Thermal Pollution Analysis

Editor: Joseph A. Schetz

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PREFACE

Thermal Pollution is the generic term applied to the unnatural heating of waterways by industrial discharges, mainly condenser cooling water attendant to electric power generation. Some observers have objected to the inclusion of the word "pollution" in this term since it is not strictly true that unnatural heating of a waterway is always detrimental. Although this reservation can be accepted, it is nonetheless true that this process is usually harmful, and this is the term that has come into general use to describe the problem under consideration here.

The reader entering into a study of this problem area should keep three general items in mind. First, the magnitude of the energy discharged into our nation's waterways is truly astronomical. It is projected that by 1980 approximately 2 trillion Btu per hour will be rejected into the environment via approximately 250 billion gallons per day of cooling water. This will comprise about 1/5th of all the fresh water run-off in the entire country. Second, although the temperature differences between the discharge and the receiving water ($\sim$10-25^{o}F) seem insignificant to the engineer or physical scientist who is accustomed to working in heat exchange problems in other areas of application, even a 1-5^{o}F change in the natural temperature of a body of water can have profound effects on the biological balance of the system. Third, public considerations of thermal pollution often have become rather emotional. The trained engineer or scientist should be prepared to hear the astonishing view expressed by those unfamiliar with the laws of thermodynamics that the power companies choose to reject this heat only because it is somehow cheaper or monetarily advantageous in some other way.

This volume contains the edited Proceedings of a Conference on Thermal Pollution Analysis held at the Virginia Polytechnic Institute and State University on May 14-15, 1974. The Conference was sponsored by the Aerospace and Ocean Engineering Department and the Virginia Water Resources Research Center. Attendees came from seventeen states and the District of Columbia and represented Federal and State governments, power companies, universities, and private engineering firms. The two primary aims of the Conference were to provide a status report on the development of predictive analyses for temperature patterns in waterways with heated discharges and to enable the principal workers in the field and the current and potential users of the results of their endeavors to interact closely. This volume has the same first aim, as well as to provide a concise reference work for others who wish to enter the field or use the results.

Predictive analyses are a vital tool in the control and regulation of the environmental impact of thermal discharges. Unfortunately, until quite recently, neither the power companies nor the regulatory agencies had reliable analyses for even relatively simple installations. Although much progress has been made, as evidenced by the papers in this volume, much remains to be done before designs can be confidently prepared by power companies and approved by regulatory agencies for the wide range of configurations and conditions of interest.

The seventeen papers in this volume have been arranged in an attempt to aid the reader in grasping the problem and our present state of knowledge relative to it. The first paper is concerned with the current practice in the electric power industry insofar as thermal efficiency, heat rejection and water flow rates, chemical treatments, etc., are concerned, and it thus serves as a useful background to the problem area. The next three papers present idealized, one-dimensional analyses of entire waterway sections. The succeeding six papers treat, in detail, the injection and mixing processes in the near field, in the vicinity of the discharge. The eleventh paper reports on a large-scale computer simulation of tidal areas under the restriction of assuming that the velocity field is unaltered by the discharge. The next paper is a large-scale computer simulation of a heated jet in a moving waterway without assumptions as to the velocity distribution. Following this are three papers which describe actual field measurements. The volume closes with a laboratory investigation of jet injection and a study of overall system optimization.

Thanks are due many people for their help with the Conference and the preparation of this volume. Dr. Peter Ashton of the Virginia Water Resources Research Center deserves special mention.

Joseph A. Schetz
July 1974

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SOME CONSIDERATIONS OF THE ENGINEERING ASPECTS OF POWER PLANT DISCHARGES

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Abstract

A necessary prerequisite to making assessments of the ecological impact of power plant discharges is a delineation of the engineering factors affecting these discharges. The present paper describes a comprehensive inventory of discharges and treatment techniques of fifteen power plants in the Maryland region. The inventory covers thermal effluents, chemical discharges from cooling and boiler water treatment systems as well as discharges from auxiliary systems. The acquired data are used to assess various control strategies and trade-offs.

Introduction

While in recent years, the possible adverse ecological consequences of power plant thermal discharges have been recognized as a problem of increasing concern, most of the ecological studies have only dealt with the prediction of the physical and biological impact of the discharges on the receiving body of water.[1] Specifically, relatively little attention has been given to the trade-offs involved among various control

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techniques. It should be noted that in thermal pollution abatement, as in other real-life pollution problems, the benefit to be attained from a specific control technique has to be weighed against the economic, social and aesthetic factors involved. The objective of the present study is to provide the inputs necessary for making the above-mentioned assessments on a sound and rational basis.

The present paper discusses the various engineering aspects involved in the control of waste effluent discharges from steam electric power plants, utilizing as examples certain selected power plants within the Maryland region. A comprehensive review is given of the current control practices at the various plants and of any problems encountered. The detailed information gathered concerns not only thermal discharges but also the wastes resulting from chemical additions to the boiler and cooling water systems as well as the ash-laden waste waters from stack cleaning.

The information gathered is then used as the basis for making engineering assessments of current control practices as well as of the improvements required in the state of the art of the control technology in order to cope with present and projected effluent standards.

Aquatic Impact and Control Strategies

The impact of waste effluent discharges into a waterbody, and the appropriate control strategies, can be viewed in terms of three more or less distinctive and consecutive phases. The first phase, which can be termed the source phase, is concerned with the various factors influencing the characteristics of the effluents and the various trade-offs involved in controlling the discharge of the effluents. The second phase, which can be termed the dispersion phase, is involved with the factors influencing the dispersion of the effluents into the aquatic environment. The third phase, which can be termed the contact phase, is concerned with the impact of the effluents themselves, as well as the changes induced by them, on the aquatic biological community.

Each of these phases has associated with it different classes of control strategies. When, for example, it is required to dissipate a given amount of waste heat into the environment, the control measure may involve the construction of cooling ponds, mechanical-draft or natural-draft cooling towers, or even closed cycle "dry" cooling towers. When once-through cooling is employed, the control measure may involve a reduction of the discharge temperature by an increase in the amount of circulating water. However, when the local temperature increase due to the discharges is of primary concern, the control measures may also be instituted in the dispersion phase by such means as the artificial promotion of turbulent mixing in the vicinity of the outfall or by the construction of submerged outfalls with multiport diffusers. Control measures concerned with the "contact phase" are also possible by locating the outfalls and their zones of influence away from vital aquatic areas (such as oyster beds).

The present study is concerned only with a characterization of the source phase, and the control technology relevant thereof. However, it is erroneous to consider all thermal discharges as being necessarily harmful to the aquatic environment and to seek their unconditional elimination. It should be noted that at least under certain conditions, thermal discharges may have a beneficial impact on the receiving waters. On the other hand, constructive use of the discharges necessarily implies proper waste-heat management, and a thorough understanding of the various factors influencing such management is presently lacking.

Much work remains to be done not only on waste-heat management alternatives but also on identifying the differences in environmental impact when various control techniques are employed. Often a control technique designed to minimize aquatic thermal impact may lead to other adverse environmental impacts. Thus the use of evaporative cooling towers to minimize thermal discharges can lead to more consumptive water use and more chemical load (in the blowdown) than in once-through cooling. Again, when cooling towers are operated in an estuarine environment, the problem of the disposal of concentrated brine will also have to be tackled. Salt deposition from brackish-water drift loss can also be a major problem. A study is currently underway for evaluating this type of possible environmental impact from a mechanical draft wet-dry cooling tower at a proposed power plant site (Brandon Shores) in Maryland. The impact of this wet tower may be felt as far as 3.5 miles away, with an estimated deposition rate of 10 lbs of salt per acre per year.[2]

Effluent Discharge Characteristics

Inventory

Even from the brief description given above, it is clear that to assess the trade-offs involved in various possible control strategies for minimizing the environmental impact of power plants, information on a wide variety of engineering aspects of cooling is required. Since such information is not generally available, a comprehensive inventory of fifteen power plants within the Maryland region was undertaken.

The heart of the inventory was a specially designed power plant questionnaire containing 226 questions on general background, cooling techniques, chemical treatment of water used, wastes from noncooling sources (such as flyash), economic factors and general engineering considerations. The questionnaire was used in conjunction with visits to individual power utilities and plants, during which both the questions and answers were discussed in detail. The information supplied by the power plants was cross-checked against that obtained from other sources, such as the Federal Power Commission. In this way, a set of thoroughly comprehensive data on all aspects of power plant discharges was compiled. The fifteen plants surveyed are listed in Table I.

Table 1 Power Plants Operating in the Maryland Region

Utility	Plant	Location	Installed Capacity MW	Type[a]
Baltimore Gas and Electric Co. (BG & E)	Westport	Baltimore	194 132	F G
	Gould St.	Baltimore	156	F
	Riverside	Baltimore	322 182	F G
	Wagner, H.A.	Baltimore	992 16	F G
	C. P. Crane	Baltimore	386 16	F G
Delmarva Power and Light Co. of Md. (DELMARVA)	Vienna	Vienna	244.5 18.6	F G
The Potomac Edison Co. (Allegheny Power Serv. Corp.) (APSCO)	Smith, R. P.	Williamsport	129	F
Potomac Electric Power Co. (PEPCO)	Dickerson	Dickerson	570	F
	Chalk Point	Aquasco	730	F
	Morgantown	Newburg	1309	F
Power Plants Operating in the Maryland Region				
Potomac Electric Power Co. (PEPCO)	Potomac River	Alexandria, Virginia	515	F
	Benning Road	Wash. D. C.	712	F
	Buzzard Point	Wash. D. C.	305 249	F G
Virginia Electric and Power Company (VEPCO)	Mount Storm	Mount Storm, W. Va	1106 14.9	F G
	Possum Point	Dumfries, Va.	477.1 91.2	F G

[a]F = fossil fuel operation, G = gas turbine.

Thermal Discharges

The rate at which waste heat is generated by a power plant is a function of not only its capacity, but also the efficiencies of the various units that comprise the plant. The plant efficiencies within the Maryland region range from 28.8% to 38.9% with the average plant efficiency being 34.2%.‡

More recently constructed plants, of course, have higher efficiencies than the older plants. However, plants with recently installed units also have high efficiencies independent of the date the plant commenced operation. Taking this into account, the trend in the improvement of the efficiency of the power plants over the last several years is shown in Fig. 1. As can be seen from the figure, within the Maryland region the efficiency of fossil fueled plants has improved at a rate of 0.3% per year. This regional figure compares well with national values for the improvement in plant efficiency (about 0.38% per year) for fossil fueled power plants.[1,3]

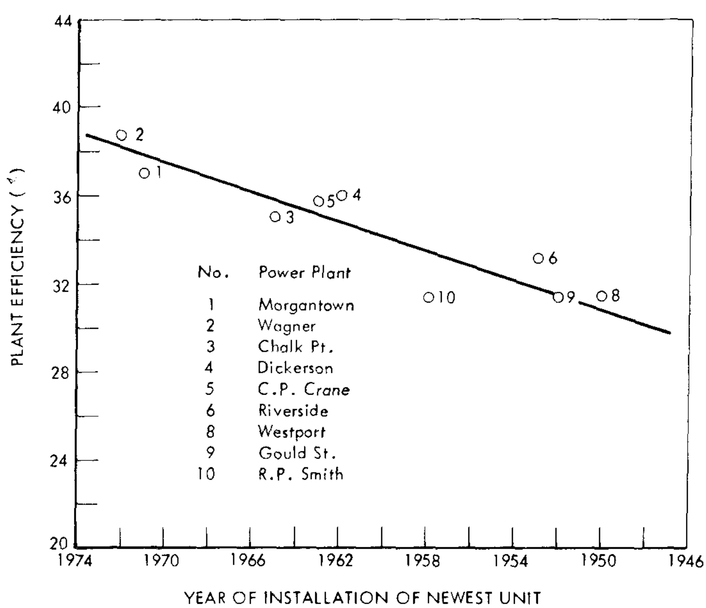

Fig. 1 Plant age vs efficiency.

‡ All the power plants being considered here are fossil fueled.

When water is used as the cooling medium, the waste heat has to be dissipated by using an appropriate temperature differential across the cooling condensers. The average temperature increases across the condenser, for power plants surveyed is 15.1°F. This average compares well with the corresponding national average value of 15°F that has been reported in a recent study.[4] To examine any possible trends in this temperature differential with the age of the power plant, the former is plotted against the latter in Fig. 2. The plant age shown in this figure is computed taking into account the time of installation of the newest unit. It can be seen from the figure that, in spite of the considerable scatter in the data, there is a very definite trend indicating that the newer power plants employ smaller temperature differentials than the older ones. It should be noted that the correlation is also with power plant capacity, since the newest plant is also the largest.

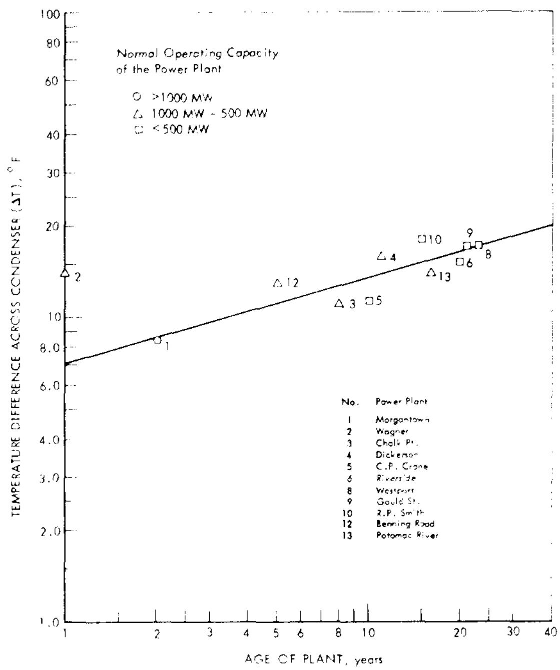

Fig. 2 Condenser ΔT vs the age of the power plant.

While it is clear that design changes due to environmental concern are probably not the cause for the correlation observed, it is nevertheless worth noting that it is significant for predicting environmental impact when the temperature of the discharges is of primary concern. In actual engineering design practice, the temperature rise across the condensers is a function of the type of cooling device used as well as the turbine back pressure. In particular, as the temperature of the cooling flow increases, the turbine back pressure also increases. Therefore, in order to maintain the best turbine efficiency, an optimum value of the back pressure