Results are presented for the dynamic calibration of temperature converters in a liquid stream using thermal heterogeneities produced in the water by pulses of infrared radiation of a neodymium laser.

A full description of the dynamic properties of a contact probe measuring the temperature of a non-stationary process is given by its transmission function [1], for an experimental determination of which one must know the form or spectrum of the input effect on the thermometer. In connection with the absence of a standard method of calibration it is carried out under the conditions which most fully simulate the conditions of employment of the thermometer [1-3]. Thus, if the thermometer is intended for the recording of temperature pulsations in a moving liquid it is calibrated in an analogous stream in which a controlled temperature process is created which provides a known form of input effect. In the present report the input effect on the thermometer is understood to be the space-time temperature distribution calculated or measured by a standard instrument in the region of the stream subsequently occupied by the thermometer. In such a determination the input effect characterizes the liquid temperature undistorted by the presence of the probe and does not take into account the distortions in the stream dynamics produced by the body of the probe or the conditions of heat exchange at the surface of the probe, but these factors enter into the description of the transmission function of the calibrated probe. If the dynamic properties of the probe do not remain unchanged during variations in the hydrodynamic parameters then they can be characterized by a family of transmission functions each of which is determined at fixed values of the principal criteria of similarity, in particular the Reynolds, Prandtl, and Peclet numbers.

The nonstationary controlled process required for calibration is organized with the help of a laminar stream modulated in temperature. The modulation of the stream consists in introducing into it dosed portions of energy determined by a modulating signal. In this case the device used for the stream modulation must not introduce into it hydrodynamic disturbances. The energy of the modulating signal is restricted by the condition of the absence of convective distortions of the stream.

The least distortions are observed in modulation of a stream by electromagnetic radiation of suitable wavelength absorbed by the liquid. A promising method is modulation using the infrared radiation of a neodymium laser which creates in the liquid a thermal marker [4, 5] in the form of a local region of increased temperature. Optical methods are used for the visualization of this marker; shadow methods in the presence of considerable temperature gradients in a small volume or interference methods with small gradients occupying a considerable region of the stream. Optical methods are contactless and inertialess and are suitable for quantitative temperature measurements, and therefore it is evidently feasible to use them for the creation of a standard apparatus in the dynamic calibration of contact thermometers. So that the standard apparatus will measure the temperature at the undistorted stream, the thermometer being calibrated is mounted downstream from the standard apparatus. Then the input effect at the thermometer will differ from that measured by the standard apparatus, since the temperature distribution of the modulated stream is a function of the coordinates and time. The degree of deformation of the input effect along the stream depends on the thermophysical properties of the liquid, the stream velocity, and the distance from the standard meter to that being calibrated and is characterized by the transmission function which


© 1975 Plenum Publishing Corporation, 227 West 17th Street, New York, N.Y. 10011. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission of the publisher. A copy of this article is available from the publisher for $15.00.
connects the Fourier transforms of the temperature in the two sections of the stream. From this it follows that in comparing the readings of any two thermometers mounted at different sections of a nonstationary stream it is necessary to allow for the transmission function of the stream.

The transmission function of the stream and the spectra of the input effect on the thermometer during modulation of a laminar stream by laser radiation can be determined analytically. However, to increase the accuracy of the testimony of the contact thermometer it is advisable to determine their values experimentally at the moment of calibration of the temperature converter.

The method of such calibration consists in the following. Three sections A, B, and C distributed along the stream are chosen so that the segment AB = BC = x (Fig. 1b). The stream is modulated by a single pulse of radiation which creates in the liquid a temperature heterogeneity moving relative to the chosen sections. The temperature distribution in the heterogeneity is measured in each section: in sections A and B by the standard apparatus which records the result in the form of the functions f(t, 0) and g(t, x), respectively, and in section C by the thermometer being calibrated in the form of the function h(t, 2x), which corresponds to the average value of the temperature distribution. The spatial scale of the averaging is equal to the geometrical size of the sensing element, such as the diameter of a thermocouple junction. The functions f(t, 0) and g(t, x) must be obtained with the same scale of averaging as the function h(t, 2x). If the constancy of the stream velocity and the average temperature of the liquid is maintained during the calibration process (i.e., during the time of travel of the heterogeneity from A to C) then one can assume the equality of the transmission function of the stream in each of the...