Free convection around a horizontal circular cylinder. 
Adimensional empirical equations

R. DIEZ, M. DOLZ, R. BELDA, J.V. HERRAEZ* & M. BUENDIA
Department of Thermodynamics, Valencia University, Avenida Blasco Ibanez 13, Valencia 46010, Spain (*author for correspondence)

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Abstract. An experimental study involving holographic interferometry has been made of the natural convection from a horizontal cylinder in air, and for an extensive range of surface temperatures covering a range of values Gr.Pr between 3600 and 5600. A number of semi-empirical equations were obtained that satisfactorily reproduce the adimensional field of temperatures around the cylinder. Moreover, the functions that provide the local and average Nusselt number values in terms of the corresponding Grashof and Prandtl numbers have also been obtained. Their close correspondence with the contrasted empirical formulas shows that the method employed may be used to obtain variation equations of both temperature and Nusselt magnitudes that involve angular position and are fully compatible with the mean values used in practice.

Nomenclature

\[ D = \text{cylinder diameter} \]
\[ \text{Gr} = \text{Grashof number based on the cylinder diameter} \]
\[ h = \text{heat transfer coefficient} \]
\[ k_f = \text{thermal conductivity at } (T_s + T_\infty)/2 \]
\[ L = \text{cylinder length} \]
\[ \text{Nu, } \text{N}\bar{u} = \text{local and average Nusselt numbers, equations (12) and (18)} \]
\[ n_\infty = \text{air refraction index at infinity} \]
\[ \text{Pr} = \text{Prandtl number, } C_p\mu/K_f \]
\[ R = \text{cylinder radius} \]
\[ S = \text{order of interference} \]
\[ \Delta S = \text{order of interference correction} \]
\[ T = \text{temperature (K)} \]
\[ T_s = \text{temperature of the cylinder (K)} \]
\[ T_\infty = \text{temperature at infinity (K)} \]
\[ x = \text{distance along the cylinder} \]

Greek symbols

\[ \alpha = \text{angular coordinate} \]
\[ \sigma_m = \text{quadratic deviation of the arithmetical mean} \]
\[ \eta = \text{dimensionless distance, equation (3)} \]
\[ \lambda = \text{laser wavelength} \]
\[ \theta = \text{dimensionless temperature, equation (4)} \]
1. Introduction

A knowledge of the temperature distribution in the space surrounding a heating system is an essential first step to determine the energy exchange between the hot surface and the medium. This problem has been dealt with by classical authors in the literature, e.g., Kennard [1] and Eckert [2], among others. More recently, Wanders [3] measured the thermal conductivity of fluids by studying temperature distribution in terms of both position and time, Koster [4] and Steinberner [5] determined the energy flow in gaps with internal heat sources, whereas Sako [6], Badr [7] and others studied the transfer processes from cylinders using numerical solutions according to the finite differences method, or theoretical solutions of movement and energy equations to obtain a dimensional isotherms around the cylinder, etc.

On the other hand, traditional methods for measuring temperatures pose two basic inconveniences: they absorb heat and therefore modify the temperature field, and are limited to a point-by-point determination of temperature within the region of interest. A global evaluation is therefore not possible. Only optical approaches such as the Schlieren method recently used by De Socio [8], or holographic interferometry are able to provide global studies without altering the temperatures undergoing measurement. Thus, Kaiser [9], Benet [10], Zemanek [11], Korchazhkin [12] and others applied the latter method to determine the temperature fields of different experimental models Lucarini [13] managed to automatize the data acquisition and analysis of interferogram fringes produced by temperature fields in a homogeneous transparent medium.

As a contribution to the many investigations underway on the subject, we studied the stationary temperature field surrounding an internally-heated horizontal metal cylinder under conditions of free convection in air, and for a broad range of surface temperatures. The experimental aspect of the study involved double exposure holographic interferometry [14–15]. Following the corresponding fitting, the great amount of data gathered made it possible to determine the empirical formulas that best describe the temperature distribution for each of the elemental experiments [16] involving a relatively small cylinder with a broad range of surface temperatures. Using adimensional magnitudes to generalize these data, it then became possible to obtain a single set of semi-empirical mathematical expressions for calculating temperature at any point around the cylinder with errors under 5% in many cases.