ABSTRACT

The increase in electric power generation and modern thermal power plant size have intensified the problem of disposal of waste heat from their condensers. Thermal and nuclear power plants need large quantity of cooling water for condensation. The cooling water is usually taken from natural or artificial water sources such as a lake, river or ocean. The cooling water after use is returned to the same water source with an allowable temperature rise of around 10°C. The warm water discharged over the surface of stagnant cold water, known as surface buoyant jet, spreads over it due to buoyancy effect and forms a local warm water zone. In recent years, this type of heat rejection into reservoirs has received considerable attention as the determination of mixing of warm water with stagnant cold water helps to avoid the re-circulation of this heat back to the condensers. Re-circulation of waste heat to the condenser affects the power plant performance. Similar waste heat rejections also happen from the industrial processes, which affect the environment. The dissolved oxygen in the water sources that receive the waste heat decreases with increase in temperature. Dissolved oxygen is essential for sustaining the plant and animal life in any aquatic system.

The warm water discharges known as surface buoyant jets may often be considered as free boundary flows and their analysis depend on fluid flow and heat transfer mechanisms with the assumptions that biological, chemical and other related processes has no effect on the physical aspects of the jet. It may be noted that the jet spread over the stagnant water surface is in axial, lateral and vertical directions and is generally influenced by the combination of flow momentum and buoyancy effect. The lateral spreading is almost entirely due to the buoyancy effect. The vertical depth-wise growth of the jet is much smaller. The buoyancy induces an upward motion counteracting the vertical growth.

The main objective of this study is to establish a general method to predict the temperature distribution at any location and velocity distribution along the axis in the flow field of a three-dimensional surface circular buoyant jet discharged horizontally over the surface of a stagnant water.

The investigations are carried out using experimental and analytical methods with the aim of

1) identifying the pattern of the jet growth in lateral and vertical directions in the flow field of the jets,
2) establishing general relationships for temperature and velocity profiles for different three-dimensional jets and
3) validating the analytical predictions with experimental data.

Experiments were conducted with three-dimensional surface buoyant water jets issued from a circular pipe over the stagnant water surface. Temperatures were measured at a number of points along the jet axis, in lateral and vertical directions in the flow field and local velocities were measured at different locations along the jet axis. From the experimental data, trends of temperature profiles were identified along the flow axis, in lateral and vertical directions and velocity profiles were identified along the jet axis for various jets. Temperature and velocity profiles of these buoyant jets were also predicted using Finite Element Analysis software. The analytical results are in good agreement with experimental results. General relationships for temperature and velocity were thus established.

The temperature and velocity relationships established in this work will be useful to design the cooling water systems for thermal and nuclear power plants without the problem of re-circulation of waste heat to the condenser. Further, the study will provide the required information for evolving environment standards for protecting under-water living organisms.