guarding power-produced plutonium from diversion to weapons.

*William G. Pollard*

191 W. Outer Drive
Oak Ridge, Tennessee 37830

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*About the reviewer: Bill Pollard became engaged in studies of the extraction and utilization of nuclear energy upon joining the gaseous-diffusion research and development team at Columbia University in early 1944, an association that continued until essentially the date of this review when he retired from the Oak Ridge Associated Universities (ORAU). The association embraces many achievements including the conception and fruition of the Oak Ridge Institute of Nuclear Studies (now ORAU), of which he was executive director for many years. He completed his graduate studies in physics at Rice University in 1935 and was a member of the faculty of the University of Tennessee in the 1940's.*

*Dr. Pollard's position in the priesthood of the Episcopal Church and his stature in the physics community have emphasized the absence of conflict between religion and science.*

**Symposium on Cooling Tower Environment—1974.** CONF-740302, U.S. Energy Research and Development Administration (1975). 682 pages. $13.60.

This symposium was conducted at the University of Maryland at College Park in March 1974. It was sponsored by the State of Maryland Power Plant Siting Program in conjunction with the U.S. Atomic Energy Commission, now the U.S. Energy Research and Development Administration.

The compelling reason for the symposium can be traced to the legally momentous Calvert Cliffs decision by the U.S. District Court in the matter of licensing of nuclear power plants. This decision set the pattern for environmental impact statements for all nuclear plants then under construction or in any phase of the licensing procedure.

As the program for preparation of these statements progressed, it soon became evident that the once rather neglected appendage to process industries, the cooling tower, suddenly was to be elevated to the rank of "super star." For operators of large electric generating plants were suddenly faced with the fact that one of the most obvious and noticeable impacts from the standpoint of public visibility was the tremendous volume of cooling water and related equipment required for removal of the waste heat from the power cycle. The obvious solution—cooling towers—soon were seen to create a totally new set of problems that up to this point had received very little attention.

With the advent of the environmental statements and court hearings, the environmental effects of the large towers soon received much attention from all concerned—designers, plant operators, environmentalists, and the lay public. The task of evaluating the cooling systems proved to be nearly as formidable as evaluating the nuclear plants themselves, in that the analyses of their environmental effects required a rigorous multidisciplinary approach.

In its efforts to answer some of the questions relating to ecological effects of power generation, the State of Maryland through its Plant Siting Program has provided a valuable research program for obtaining much needed information at an existing generating station. It was apparent that this program fit well with several other ongoing programs in both the government's and the private sector's efforts relating to studies of the electric power industry. The purpose of the symposium was to bring together many of the researchers doing important work in the field to report on their latest results and to encourage free discussion and exchange of information. The papers presented represent work done in all the major areas associated with the environmental effects of cooling tower operation.

Among the papers presented are studies of the overall economic and social implications of selecting a cooling system for a steam electric plant. Included is a review of the many possible choices, including wet cooling towers of both mechanical- and natural-draft type; a combination of wet-dry cooling towers; and a choice of cooling lakes, ponds, or spray canals. It should be recalled that when the merits of a cooling system for a given unit are assessed, any reduction of the net plant capability below its design rating must be replaced by additional generating capacity or the incremental cost of power resulting from that particular cooling system must be considered. This requires a very careful analysis of both capital expenditures and operating costs. The environmental cost, therefore, must be considered versus the selection of the system on a strictly economic basis. Although this area is not the central theme of this symposium, it is addressed in at least two papers.

Several papers deal with the phenomena associated with the operation of these large cooling systems. Included are papers related to the large vapor plumes whose traverse depends on external meteorological conditions, the possibility of plume recirculation, and ground level interference from downwind mechanical-draft cooling towers. The effect of vapor plumes on the environment, as well as the possibility of contribution of moisture to additional fogging, is discussed. The latter is of particular significance where cooling towers are close to well-traveled or major highways.

Mathematical models for the cooling tower plumes were presented. Although these models all involve very sophisticated analytical techniques, it is rather unfortunate that validation of the models is far less sophisticated at this time. In most cases, there are insufficient data taken at the actual sites to clearly substantiate the accuracy of the models. However, with the increasing addition of meteorological towers at newer installations and observations at many more operating facilities, plume model validation techniques should improve in the near future.

Another area of significance associated with the operation of cooling towers relates to the amount of chemical drift deposition associated with the traverse of the plume. The discussion included a presentation of several techniques for measuring drift particle characteristics. Development of a laser-light scattering measurement system for determining the distribution and particle size of the solids is described. When drift measurement problems were first discussed four years ago, the accepted measure available on the basis of manufacturers' guarantees was on the order of 0.2% of the total recirculating water flow. It was also known that air flows associated with cooling towers could carry droplets as large as 1000 μm out of the tower to the surroundings. Fortunately, through the use of the more sophisticated measuring techniques involving isokinetic sampling, sensitized paper measurements, and the laser particle detection method, it has been found that several pre-1974 state-of-the-art towers exhibit drift fractions that are several orders of magnitude less than their guarantees.

Perhaps the most comprehensive study on the environmental effects of chemicals carried in the cooling tower plumes presented was conducted by F. G. Taylor, Jr. along with other members of the Environmental Sciences Division of the Oak Ridge National Laboratory, using the very large mechanical-draft cooling towers associated with the Oak Ridge Gaseous Diffusion Complex as their model. An inventory of plant and soil materials in the environs of the Gaseous Diffusion Plant reservation provided quantitative evidence of transfer of chromium and zinc to vegetation from cooling tower operation. As expected, from the atmospheric dispersion models, chromium and zinc, which are chemicals used in the corrosion treatment of the circulating water system, are found in concentrations in vegetation that are highest adjacent to the tower and decrease exponentially with increasing distance from the source. Using vegetation analyses, along a horizontal gradient, it was determined that the concentration in foliage and litter remains relatively constant. Distribution coefficients for hexavalent chromium added in solution to soils show that little chromium is absorbed. Values for zinc indicated the soil acts as a reservoir for the small quantities derived from drift.

The book also includes investigations of ecological effects of airborne salt. This subject is a particular concern of those on the coastal area or where brackish waters will result in a drift loss containing relatively high concentrations of salts. Techniques for experimentation and measurement of effects on vegetation are discussed. The results are compared with wind-tunnel studies and are considered along with impingement techniques for measurement of sodium and chloride uptake of various vegetation. The Chalk Point program for determining the ecological effect of salt spray from cooling towers is perhaps one of the best organized programs available at the present time. This program, operating in conjunction with the University of Maryland, is a sophisticated in-depth attempt to measure both the characteristics of the cooling towers themselves and the effect of the salt spray transported in the cooling tower plume.

James E. Carson of Argonne National Laboratory, in his comments on the meteorological consequences of thermal discharges from nuclear power plants and associated research needs, puts the problem in terms of the real world quite succinctly in stating "costly engineering decisions are presently being made which are based in part, on estimates of models which are not adequately substantiated by quantitative observations of the effects of thermal discharges from proposed nuclear plants on the atmospheric environment." His contention is that the state-of-the-art in meteorological knowledge and modeling is not quite adequate to yield the accurate predictions of atmospheric effects with a required degree of confidence.

An interesting comparison is presented by D. J. Moore of the Central Electricity Generating Board in England. The Board is responsible for power generation in that country. He reports the observations the British have experienced with their large natural-draft cooling towers that have been in operation in that country for a relatively long period, and his conclusions are as follows:

> The records at 10 climatological stations situated between 4 and 112 kilometers from the 2000 MWe station at Ratcliffe in Nottinghamshire concludes that no significant changes in rainfall, bright sunshine, or occurrence of fog can be attributed to the power station. The observer arrived at this conclusion by comparing the period between 1960 and 1967, before the station was commissioned, and from 1968 to 1971, after it was commissioned. As a result of this observation, the author states that they conclude persistent plumes are shown to occur mainly in conditions of high ambient relative humidity when natural clouds are usually present and that precipitation is very slight and again only occurs when natural rain is falling or conditions are close to those in which natural rain would occur and that fog, at ground level, is not observed.

In addition to the presentation of the technical papers, the symposium offered an opportunity for many of the investigators who were concurrently working in related fields to confront each other and discuss their conclusions in an atmosphere that could be considered highly productive and could result in an improvement in those areas about which there still appears to be some uncertainty. All in all, my feeling is that the symposium was an important conference with regard to the cooling tower problem and is probably the best single source for overall discussion of the problem available today. It should be a valuable reference source for those who are confronted with the problem of the evaluation of the environmental effects of cooling tower operation.

*T. Shapiro*

Oak Ridge National Laboratory
Engineering Division, P.O. Box X
Oak Ridge, Tennessee 37830

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*About the reviewer: Ted Shapiro is a member of the Design Staff of the Oak Ridge National Laboratory General Engineering Division of Union Carbide Corporation. In this position he does conceptual designs and early evaluations of chemical processing aspects of major new projects at the Laboratory. Mr. Shapiro received a BS in chemistry from Boston University and has been engaged in graduate studies at the Massachusetts Institute of Technology, and continuing education at the University of Tennessee. He is the author of several publications relative to the environmental effects of large cooling systems.*

**Energy: Historical Development of the Concept** (Benchmark Papers on Energy, Vol. I). Edited by R. Bruce Lindsay. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania (1975). xiii + 369 pages. $25.00.

The present volume is an introductory volume for one of the 20 series envisioned by the publishers, each series consisting of "from 12 to 40 or more volumes" that provide reprints of "classic and recent papers" in particular fields, with accompanying editorial comment. The papers in this volume are concerned with the development of the concepts of the various forms of energy, the transformation from one kind of energy to another, and the general principle of conservation of energy. The excerpts and full-length papers included here come from the writings of 32 individuals, from Aristotle (384-322 BC) to Joule (1818-1889). These constitute approximately 80% of the book; the remaining 20% is devoted to brief biograph-