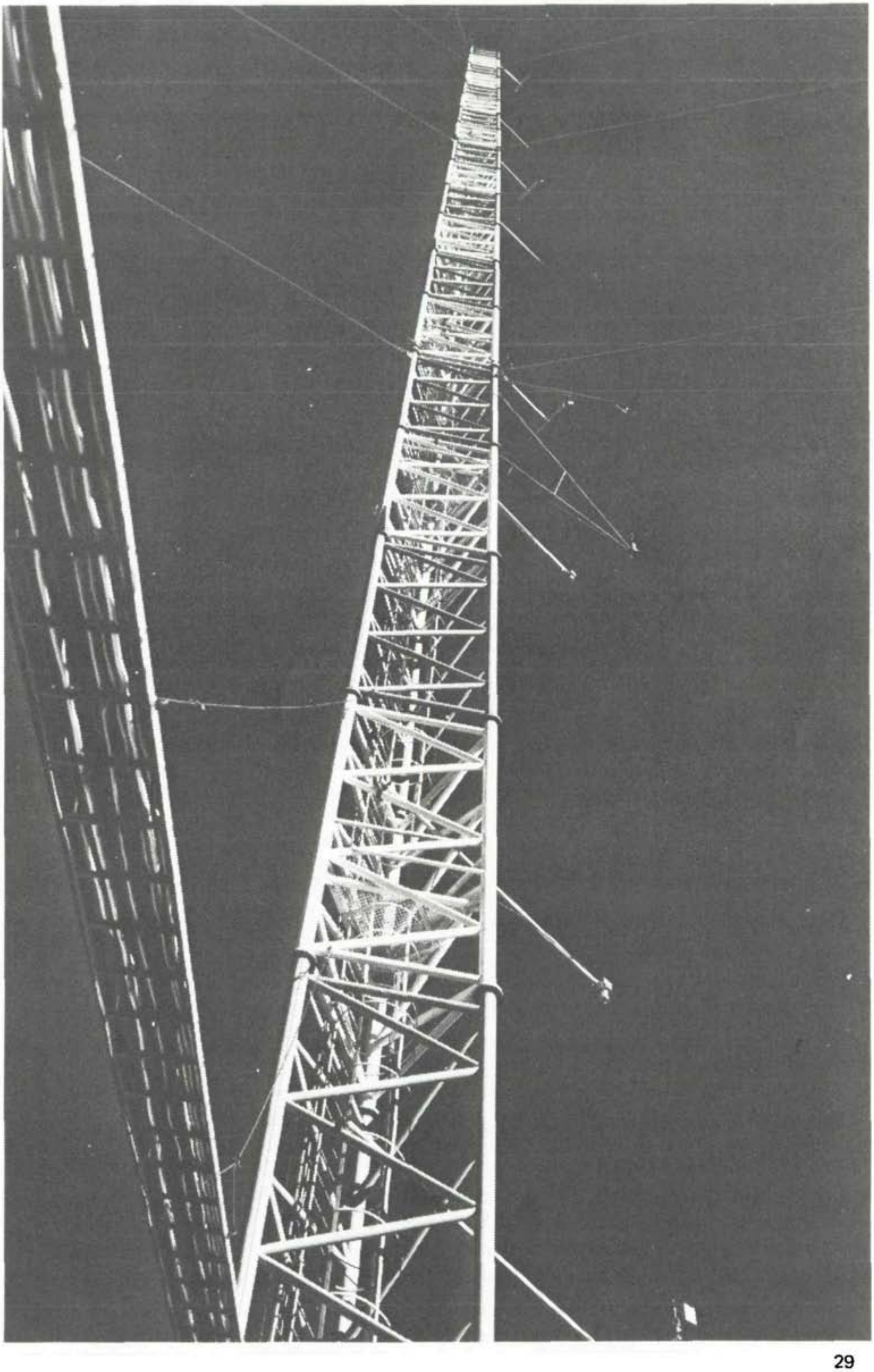
REPORT OF AN IAEA SYMPOSIUM, NORWAY, AUGUST 1974
The Symposium was attended by
197 specialists representing 25 countries and 8 international organizations.

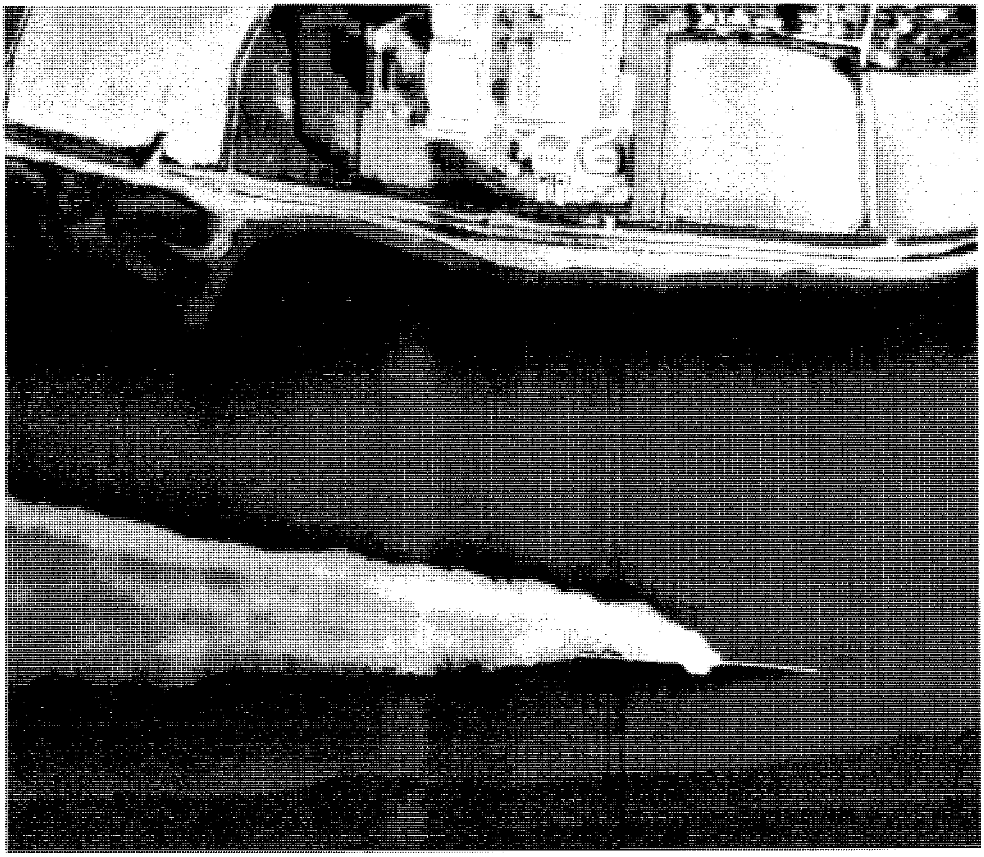
Environmental Effects of Cooling Systems and Thermal Discharges at Nuclear Power Stations

The problem of the impact on the environment of thermal discharges from power stations is certainly not a new and specific problem of nuclear power production by fission reactors. Every thermal power station creates the problem of waste heat management and of possible impairment to man's environment. However, although the problem is not a new one, it has become of particular importance for two principal reasons: man's increasing awareness of the need to preserve or improve the quality of his environment, and the very magnitude of the growth in electrical energy demand.

During the past few years a number of estimates have been prepared by a variety of national and international sources of the expected rapid growth in this energy demand to sustain and improve the quality of life for an expanding world population. Such estimates need to be reviewed from time to time, particularly in respect to nuclear power, due to the sensitivity of the world's economy to changes in the cost of energy resources. The recent extensive increase in the price of oil has led to a much broader interest in nuclear power for electricity generation. Even if there is some decline in oil prices, electricity from nuclear power will remain very competitive with that from coal, oil and other thermal sources even down to a unit size of 200 MW, and thus nuclear power will become attractive to an increasing number of developing countries. Recent projections of installed nuclear generating capacity indicate a world growth from 105 GW(e) in 1975 to 5330 GW(e) at the year 2000 with an interim figure of 890 GW(e) in 1985. For a model 1000 MW(e) light water reactor the waste heat rejection is calculated to be 50×10^{12} BTU per year, and for the supporting services for the model, such as uranium milling, hexafluoride conversion, enrichment and fuel reprocessing the waste heat rejection is 3.4×10^{12} BTU per year. Thus assuming a 70% load factor the total waste heat rejection from nuclear power in the year 2000 would be 2.0×10^{17} BTU, or 5×10^{14} BTU per day, of which only 7% is due to the supporting services. The dispersal of this heat to the environment without unacceptable disturbances is therefore of considerable importance.

The meteorological mast at Studsvik, Sweden, which registers wind speed and direction, and temperature for the study of behaviour of thermal plumes in the atmosphere. Photo: AB Atomenergi. ▶





A picture of the outflow of cooling water from the Bradwell Power Station, England, obtained at 2000 feet by infra red linescan equipment developed by the Royal Radar Establishment, Malvern. Photo: U.K.A.E.A.

Among the topics discussed at the Symposium were:

- **Heat dissipation and the physical behaviour of heated effluents in the atmosphere and in various types of aquatic systems.**
- **Effects on biota and environment ecosystems of cooling systems and thermal discharges**
- **Alternative methods for the management of heated effluents, and possible beneficial uses of waste heat.**
- **Criteria for the establishment of thermal release standards**
- **Effects of cooling systems and thermal discharges on siting policies for nuclear power plants.**

The papers presented and the discussions that followed the meeting outlined the experience and research results of countries with large developing nuclear power programmes, and also some of the plans and studies of the smaller countries as they assess the potential environmental and thermal impact of installing large steam-electric generating stations in their countries. One conclusion expressed by a number of speakers was that each individual site must be evaluated on a case by case basis to ensure that the impact of this site's operations will be environmentally acceptable.

It was reported that to meet the rapid growth in electrical energy demand plants of larger unit capacity were being constructed as well as multiple unit facilities. At the same time water for condenser cooling for these large plants, particularly on once-through systems, is becoming more scarce as the energy requirements continue to expand. For example in England over 300 cooling towers are now in operation for the control of thermal discharges; in the Federal Republic of Germany and the Soviet Union cooling towers or closed cycle systems are becoming more common, and in the USA it has been estimated that by the year 2000 over half the available natural water run-off would be needed for steam-electric power plant cooling.

The physical behaviour and environmental impacts of visible plumes from wet cooling towers were described in a number of papers. The performance of natural draft and assisted draft towers and the development of dry cooling towers were also discussed. Thermal releases from possible multiple unit sites of up to 40 000 MW(e) would pose problems and there is incentive for the development of dry cooling towers to overcome the problem of potential water supply requirements for this type of facility. Studies are being made of the possible local atmospheric disturbances that might arise from the release of up to 80 000 MW of heat at a concentrated site. The off-shore siting of such large power plant complexes was suggested as a possible means to offset some of the environmental limitations of such installations; in certain coastal areas where the continental shelf is narrow enough, the cooling capacity of the deeper ocean might be utilized by pumping water from great depths at low temperature. At the same time further benefit might be gained by the use of the high concentrations of nutrients in this extracted deep water for aquaculture.

From the reports of delegates it was apparent that methods for conserving energy are being sought on a concerted basis all over the world. It is reasoned that every BTU of heat energy saved not only extends our critical fuel supply, but also results in a reduction in the waste products of fuel consumption such as atmospheric and thermal pollution. One way to conserve energy is to use the heat which has been discharged from some conversion or industrial process, and an abundance of such heat is available, often at low cost and usually at the 15-35°C temperature range from steam electric power plants. A single 1000 MW(e) nuclear power plant using once-through cooling requires about 50 m^3/sec of water for cooling, which is equivalent to the entire water consumption of a city as large as Chicago.

A number of applications of waste heat in agriculture and aquaculture were also described. Agricultural aspects include greenhouse heating, warm water irrigation, soil heating, and frost protection of crops. Probably the largest greenhouse range in the world is at Ploesti in Romania; this 130 hectare complex consumes 400 MW of heat which is supplied by hot water heating.

In aquaculture the use of heated effluents from power plants to maintain optimal temperatures for growth and high yields of fish and seafood is only a recent development. On an international basis, the Japanese have led the way in demonstrating the benefits of waste heat utilization for aquaculture. During the past 10 years culture experiments with shrimp, eel, seabream and with fish have been carried out with thermal effluents from steam-electric power generating stations. Since 1971, a large culture programme involving shrimp and fish has been in progress at Japan's first nuclear power station, the Tokai reactor plant of the Japan Atomic Power Company. Another successful use of waste heat in aquaculture is the commercial operation by the Long Island Oyster Farms in the USA, which utilizes thermal effluents of the Long Island Lighting Company to enhance the growing during the early stages of oyster culture. Normal growing periods of 4-6 years have been reduced to 2.5 – 3.5 years by selective breeding, spawning, larvae growth, and by seeding the oysters in the hatchery, and then placing them in a warmed discharge lagoon of the plant for 4-6 months. Sales from this commercial activity are reported to be about five million dollars per year.

Laboratory and field studies of effects on biota from thermal discharges were reported in a number of papers. The development by the Oak Ridge National Laboratory of a temperature sensing ultrasonic transmitter that could be implanted in freely swimming wild fish, had enabled extensive field studies to be made of the tendency of fish to select certain temperatures in thermal gradients. The tag is a cylindrical electronic package covered by silicone rubber measuring 1.8 X 4 cm and weighing 26 g (in air) with a thermistor probe on a flexible appendage. Signals can be received with a quality sufficient to accurately decode temperature data up to distances of 1/2 to 3/4 mile in quiet water, and the tags have a nominal lifetime of 5 months. Much valuable data had already been gained through the use of this equipment on temperature selection by fish encountering thermal gradients, and field studies are continuing. Another study reported on behavioural responses of Lake Michigan fishes to a nuclear power plant thermal discharge, and the effects of heat enrichment on species succession and primary production in fresh-water plankton was also discussed. The ecology of artificially heated streams, swamps, and reservoirs was described in a report on studies carried out at the Savannah River Plant in USA. It was generally apparent from discussions that there was a growing need for continued research and studies on effects of thermal discharges on biota in order to provide more data which would be of value in developing criteria for the development of standards for thermal release, and also as an aid to siting nuclear power stations.

The question of having criteria or standards has come about because at some power stations under observation environmental effects from thermal releases have been observed. Some of these have been clearly detrimental; others have probably been beneficial, and in a large number of cases they are very uncertain. Since there are probabilities of having detrimental effects, some limits ought to be established so that planners don't go too far beyond what could either be beneficial,inconsequential or detrimental. The real questions are what kind of criteria should one adopt? How detailed should the criteria be? Where should the criteria be applied? While debating these issues power plants are going to be built – they have to be built – and we have the real danger of formulating technically poor criteria too soon, or the danger of coming up with very excellent criteria too late. Varied views were expressed on the distinction between criteria and standards. On the one hand it was suggested that criteria were socially desirable objectives, whereas standards were obtainable objectives. Alternatively, and a more readily acceptable distinction, is that criteria are the scientific data on which one can base recommendations for the particular standards that may be necessary.

This symposium was the first to be organised by the Agency on the specific question of environmental effects of cooling systems and thermal discharges, and the participation in the symposium evidenced both the timely need for such a meeting and its particular value as a forum for exchange of information in this field with application to all steam-electric power plants.