point measurements made in December 1975 and June 1976 included: (1) water droplet size and concentration, (2) visibility, (3) turbulence, (4) dew point, (5) sodium chloride--MRI Film sampler (chemically sensitive film), (6) sulfuric acid, (7) sulfur dioxide, and (8) temperature. Methods and instrument sensitivity ranges are given. Droplets typically had a number mean diameter of approximately 50 um and a mass median diameter ranging from 50 to 400 um, usually around 300 um. The visible plume disappeared within a few tower diameters except during very high humidity mornings. Moderate turbulence was encountered in the immediate vicinity of the visible plume, but was very localized. Sulfuric acid and SO2 were found in the boiler plume and the interaction zone with the cooling tower plume. Sodium chloride concentrations were in the order of 100 ug/m(E+3) (in water droplets with mass median diameters typically 300 um). Plume cross sections were measured from directly over the tower to 10 miles downwind; most measurements, however, were between 500 and 3,600 feet downwind. Measurements show changes in the plume characteristics with downwind distance. (Auth)(ND)

<462>

Aircraft Survey, Chalk Point Cooling Tower Plume, December 1975.
PPSP-CPCTP-5
1976
Woffinden, G.J.; Anderson, J.A.; Harrison, P.R.
Meteorology Research, Inc., Altadena, CA
Maryland Department of Natural Resources, Power Plant Siting Program

The results of experimental field measurements of plume characteristics in the atmosphere under a variety of meteorological conditions are reported. Size, shape, and properties of the plumes are being measured using a single engine Cessna 205 light research aircraft. This report summarizes data collected by MRI during the first intensive test period, December 15-19, 1975, of the Chalk Point Program. Results of the program will show environmental effects of power plant emissions including: drift and fallout potential contaminants such as sodium chloride and sulfuric acid; aircraft hazards from icing, turbulence, and decreased visibility; and other weather modifications such as increased fog. (ND)

<463>

Chalk Point Cooling Tower Project FY 1977 Final Report: Cooling Tower Drift Dye Tracer Experiment Surface Weather and Ambient Atmospheric Profile Data June 16 and 17, 1977.
PPSP-CPCTP-16, Vol. 3 of 3, 187 pp.; PB-284 060, 187 pp.
1977
Meyer, J.H.; Jenkins, W.R.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

This report covers the surface weather observations made at PEPCO's Chalk Point Power Plant, Andrews Air Force Base and Patuxent Naval Air Station; and the Chalk Point rawinsonde soundings made during the cooling tower drift dye tracer experiment, June 16 and 17, 1977. Numerous computer atmospheric parameters from these data are reported for the user's convenience to facilitate the use of these data to plume and drift modeling. (ND)

<464>

Chalk Point Cooling Tower Project: Progress Report #1 - FY 77 July 1, 1976 - February 28, 1977.
TID-27683, 30 pp.
1977
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program
U.S. Energy Research and Development Administration

Progress is reported on equipment documentation, meteorological data acquisition and reduction, data archiving format preparation and data analyses for the Chalk Point cooling tower project. A description of the work performed in these areas together with recommendations for future work is presented. Data analysis includes drift emission data and associated plant and cooling tower operational and meteorological data, the analysis of airborne sodium concentration data with regard to time-mean ambient concentrations and contributions of the cooling tower and stack to the ambient concentration. (ND)

<465>

Chalk Point Cooling Tower Project: Summer Seasonal Test Data, Comprehensive Project Final Report October 1, 1975 - June 30, 1976.
PPSP-CPCTP-12, Vol. 2 of 2, 278 pp.
1977
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program

Results of a drift measurement program conducted by Environmental Systems Corporation as part of the Chalk Point Cooling Tower Project for the Fiscal Year 1976 are presented. This volume contains Summer Seasonal Test Data. (ND)

<466>

Chalk Point Cooling Tower Project: Cooling Tower Drift Dye Tracer Experiment, FY77 Final Report July 1, 1976 - August 31, 1977.
PPSP-CPCTP-20, Vol. 2 of 2, 120 pp.; PB-284 827/3SL;
1977
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program

A description and results of ESC's participation in the Chalk Point Cooling Tower Project Dye Tracer Experiment is presented together with reduced data.

Measurements were conducted during two data acquisition periods on the afternoon and evening of June 16 and 17, 1977, at PEPCO's Chalk Point Generating Station. Data were acquired in four major areas: Unit #3 cooling tower emission characterization, meteorological tower data, ground-level measurements, and plume photography. In addition, Unit #3 power generation data for the test period are included as summarized from PEPCO's log and are given in Section E of each Appendix. The measurements were performed successfully without major problems. Results of the measurements are compared with the results of the CPCTP Summer Seasonal Test conducted in June 1976. (Auth)

<467>

Chalk Point Cooling Tower Project Phase IV, Comprehensive Field Program Description, Comprehensive Project Final Report October 1, 1975 - June 30, 1976.
PPSP-CPCTP-12, Vol. 1 of 2, 280 pp.
1977
Not Given
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program

Results of a field measurement program conducted by Environmental Systems Corporation as part of the Chalk Point Cooling Tower Project for the Fiscal Year 1976 are presented. Source measurements of droplet size and mineral mass emission were conducted in the Unit #3 cooling tower and scrubber stack together with downwind measurements of a number of parameters including droplet size during two Intensive Monitoring Periods (Seasonal Tests). In addition, results are presented of Continuous Monitoring measurements wherein downwind sodium concentration, cooling tower droplet size measurements and time-lapse plume photography were acquired. On-site meteorological data was also acquired over the report period and is presented in summary form. A portion of the First Seasonal Test data was used as input to drift transport models as a first step in model verification and determination of stack drift interference with measurements aimed at determining downwind cooling tower contributions. Conclusions are presented together with recommendations for future work. (Auth)

<468>

Chalk Point Cooling Tower Project Phase V, Analysis and Archiving Program Final Report July 1, 1976 - August 31, 1977.
PPSP-CPCTP-20, Vol. 1 of 2, 335 pp.; PB-284 826;
1978
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program

Results of field measurements, data analysis and data archiving conducted by Environmental Systems Corporation (ESC) as part of the Chalk Point Cooling Tower Project (CPCTP) for the Fiscal Year 1977 are presented in two volumes. Volume 1 contains results from the following program areas: (1) Chalk Point Meteorological Tower operation including summaries of meteorological data for the site; (2) Scheme for archiving the Chalk Point data sets; (3) Analysis of cooling tower emission data, ambient salt concentration data, and plume photography; and (4) Modeling including a model survey, preliminary model sensitivity work and an examination of Chalk Point data for consistency and sufficiency for modeling.

<469>

Chalk Point Cooling Tower Project: Comprehensive Project Status Report for the Period July 1, 1974 - October 1, 1975. Final Report FY'75 Preliminary Data.
PPSP-CPCTP-9, Vol. 2 of 2, 200 pp.; TIP-27331
1976
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program
U.S. Energy Research and Development Administration
Electric Power Research Institute
Potomac Electric Power Company

The preliminary data of experimental efforts regarding the Cooling Tower Initial Characterization Test are reported. This data is preliminary in the sense that, although it has been reduced and reviewed for completeness, it must be considered with the sum of the Chalk Point Cooling Tower Program data before full scale analysis is initiated. Volume 1 of this set describes the experimental effort over the period July 1, 1974 through October 1, 1975. The third volume will document the experimentation and data of the Initial Characterization of the cooling tower. Documentation of all experimentation, data and analyses since October, 1975 (excluding the Initial Characterization Tests) through June 30, 1976 will be included in the FY1976 CPCTP Comprehensive Project Status Report to be published in July, 1976. The preliminary results include: sea salt deposition data, sea salt concentration data, meteorological data, drift data, and the time-lapse camera log. (ND)

<470>

Sea-Water Cooling Tower.
Mitsubishi Jukogo Kabrushiki Kaisha. Tech. Rev., 11(3):238-248
1974
Fukuda, S.; Aramaki, M.; Oda, M.; Shoji, I.
Nagasaki Technical Institute, Technical Headquarters
Shimonoseki Shipyard and Engine Works

Saltwater cooling towers are widely used abroad and have proved highly useful in industrial and power plant applications. They, however, do not offer much in the way of eliminating the environmental problems caused by salt contamination. Basic research and development of pollution-free saltwater tower has been underway for several years. The first such mechanical draft cooling tower was built and delivered to Muroran Refinery of Nippon Petroleum Refining Co., Ltd. in August 1973. The tower (12,000 m(E+3)/h capacity) is designed with a drift eliminator to drastically reduce the drift rates. The drift has been reduced to approximately 6 to 7 x 10(E-7) of the quantity of saltwater circulated for cooling, or as low as 1/2000 or less as compared with 0.2% in the conventional freshwater cooling towers. The service results of this tower and the particulars of a 400 m(E+3)/h test cooling tower used at the Nagasaki Technical Institute are given. (Auth)(ND)

<471>

Experimental Design for a Case Study of Drift from a Mechanical Draft Cooling Tower.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 25-37), 462 pp.
1978
Laulainen, N.S.
Battelle Pacific Northwest Laboratories, Atmospheric Sciences
Department, Richland, WA

A comprehensive experimental study of drift emissions and downwind deposition from a mechanical draft cooling tower is planned for early spring 1978 at the Pittsburg (CA) power plant. The objective of the experiment is to develop a data base which can be used for validation of drift deposition models. The key aspects of the study are to measure the characteristics of the drift emitted from the tower, the ambient meteorological conditions responsible for the transport and dispersion of the drift, and the downwind deposition and near surface air concentration patterns of the drift. The source characteristics, including air temperature and velocity profiles at the tower exit, and the transport parameters are to be used as inputs to the models, while the deposition patterns are to serve as comparisons to the outputs of the models. (Auth)(ND)

<472>

Predicted Annual Ground Level Salt Deposition from the Natural Draft Cooling System in the Sector East-Southeast of the Plant Site.
Table 5, Applicants' Direct Testimony with Respect to Use of Closed-Cycle Cooling at Seabrook and Analyses of Alternative Sites. Presented before U.S. Nuclear Regulatory Commission, Atomic Safety and Licensing Board, 1977. 1 p.

Table lists the expected salt deposition rates for 19 locations associated with the natural draft cooling system being considered for the proposed Seabrook nuclear plant site, Rockingham County, NH.

<473>

Salt Deposition from Mechanical Draft Cooling Towers at the Seabrook Site.
(NUS-953B) Prepared by Fisher, G.E., NUS Corp. for Public Service Co. of New Hampshire, Jan. 1975. 11 pp.

Report presents results of a computer analysis of salt deposition from the proposed mechanical draft cooling towers at the Seabrook nuclear plant, Rockingham County, NH. The NUS-FOG prediction model, which contains a sophisticated drift transport and deposition routine not present in previous models, was used. The maximum predicted deposition is over 2000 lbs. per acre per year immediately northeast and southwest of the towers. Predictions were made for distances up to 170 km from the plant. Report includes a description of the NUS-FOG model, 2 figures, 1 table, and references.

<474>

Salt Deposition Rate (Lbs/Acre/Year) For Unit No. 4 Mechanical Draft Cooling Tower Array.
Army Engineer Dist., Philadelphia, PA . Figure 4.3-1, Draft Environmental Impact Statement Indian River Power Station, Unit 4, Delmarva Power & Light Co., Sept. 1976. 1 p.

Figure illustrates results of a computer program calculation of the salt deposition rate for Indian River Power Station, Sussex County, DE. Isolines of salt deposition rate, expressed in lbs/acre/year are superimposed over a map of the area.

PLUME DYNAMICS - OTHER CLOSED CYCLE COOLING SYSTEMS

<475>

Salt Deposition Rates for the Spray Canal.
Table 10.1-6, WPPSS Nuclear Projects No. 3 & 5 Environmental Report, Washington Public Power Supply System, Aug. 1974. 1 p.

Table estimates the salt deposition rates at 5 distances from the edge of spray canal alternative at WPPSS Nuclear Projects No. 3 and 5. Data are based on 7.5mph wind normal to canal axis.

<476>

Plume Rise from Large Thermal Sources Such as Dry Cooling Towers.
Journal Heat Transfer (Transactions ASME) 96(C2):232-238
1974
Sneck, H.J.; Brown, D.H.
Rensselaer Polytechnic Institute, Troy, NY
General Electric Company, Schenectady, NY

An experimental study of the dry buoyant plume rise from a finite size source into a stably stratified atmosphere has been performed. The test results are correlated with a recently published theory, which is shown to be applicable to a wide range of discharge conditions. Methods for predicting the height of the stratified plume accumulation, as well as the maximum rise height of the plume are presented. (Auth)

<477>

Plume Behavior and Potential Environmental Effects of Large Dry Cooling Towers.
Gulf-GA-A12346, 176 pp.
1973
Boyack, B.E.; Kearney, D.W.
Gulf General Atomic Company, San Diego, CA
U.S. Atomic Energy Commission, Division of Reactor Technology

The results of a study on the hot air plume behavior and possible effects on the environment of the waste heat rejected from 1000 MWe power generating plants by dry cooling systems are presented. Publications related to dry cooling tower systems, the behavior of dry hot plumes, and the environmental effects associated with the discharge of energy directly to the atmosphere were reviewed and are discussed. Papers dealing with plume rise and the meteorological consequences of man-made heat rejection systems are reviewed and evaluated in relation to dry cooling tower systems. Calculations were carried out to define the plumes produced by dry cooling tower systems. Potential environmental effects due to large dry cooling towers were evaluated. Consideration was given to cloud formation and precipitation, local induced winds, penetration of atmospheric inversion layers, local heating, noise, aesthetics, land usage, and other effects. Where it was possible to quantitatively evaluate these areas, it appears that adverse environmental effects are unlikely with the use of large dry cooling towers for single 1000 MWe power plants. Other effects that were considered and found to be within acceptable limits include the possibility of increased lightning strikes due to a hot, dry plume, ecological damage, and possible danger to light aircraft by the plume updraft. The results show that, even though the dry cooling tower plumes will rise to considerable heights, either large clouds or clouds that develop substantial precipitation are not likely to occur. Potential beneficial effects are noted. (ND)

<478>

Present Knowledge of Physical Relationships in Drift Emission from Wet Cooling Towers and Measures Taken to Date for Determining Drift Dimensions.
VGB Kraftwerkstechnik 58(5):337-342
1978
Vodicka, V.
Blacke-Duerr A.G., Bochum, Germany
Recently built cooling towers are fitted with drift eliminators. Theoretical possibilities for improving the collection efficiency of drift eliminators are presented. These theories are confirmed by measurements. In addition, methods for determining drift emission rates and drift dimensions are presented. Drift spectra of various drift eliminators and cooling tower designs are presented. (ND)

<479>

Droplet Behavior and Collection by Counterflow Cooling Tower Eliminators.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey, England, 135
Foster, P.M.; Williams, M.I.; Winter, R.J.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England
Theoretical and experimental investigations were made to establish the variation in collection efficiency with drop size for two types of cooling tower eliminators, namely the wooden lath and the corrugated asbestos-cement types. It was found that although the majority of droplets were collected as predicted, a minority escaped collection due to air turbulence and bouncing on water covered regions of the eliminator. Turbulence effects were found in both eliminator systems but droplet bounce was only observed in the lath type eliminator where it was confined to droplets above 150 um diameter. (Auth)

<480>

Drift--A Numerical Simulation Solution for Cooling Tower Drift Eliminator Performance.
MIT-EL 77-006, 143 pp.
1977
Chan, J.K.; Golay, M.W.
Massachusetts Institute of Technology, Energy Laboratory, Cambridge,
MA
New England Electric System, Northeast Utilities Service Company
A method for the analysis of the performance of standard industrial evaporative cooling tower drift eliminators using numerical simulation methods is reported. The simulation methods make use of the computer code SOLASUR as a subroutine of the computer code DRIFT to calculate the two dimensional laminar flow velocity field and pressure loss in a drift eliminator geometry. This information is then used in the main program to obtain the eliminator collection efficiency by performing trajectory calculations for droplets of a given size by a fourth order Runge-Kutta numerical method. (Auth)

<481>

Comparative Evaluation of Cooling Tower Drift Eliminator Performance.
MIT-EL 77-004, 263 pp.; PB-272 366
1977
Chan, J.K.; Golay, M.W.
Massachusetts Institute of Technology, Energy Laboratory, Cambridge,
MA
New England Electric System, Northeast Utilities Service Company
The performance of standard industrial evaporative cooling tower drift eliminators is analyzed using experiments and numerical simulations. The experiments measured the droplet size spectra at the inlet and outlet of the eliminator with a laser light scattering technique. From these measured spectra, the collection efficiency was deduced as a function of droplet size. The numerical simulations use the computer code SOLASUR as a subroutine of the computer code DRIFT to calculate the two-dimensional laminar flow velocity field and pressure drop in a drift eliminator. The SOLASUR subroutine sets up either no-slip or free-slip boundary conditions at the rigid eliminator boundaries. This flow field is used by the main program to calculate the eliminator collection efficiency by performing trajectory calculations for droplets of a given size with a fourth-order Runge-Kutta numerical method. The experimental results were in good agreement with the collection efficiencies calculated with no-slip boundary conditions. The pressure drop data for the eliminators was measured with an electronic manometer. There was good agreement between the measured and calculated pressure losses. The results showed that both particle collection efficiency and pressure loss increased as the eliminator geometry became more complex, and as the flowrate through the eliminator increased. (Auth)

<482>

Design Study of Cooling Tower Drift Eliminators.
American Nuclear Society Annual Meeting, Proceedings of a Symposium, New York City, NY, June 12-16, 1977; Transactions American Nuclear Society 26:113-114
1977
Chan, J.K.; Golay, M.W.
Massachusetts Institute of Technology, Cambridge, MA
An analysis of the performance of three standard industrial drift eliminators was performed both by numerical simulation methods and laboratory-scale experimental techniques. Numerical predictions and experimental data measured by an electric manometer agreed within the bounds of experimental error. (ND)

<483>

The Research and Development Background to the Environmental Problems of Natural Draught Cooling Towers.
Environmental Effects of Cooling Towers, Proceedings of a Symposium, March 27-28, 1973, Leatherhead, Surrey,

England, 135 pp.; Atmospheric Environment 8(4):313-321
1973
Gardner, B.R.; Lowe, H.J.
Central Electricity Generating Board, Central Electricity Research
Laboratories, Leatherhead, Surrey, England

The development of eliminators in the early 1950s and their satisfactory performance in C.E.G.B. cooling towers is discussed. More recently, significant droplet carry-over (drift) has been detected at two new 2000 MW stations; relevant factors are that more spray is created in the bigger installations and that longer residence time in the larger towers increases droplet growth. However, the two recent occurrences were principally due to the use of eliminators which differed from the originally recommended designs in construction in one case, and in installation in the other. There is a PRIMA FACIE case for adopting eliminators of a higher standard for future installations. It seems very possible that a closer pitched (1 3/4 in.) asbestos-cement louvre type would meet the need without penalizing the thermal performance of the tower. Blow-out and stripping of spray from the air inlets in high winds and at exposed sites remains a problem of conventional hyperbolic towers for which there is no complete solution. (AUTH)

PLUME DYNAMICS - ANALYTICAL METHODS AND MODELS

<484>

Comments on the Consequences of Inherent Assumptions in Drift Measurement and Data Utilization.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 51-82), 462 pp.
1978
Shofner, F.M.
Shofner Engineering Associates, Knoxville, TN

Fundamental definitions and interpretations concerning drift modeling, and practical field measurements related to them are reviewed. Predictions are very sensitively dependent upon drift emission characteristics. Measurements which are accurately representative of the physical process of evaporative cooling and which are directly input into the transport models are required for accurate assessment of environmental effects. Some drift assumptions can lead to an order of magnitude over predictions for near-in deposition. Improvements in data manipulation and field measurements are recommended. Near-ground airborne concentration is recommended as the more meaningful parameter tc neasure and model, rather than deposition flux. (ND)

<485>

The METER-ORNL Precipitation Network: from Design to Data Analysis.
ORNL/TM-6523, 54 pp.
1978
Miller, R.L.; Saylor, R.E.; Patrinos, A.A.
Oak Ridge National Laboratory, Engineering Technology Division, Oak
Ridge, TN
U.S. Department of Energy

The development of the METER-ORNL precipitation network is described from the initial planning stages through the preliminary data analysis at present. The foremost objective of the field study is to resolve the question of Plant Bowen's (using four natural draft cooling towers) potential effect on the precipitation patterns by means of extensive data analysis. Emphasis is placed on the importance of the thorough planning which has ensured the success of the field study. Discussions include: network design; procurement of equipment; public relations; siting, installation, and operation of equipment; data processing; and results of initial analysis. No conclusive precipitation effects can be attributed to Plant Bowen at this early stage of analysis. (Auth)(ND)

<486>

Variability of Drift Data and Its Consequences to Calculated Drift Depositions.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9(Supplement); PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. 54-75), 90 pp.
1978
Schrecker, G.O.
Science Applications, Inc., Environmental Sciences and Safety
Division, McLean, VA
Electric Power Research Institute, Palo Alto, CA

Salt drift transport models which predict the long-term salt deposition rates around a cooling tower on the basis of drift emission characteristics and local climatology are important tools in the assessment of the environmental impact of brackish water cooling towers. The drift droplet size distribution is one of the most important model input parameters which strongly affects the predicted salt deposition rates. The extensive measurement program at the Chalk Point natural draft cooling tower yielded, among many other data, a total of 16 drift droplet size distributions that were acquired near the tower's exit plane. Three mean drift rate distributions were derived from this data base: an overall mean distribution, and a summer and a winter mean distribution. The variability of the measured data around the calculated means was expressed in terms of the standard deviation. Upper and lower bounds of the overall mean drift rate distribution were determined and used as input to a salt deposition model. At distances larger than several hundred meters from the cooling tower the variability of the drift data is expected to result in an upper bound of the long-term salt deposition that is two or three times larger than the lower bound. (Auth)

<487>

Plumes from One and Two Cooling Towers.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 213-238), 320 pp.; ORNL/TM-6248;
1978
Kannberg, L.D.; Onishi, Y.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy

Experimental data concerning the temperatures of downwind plumes and of air drawn into the tower for stations having one or more mechanical draft cooling towers in flat terrain is presented. Parameters investigated include the effects on plume mixing and recirculation of wind speeds, Froude numbers, orientation, and spacing between two cooling towers. Mechanical draft cooling towers similar to those now in operation at the Centralia Power Plant in southwestern Washington were used as prototypes for physical models. Simulations employing the physical models were made in a glass-walled hydraulic flume. The data obtained from these physical model simulations are presented first for a single tower and then for two towers in series. Comparisons are also made between data from this study and data from other studies and with formulations by Briggs. The results indicate that optimal siting of cooling towers, particularly multiple towers, is a task requiring knowledge of ambient wind history, plume dynamics, and tower operating conditions. Based on the tower wake effects and on the results for interactions of plumes from two cooling towers, site terrain might be a very significant factor in plume dynamics and interaction. (ND)

<488>

Modeling Near-Field Behavior of Mechanical Draft Cooling Tower Plumes.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. II 13-30), 462 pp.
1978
Subhash, C.J.; Kennedy, J.F.
University of Iowa, Institute of Hydraulic Research, Iowa City, IA
Electric Power Research Institute, Palo Alto, CA

Techniques were developed for small-scale model tests of cooling tower installations which would provide relatively complete data on the near-field characteristics of the plumes and their effects on cooling tower performance. Model testing was validated as a reliable means of plume prediction by comparing model data with corresponding prototype data. Laboratory tests of 1:150 scale models of two existing plants (Jack Watson Station, and Gaston Steam Plant) were conducted in the Environmental Flow Facility of the Iowa Institute of Hydraulic Research. Ambient wind conditions (including vertical profiles) and tower conditions were reproduced at dynamically scaled values in the laboratory flume. The effects of ambient velocity and buoyancy on the recirculation ratio and downwind distance to the point of plume lift-off from the ground were examined. The boundaries of the visible plumes obtained from the model data are in very good agreement with those obtained from photographs of the prototype plumes. (Auth)

<489>

Cooling Tower Drift Study at Oak Ridge Gaseous Diffusion Plant.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 215-230), 462 pp.
1978
Park, S.H.; Vance, J.M.
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

New drift studies on the mechanical draft cooling towers at the Oak Ridge Gaseous Diffusion Plant are being planned to provide data necessary for the building and evaluation of a practical analytical model that will describe drift transport and deposition for existing and new towers. A previous study in 1973 provided the groundwork, but needs to be extended to characterize the effect on drift mechanisms of variations in meteorological and operating conditions, as well as the influence imposed by tower condition, tower type, and terrain. Some inconsistencies in source measurements in the 1973 study also need to be resolved, since errors in this input measurement to existing models are magnified by a factor of seven in the deposition results. It is contended that large droplets (>900 um) constitute a significant fraction of the total drift and must be accounted for in future measurements. Based on the results of the previous study, a new test plan and measuring method have been formulated and are outlined. It is believed that the extensive measurements of the new study will provide reliable data in quantity for a better statistical analysis that will enhance the formulation of a credible drift model. (Auth)

<490>

Drift Model Development and Validation.
Chapter 3, Environmental Assessment of Chalk Point Cooling Tower Drift and Vapor Emissions. Potomac Elec. Power Co. Prepared by Johns Hopkins Univ. for Maryland Power Plant Siting Program, March 1979. 16 pp.

Chapter describes a saline drift model developed by the Applied Physics Laboratory of Johns Hopkins University (APLSD or APL-JHU model) to provide estimates of salt deposited in the area surrounding the Chalk Point Generating Station, Prince Georges County, MD. Model, structured for impact studies, is designed to be used in conjunction with a large meteorological data base so that meteorological cases can be considered and results tabulated as a function of range and direction from the tower. Model consists of 2 main submodels, the vapor plume behavior and the drift transport and deposition submodels, which, along with input and output routines, the control structure, and a variety of support routines, form the complete model. Document states that the model may also be used with large data bases as a tool for study of variations in plant operating conditions. Chapter contains 3 figures, 4 tables, and references.

<491>

Why Froude Number Replication Does Not Necessarily Ensure Modeling Similarity.
1978
Frick, W.; Winiarski, L.D.
Waste Heat Management and Utilization Conference, Prodeedings of the
Second Symposium, Coral Gables, FL December 1978, 9 pp.

It is commonly assumed that Froude number replication ensures similarity between fluid phenomena prototypes and their fluid models. It is generally assumed that equivalent predictions will result when equal Froude numbers and dimensionless coordinates are used. However, the nonlinear density behavior of many fluids as functions of temperature, salinity or water vapor proves this assumption to be false, and the discrepancy is not trivial. A buoyant plume in water may not behave the same as a buoyant plume in air even if both have the same Froude number as defined above. There can be a noticeable difference between plumes in the same medium with the same Froude number but at different temperature conditions. For example, a horizontal water plume at 40 degrees C in stagnant water of 0 degrees C rises only briefly before sinking, while another water plume at 40 degrees C in ambient water of 20 degrees C with the same Froude number rises monotonically. The implications for various plumes and outfalls are numerous. The explanation for this behavior is the subject of this paper.

<492>

A Method to Measure Drift Deposition from Saline Natural Draft Cooling Towers.
Atmospheric Environment 11:123-130
1977
Isreal, G.W.; Overcamp, T.J.; Pringle, W.J.B.
Technical University of Berlin, Berlin, Germany
Clemson University, Department of Environmental Systems Engineering,
Clemson, SC
USAEHA-APED, Aberdeen Proving Ground, MD
Maryland Department of Natural Resources, Power Plant Siting Program

An automated drift sampler is described which collects drift with an efficiency of (94 + or - 3)% and a precision (1 S.D.) of 13% from saline water cooling towers. Sampler calibrations and drift deposition measurements were conducted in the vicinity of a brackish-water natural draft cooling tower at Chalk Point, MD. The drift deposition measurements are compared with drift deposition rates predicted from model calculations. Preliminary results show that measurements and model predictions exhibit the same trend in changes of drift size and deposition rate with increasing distance from the tower. With one exception the preliminary model over-estimates, however, the total deposition rates by a factor of two to ten. The experiments show that the samplers are suitable for collecting field data appropriate for testing and verification of drift dispersion models. (Auth)(ND)

<493>

Laboratory Experiments on the Motion of a Buoyant Plume in a Stratified Flow.
Second International Clean Air Congress, H.M. Englund and W.T. Berry, Proceedings of a Symposium, Washington, DC, December 6-11, 1970. Academic Press, New York City, NY, (p. 1018-1021), 1354 pp.
1970
Fay, J.A.; Hoult, D.P.; Hewett, T.
Massachusetts Institute of Technology, Cambridge, MA

The principles for modeling a buoyant turbulent plume are discussed and a method of sizing wind tunnels which will simulate flows having a degree of stratification comparable to that observed in field tests is outlined. The design and operation of the M.I.T. stratified flow tunnel and some results of tests with buoyant plumes are discussed. The stratified flow tunnel succeeded in providing the experimental data originally sought. Quantitative information for comparison with the theoretical models was obtained. Geometric similarity to field measurements of plume rise was clearly demonstrated. The minimum Reynolds number for similarity was also determined. The close agreement between model test and field experiment lends additional support for the contention that atmospheric turbulence does not play a significant role in plume rise phenomena. (ND)

<494>

Meteorological Measuring System of the Karlsruhe Nuclear Research Centre - Evaluation of Special Measurements to Determine the Seasonal and Daily Distribution of Long Cooling Tower Plumes.
Staub-Reinhalt. Luft 37(5):194-199
1977
Dilger, V.H.; Vogt, S.
Karlsruhe, Germany

The measurement program at Karlsruhe serves to record the atmospheric parameters which are relevant for the diffusion of offgas plumes and involves a total of 47 instruments. Measurements include wind velocity, wind direction, wind vector, temperature, dew point, global and thermal radiation, precipitation, and atmospheric pressure. An account is given of the methods of measurements, measurement accuracy and operating experience gathered during several years. As an example of the versatile application of the data stored, a statistical evaluation of humidity conditions is performed taking into account the length of visible cooling tower plumes. Work concentrates on the representation of the seasonal and daily distribution of situations during which the visible plumes get longer than 2.5 km. (ND)

<495>

Field Investigations of Mechanical Draft Cooling Tower Plumes.
EPA-600/7-77-025, 60 pp.
1977
Winiarski, L.D.; Frick, W.
U.S. Environmental Protection Agency, Corvallis Environmental Research
Laboratory, Assessment and Criteria Development Division, Corvallis,
OR
U.S. Environmental Protection Agency, Office of Research and
Development

Tethered kitoon (small blimp) sampling techniques were divised to measure the distribution of temperature and humidity in the invisible portion of power plant cooling tower plumes. Corresponding ambient and efflux data were also taken. Measurements were made on plumes from both single cell and multiple cell cooling towers under several conditions at the Turkey Point Plant, Florida; Comanche Power Plant, Colorado; and (Duke) Cliffside Power Plant, North Carolina. The plume data can be used to verify various modeling techniques. (ND)

<496>

The Oak Ridge Fog and Drift Code (ORFAD) User's Manual.
ORNL/TM-5201, 122 pp.
1977
LaVerne, M.E.
Oak Ridge National Laboratory, Energy Division, Oak Ridge, TN

ORFAD is a computer program written for the purpose of providing estimates of fog and salt drift resulting from the operation of wet cooling towers in the vicinity of a power plant. The program uses hourly weather data from tapes. Several modifications have been made in the program since the first publication, most notably in the method employed for drift calculation. The physical and calculational models are described, and detailed instructions are given for input preparation and running the program. A program listing and sample output are appended. (Auth)(ND)

<497>

Measurements at Cooling Tower Plumes. Part 1. Mathematical Simulation and Importance of Measurement.
JUL-1250, Part 1, 113 pp.; ANL-Trans-1115, 95 pp.
1976
Gassmann, F.; Haschke, D.; Solfrian, W.
Kernforschungsanlage, Juelich, Germany

Assumptions and approaches presently used in model conceptions are summarized which can lead to mathematical models for the simulation of dry or wet cooling tower plumes. Important spreading models and the interaction between measurement data and model computation are described. The selection of the measurement methods as well as the scope and process of the various measurement campaigns are outlined. A one-dimensional plume model (FOG) is developed to consider the important problems in detail. It is shown that for the calibration of the necessary parameters as well as for the development of models full scale measurements are important. (ND)

<498>

A Note on the Geometry of Plume Diffusion Measurements.
Atmospheric Environment 10:655-658
1976
Millan, M.M.
Environment Canada, Atmospheric Environment Service, Downsview,
Ontario, Canada

In plume diffusion studies, the researcher is often confronted with the problem of deciding how well his data represents actual instantaneous or average plume cross-sections. In particular, there are limits to the geometry of plume measurements beyond which commonly used techniques for the projection of profiles yield unrealistic results. This note proposes a projection scheme, and criteria for various transect geometrics, such that the derived plume profiles do not deviate from the actual profile beyond acceptable limits. (Auth)

<499>

A Plume Management Model.
Journal Air Pollution Control Association 26(7):679-680
1976
Nagy, G.
Ontario Ministry of Environment, Air Resources Branch, Ontario, Canada

A plume management model is described which is designed to provide a permanent daily record of emitted plumes analogous to accounting records and useful for further analyses by various investigators. The plume management record is defined as a one hour period for which the following plume characteristics are computed and displayed: (1) trajectory of the plume centerline in Universal Transverse Mercator coordinates, (2) wind speed and direction; (3) precipitation; (4) ground level pollutant concentration; (5) maximum possible washout; (6) plume height; and (7) plume depth and plume width. The cost of preparing plume records is estimated at less than $50 per record. (ND)

<500>

Measurements at Cooling Tower Plumes. Part 2. Lidar Measurements at Cooling Tower Plumes.
JUEL-1250, Part 2; EIR Report No. 302; ANL-Trans-1116, 54 pp.
1976
Borchardt, H.; Gassmann, F.; Haschke, D.; Rudin, F.; Trepp, J.P.
Juelich Nuclear Research Center

The use of Lidar-Systems to detect the plumes of dry or wet cooling towers showed definite advantages compared with other measuring techniques. Two test measurements with the Lidar-Systems of the DWD Meteorological Observatory Aachen (BRO) are described. The measurements of the dry cooling tower plume at the Preussag power station Ibbenburen (BRO) showed that the smoke produced by a few smoke candles was a good Lidar-tracer for the warm air. Fortran programs for the transformation of the Lidar signals into reflectivity isolines are discussed with reference to the results from the wet cooling tower plume measurements of the RWE power station Weisweiler I (BRO). This is the second part of a four-part series concerning measurements at cooling tower plumes; the first part dealt with the mathematical simulation of cooling tower plumes; the third described three-dimensional measurements at cooling tower plumes; and part four presented selected data from the three dimensional measurements at cooling tower plumes. (ND)

<501>

Chalk Point Cooling Tower Project: Comprehensive Project Status Report for the Period July 1, 1974 - October 1, 1975. Final Report FY'75 Salt Drift Measurement and Modeling.
PPSP-CPCTP-9, Vol. 1 of 2, 135 pp.
1976
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program
U.S. Energy Research and Development Administration
Electric Power Research Institute
Potomac Electric Power Company

This volume describes the experimental effort over the period July 1, 1974 through October 1, 1975 relative to data acquisition and analysis for the selection and validation of a practical salt drift transport model in the assessment of the environmental impact of the Chalk Point Cooling Tower. Included are current discussions of instrumentation and equipment, data requirements and data acquisition techniques, and data reduction and analysis. Volume 2 contains the preliminary data taken during the period described in Volume 1. Volume 3 will document the experimentation and data of the Initial Characterization of the cooling tower. (ND)

<502>

Droplet Size of Cooling Tower Fog.
Environmental Letters 10(3):191-203
1975
Rothman, T.; Ledbetter, J.E.
U.S. Air Force
The University of Texas at Austin, Department of Civil Engineering,
Austin, TX

Fog from cooling towers causes problems of visibility and icing along roadways adjacent to the towers; moreover, the visible plume from the towers offers difficulty in that it is equated by much of the public with air pollution. Knowledge of the size of the fog droplets is necessary in order to plan abatement procedures and to determine the airborne lifetimes of such fogs. A new method to evaluate fog droplet size is described. The methodology involved capturing the droplets from a model induced draft counter-flow cooling tower on slides coated with a vaseline-mineral oil mixture, making photomicrographs of the droplets, counting and sizing the droplets into eight droplet diameter increments; namely, less than 5 um, 5-10 um, 10-20 um, 20-40 um, 40-60 um, 60-80 um, 80-100 um, and greater than 100 um. The resulting distribution was similar to that for natural fogs and clouds; i.e., it was bi-modal, the first mode at less than 5 um containing the vast majority of the droplets, and the second at 20-40 um. This study agrees with others that the size distribution of a fog in a saturated environment is continuously changing, with the smaller droplets tending to evaporate and the larger ones tending to grow, thus shifting the second mode toward larger sizes. (Auth)(ND)

<503>

An Analytical Search for the Stochastic-Dominating Process in the Drift-Deposition Problem.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 483-500), 638 pp.; BNWL-SA-4888, 25 pp.
1975
Slinn, W.G.N.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Atomic Energy Commission

The random processes in the drift deposition problem are examined separately to see if any one of them dominates the statistical properties of the outcome. The three prime candidates are assumed to be the drop size distribution, the distribution of breakaway points, and turbulent diffusion. It is seen that the drop size distribution probably has dominant influence on the deposition of the large-size (drift or carryover) drops. Turbulence has a comparable influence on the deposition of the small drops for downwind distances of the order of 10 tower heights and then dominates for large downwind distances, provided the atmosphere is not stable. Uncertainties in details of how the drops break free from the updraft of the plume preclude an accurate evaluation of this effect and seriously limit the accuracy of any drift deposition prediction. More field data are needed to remedy this. (Auth)

<504>

Experience with Combined Wind Tunnel-Plume Model Analysis of Cooling-Tower Environmental Impact.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 265-290), 638 pp.
1975
Bogh, P.
Motor-Columbus Consulting Engineers Inc., Baden, Switzerland

At moderate and strong wind conditions, the behavior of cooling tower plumes is influenced by aerodynamic effects due to the tower structure itself, nearby buildings, irregularities in the landscape, etc. For a single natural draft cooling tower, the mathematical plume models adopted in Switzerland and Germany could be changed to fit these conditions by empirical equations, determined after field tests at a cooling tower in service in Germany. For more complicated cases, as for mechanical draft cooling towers, or plants with a high tower-type boiler house, etc., wind-tunnel experiments are normally necessary. About 50% of the sites for large power plants may require the combined environmental evaluation by wind-tunnel and plume-model analysis, as described here for the two 1300-MW(e) units of the nuclear power plant Biblis, in Germany, and others. The complete evaluation procedure for classification of the meteorological data, statistics, plume- and impact-model calculations, wind-tunnel simulations, and feedback of all data in the evaluation program is discussed. (Auth)

<505>

Atmospheric Dispersion and Deposition of Saline Water Droplets.
M.S. Thesis, 70 pp.
1976
Tompkins, D.M.
University of Maryland, Department of Civil Engineering, College Park,
MD
Maryland Department of Natural Resources, Power Plant Siting Program

The deposition of simulated drift was experimentally determined by releasing saltwater droplets as a point source and collecting them on Whatman filter paper at ground level. As a partial test of cooling tower drift deposition theory, twenty droplet deposition experiments were conducted in which simulated cooling tower drift was released from an elevated point source. A vibrating capillary type droplet generator was suspended from a 12.2 meter instrumented tower to provide a controlled (drop size) source of simulated drift. The simulated drift was collected on an array of filter papers at ground level. After photo-chemical treatment of the filter papers, the droplets deposited on each filter were counted. Determination of the actual size of generated and deposited droplets was made possible by a calibration curve developed for Whatman and Millipore Filters relating droplet size to stain size. Instruments mounted on the tower measured wind speed and temperature (delta T) at two levels. A wind vane and a vertically mounted anemometer were used to estimate dispersion parameters (horizontal crosswind) and vertical standard deviations. The deposition data were compared to a non-dimensionalized prediction equation and good correspondence between theory and experiment was found. (Auth)(ND)

<506>

Cooling Tower Plume Measurements.
International Conference of Environmental Sensing and Assessment, Proceedings of a Symposium, September, 1975, Vol. 2, 1-4
1975
Winiarski, L.; Frick, W.; Tichenor, B.
U.S. Environmental Protection Agency, Corvallis Environmental Research
Laboratory, Corvallis, OR

A novel plume sampling technique was devised in order to measure the distribution of temperature and humidity in the INVISIBLE portion of a cooling tower plume. Studies with a baloon/radiosonde device were made at the Turkey Point Power Plant's mechanical draft (salt water) cooling tower and the Comanche Power Plant's freshwater cooling tower. These measurements, together with simultaneous measurements of the local meteorology and the exit plume conditions, are particularly useful in moist plume modeling work. The data were reduced to a series of plots to show the temperature and mixing ratio (grams of water per kilogram of air) as a function of the height above the ground. Data on the tower effluent including velocity, temperature and particle size distribution were also collected. These coupled with the onsite wind speed as well as the temperature and humidity data taken above and below the plume, gave a complete data set of the pertinent factors governing moist plume behavior. (ND)

<507>

Prediction and Measurement of Airborne Particulate Concentrations from Cooling-Device Sources and in the Ambient Atmosphere.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 455-482), 638 pp.
1975
Schrecker, G.O.; Wilber, K.R.; Shofner, F.M.
Environmental Systems Corporation, Knoxville, TN

Sensitivity of drift-particle mineral-residue transport calculations to source and meteorological parameters is discussed. Emphasis is on identification of those source parameters for which good experimental input data for transport models are needed. Estimates for the ranges and accuracies required for these parameters are given for representative natural and mechanical draft cooling towers and spray module systems. Principles, operating procedures, and accuracies for the Airborne Particle Sampler system are reviewed and compared briefly with other techniques. Application of the system to measurement of ambient salt levels at the Forked River Power Plant is described. (Auth)

<508>

Salt Drift Model - Description.
Appendix C, The Sterling Power Project, Cooling Tower Report. Prepared by Rochester Gas & Elec. Corp., 1974. 36 pp.

Appendix describes the salt drift model used to predict the environmental effects of a natural draft cooling tower considered as an alternative cooling system at the proposed Sterling nuclear plant site in Cayuga County, NY. Assumptions and variables adapted to the mathematical modeling include washout by rain, ice formation, wind interaction with tower wake, and salt deposition.

<509>

Measurements at Cooling Tower Plumes. Part 3. Three-Dimensional Measurements at Cooling Tower Plumes.
JUEL-1250, Part 3; ANL-Trans-1117, 82 pp.
1975
Fortak, H.
Juelich Nuclear Research Center

Cooling tower plumes were studied by means of a three-dimensional in situ measurements using high resolution aerology and small aircraft. The purpose of the study was to obtain input data for numerical models of cooling tower plumes, particularly data for testing or developing assumptions for sub-grid parameterizations. Four measuring campaigns were conducted: two campaigns (1974) at the cooling towers of the RWE power station Neurath and also two (1975) at the single cooling tower of the RWE power station Meppen. Because of the broad spectrum of weather situations it can be assumed that the results are representative with regard to the interrelationship between structure of cooling tower plume and large-scale meteorological situations. Aerial flights showed that the plume could be identified up to large downwind distances by discontinuous jumps of temperature and vapor pressure. In all cross sections a vertical circulation could be observed. At the plume boundary a maximum of downwind vertical motion could be observed in most cases. Entrainment along the boundary of a cross section seemed to be very small, except at the lower part of the plume. There, the mass entrainment is maximum and is responsible for plume rise as well as for enlargement of the cross section. The visible part of the plume was only a small fraction of the whole plume. The discontinuities of temperature and vapor pressure showed that the plume fills the space below the visible plume down to the ground. All effects decrease rapidly approaching the ground. High resolution aerology was necessary to explain the structure and behavior of such plumes. This was especially the case in investigations regarding the dynamic break-through of temperature inversions. Such cases were observed frequently under various meteorological conditions and are described. (Auth)(ND)

<510>

Determination of Salt Deposition Rates from Drift from Evaporative Cooling Towers.
Journal Engineering Power (Transactions ASME) 96(3): 283-291; American Society Mechanical Engineers, Paper No. 74-PWR-C

1974
Hosler, C.L.; Pena, J.A.; Pena, R.
The Pennsylvania State University, Department of Meteorology,
University Park, PA

A method for estimating the deposition rate of the salt ejected in drift drops from a cooling tower in which saltwater is circulated is described. The surface over which the salt will be distributed depends upon the wind speed, the maximum height the drops can reach, and the drop fall velocities. The drop fall velocity changes because of the evaporation in the air outside of the plume. The rate and extent of the evaporation is a function of the drop size, salt concentration, and ambient relative humidity. Three degrees of evaporation have been considered: (1) no evaporation; (2) evaporation to saturated solution and (3) evaporation to dry salt particles. For each degree of evaporation a graph was constructed that permits determination of the distance from the tower at which the salt contained in given drop size will fall. To use these graphs, the salt concentration, wind speed, and the maximum height a drop can reach must be known. The choice of the graph to be used for a particular case is made on the basis of humidity data for the site and the drift drop size. Corrections to compensate for the errors introduced by some of the assumptions are presented. (Auth)

<511>

Cooling Tower Drift: Experiment Design for Comprehensive Case Study.
Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 48-58), 320 pp.; ORNL/TM-6248;
1978
Laulainen, N.S.
Battelle Pacific Northwest Laboratories, Atmospheric Sciences
Department, Richland, WA
U.S. Department of Energy

Work has begun to develop a data base which can be used for validation of drift deposition models for mechanical draft cooling towers. Data will include measurements of the source characteristics and the meteorological conditions responsible for transport and dispersion of the cooling tower plume containing the drift component, and measurements of the downwind deposition and air concentrations of drift. A comphrensive experimental effort is planned for early spring 1978. The importance of study accuracy and experimental design is discussed. (ND)

<512>

Chalk Point Cooling Tower Project: Chalk Point Meteorological Station Report for the Period July 1, 1978 - November 30, 1978.
PPSP-CPCTP-26, 23 pp.
1979
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, power Plant Siting Program

Operation, maintenance, calibration, data acquisition, and data reduction at the Chalk Point Meteorological Station for the period July 1, 1978 to November 30, 1978 are reported. The meteorological tower system was checked and calibrated on a regular basis during the period and monthly progress reports generated. Problems experienced with the operation of the station are identified and discussed, with recommendations for FY79 given. Climatological data summaries for each month and calibration data are included together with the meteorological systems data recovery for the period. (Auth)

<513>

Predicted and Observed Cooling Tower Plume Rise and Visible Plume Length at the John E. Amos Power Plant.
ATDL Contribution File No. 75/21, 33 pp.; Atmospheric Environment 10:1043-1052; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1975 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 509-551), 590 pp.; ATDL-76/14
1975
Hanna, S.R.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

A one-dimensional numerical cloud growth model and several empirical models for plume rise and cloud growth are compared with twenty seven sets of observations of cooling tower plumes from the 2900 MW John E. Amos power plant in West Virginia. The three natural draft cooling towers are 200 m apart. In a cross wind, the plumes begin to merge at a distance of about 500 m downwind. In calm conditions, with reduced entrainment, the plumes often do not merge until heights of 100 m. The average plume rise, 750 m, is predicted well by the models, but day-to-day variations are simulated with a correlation coefficient of about .5. Model predictions of visible plume length agree, on the average, with observations for visible plumes of short to moderate length (less than about 1 km). The prediction of longer plumes is hampered by our lack of knowledge of plume spreading after the plumes level off. Cloud water concentrations predicted by the numerical model agree with those measured in natural cumulus clouds (about .1 g/kg to 1 g/kg). (Auth)

<514>

Observed and Predicted Cooling Tower Plume Rise at the John E. Amos Power Plant, West Virginia.
ATDL Contribution File No. 76/6; Atmospheric Turbulence, Diffusion and Air Quality, Proceedings of the Third Symposium, Raleigh, NC, October 26-29, 1976. American Meteorological Society, Boston, MA, (p. 571-575); Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1976 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 239-244), 627 pp.; ATDL-77/23;

1976
Hanna, S.R.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

The predictions of a one dimensional plume and cloud growth model are compared with observations of cooling tower plume rise at the John E. Amos power plant. The model uses Weinstein's, 1970, one dimensional cloud growth model as a basis but alters its entrainment assumption so that it agrees with known relations for the rise of buoyant stack plumes. Four aspects of the model have been improved over previous versions. Average model and observed plume rise were in fair agreement. (ND)

<515>

Laboratory Experiments to Check Cooling Tower Computer Models.
Nuclear Technology 28:172
1976
Werle, H.
Kernforschungszentrum Karlsruhe, Institut fur Neutronenphysik und
Reaktortechnik, Germany

Similarity theory shows that some essential features of cooling tower plumes can be simulated in laboratory experiments. Therefore, such experiments should be used to check computer models, which are used to estimate the environmental effects of cooling towers. The final validation with field data can then be confined to more integral data for a limited number of cases. (Auth)

<516>

The Chalk Point Dye Tracer Study: Validation of Models and Analysis of Field Data.
Waste Heat Management and Utilization, Proceedings of a Symposium, Miami Beach, FL, December 4-6, 1978. S.S. Lee and S. Sengupta (Eds.), 34 pp.
1978
Policastro, A.J.; Dunn, W.E.; Breig, M.; Ziebarth, J.P.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
University of Illinois, Department of Mechanical and Industrial
Engineering, Urbana, IL
Electric Power Research Institute

Predictions of ten drift deposition models are compared with field data taken during the Chalk Point dye tracer study of June 1977. The ESC/Schrecker, Hosler-Pena-Pena, and Wigley-Slawson models compared most favorably with the deposition data from the cooling tower alone and are generally within the error bounds of the data. Most models predict larger drop diameters at deposition than were measured. No model predicted each of the deposition parameters consistently within a factor of three. Predictions of stack deposition compared rather poorly with the stack deposition data probably due to the lack of good information on exit conditions. A comparison of Johns Hopkins University (JHU) and Environmental Systems Corporation (ESC) ground-level drift data showed that the JHU data had larger drop size ranges yet both sets of data agreed quite well in the intermediate drop size range. The JHU methodology appears superior since their data were more internally consistent and their technique of using large sensitive paper samplers and counting all drops on the paper yields a greater statistical accuracy. (Auth)

<517>

Modeling Analysis of the Chalk Point Dye Tracer Experiment.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 119-126), 462 pp.
1978
Davis, E.A.; Moon, M.L.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD

The drift deposition data collected in the 1977 Dye Tracer Experiment of the Chalk Point Cooling Tower Project has been analyzed for its variation as a function of position and compared to the predictions of several models including a trajectory model of the Hosler-Pena-Pena type, a recent version of the Overcamp trajectory model with Gaussian dispersion of droplets and an incremental trajectory simulation developed at APL. The tower and meteorological conditions during the five hour experiment were reasonably constant except for a marked shift in wind direction about half way through the collection of ground deposition data. Despite this variation, the total deposition data at both the 500 and 1000 meter downwind receptor arrays show very nearly Gaussian crosswind variation with standard deviations of 74 meters and 143 meters respectively. To remove the wind variation the deposition data have been integrated over each receptor array giving an estimated total salt deposition of 1.2 x 10(E+6) kg/km(E+2) -month at 500 meters and of 0.60 x 10(E+6) kg/km(E+2)-month at 1000 meters. After tuning to the observed plume rise, model predictions have been compared to these values and to their ratio as a test of each model's capability to predict deposition rates as well as downwind variation of deposition. The differences in model predictions are to be explained in terms of the various modelling assumptions and representations of plume rise, droplet trajectory and ground deposition. In addition each model is being modified to provide the predicted droplet size spectra at the ground receptor locations so that comparison with the observed spectra can be made. This will provide a more stringent test of each model's capability to predict the results of the drift deposition process. (Auth)

<518>

Chalk Point Cooling Tower Project: Cooling Tower Drift Dye Tracer Experiment June 16 and 17, 1977.
PPSP-CPCTP-16, Vol. 2 of 3, 95 pp.; PB-284 059/3WE, 95 pp.
1977
Meyer, J.H.
The Johns Hopkins University, Applied Physics

Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

A drift dye tracer experiment was conducted on airborne drift from the natural draft cooling tower at PEPCO's Chalk Point Power Generating Station. The experiment was designed to determine the degree to which positive identification of aerosol deposition from the cooling tower is possible and to provide a data base for use in the estimation of salt loading from the cooling tower and in model validation. Laboratory tests to establish proof of principle, environmental safety, and chemical controls for the use of the dye were conducted. The only limitation for the rhodamine dye was its chemical decomposition in the presence of ultraviolet radiation, requiring that the test be conducted at night. Analysis of the deposition data from the field test indicated that positive identification can be made of deposition from the natural draft cooling tower in the presence of significant salt deposition from the boiler stack and background sea salt. It has been concluded that the use of a unique tracer to identify the cooling tower drift is of value and that Rhodamine (WT) provides such a tracer which can be used successfully under carefully controlled conditions. (Auth)(ND)

<519>

Chalk Point Cooling Tower Project: Chalk Point Meteorological Station Report July 1, 1977 - June 30, 1978.
PPSP-CPCTP-25, 45 pp.
1978
Environmental Systems Corporation, Knoxville, TN
Maryland Department of Natural Resources, Power Plant Siting Program
U.S. Energy Research and Development Administration
Electric Power Research Institute
Potomac Electric Power Company

The operation, maintenance, calibration, data acquisition, and data reduction at the Chalk Point Meteorological Station for the period July 1, 1977 to June 30, 1978 are documented. The meteorological tower system was checked and calibrated on a regular basis during the year and monthly progress reports generated. Problems experienced with the operation of the station are identified and discussed, milestones are noted, and recommendations for FY79 given. Climatological data summaries for each month of the year and calibration data are included together with the meteorological systems data recovery for the period. (Auth)

<520>

Data Requirements and Their Implications Relative to the Experimental Design for Chalk Point.
Chalk Point Cooling Tower Project Task Report: Experimental Design Analysis, (p. 17-52), 52 pp.
1976
Moon, M.L.; Meyer, J.H.; Eagles, T.W.
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The completeness of the proposed Chalk Point Cooling Tower data acquisition program, instrumentation accuracy and the characteristics of the data as related to the statistical adequacy fo. use in the intended modeling analysis are reviewed. Cooling tower emission data include updraft velocity, drift droplet/number density distribution, drift mass, drift droplet salinity, basin water salinity, temperature, absolute humidity, and liquid water content. Supporting data for the above includes plant electrical load, cooling water circulation rate, inlet water temperature, outlet water temperature, makeup water rate, makeup water temperature and blowdown rate. Plume rise data should include plume photography, plume temperature and ambient temperature near the plume, plume humidity and ambient humidity, plume vertical vorticity, liquid water content, plume salt drift size/number density distribution, radiosonde and pibal data, insolation cloud cover, and ceiling, and meteorological conditions. Visible plume monitoring should include plume photography, and aircraft measurements. Methods and problem areas for measurements are discussed. (ND)

<521>

A Simple Drift Deposition Model Applied to the Chalk Point Dye Tracer Experiment.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 105-118), 462 pp.
1978
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN

The Chalk Point Dye Tracer Experiment provided accurate measurements of Na drift deposition at the ground due to emissions from the cooling tower. Na deposition over a 30 degree arc on the ground at distances of .5 km and 1.0 km from the tower was found to be 1080 and 330 kg/km(E+2)-month respectively. Mass median drop diameters on the two arcs were 340 um and 260 um, respectively. The necessary cooling tower and atmospheric parameters that must be used in the application of a drift deposition model were also measured. A simplified drift deposition model was used to satisfactorily predict drift deposition using the dye study data. Drift drop evaporation was neglected in a model of drift deposition applied to this experiment, because the ambient relative humidity was 90% or greater from the surface up through plume height. The plume trajectory was calculated by the usual 2/3 law. The fraction of drift in each drop size class which breaks away from the plume in each downwind distance increment delta x was assumed to equal v(d) (delta x/u)/2R, where v(d) is the fall velocity of the drops, R is plume radius, and u is wind speed. A straight ballistic trajectory was then used to calculate the point at which the drops in a given class, released from a given delta x interval, strike the ground. Based on the observed wind meandering, an arc width of 30 degrees was chosen for the pie-shaped deposition pattern. The calculated Na deposition rate is 3600 kg/month km(E+2) at x = .5 km, and 800 kg/month km(E+2) at x = 1 km, or about a factor of three greater than the observed Na deposition rate. Predicted mass median drop diameters on the two arcs were 470 um and 290 um, respectively, which are within 50% of the observed values. (Auth)(ND)

<522>

Chalk Point Cooling Tower Project: Salt Loading, Modeling and Aircraft Hazard Studies.
PPSP-CPCTP-16, Vol. 1 of 3, 359 pp.; PB-284 058/5WE, 359 pp.
1977
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

Experiments were conducted to support the studies being performed at the Chalk Point cooling towers. A water soluble dye was used as a tracer for cooling tower drift to provide unambiguous identification of salt drift originating from the natural draft cooling towers. Initial data reduction indicates that the data obtained is of excellent quality, and suitable for subsequent use in drift model validation. This experiment is reported in Volume 2 of PPSP-CPCTP-16. A preliminary estimate of salt loading impact due to drift from the cooling tower indicates that the annual salt loading is a maximum of 64 kg/hectare at a distance of approximately 0.5 km from the tower and less than 5 kg/hectare at all off-site locations (on land). It is tentatively concluded that the cooling tower poses no threat to commercial agriculture. A comparative study of various drift models was made and an input parameter sensitivity analysis was conducted. Sensitivities to drop size distribution and uncertainty in various input data errors was conducted and is reported. A tentative selection of the Isreal-Overcamp model and the APL models for further detailed use in the model validation program is described. The possible hazard which the cooling tower plume may pose to aircraft flight has been investigated. It is concluded that hazard due to low visibility and aircraft engine or airframe icing is negligible. (Auth)(ND)

<523>

Meteorological Aspects of the Chalk Point Cooling Tower Study.
Chalk Point Cooling Tower Study, R.L. Green, (p. 3-22), 42 pp.
1973
Isreal, G.W.; Overcamp, T.J.
University of Maryland, Meteorology Program, College Park, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The objectives and present status of the three phases of the meteorological aspects of the Chalk Point Cooling tower study are discussed. The research topics include making a preliminary estimate of the salt deposition that can be expected from the cooling tower to help agronomists set up test plots in areas of maximum deposition rates, evaluating present drift dispersion models and determine the sensitivity of these models to various atmospheric parameters, and planning a sampling program that will allow the verification of drift dispersion models. Calculations of drift deposition showed large deposition rates near the tower decreasing to about 1 kg/m(E+2)-month at distances of 10 km from the ' wer. Present models need to be verified through extensive and well-planned field tests to determine their important features and develop plume rise formulas for cooling towers. The data that is needed includes drift rate, actual droplet size distribution, local meteorology. (ND)

<524>

Verification of Cooling Tower Salt Drift Models at Chalk Point.
Chalk Point Cooling Tower Project Task Report: Experimental Design Analysis, (p. 1-16), 52 pp.
1976
Isreal, G.W.; Overcamp, T.J.; Weil, J.C.; Meyer, J.H.; Eagles, T.W.
University of Maryland, College Park, MD
Clemson University, Clemson, SC
Martin-Marietta Corporation
The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD
Maryland Department of Natural Resources, Power Plant Siting Program

The necessary data base for Chalk Point cooling tower emission models validation and the outline of a field program which could provide this data base and gaps in the present data collection program are discussed. Model errors are caused by inaccuracy of input parameters and inadequacies of the model in representing the behavior of the plume and the atmosphere. In the experimental field program the model input parameters must be determined as accurately as possible and the accuracy of all data must be established. The program should include measurements of tower exit parameters, atmospheric conditions, vapor plume, and salt drift. (ND)

<525>

A Guide to Mathematical Models Used in Steam Electric Power Plant Environmental Impact Assessment.
FWS/OBS-78/01, 153 pp.
1978
Bloom, S.G.; Cornaby, B.W.; Martin, W.E.
Battelle Columbus Laboratories, Columbus, OH
U.S. Department of the Interior, Fish and Wildlife Service

This guide provides a nontechnical overview of modeling approaches for predicting and assessing environmental impacts of steam electric power plant operation on fish and wildlife resources. Process models, hydrodynamic models, aquatic dispersion models, atmospheric dispersion models, biological transfer models, and biological effects models are described. The three atmospheric dispersion models described are the Oak Ridge Fog and Drift (ORFAD) Model, the Cooling Tower Plume Rise Model, and the Reactive Plume Atmospheric Dispersion Model. The ORFAD Model is a combination of relatively simple plume rise and far-field models that are applied toward estimating fog and suspended water concentrations resulting from the operation of wet cooling towers. It also estimates the deposition of suspended water on the ground. The Cooling Tower Plume Rise Model also concentrates on the dispersion of water, however, it is of the near-field type. The Reactive Plume Atmospheric Dispersion Model is a more detailed combination of plume rise and far-field models which includes the ability to treat reacting materials and very dense materials (for which the plume sinks rather than rises). Model predictions, interpretation, limitations, and influencial factors are described for each of the models.

<526>

Some Developments in Plume and Drift Deposition Modeling Since 1974.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. III 1-23), 462 pp.
1978
Brog, P.; Hofmann, W.; Sutter, H.; Von Euw, H.M.; Fuchs, H.
Motor-Columbus Consulting Engineers Inc., Baden, Switzerland

New developments by Motor-Columbus in cooling tower plume modeling in Switzerland are described. The need to investigate the impact of multiple unit sites, cell-type towers or notable contributions from moisture emitted from stacks prompted the development of a multiple source program KUMULUS as a successor to SAUNA-S. The environmental effects considered include plume dimensions, shadowing, ground temperature and humidity, precipitation, drift deposition and interaction with stack emissions. Up to 100 sources can be taken into account such as wet, dry or hybrid cooling towers or stacks. Atmospheric conditions are taken from radiosoundings. Peripheral programs for the selection of representative soundings and for isocurve representations of environmental impacts are described. The main features of a refined drift deposition model BIG BEN are given. Wind tunnel experiments are required to determine aerodynamic effects of the cooling tower on the dispersion of stack emissions. A KUMULUS subroutine describes the phenomena occurring in the case of stack and vapor plume mixing mainly in terms of droplets carrying some of the stack emissions towards the ground. (Auth)(ND)

<527>

Methods of Improving Plume Models.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9; PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. II 1-13), 462 pp.
1978
Winiarski, L.D.; Frick, W.
Corvallis Environmental Research Laboratory, Corvallis, OR
U.S. Environmental Protection Agency

Nine key areas in plume modeling which are critical to better understanding of the process are identified. By making a few simple assumptions relating to plausible mechanisms for approximating plume behavior in these areas a plume model will obtain good agreement with a broad range of data without using adjustment coefficients. These areas are (1) mass, momentum and energy accountability; (2) wind momentum transfer to the plume; (3) plume aspirated entrainment; (4) wind induced entrainment; (5) projected area computation; (6) combined entrainment; (7) distribution of plume properties throughout the cross section; (8) moist plume visibility criteria; and (9) data comparison and interpretation. Each area is discussed. (Auth)(ND)

<528>

Evaluation of Droplet Evaporation Formulations Employed in Drift Deposition Models.
CONF-780533; PPSP-CPCTP-22, WRRC Special Report No. 9(Supplement); PB-284 149; Cooling Tower Environment-1978, R.S. Nietubicz and R.L. Green (Eds.), Proceedings of a Symposium, College Park, MD, May 2-4, 1978. Water Resources Center, University of Maryland, College Park, MD, (pp. 11-31), 90 pp.; Evaluation of Mathematical Models for the Prediction of Salt-Drift Deposition from Natural-Draft Cooling Towers, A.J. Policastro, et al., Appendix B. Argonne National Laboratory, Argonne, IL;
1978
Dunn, W.E.; Boughton, B.; Policastro, A.J.
University of Illinois, Department of Mechanical and Industrial
Engineering, Urbana, IL
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
Electric Power Research Institute, Palo Alto, CA

Six models commonly used to predict drift deposition from evaporative natural draft cooling towers are evaluated in terms of their formulation for droplet evaporation. The fundamental theory of droplet evaporation in an unsaturated atmosphere is reviewed and the different treatments of evaporation used by the models are compared with the exact formulation. The major discrepancies arise due to approximations to the droplet temperature. The best (nonexact) treatment of droplet evaporation of those tested is Mason's equation (employed in the Overcamp-Israel and Wigley-Slawson models) yielding differences from the exact solution which are generally less than 20%. The worst is the case of the drop temperature taken equal to the ambient dry-bulb temperature (employed in the Hanna drift model) yielding evaporation rates consistently too large by about 130%. To determine the range of difference between the predictions of the evaporation models for drift drops, a comparison is made of droplet trajectories as predicted by the models for a hypothetical case of a salt-containing drop released from a fixed height. It was found that (a) significant differences can exist among model predictions of distance to deposition, final diameter and final settling velocity, (b) these differences are generally smaller for the larger drop sizes, (c) model predictions are quite sensitive to changes in relative humidity at the relative humidities above 70%, but are fairly insensitive to changes below this value, (d) larger ambient temperatures and lower drop salt concentrations lead to larger distances to deposition. It was found that initial drop diameter is the most important parameter in determining deposition history. Ambient relative humidity is important in determining the final state of the smaller drops. General rules of thumb are provided for extreme behaviors such as deposition with little evaporation and deposition after near instantaneous evaporation. (Auth)

<529>

Critical Review of Wind Tunnel Modeling of Atmospheric Heat Dissipation.
BNWL-2221, 34 pp.
1977
Orgill, M.M.
Battelle Pacific Northwest Laboratories, Atmospheric Sciences
Department, Richland, WA
U.S. Energy Research and Development Administration

A critical review of the potential application of physical modeling (wind tunnels) to assess possible atmospheric effects from heat dissipation systems, such as cooling towers, is presented. A short inventory of low-speed wind tunnel facilities is included in the review. The useful roles of wind tunnels are assessed and the state-of-the-art of physical modeling is briefly reviewed in the report. Similarity criteria are summarized and present limitations in satisfying these criteria are considered. Current physical models are defined and limitations are discussed. Three experimental problems are scoped in which physical modeling may be able to provide data. These are: 1) defining the critical atmospheric heat load; 2) topographic and local circulation effects on thermal plumes; and 3) plume rise and downstream effects. (ND)

<530>

EPA's Cooling Tower Plume Research.
Journal Power Division (Proceedings ASCE) 103(PO1):1-13
1977
Shirazi, M.A.; Tichenor, B.A.; Winiarski, L.D.
U.S. Environmental Protection Agency, Corvallis Environmental Research
Laboratory, Corvallis, OR

The environmental effects of wet cooling towers, both potential and real, have been the subject of research investigations at the U.S. Environmental Protection Agency Laboratory in Corvallis, OR. Important aspects of this research are reviewed with special emphasis on the plume modeling efforts. Other areas of research discussed include (1) identification of the regions in the U.S. most susceptible to weather modification from cooling towers, (2) development of a better understanding of the heat and mass transfer occurring within a cooling tower and (3) development of instrumentation and methodologies for measuring cooling tower plume properties and drift emissions. The plume modeling effort is to examine current models and critically assess the physical assumptions involved, develop detailed single and multiple plume models applicable near the source, develop a less detailed model applicable to multiple tower units, and obtain the extensive laboratory and field data needed to assess one or combinations of more than one model for application. A brief description of completed and ongoing work at Turkey Point and Centralia power plants is given. (ND)

<531>

Cooling Tower Plume Modeling and Drift Measurement, A Review of the State-of-the-Art.
American Society of Mechanical Engineers, New York City, NY, 180 pp.
1975
Research Committee on Atmospheric Emissions and Plume Behavior from Cooling Towers
American Society of Mechanical Engineers

The present state-of-the-art for predicting and measuring characteristics of cooling tower plumes has been reviewed and summarized. Currently available methods are discussed and a critical evaluation of their applicability is reported. Recommendations for field data collection and future research are provided. A complete bibliography and subject index for the literature used in the study are included. It was concluded that no mathematical models exist that have been adequately validated by field measurements for a variety of tower types and meteorological conditions. However, several recent models for predicting visible plume height and length appears to give satisfactory results for particular source and climatological conditions when calibrated against appropriate data. A major problem in prediction of plume effects is characterization of the source; determination of aerodynamic effects and the combination of plumes from multiple sources. No demonstrated ability exists to accurately predict ground fog at large distances from towers or meteorological effects of large cooling tower complexes. No single model provides reliable drift predictions at present. Measurements of the properties of cooling tower emissions can be made with acceptable accuracy at present. Field programs to observe cooling tower emissions, plume properties and emission effects are recommended. (ND)

<532>

Meteorological Consequences of Thermal Discharges from Nuclear Power Plants-Research Needs.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 221-238), 638 pp.
1975
Carson, J.E.
Argonne National Laboratory, Environmental Statement Project, Argonne,
IL

Meteorologists in the U.S. Atomic Energy Commission's Environmental Impact Statement Program are required to make quantitative predictions of the effects of thermal discharges from proposed nuclear power plants on the atmospheric environment. Unfortunately the state-of-the-art in meteorological knowledge and modeling is not adequate to yield accurate predictions of atmospheric effects with the required degree of confidence. Hence research on the response of the atmosphere to the large quantities of waste heat and water vapor discharged from nuclear and fossil-fuel power plants by means of cooling towers, cooling ponds, and spray canals is urgently required. A comprehensive and critical review of the state of the art in meteorological information and modeling which can be used by the utilities and the regulatory agencies in their decision-making procedures is needed. This review should include a quantitative comparison of the various models not only with each other but also with the field data available. The primary need is a series of field studies at operational plants to determine exactly what a cooling tower does to the atmospheric environment and to provide data for the preparation and testing of mathematical models. Areas in which additional field measurements and research are most urgently required include (1) plume rise and the length of the visible plume from all types of cooling towers, (2) fogging and icing from cooling ponds and mechanical draft cooling towers, (3) drift and the effects of salt deposition, and (4) interaction of cooling tower plumes with other pollutants, especially SO2. The field observations should also define nonproblem areas; i.e., environmental objections to cooling towers which are raised by theoretical and other arguments but which are not observed, such as fogging and icing from natural draft cooling towers. (Auth)(ND)

<533>

Drift Deposition Model for Natural-Draft Cooling Towers.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 614-628), 638 pp.
1975
Isreal, G.W.; Overcamp, T.J.
University of Maryland, College Park, MD

A model to calculate salt deposition from (brackish or saltwater) natural draft cooling towers is presented. This model incorporates a method for estimating the effective height of emission of the drift droplets and the combined effects of sedimentation, evaporation, and dispersion of the droplets due to atmospheric turbulence. The major conclusions of the model are that the effects of turbulence must be incorporated to calculate correctly the deposition around the tower except for a very stable atmosphere. Sample calculations are presented to show the effects of the initial size of the droplets and the mean wind. (Auth)(ND)

<534>

Plume Rise: A Recent Critical Review.
Nuclear Safety 12(1):15-24
1971
Briggs, G.A.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN

The comparison of results of a large number of plume rise formulas and the conclusions of a lengthy critical review prepared for the Nuclear Safety Information Center in 1969 are summarized. Comparison of the plume rise observations and formulas indicated that a relatively simple model revealed the best predictions of plume rise in a variety of meteorological conditions. The model predicts that near the stack the rise of a hot, buoyant plume is proportional to the reciprocal of the wind speed, to the one-third power of the heat emission, and to the two-thirds power of the distance downwind. This two-thirds law of rise fits the bulk of published observations. Dependence on distance downwind gradually diminishes in neutral atmospheric conditions beyond the distance related to the heat emission and stack height. In stable conditions, rather abrupt leveling of plumes occurs at a distance dependent on the wind speed and the atmospheric vertical temperature gradient. The model was also applied to the prediction of whether a hot plume will penetrate an elevated inversion and was found to agree with observations. (Auth)(ND)

<535>

Generic Report on Atmospheric Effects of Evaporative Cooling Systems.
Progress Report August 1-October 31, 1976, 38 pp.
1976
Policastro, A.J.; Dunn, W.E.; Carhart, R.A.
Argonne National Laboratory, Argonne, IL

The acquisition and adaption of three more plume rise models and four drift deposition models has been completed for a project to compare and evaluate model predictions. Predictions of the ORFAD, Slawson-Coleman, and Hanna plume models have been extended to comparisons with Neurath data. The models of Weil, Frick, and Winiarski-Frick) have been compared to single-tower data at Lunen. The four drift-deposition models are compared to ground-level drift data taken at the Chalk Point Plant in Maryland. The results and limitations of the comparisons are discussed. The results of each of the comparisons are summarized. Preliminary results indicate that the single aspect of the various models that most affects predicted deposition rates is the droplet breakaway criterion used. Also, the Israel-Overcamp model appears to perform best and appears accurate to within an order-of-magnitude. (ND)

<536>

Progress Report Validation of Cooling Tower Plume Rise and Salt Drift Deposition Models: November 1, 1976 - January 31, 1977.
77 pp.
1977
Policastro, A.J.; Carhart, R.A.; Shobrys, D.; DeVantier, B.;
Dunn, W.E.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
U.S. Department of Energy

Acquisition and adaptation of plume rise models and salt drift deposition models to the Argonne National Laboratory IBM/370-195 computer were undertaken to allow model comparisons. Field data at the Paradise and Chalk Point cooling towers were used to make model/data comparisons of plume dispersion. Compared here are the Hanna (1-D Cloud), Slawson-Wigley, and ORFAD models to four of the thirteen Paradise data as well as those same models along with Weil, Frick, Winiarski-Frick, Batty-Lee, and Stone & Webster to all of the previously available Chalk Point Data. Five drift deposition models (ORFAD, Hanna, Slawson I, Isreal-Overcamp, Hosler-Pena-Pena) were compared to all the ground level drift data taken by Overcamp et al. at the Chalk Point Plant in Maryland. The results and limitations of the comparisons are discussed. A sensitivity analysis of the best-performing drift model (Isreal-Overcamp) to input conditions was also performed. The results of each area of model/data comparisons are compared.

<537>

Evaluation of Theory and Performance of Salt-Drift Deposition Models for Natural-Draft Cooling Towers.
Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, Proceedings of a Symposium, K. Torrance and R.S. Watts (Eds.), Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, 12 pp.
1978
Policastro, A.J.; Dunn, W.E.; Breig, M.; Ratcliff, M.
Argonne National Laboratory, Division of Environmental Impact Studies,
Argonne, IL
University of Illinois, Department of Mechanical and Industrial
Engineering, Urbana, IL
U.S. Nuclear Regulatory Commission
Electric Power Research Institute

Significant variability exists among the predictions of various mathematical models formulated to predict drift deposition patterns surrounding large natural draft cooling towers. This paper provides insights into which of the alternative formulations give the best results, although, in comparisons with field data acquired recently at the Chalk Point Power Plant, none of the existing models performed well. The sensitivity of model predictions with field data taken at Chalk Point are evaluated. Areas for future improvement are identified. (Auth)(ND)

<538>

A Review of Cooling Tower Drift Deposition Models.
ORNL/TM-5357, 99 pp.
1977
Chen, N.C.J.
Oak Ridge National Laboratory, Oak Ridge, TN

The behavior, basic assumptions, and limitations of ten different models for calculating the drift deposition rate from wet cooling towers are reviewed and then their predicted results for such deposition with a common set of input parameters are compared. The predicted maximum deposition differs among the models by two orders of magnitude with a wide range in peak location. Comments and suggestions to improve the models are included. (Auth)

<539>

Drift - Modeling and Monitoring Comparisons.
ATDL Contribution File No. 76/24, 30 pp.; Cooling Tower Institute Annual Meeting, Proceedings of a Symposium, Houston, TX, January 31-February 2, 1977; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1976 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 597-627), 627 pp.; ATDL-77/23
1977
Chen, N.C.J.; Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

Several drift deposition models are compared using a set of standard input conditions. The predicted maximum drift deposition differs by two orders of magnitude, and the downwind locations of the maximum differ by one order of magnitude. The discrepancies are attributed mainly to different assumptions in the models regarding the initial effective height of the droplets. Current programs in which drift characteristics at the tower mouth and drift deposition downwind of the tower are being measured are summarized. At the present time, drift deposition measurements, sufficiently comprehensive for model verifications, are unavailable. Hopefully, the Chalk Point Program will satisfy this need. (Auth)

<540>

Drift Modeling and Monitoring Comparisons.
Atmospheric Environment 12:1725-1734
1978
Chen, N.C.J.; Hanna, S.R.
Oak Ridge National Laboratory, Engineering Technology Division, Oak
Ridge, TN
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Department of Energy

Ten drift deposition models are compared using a set of standard input conditions for a natural draft cooling tower. Most of the models agree within a factor of three. However when all ten models are compared, the predicted maximum drift deposition differs by two orders of magnitude, and the downwind locations of the maximum differ by one order of magnitude. The discrepancies are attributed mainly to different assumptions in the model regarding the initial effective height of the droplets. Current programs measuring drift characteristics at the tower mouth and drift deposition downwind of the tower are summarized. At the present time, drift deposition measurements, sufficiently comprehensive for model verifications, are unavailable. Hopefully, the Chalk Point Program will satisfy this need. (Auth)

<541>

A Mathematical Model of Drift Deposition from a Bifurcated Cooling Tower Plume.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 39-45), 120 pp.
1978
Chen, N.C.J.; Jung, L.
Oak Ridge National Laboratory, Engineering Technology Division, Oak
Ridge, TN
U.S. Department of Energy

Cooling tower drift deposition modeling has been extended by including the centrifugal force induced by plume bifurcation as a mechanism for droplet removal from the plume. The model is capable of predicting the trajectory of a single droplet from the stage of strong interaction with the vortex field soon after droplet emission at the tower top through the stage droplet evaporation after breakaway from the plume. Applications showed the droplet to follow a helical trajectory within the plume, with breakaway and ground impact depending upon plume rise, ambient wind, evaporation, and vortex strength. (Auth)

<542>

A Model for Salt Drift Deposition from Spray Ponds.
IAEA-SM-187/37; Environmental Effects of Cooling Systems at Nuclear Power Plants, Proceedings of a Symposium, Oslo, August 26-30, 1974. International Atomic Energy Agency, Vienna, (pp. 331-345), 830 pp.
1975
Guyer, E.C.; Golay, M.W.
Massachusetts Institute of Technology, Cambridge, MA

An approach to the drift-droplet dispersion problem was proposed and applied to saltwater spray pond systems. The mathematical model developed to predict downwind salt deposition is based on a stepwise non-turbulent trajectory calculation and allows for a detailed accounting of variations in the transport parameters over the trajectories of individual drift droplets. The direct application of the model, however, has been hindered by the present inability to describe the drift-droplet source in a typical large spray device. Sensitivity studies using the proposed model indicate strong dependence of the downwind salt deposition on plume humidity, wind speed, spray height, and drift-droplet size spectrum. The available field measurements of spray pond drift are assessed in relation to the model. (Auth)

<543>

Numerical Model for Investigation of Moist Buoyant Cooling Tower Plumes.
Taft, James, Systems Science and Software, LaJolla, CA. In: Cooling Tower Environment - 1974, Proceedings of a Symposium sponsored by Maryland Power Plant Siting Program and U.S. Atomic Energy Commission, March 4 through 6, 1974. Published by Energy Research & Development Adm., 1975. pp. 180-204. (Available from NTIS, CONF-740302).
1974
Taft, James
Systems Science and Software
Maryland Power Plant Siting Program
U.S. Atomic Energy Commission
Energy Research & Development Adm.

A computer model is presented which predicts buoyant thermal plume behavior as a function of downwind distance. The model solves an equation set that expresses the conservation of mass, energy, and momentum. The dynamic and energetic effects of moisture are included. A heuristic model of fluid turbulence is also included which allows the specification of a local kinematic eddy viscosity. The model approach is Eulerian. Input requirements are minimal. Predicted values have been compared with observations.

<544>

Numerical Dispersion Models.
Westinghouse Environmental System Dept. . Appendix C, Section C.1, Colstrip Generation and Transmission Project Environmental Analysis, Montana Power Co.; Puget Sound Power & Light Co.; Portland General Elec. Co.; Washington Water Power Co. and Pacific Power & Light Co., Nov. 1973. 4 pp.

Appendix discusses the numerical dispersion models used to calculate effects of stack emissions and cooling tower drift at Colstrip Generation and Transmission Project, Rosebud County, MT. First part discusses short-term ground level concentrations of pollutants, and gives the equations incorporated into the 'STAD' model (Short-Term Atmospheric Dispersion) used to calculate these concentrations. Second part discusses estimated concentrations on a long-term basis, and gives equations incorporated into the 'Diffusion' model. Third part discusses a cooling tower plume dispersion model. Fourth part discusses 2 deposition models, for particulate matter and for drift from cooling towers. Includes 11 references and 3 figures.

<545>

Sensitivity Tests with a Vapor Plume Model Applied to Cooling Tower Effluents.
M.S. Thesis, 100 pp.
1976
Batty, K.T.
The Pennsylvania State University, Department of Meteorology,
University Park, PA

Experiments were conducted to test the sensitivity of a plume model to determine its reliability for meshing with an atmospheric background model. These sensitivity tests are a first step in studying the impact on the environment of vapor plumes from electrical generating stations. Four important modifications to the active plume models of Weil (1974) and Wigley and Slawson (1975) are made prior to the sensitivity testing which deal with (1) adjusting the entrainment velocity after maximum plume rise, (2) changing the energy conservation equation, (3) relaxing the restriction that the plume maintain a circularly symmetric configuration, and (4) using a value of 0.4 for the entrainment parameter. The present results tend to support the findings of other studies regarding the sensitivity of plume rise to the entrainment parameter, the ambient stability, and the condensation of water vapor. The finding by Wigley and Slawson (1975) that plume length is relatively insensitive to changes in the entrainment parameter over the range of 0.3 to 0.5, is also supported by the present study. Several results not specifically discussed in past studies were also obtained which indicate that the present form of the active model is a useful tool in studying plume behavior. Available observational data support many of the model findings, such as the dominance of the short and long plumes over the medium length classification, the rapid cooling of the plume, and the existence of plume temperatures 0.5 degrees K cooler than those of the environment. Though the current plume model has demonstrated its reliability, at least three problems still exist in the model formulation where future improvements can be made. The first prorblem involves the resolution of the model, the second involves the consideration of plume shape, and the third involves the method of parameterizing entrainment. Continued plume research is recommended.

<546>

Plume Rise Predictions.
ATDL Contribution File No. 75/15, 53 pp.; CONF-7509171; Lectures on Air Pollution and Environmental Impact Analyses (Workshop on Meteorology and Environmental Assessment), Proceedings of a Symposium, Boston, MA, September 29-October 3, 1975. American Meteorological Society, Boston, MA, (pp. 59-111) ; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1975 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 425-471), 590 pp.; ATDL-76/14
1975
Briggs, G.A.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

Methods for predicting dry plume rise covering a very wide variety of situations are suggested. All of the predictions are based on a relatively simple, yet versatile, theoretical model. The model is similar to some past models, but they are extended somewhat and the conservation equations are more carefully derived. Reasoning behind the equations and theories is discussed. Appendix B provides information concerning extension of the model to cover moist plume behavior (i.e. cooling towers). Conclusions are drawn based on models already available, relevant considerations are pointed out, and some simple models with actual observations of condensed plume length are compared.

<547>

Prediction of Temperature and Moisture Distributions in Cooling Tower Plumes.
Atmospheric Diffusion and Air Pollution, Proceedings of a Symposium, Santa Barbara, CA, September 9-13, 1974. American Meteorological Society, Boston, MA, (p. 400-406), 435 pp.
1974
Calabrese, R.V.; Halitsky, J.; Woodard, K.
University of Massachusetts, Amherst, MA
Pickard, Lowe and Associates, Inc., Washington, DC

A model has been developed which enables the prediction of the distributions of temperature and moisture in both the visible and invisible portions of a cooling tower plume. The model accounts for the real jet properties of the plume as well as dispersion due to atmospheric turbulence. Ambient profiles of temperature and moisture are considered and an equivalent jet is defined to account for the combined plume from several towers. The length of the visible plume depends strongly on ambient temperature and relative humidity. Accurate knowledge of the ambient profiles of temperature and moisture is needed to obtain reasonable predictions. The model cannot be fully validated until more accurate data become available for both the visible and invisible plume regions. (ND)

<548>

Environmental Effects of Heat and Moisture Release from Atmospheric Spray Cooling Systems.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 65-74), 120 pp.
1978
Chaturvedi, S.; Porter, R.W.
Illinois Institute of Technology, Chicago, IL
U.S. Department of Energy

Computations of the downwind environmental effects of a spray cooling device are presented. The present work deals with a source of finite width and height with a distributed internal heat and moisture release consistent with a thermal model for atmopheric sprays including heating and humidification of downwind elements. The self-consistent fully-developed ambient wind and turbulent diffusivity profiles depending on aerodynamic surface roughness and atmospheric stability are presumed to prevail throughout the domain of interest. The convective diffusion equation governing the enthalpy of the air-moisture mixture is integrated numerically continuing through and beyond the source, and the local temperature and vapor concentration are computed. Fogging is described by an equilibrium model which requires condensation of vapor in excess of saturation. Ground-level dispersent concentration and height are compared with those of ground-level line sources, and of field studies (Quad-Cities Nuclear Station) and wind-tunnel experiments with a finite source. (Auth)(ND)

<549>

Bent-Over Vapor Plumes.
Journal Applied Meteorology 10(1):36-42
1971
Csanady, G.T.
University of Waterloo, Department of Mechanical Engineering,
Waterloo, Ontario, Canada

A theory is developed to predict the behavior of bent-over continuous plumes of substantial moisture content in the atmosphere. Main interest is focussed on the prediction of condensation. It is found that in a well-mixed environment, under appropriate conditions, a finite portion of the plume may contain some liquid-phase water, beginning to condense at some distance from the source and re-evaporating at some larger distance. Plumes, which are initially saturated and contain some liquid, will begin to re-evaporate immediately on release, provided that the environment is not saturated and that the excess temperature of the plume is smaller than a given limit (of the order of 20F at 65% relative humidity). The direct dynamical effects of evaporation and condensation of plume path are found to be minor. In a stratified environment the calculations become more complex but the above conclusions are fundamentally unchanged (except perhaps that there may be several finite portions of the plume exhibiting condensation). (Auth)

<550>

Buoyant Plume Rise in Atmospheric Inversions.
International Journal Heat and Mass Transfer 20:403-407; 1977
Ero, M.I.O.
Purdue University, School of Mechanical Engineering, West Lafayette,
IN
The rise of a buoyant plume into atmospheric inversions is investigated analytically for a range of inversion rates. The analysis assumes Gaussian distribution of velocity and temperature. The results show that maximum plume rise decreases with inversion intensity, and the ratio of maximum rise to the height at which zero buoyancy occurs is a function of the densimetric Froude number and the inversion intensity. (Auth)

<551>

The Effect of Cooling Towers on Atmospheric Dispersion.
VGB Kraftw..kstechnik 54(12):825-827; OLS-79-48, 5 pp.
1974
Fuchs, H.
Motor-Columbus Consulting Engineers Inc., Baden, Switzerland
Model experiments in a wind tunnel were carried out to evaluate the effects of natural draft cooling towers on stack effluent behavior at various nuclear power plants, among them the Gosgen-Daniken plant. It was found that with appropriate wind strengths and wind directions, the presence of a cooling tower can slightly increase the ground level concentrations of radioactivity exhausted through the stack in the adjacent zone. This increase is not generally a problem, however, if the stack height is selected accordingly. In the case of the Gosgen plant, a stack height of 100 m was recommended on the basis of the studies. (ND)

<552>

Fog and Drift Deposition from Evaporative Cooling Towers.
Nuclear Safety 15(2):190-196; ATDL Contribution File No. 94, 8 pp.; Environmental Research Laboratories, Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1974 Annual Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (p. 127-133), 250 pp.; ATDL-75/17;
1974
Hanna, S.R.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Atomic Energy Commission
Methods of determining fog and drift deposition due to emissions from evaporative cooling towers are reviewed and formulas suggested that can be used as a basis for calculations. The Gaussian plume formula is recommended for calculating fog concentrations from which visibility can be estimated. For drift droplets with diameters greater than 200 um, deposition is calculated by ballistics methods, knowing the environmental wind speed and relative humidity and the vertical velocity of the plume and the droplet. Evaporation of the droplets is accounted for. Drift droplets with diameters less than 200 um are assumed to be dispersed according to the Gaussian plume formula, with the plume tilted downward to account for the settling speed of the droplet. (Auth)

<553>

Plumes from One and Two Cooling Towers.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 17-26), 120 pp.
1978
Kannberg, L.D.; Onishi, Y.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy
Thermal plumes from mechanical draft cooling towers were studied by physical model simulation in a hydraulic flume. Downwind temperature fields were measured by a cross-sectional thermistor sampling array. Temperature measurements within the tower permitted the computation of recirculation of plumes back into the tower. Parameters varied during the study included the number of towers, tower orientation with respect to wind, spacings between towers, wind speed, and plume excess temperature. Plume trajectories and recirculation were greatly affected by Froude Number, ambient wind speed, orientation, and an upstream tower. However, plume temperature decay was a less pronounced function of such parameters. (Auth)

<554>

Plume Recirculation and Interference in Mechanical-Draft Cooling Towers.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 58-87), 638 pp.
1975
Kennedy, J.F.; Fordyce, H.
University of Iowa, Institute of Hydraulic Research, Iowa City, IA
Marley Company, Engineering Division, Mission, KS
An extended model investigation was conducted in a laboratory flume to determine downwind temperature distributions and the recirculation and interference characteristics of buoyant jets (forced plumes) issuing from 1/150-scale models of The Marley Company class 600 double-flow and from Marley round, mechanical draft cooling towers. The dynamic scaling was based on equality of the densimetric Froude number (FD) in model and prototype. Plumes of positive (lighter effluent)

and negative (heavier effluent) buoyancy were obtained by supplying heated and cooled, respectively, water through the model tower stacks. In the investigation, FD ranged from 2 to 7 and K from 0.4 to 12. Downwind temperature profiles and recirculation ratios for single towers and tower groups were determined from temperature measurements made with thermistor temperature probes for different tower orientations with respect to the approach flow. Various tower lengths, stack heights, and stack spacings were tested to quantify the recirculation ratio and to delineate temperature contours in the plumes as functions of FD, K, and tower geometry. It was found that recirculation generally increases with decreasing FD for negative-buoyancy plumes and with increasing FD for positive-buoyancy plumes. With increasing K the recirculation ratio generally decreases for positive-buoyancy plumes; for negative-buoyancy plumes, recirculation first decreases and then increases with K. Increasing stack height and stack spacing reduces recirculation. The plume configuration is slightly sensitive to FD in the range investigated and is strongly affected by K. Round towers have significantly lower recirculation ratios than rectangular ones. The recirculation ratio for a two-tower system, with the second tower downwind from the first, is relatively insensitive to FD but decreases markedly with increasing K. (Auth)(ND)

<555>

Multiple Cell Mechanical Draft Cooling Tower Model.
Thermophysics and Heat Transfer Conference, Proceedings of the Second Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 1-8), 120 pp.
1978
Macduff, R.B.; Davis, L.R.
Oregon State University, Department of Mechanical Engineering,
Corvallis, OR

An integral analysis of multiple cell mechanical draft cooling tower plumes is presented which accounts for moisture effects and merging of neighboring plumes. The analysis includes detailed dynamics and allows for gradual merging of plumes without discontinuity of plume properties. Merging is allowed to occur anywhere along the plume trajectory including the zone of flow establishment. Moisture effects are modeled using the Clausius-Clapeyron equation. Property profiles are assumed to be Gaussian-like with modifications in the merging zone. Entrainment modeling is consistent with models found throughout the field with modifications to account for interference of merging plumes and varying entrainment surface. Complete results and computer model tuning are being prepared for future publication. (Auth)(ND)

<556>

Mathematical Transport Model for Salt Distribution from a Saltwater Natural-Draft Cooling Tower.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 598-613), 638 pp.
1975
Laskowski, S.M.
Pickard, Lowe and Associates, Inc., Washington, DC

The development of a mathematical model is described which predicts salt deposition rate and air salt concentration vs. distance and direction from the tower as a function of tower characteristics, drop size distribution, mass drift rate from the tower, and the meteorology of the site, i.e., atmospheric conditions, including wind direction and speed, relative humidity, stability, and precipitation rate. The model follows the behavior of representative drift droplets of selected initial size and salinity as they travel from the top of the drift eliminators through the plume and the ambient air until they deposit upon the ground. Growth and/or evaporation of the drops is accounted for as a function of the droplet salt concentration, temperature, and atmosphere surrounding the drop. The effect of gravity and air currents on their average motion and on their statistical distribution in space (around average trajectories) due to turbulent dispersion are also included. Plume behavior is based on the formulas of Briggs and of Slawson and Csanady. The effect of precipitation (i.e., rainfall) and the aerodynamic wake of the tower are also incorporated in the model. (Auth)

<557>

A Numerical Study of Wet Cooling Tower Plume.
Transactions American Nuclear Society 16:32-33
1973
Lee, J.L.
NUS

A numerical model of a wet cooling tower plume was developed by NUS corporation. The model can simulate both dry and moist plumes. It was found in the model solutions that the buoyant flux in a moist plume is due mainly to the sensible heat of the tower effluence; the buoyancy contributed by latent heat of condensation is almost compensated by the gravitational drag and the evaporation of the condensed water. Thus, unlike natural cumuli, most wet cooling tower plumes are characterized by high rates of dissipation. (ND)

<558>

Potential Environmental Modifications Produced by Large Evaporative Cooling Towers.
Final Report, 65 pp.
1971
EG&G, Inc., Environmental Services Operation, Boulder, CO
Federal Water Pollution Control Administration, Corvallis, OR

Techniques to model and predict the behavior of cooling tower effluents when discharged into the atmosphere under various meteorological conditions were developed. The study was limited to numerical calculations of the general characteristics of plume behavior, primarily height. Parameters used in the numerical model are those for a typical wet natural draft cooling tower. Some consideration is also given to the behavior of plumes from mechanical draft towers. The models were also used to describe plume interaction with the environment. Classical atmosphere diffusion theory was used to determine the downwind spread. A map of the U.S. indicating locations of potential adverse atmospheric effects due to cooling towers can be used in conjunction with local data. The appendix contains a description of the computer program, including input specifications. (ND)

<559>

Mathematical and Experimental Investigations on Dispersion and Recirculation of Plumes from Dry Cooling Towers at Wyodak Power Plant in Wyoming.
BNWL-1982, 255 pp.
1976
Onishi, Y.; Trent, D.S.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Energy Research and Development Administration

The purposes of this study were to (1) develop a two dimensional mathematical simulation model for determination of plume dispersion and recirculation from an existing code; (2) investigate experimentally and mathematically the recirculation and temperature distributions of plumes from two dry cooling towers at the Wyodak Power Plant in Wyoming; and (3) elucidate the effects of wind velocity, temperature of heated effluent, adjacent cooling towers and local topography on plume dispersion and recirculation. The mathematical model is based on solution of the steady flow momentum and energy equations using the stream function-vorticity technique. Experiments were conducted in a 10-foot-wide hydraulic flume, using water as a model flow. The study showed that plume recirculation and dispersion were strongly influenced by local topography and nearby structures such as adjacent cooling towers and buildings, as well as by the ambient wind velocity and effluent exit temperature. Nearby cooling towers and local topography produced up to approximately 18 percent of the recirculation ratio, which is a nondimensional temperature rise in the cooling tower's withdrawal air. This caused a 7 percent reduction in the cooling tower's heat rejection capability. This reduction of heat rejection capacity could be two to three times more for wet cooling towers. The study also revealed very strong nonuniform distributions of cooling tower inlet air temperature within the cooling tower, implying that it may not be appropriate to assume that the ambient air temperature is the true inlet cooling air temperature as is commonly done to evaluate cooling tower performance. (ND)

<560>

Influence of the Choice of the Plume Diffusion Formula on the Salt-Deposition-Rate Calculation.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 573-584), 638 pp.
1975
Pena, J.A.; Hosler, C.L.
The Pennsylvania State University, University Park, PA

The salt deposition rate from cooling towers is considered as a particular case of dust deposition where the particles have a variable fall velocity. Average fall velocities are assigned to drift drops, according to the ambient relative humidity, following the scheme proposed by Hosler, Pena, and Pena. Three different formulas have been used to calculate the deposition rate, two assuming turbulence and one with no turbulence. The results of the calculations indicate that any of the three formulas can be used to predict the salt deposition rate with the same degree of confidence. The only way to make a choice would be to compare the values from each of these formulas with observational values, not yet available. Before any testing, improvement is necessary (1) in the quality of data, such as drift-drop size distribution and drift-drop mass fraction, and (2) in the theoretical approach by including natural precipitation effects. (Auth)

<561>

Convection Above Cooling Towers.
Ann. Meteorol. 9:65-68; ANL-Trans-1145, 14 pp.
1974
Rudolf, B.; Fraedrich, K.

Cooling towers are local sources of heat and moisture. The convection above such a source is computed by a simple one-dimensional model based upon the equation of motion in the vertical, the first law of thermodynamics, and the continuity equation. The following assumptions are introduced: quasi-hydrostatic equilibrium, steady state conditions, and a top-hat profile. Temperature, vertical velocity, and water content of the ascending air above the cooling tower are calculated for given environmental conditions (wind, temperature, moisture). The net fluxes of sensible and latent heat and the rate of condensation are derived. The processes inside the cooling tower are computed by a separate model to obtain the boundary conditions at the base of the plume (i.e., the top of the cooling tower). The behavior of the ascending air is classified as follows: (1) no cloud generation, (2) vertically limited cloud generation, and (3) a cloud which rises to an unlimited height. Through computation it is determined which of the above classes can be expected under different environmental conditions. The results are represented by stability-moisture diagrams for a dry and a wet cooling tower of the same heat generating magnitudes. (Auth)

<562>

Numerical Model for the Investigation of Moist Buoyant Cooling-Tower Plumes.
CONF-740302; ERDA Symposium Series 35; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, (pp. 180-204), 638 pp.
1975
Taft, J.
Systems, Science and Software, LaJolla, CA

A computer model (STIFF-Q3) is presented which predicts buoyant thermal plume behavior as a function of downwind distance. The model solves an equation set that expresses the conservation of mass, energy, and momentum. The dynamic and energetic effects of moisture are included. A heuristic model of fluid turbulence is also included which allows the specification of a local kinematic eddy viscosity. The model approach is Eulerian. Input requirements are minimal. Predicted values have been compared with observations, and the agreement is seen to be excellent. (Auth)

<563>

A Two-Dimensional Hydrodynamic Model for Cooling-Tower Plumes.
IAEA-SM-187/3; Environmental Effects of Cooling Systems at Nuclear Power Plants, Proceedings of a Symposium, Oslo, August 26-30, 1974. International Atomic Energy Agency, Vienna, (pp. 37-44), 830 pp.
1975
Trepp, J.P.
Swiss Federal Institute for Reactor Research, Wurenlingen, Switzerland

Large power plants with cooling towers, whether of the wet or dry type, have certain effects on the microclimate owing to the waste heat which is transferred to the atmosphere. In this paper, the plume physics simulation is described, and it is hoped that better predictions of the influences on the microclimate can be made. The cooling tower plume is simulated in a two-dimensional computer model, which solves numerically the time-dependent equations of motion, continuity and those that describe the transport of heat, water vapor and water droplets for the lower atmosphere. The cloud physics work of Takeda and Orville and the early turbulence studies by Boussinesq and Prandtl are used to describe the turbulent flow hydrodynamic model. The turbulent transfer is represented either by a constant eddy viscosity or by the Prandtl mixing-length hypothesis. Condensation, evaporation, coagulation, breaking and the terminal fall velocity of water droplets relative to air are included. The size distribution of the water droplets is given as a discrete spectrum of five droplet sizes. The model calculates for each time step the temperature, relative humidity, cloud and rainwater content for each grid point, and also the wind field. The model requires experimental verification. To this end, measurements on existing dry and wet cooling towers have already been started for a three-dimensional field of the above parameters. (Auth)

<564>

Cooling Tower Drift Model.
Modeling and Simulation, Proceedings of a Symposium, Pittsburgh, PA, April 24-26, 1974. Instrument Society of America, Vol. 5, Part 1, (p. 143)
1974
Tsai, Y.J.; Johnson, D.H.
Stone and Webster Engineering Corporation, Boston, MA

A computer model has been developed to predict the distribution of drift from brackish or saltwater cooling towers for power plant condensate cooling. Drift from mechanical or natural draft towers can be evaluated, taking into account tower characteristics, drift rate, droplet size distribution, total dissolved solids in cooling water, rise of droplets in the plume, evaporation and trajectory of falling droplets, and ambient weather data. The drift model has four groups of output; annual deposition of dissolved solids, annual deposition of water, maximum near-ground air concentration, and annual near-ground air concentration. These data are then used to evaluate cooling tower impact upon the environment. The model compares well with other existing models but has the added flexibility of using historical meteorological data and produces a comprehensive set of predictions for evaluation of cooling tower drift environmental impact. (Auth)(ND)

<565>

Condensation in Jets, Industrial Plumes and Cooling Tower Plumes.
Journal Applied Meteorology 14(1):78-86
1975
Wigley, T.M.L.
University of Waterloo, Department of Mechanical Engineering,
Waterloo, Ontario, Canada

The one-dimensional theory for the condensation of buoyant plumes is extended to include supersaturation as an extra variable. An additional equation describing the dynamics of droplet growth is used to make the system tractable. Some simple mathematical results are obtained which allow one to relate the theory to, and so extend, a commonly used graphical representation of the condensation process. The theory is then simplified to a single nonlinear first-order differential equation for the condensed water content. This is solved numerically for a typical jet, scrubbed industrial plume and natural draft cooling tower plume to obtain down-plume profiles of condensed water content, supersaturation and mean droplet size. High supersaturation is predicted in all three cases, corresponding to mean relative humidities of up to 170% (jet), 150% (scrubbed plume) and 105% (cooling tower). These results may be important in predicting the growth of 'foreign' carry-over droplets in plumes from industrial sources or cooling towers. Predictions of plume length in these cases is found to be insensitive to supersaturation, but plume length is noticeably affected by supersaturation in the case of a jet. In the examples considered maximum mean droplet radii never exceed 10 um which supports the belief that rain-out is caused primarily by carry-over from imperfect mist eliminators. (Auth)

<566>

A Simple Method of Predicting Plume Behavior from Multiple Sources.
Waste Heat Management and Utilization Conference, Proceedings
Winiarski, L.D.; Frick, W.; Carter, A.
U.S. Environmental Protection Agency, Corvallis Environmental Research
Laboratory, Corvallis, OR

A method for predicting the behavior of plumes from multiple sources with the aid of a computer program of nomograph is illustrated and compared with field data. Sources close together are treated as an equivalent single source which is designed to have the same efflux of mass, momentum and energy. The perimeter of the equivalent single source is taken to be the same as the total perimeter of the multiple sources. The apparent area of the actual sources as projected normal to the wind is used with the equivalent source to determine the wind-induced entrainment. (Auth)

<567>

Mathematical Model for Multiple Cooling Tower Plumes.
EPA-600/7-78-102, 119 pp.; PB-286 364; KH-R-37, 119 pp.
1978
Wu, F.H.Y.; Koh, R.C.Y.
California Institute of Technology, W.M. Keck Laboratory of Hydraulics
and Water Research, Pasadena, CA
U.S. Environmental Protection Agency, Environmental Research
Laboratory, Corvallis, OR

A mathematical model was developed resulting in a computer program for the prediction of the behavior of plumes from multiple cooling towers with multiple cells. A general integral method based on the conservation of mass, momentum, energy (heat), and moisture fluxes (before and after a plume merging), were employed in the prediction scheme. The effects of ambient stratifications of temperature, moisture, and wind are incorporated in the model. An axisymmetric round plume is assumed to be emitted from each individual cell before interference with neighboring plumes. A finite length slot plume in the central part and two half round plumes at both ends of the merged plume were used to approximate the plume after merging. The entrainment and drag functions are calculated based on the modified merged plume shape. The computer output provides the predicted plume properties such as excess plume temperature, humidity and liquid phase moisture (water droplet), plume trajectory, width, and dilution at the merging locations and the beginning and ending points of the visible part of the plumes. Detailed printout and contour plots of excess temperature and moisture distribution can also be obtained if desired. Based on comparison with laboratory data this model gives good predictions for the case of dry plumes (no moisture involved). It should be noted that several empirical coefficients are as yet not accurately known. Verification of this model for the wet plume (such as for prototype cooling tower plumes) and the determination of values for these empirical coefficients to be used in prototype applications must await detailed comparison with field data. (Auth)

<568>

A Preliminary Result of a Three-Dimensional Numerical Simulation of Cloud Formation Over a Cooling Pond.
CONF-780520; Thermophysics and Heat Transfer Conference, Proceedings of the second Symposium, Palo Alto, CA, May 24, 1978; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds and Area Sources, K.E. Torrance and R.G. Watts (Eds.), Proceedings of the Symposium, Palo Alto, CA, May 24, 1978, American Society of Mechanical Engineers, New York City, NY, (p. 79-987)
1978
Yamada, T.
Argonne National Laboratory, Radiological and Environmental Research
Division, Atmospheric Physics Section, Argonne, IL

Cooling ponds receive large amounts of waste heat from industrial sources and release the heat to the atmosphere. These large area sources of warm and moist air may have significant inadvertent effects. This paper is a preliminary step in the development of a method for estimating the perturbations in the atmosphere produced by a cooling pond. A three-dimensional numerical model based on turbulence second-moment closure equations and Gaussian cloud relations has been developed. A simplified version of the model, in which partial differential equations for only turbulent energy and a master length-scale equations are solved, is used. Numerical simulations are conducted using as boundary conditions the data from a cooling pond study conducted in northern Illinois during the winter of 1976-77. Preliminary analyses show, not surprisingly, that formation of clouds over a cooling pond is sensitive to the moisture content in the ambient atmosphere. (Auth)

<569>

Development and Verification of a Wet Cooling Tower Drift Deposition Model.
Air Pollution Control Association 71st Annual Meeting, Proceedings of a Symposium, Houston, TX, June 25-30, 1978, 15 pp.
1978
Miksad, R.W.; Ratcliff, M.A.
The University of Texas, Austin, TX

The preliminary results of a model which is designed to predict drift deposition drop size distributions as well as number flux are presented. The influence of evaporation and the drop breakaway process was investigated by using both a bulk breakaway criteria (as commonly used in other models), and a distributed partial breakaway criteria, for each drop size. The best features of several existing models for plume rise and vertical velocity, drop evaporation, drop terminal velocity, and drift plume dispersion were incorporated into the model. The results of the model predictions were compared with data measured by the Chalk Point Cooling Tower Project. Comparisons were made at several downwind receptor sites for drop size distribution and number flux. The results indicated that the bulk breakaway criteria used by most of the present drift models did not do a good job in predicting drop size distribution for drops greater than 100 microns. The use of a multiple breakaway option improved the distribution of size ranges, at the expense of increased inaccuracy in total number count. The investigation of multiple breakaway mechanisms indicated that inaccuracies in total number count can be reduced with more realistic model representations of the partial breakaway process than the initial choice used in this study. (ND)

<570>

Sensitivity Analysis of a Salt Deposition Model for Natural Draft Cooling Towers.
Atmospheric Environment 13(1):61-69
1979
Overcamp, T.J.; Isreal, G.W.
Clemson University, Environmental Systems Engineering, Clemson, SC
Technische Universitat Berlin, Fachgebiet Luftreinhaltung,

Berlin,
Germany

A salt deposition model for natural draft cooling towers was modified so that different modeling assumptions could be tested. These included the method of estimating the effective height of emission of droplets as a function of their size and the use of either a simple trajectory method or a modified Gaussian diffusion-deposition equation for computing the deposition. This model was tested using two different emission droplet size distributions. The major conclusions are that the trajectory method can give comparable results to the diffusion-deposition equation for droplets greater than several hundred micrometers in diameter, and that the deposition predictions within the first kilometer or two are very sensitive to the emission droplet size distribution and the method of predicting the effective height of emission of the droplets. (Auth)

<571>

The Rise of a Plume from a Wet, Natural-Draft Cooling Tower in Strong Winds.
M.S. Thesis, 85 pp.
1972
Stephen, D.W.
The Pennsylvania State University, Department of Mechanical
Engineering, University Park, PA

A mathematical model was developed that would predict as a function of distance downwind the height of the center line of visible plumes from wet, natural draft cooling towers in strong winds. The Lagrangian system was used, i.e., the behavior of a small section or parcel of plume was studied as a function of time. Eight first order differential equations were developed to describe the change in mass, vertical velocity, vertical displacement, length of the side of the parcel, temperature, mass of the liquid water, horizontal velocity and horizontal displacement of the parcel. These equations were solved by well-known computer integration techniques. Several assumptions had to be made to represent the merging of the plumes from different towers. Best results were obtained by using dry plume entrainment rates in the early stages and cloud entrainment rates in the later stages. The major flaw in the theory is that the axis of the parcel should remain vertical in order to predict the change in length of the side of the parcel but it should remain tangent to the plume path in order to calculate the entrainment rates. However, the model can be used to illustrate the nature of plume behavior and, using reasonable approximations where necessary, it gives results which agree with actual observations taken on a day of high relative humidity for 1500 meters downwind. (Auth)

<572>

Wet Plume Rise from Cooling Towers in Strong Winds.
Water, Air, and Soil Pollution 6:9-24
1976
Stephen, D.W.; Moroz, W.J.
The Pennsylvania State University, Center for Air Environmental
Studies, University Park, PA

A mathematical model is presented that predicts, as a function of distance downwind, the height of the center line of a single visible plume from a wet natural draft cooling tower in moderate to strong winds. The analytic method is quasi-Lagrangian; that is, the behavior of a small section or parcel of the plume is analyzed as a function of time. Eight first-order differential equations describe the parcel in terms of change in mass, vertical velocity, vertical displacement, length of side, temperature, mass of liquid water, horizontal velocity, and horizontal displacement. The equations are tractable for solution by well-known computer integration techniques. The model was tested on plumes from four cooling towers at the Keystone electric generating plant, and its predicted plume path was compared with data interpreted from time-lapse photographs of the plumes. Best results were obtained by applying dry plume entrainment rates in the early stages and cloud entrainment rates in the later stages. The computed prediction, employing reasonable estimates where necessary, closely approximated the photographic data for a distance of 1500 m downwind on a day with high relative humidity. The model can also be used to analyze the nature of wet plume behavior. (Auth)

<573>

Salt Drift Model Description.
Appendix 5B, Douglas Point Nuclear Generating Station Units 1 & 2 Environmental Report, Potomac Elec. Power Co., 1973. 27 pp.

Model is based on behavior of single particles as they travel from the top of drift eliminator to the ground. Plume growth measured according to Slawson and Csanady and derived from photographic observations. General mathematical equations for estimating single particle behavior are described. Calculation procedures for salt deposition and wind interaction with tower wake are outlined. Also described are 3 computer programs used to predict average salt deposition rates.

<574>

Plume Rise from Multiple Sources.
ATDL Contribution File No. 91, 33 pp.; CONF-740302; Cooling Tower Environment-1974, S.R. Hanna and J. Pell (Eds.), Proceedings of a Symposium, College Park, MD, March 4-6, 1974. ERDA Technical Information Center, Oak Ridge, TN, 1975, (p.
Briggs, G.A.
National Oceanic and Atmospheric Administration, Environmental
Research Laboratories, Atmospheric Turbulence and Diffusion
Laboratory, Oak Ridge, TN

A simple enhancement factor for plume rise from multiple sources is proposed and tested against plume rise observations. A formula is given for calculating bent-over, buoyant plumes from multiple sources. For calm conditions, a crude but simple method is suggested for predicting the height of plume merger and subsequent behavior, based on the geometry and velocity variations of a single, buoyant plume. It is suggested that large clusters of buoyant sources might occasionally give rise to concentrated vortices, either within the source configuration or just downwind from it. (Auth) (ND)

<575>

The Fire Analog: A Comparison Between Fire Plumes and Energy Center Cooling Tower Plumes.
PNL-2453, 70 pp.
1977
Orgill, M.M.
Battelle Pacific Northwest Laboratories, Richland, WA
U.S. Department of Energy

Thermal plumes or convection columns associated with large fires were compared to thermal plumes from cooling towers and proposed energy centers to evaluate the fire analog concept. Energy release rates of mass fires were generally larger than for single or small groups of cooling towers but were comparable to proposed large energy centers. However, significant physical differences exist between cooling tower plumes and fire plumes. Cooling tower plumes are generally dominated by ambient wind, stability and turbulence conditions. Fire plumes, depending on burning rates and other factors, can transform into convective columns which may cause the fire behavior to become more violent (strong inflow winds and updrafts, turbulence and concentrated vortices). Intense convective columns may interact with ambient winds to create significant downwind effects such as, wakes and Karman vortex streets. The differences in physical characteristics between cooling tower and fire plumes makes the fire analog concept very questionable. Additional research is suggested in studying the upper-level plume characteristics of small experimental fires for correlation with similar data from cooling towers. Numerical simulation of fires and proposed multiple cooling tower systems could also provide comparative data. (Auth)

<576>

A Numerical Study of Meteorological Effects of Waste Heat and Moisture Releases from Hypothetical Power Parks.
Thermophysics and Heat Transfer Conference, Proceedings of a Symposium, Palo Alto, CA, May 24-26, 1978, American Society of Mechanical Engineers; Environmental Effects of Atmospheric Heat/Moisture Releases: Cooling Towers, Cooling Ponds, and Area Sources. K.E. Torrance and R.G. Watts (Eds.), Proceedings of a Symposium, Palo Alto, CA, May 24-26, 1978. American Society of Mechanical Engineers, New York City, NY, (p. 97-106); ATDL Contribution File No. 77/26; Appendix Cs Report on ATDL Research on Meteorological Effects of Thermal Energy Releases, August 1, 1976-September 31, 1977, S.R. Hanna, K.S. Rao, and R. P. Hosker in: Meteorological Effects of Thermal Energy Releases (METER) Program Annual Progress Report October 1976 to September 1977, A.A. Patrinos and H.W. Hoffman (Eds.). Oak Ridge National Laboratory, Oak Ridge, TN, (p. 105-132), 320 pp.;
Rao, K.S.; Hosker, R.P. Jr.
National Oceanic and Atmospheric Administration, Air Resources
Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, TN
U.S. Energy Research and Development Administration

A two-dimensional nonprecipitating shallow cloud model has been developed for the Meteorological Effects of Thermal Energy Releases (METER) program. This second-order-closure turbulence model utilizes a full set of equations for mean wind velocities, potential temperature, specific humidity, and liquid water content, as well as equations for the corresponding turbulent fluxes which are closed approximately. Vapor-liquid water phase changes are included in terms of saturation adjustments. A hypothetical power park was treated as an area source with idealized distributions of waste heat and water vapor fluxes from several cooling towers. These fluxes were utilized as boundary conditions to the model. Numerical experiments were performed for a 10,000 MWe power park in a convective atmosphere with variable surface relative humidity and mean wind direction. The total waste heat flux over the power park area was also arbitrarily varied. Preliminary results presented include typical vertical profiles of mean potential temperature, specific humidity, and liquid water in the atmosphere, as well as perturbations in the surface temperature and humidity due to the power park. (Auth)

<577>

Mathematical Model for Calculation of Length of the Visible Plume.
Appendix 5A, Douglas Point Nuclear Generating Station Units 1 & 2 Environmental Report, Potomac Elec. Power Co., 1973. 5 pp.
1973
Potomac Elec. Power Co.

A condensed plume dispersion model modified from Halitsky non-condensing transverse jet plume model was developed to calculate the visible length of plume for each of the hours in a typical year at the proposed Douglas Point station. Model uses temperature, humidity and wind data measured at several elevations on a meteorological tower at the Douglas Point site and typical cooling tower emission characteristics. Plume rise is calculated according to Briggs.

<578>

Prediction and Verification of Visible Plume Behavior.
Cooling Towers, Chemical Engineering Progress Technical Manual, Proceedings of a Symposium, Houston, TX, February, 1970. American Institute of Chemical Engineers, New York City, NY, (p. 36-41), 145 pp.
1970
Kaylor, F.B.; Petrillo, J.L.; Tsai, Y.J.
Stone and Webster Engineering Corporation, Boston, MA

Methods of predicting the configuration and characteristics of the visible plumes resulting from the cooling towers are presented. A mathematical model CLOUD consisting of two methods has been developed to predict the behavior of wet plume discharges. The models' results compare favorably with observed data from mechanical and natural draft cooling towers. The model can be used to evaluate environmental design consideration which will minimize the effects of moisture-laden plume discharges on the environment. Further refinement of the model is planned. (ND)

<579>

Plume Lengths Predicted Mathematically.

Electrical World 173(18):39
1970
Electrical World

A mathematical model, using actual weather data to predict the number of occasions when icing and fogging conditions may be hazardous around a plant, has recently been developed by Stone and Webster. The model can also be used to locate proposed cooling tower sites to minimize the occurrence of these conditions in sensitive areas. Model predictions and field observations at the E.W. Stout plant, Indiana, showed that plume length was predicted with sufficient accuracy to enable its use in predicting the lengths of visible plumes for a larger proposed mechanical draft cooling tower. Although the model was developed for a mechanical draft cooling tower, the technique could be applied to natural draft cooling towers, if operating characteristics are well defined. (ND)

<580>

Plume Rise and Dispersion Model.
Appendix 10.1-B, Fort Calhoun Station Unit No. 2 Environmental Report, Omaha Public Power District, Jan. 1976. 9 pp.

Appendix describes predictions of rise and dispersion of plumes which result from operation of mechanical draft cooling towers of Fort Calhoun Unit 2, as modeled by Gibbs and Hill's computer model MPLM. Life of the plume is divided into two stages. In stage 1 the rise and dispersion of the plume is dominated by its buoyancy and momentum. In stage 2 the dispersion of the plume is dominated by atmospheric diffusion. Verification of the stage 1 model was made using observations taken at the 4 natural draft cooling towers of Keystone Power Plant, Armstrong County, PA. Appendix contains 7 references, 1 table, and 1 figure.

<581>

Characteristics of Temperature Fluctuations in Cooling Tower Plumes.
M.S. Thesis, 71 pp.
1977
Miller, R.L.
The Pennsylvania State University, Department of Meteorology,
University Park, PA
U.S. Energy Research and Development Administration

The characteristics of temperatures obtained from airborne measurements in natural draft cooling tower plumes at the Keystone Power Plant, near Indiana, Pennsylvania are analyzed. Emphasis is placed on interpretation of frequency distributions and composite horizontal temperature profiles within the plume for several different flights. Discussion of the inadequacies of a simple mean temperature for the plume as a function of range is featured. Airborne measurements used in this study were obtained as part of a larger continuing field program by the Penn State Meteorology Department. Since the beginning of 1975, the Meteorology Department has made over thirty-five flights to the Keystone Power Plant for measurements of plume turbulence, drift water and aerosol, and other related meteorological parameters. The observations and analysis presented should be useful in evaluating current moist plume models and adjusting them, if necessary, so that the models will more accurately reflect the structure and behavior of actual plumes. (ND)

<582>

Mathematical Models for Plumes From Wet Cooling Towers.
Appendix 3A, Edgewater Generating Station Unit 5 Environmental Report. Prepared by Wisconsin Power & Light Co., May 1976. 23 pp.

Appendix presents data describing 3 mathematical models for plumes from wet cooling towers: observed plume height vs. vertical rise; observed vs. predicted plume length, and downwash cooling tower plume regimes. Models present projection for mechanical draft wet cooling towers to be used at the proposed 400-MW Edgewater Unit 5, in Sheboygan County, WI. The first model is used to predict size, location, and characteristics of the visible plume. The second model calculates the probability and extent of ground level fog and icing due to downwash, and the third model determines plume drift.

<583>

Atmospheric Transport of Hydrogen Sulfide from Proposed Geothermal Power Plant (Unit 16) - Predictions by Physical Modeling in a Wind Tunnel.
Appendix F, Environmental Data Statement Geysers Unit 16. Prepared by Cermak, J.E., and Peterson, R.L., Colorado State Univ., Fluid Dynamics and Diffusion Lab. for Pacific Gas & Elec. Co., March 1977. 97 pp.

Appendix describes tests concerning the transport and dispersion of hydrogen sulfide plumes emanating from the cooling tower of the proposed 110-MW geothermal Geysers Unit 16 in Lake County, CA. The tests were conducted in a wind tunnel with a cooling tower and terrain model simulating 2 possible sites for the plant. Descriptions of test apparatus and plume visualization and concentration measurement results are discussed for both sites. Appendix includes 41 figures, 13 tables, and references.

<584>

Mathematical Model for Calculation of Length of Visible Plume, Ground Fog Potential, and Increase in Relative Humidity.
Appendix B, The Sterling Power Project, Cooling Tower Report. Prepared by Rochester Gas & Elec. Corp., 1974. 7 pp.

Appendix explains the mathematical model used to calculate the length of a visible plume, extent of ground fogging, and increases of relative humidity at ground level. The Halitsky noncondensing transverse jet plume model is adapted to describe condensation and evaporation behavior. Principal assumptions of the model were summarized. Data are used to calculate environmental effects of a natural draft cooling tower being considered as an alternative cooling system at the proposed 1200-MW Sterling nuclear plant in Cayuga County, NY.

<585>

Numerical Dispersion Model Study of Trimble County Cooling Tower Plumes.
Technical Appendix 8, Draft Environmental Impact Statement, Trimble County Generating Station. Prepared by Environmental Science & Services Corp. for Fluor Pioneer, Inc. for Louisville Gas & Elec. Co. and U.S. Environmental Protection Agency, Feb. 1976. 57 pp.

Appendix assesses character of the natural draft cooling tower plumes from the proposed Trimble County Generating Station, Trimble County, KY, through the use of a model. Plant operation, cooling tower, and meteorological parameters were input into the consultant's Cooling Tower Plume Impact Model (COTPIM) to determine plume visibility, fogging potential, icing probability, plume trajectories, and drift deposition. Appendix includes 14 figures and 32 tables.

<586>

(Air Quality Considerations - Lower Armstrong Power Station.)
Appendix 3, Draft Environmental Impact Statement: Lower Armstrong Power Station. Allegheny Power Service Corp. Prepared by U.S. Environmental Protection Agency, Dec. 1978. 38 pp.

Appendix 3A presents mathematical models used to evaluate environmental effects of the natural draft cooling towers at the proposed Lower Armstrong Power Station, Armstrong County, PA. Topics covered include treatment of meteorological data, plume rise, length and spread of the visible plume, criteria for ground-level fogging and icing, mathematical techniques, and aerodynamic downwash analysis. A salt deposition rate is also derived and presented. Appendix 3B details the mathematical diffusion model used to evaluate plant impact with regard to ground-level concentrations of sulfur dioxide, nitrogen dioxide, and total suspended particulates (TSP). Model description, operation, and required input are presented. Appendix 3C reviews meteorological data required for stack dispersion analysis. Appendix 3D summarizes estimated boiler trace element emissions from the plant. Appendix 3E presents tables enabling determinations of annual maximum and short-term concentrations of various stack emissions in 16 sectors at incremental distances from the plant. Appendix contains 14 tables and 2 figures.

<587>

Evaluation of Environmental Effects from Evaporative Heat Dissipation Systems at the Seabrook Site.
(NUS-953A) Prepared by Koss, T.C., NUS Corp. for Public Service Co. of New Hampshire, Oct. 1972. 61 pp.

Document presents raw numerical results of 4 computer programs used in the evaluation of environmental effects of evaporative heat dissipation systems at the Seabrook nuclear plant site, Rockingham County, NH. Report includes WINDIF and WINDIF-FOG meteorological tabulations, diurnal variation of the Relative Humidity Defect for each season, predicted elevated plume lengths as a function of direction for each cooling system, and induced fog probability as a function of distance and direction for each cooling system.

<588>

Report on Aerodynamic Model Tests of the Shawville Station.
Prepared by Hoult & Co. for United Engineers & Constructors, Inc. for Pennsylvania Elec. Co., 1975. 83 pp.

A series of laboratory tests were conducted to predict the environmental effects of a new chimney and cooling tower to be installed at the Shawville power plant, Clearfield County, PA. Specific objectives were to identify any special or unique problems associated with placing the cooling tower and chimney in the narrow valley where the plant is located, to identify worst-case environmental conditions, and to estimate the severity of environmental effects under such conditions. Study program consisted of several hundred wind tunnel tests of both cooling tower and stack plumes. Report details wind tunnel modifications and modeling techniques necessary to properly model a buoyant plume in a turbulent atmospheric boundary layer. Scale models of the power plant and immediate environs were made. Both meteorological effects on the cooling tower plume and cooling tower plume effects on stack plumes were then investigated. Report contains 16 figures, 12 tables, 5 appendices, and references.

<589>

Cooling Tower Models.
Appendix H.2, Skagit Nuclear Power Project Environmental Report, Puget Sound Power & Light Co., Oct. 1974. 8 pp.

Contains detailed description of 3 cooling tower models used to predict environmental effects of cooling towers at the Skagit Nuclear Project site. Models include diffusion, plume downwash, and drift. With references.

<590>

A Comprehensive Model Study of Salt Drift Deposits, Induced Fogging and Icing from Mechanical Draft Cooling Tower Plumes at Indian Point.
Included as Appendix C in Economic & Environmental Impacts of Alternative Closed-Cycle Cooling System for Indian Point Unit No. 2, Consolidated Edison Co. of NY., Dec. 1974. 104 pp.

Appendix discusses in detail the theory, implementation, and results of experimental modeling of the behavior of mechanical draft cooling tower plumes in the area of the Indian Point facility. Environmental effects are quantified in terms of salt drift deposits, including fogging and icing in an 18-square mile surrounding area. The principal equations and physics of droplet dispersion, as well as the criteria for fog and icing, are included. All primary variables are covered, including inversion layers, stack height, topography, humidity, wind direction/speed, etc. There are 6 tables, 48 figures, and 13 references.

<591>

Results of Model Computations of Natural Draft Plume Rise.

Table 10.1-7, Clinton Power Station Units 1 & 2 Environmental Report, Illinois Power Co., Oct. 1973. 1 p.

Table lists typical results of several computer runs made to document expected plume rise due to alternative natural draft cooling towers at Clinton Power Station. Parameters include: 1) temperature variation between top of tower and 2,500 ft.; 2) mean relative humidity; 3) mean wind speed; 4) maximum plume rise with no wind; and 5) maximum plume rise with actual wind.

<592>

Mathematical Models Used to Evaluate the Environmental Effects of the Heat Dissipation System.

Appendix 3C, Environmental Report for Pleasants Power Station Units 1 and 2, Monongahela Power Co.; Potomac Edison Co., and West Penn Power Co., Dec. 1973. 15 pp.

Appendix gives the mathematical models used to assess environmental effects of cooling towers at Pleasants Power Station, Pleasants County, WV. Models were used to: 1) determine whether the plume would touch the ground and cause surface fogging and/or icing; 2) evaluate the length and spread of the visible plume; 3) determine liquid water content and visibility, and 4) determine chemical deposition under normal conditions and conditions of aerodynamic downwash. Includes 2 figures.

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ABBREVIATIONS USED

CL - Cooling Lake

CP - Cooling Pond

CT - Cooling Tower

HT - Helper Tower

MDCT - Mechanical Draft Cooling Tower

NDCT - Natural Draft Cooling Tower

OT - Once Through

SC - Spray Canal