ABSTRACT

The subject of heated water flow from power plants into natural reservoirs of water has received considerable attention in recent years. One of the main problems in the design of cooling water system for both nuclear and thermal power plant, is the determination of mixing of warm water with stagnant cold water to minimise recirculation of waste heat. For this purpose, the study of temperature distribution in stagnant reservoir becomes essential. It is necessary to determine the increase in temperature of the water taken to the condenser from the same reservoir, as it adversely affects the efficiency of the power plants. For low level heat rejection, the intake water temperature is usually unaltered. In the case of power plant cooling system, the heat rejection level being higher, it results in considerable increase in water body temperature, and these aspects require detailed investigation.

The flow in the neighbourhood of discharge point may often be approximated as a free boundary flow in a stratified or isothermal ambient medium, particularly for the large water bodies. The temperature decay away from the discharge together with downstream spread and decay of the flow field are currently gaining considerable importance. If an assumption is made that biological, chemical and other related processes associated with heated water discharge has no feedback on the physical aspects, then the problem reduces to one of fluid flow and heat transfer. It may be noted that the combination of flow momentum with buoyancy influence the temperature distribution in the flow field of a jet.

The objectives of this work are to investigate the temperature distribution of two-dimensional surface buoyant jets discharged horizontally over a bed of stagnant cold water. Specifically, the following aspects are addressed : (1) experimentation to measure temperatures at number of points in the flow field of a two-dimensional surface buoyant jets. (2) comparison of the experimentally determined temperature profiles of two-dimensional laminar surface buoyant jet with the corresponding temperature distribution of turbulent jets. (3) investigation of the influence of buoyancy force on the temperature profiles of the laminar and turbulent surface buoyant jets. (4) development of a numerical model suitable for both laminar and turbulent surface buoyant jets to predict their temperature distribution characteristics and verification of the numerical results based on experimental studies. (5) analysis of the test results to establish simple relationships based on statistical methods to represent the temperature profiles of the laminar and turbulent surface buoyant jets.

The experiments on plane laminar and turbulent surface buoyant jets were conducted in a glass-walled horizontal rectangular open channel. In order to study the heat dispersion in the field, temperatures were measured at number of points in the flow field located vertically below the centerline of the jet at various stations in the flow direction using thermocouples. Analysis of the experimental data of temperature distribution of surface buoyant jets reveals that the temperature profiles in the flow field do not strictly follow Gaussian distribution. Factors responsible for the above observed deviation were studied based on the different heat transfer mechanisms existing in the flow field.

Significant thermal buoyancy effects could be observed in the flow field of surface buoyant jets when the discharge temperature of the jet increase. However, with increase in flow velocity, the influence of the buoyancy decreases. In order to consider the combined effect of forces due to buoyancy and momentum in the study of temperature distribution of laminar and turbulent surface jets, a ratio of the above two forces is considered in this work and is designated as mixed convection factor Gr/Re^2, where Gr is the Grashof number and Re is the Reynolds number. It was noted that the trends in the temperature profiles of both laminar and turbulent surface buoyant jets were dependent on the magnitude of the mixed convection factor.

A numerical method is proposed to solve the governing equations of two-dimensional surface buoyant jets, incorporating mixed convection factor, for the purpose of prediction of temperature profiles. The governing partial differential equations of mass, momentum and energy were reduced to ordinary differential equations by similarity transformation technique. A similarity parameter is designed to include the mixed convection factor. The resulting simultaneous coupled ordinary differential equations were solved by Runge-Kutta method of 5th order with appropriate flow and thermal boundary conditions. The results of the above numerical approach were found to be in close agreement with the experimental values.

A set of simple expressions have been developed based on statistical analysis. These expressions are of the generalised type in view of the fact that several non-dimensional factors have been incorporated. It is found that the these expressions describe the temperature distribution obtained from the experimental studies to a close degree of accuracy. The degree of closeness of prediction of these expressions are compared with other relationships reported in literature. An interpolation method suggested in the present work greatly reduces the number of experimental measurements required for establishing the trends in temperature profiles.

The results of the work reported in this work will be of immense use to the designers involved in the design of cooling systems of power plants. Further, the studies will provide the required background for evolving environment standards for protecting under-water living organisms.

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