INFLUENCE OF A LARGE FREE STREAM DISTURBANCE LEVEL ON DYNAMICS OF A JET IN A CROSS FLOW

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INTRODUCTION

Jets of relatively high speed (V_j) and low temperature (T_j) are often used, in a gas turbine combustor, to cool the gases and to quench the chemical reactions. The prior studies, of this particular class of the "jet in a cross flow" problem have commonly been executed with the specific momentum flux ratio $[\rho_j V_j^2/\rho_o U_o^2]$ as the primary variable, values of 10-100 characterize the range of technological interest for the combustor cooling problem.

The jet in a cross flow may be subdivided into two general regions: "interacting" and "downstream". Our interest is in the former and in the physical agents that are responsible for the: "jet turning into the streamwise direction" and the mixing of the jet and the cross stream fluid. A representation of the interaction region for isothermal mixing at $(V_j/U_o) \simeq 3.0$ is shown in Figure 1; this figure, from Foss [1980], serves to characterize the interaction region.

The prior research studies of this problem have used wind tunnels for the cross stream; a concomitant attribute of these studies has been the presence of a low free stream disturbance level. The purpose of our investigation is to provide direct observations of the jet trajectory and mixing in the presence of a large disturbance condition. There are two distinctive features of our investigation. These are described below.

The flow facility, of the MSU Free Shear Flows Laboratory (Figure 2), provides a large, planar, shear layer for use in the present study. Specifically, we have placed the jet (d_j = 10mm) such that it exhausts into the middle region ($\overline{u}/U_0$ = 0.5) of the shear layer at the end of the 3 meter test section. The local vorticity thickness (δ_ω) is large with respect to the jet diameter $\delta_\omega/d_j \simeq 58$. Based on this jet diameter, the turbulence filed is essentially homogeneous. (The gradients of the mean velocity and the turbulence intensity are considered to cause second order effects; the influence of these distributions could be examined with appropriate numerical models of the flow.) The details of the experimental facility are shown in Figures 3 to 4.

The second distinctive feature of our study is the use of an array of 76, fast response ($\tau \cong 0.1$ msec) thermocouples to document the instantaneous temperature field at the "end" of the interaction region. Specifically, the array will be placed in the flow, as shown in Figure 3 and the complete set of simultaneously sampled thermocouple voltages will provide discrete values to characterize the temperature field: $T(y, z, t_j)$. The temperature field measurements will be repeated such 2.5 msec; hence, both the instantaneous field and its temporal evolution will be evaluated. For comparison, the experiments will be repeated in the undisturbed, high speed, region of the flow field.

The "planes" of the instantaneous temperature field provide a unique data base for the evaluation of the trajectory and the mixing of a "jet in a cross flow." The temperature data, in the undisturbed cross stream, will be used to extend our understanding of this basic flow field. The comparative measures: with and without a disturbed cross stream, will be used to identify the influence of this disturbance parameter on this flow field.

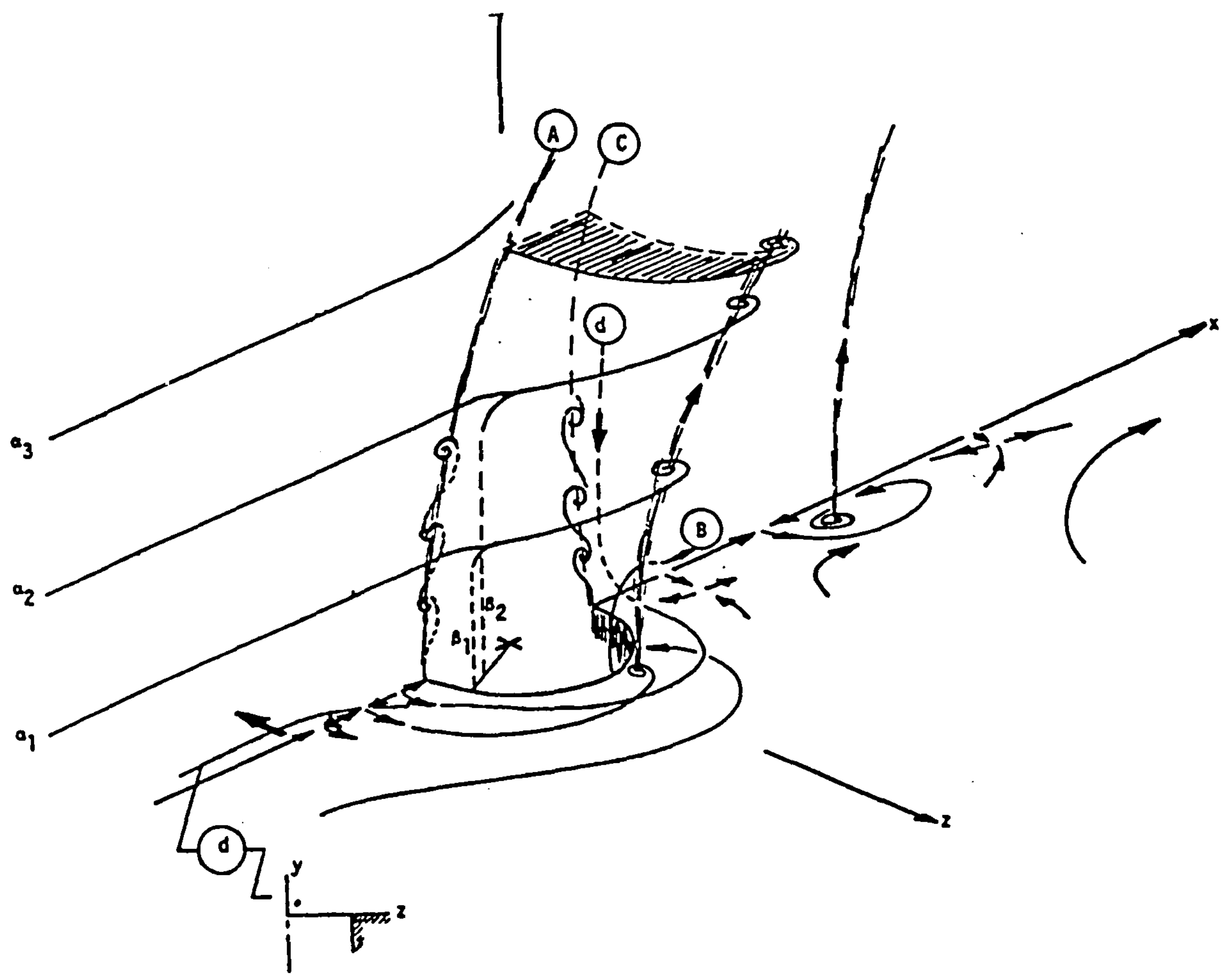

Figure 1. Schematic representation of a "large R" jet in a cross flow from Foss [1979].

Notes: ..... schematic representation of the observed shear layer instability

..... schematic representation of the vorticity vector.

Surface stress and A,B,C,d fluid trajectory lines have been traced from the appropriate photographs...their positions are shown to proper scale with respect to the jet hole diameter.

The "shroud" of fluid, which covers the flanks of the wake region and which is marked to the sheared fluid from the A and B inputs, is not shown.

The forward stagnation nodes (N_1,N_2), as shown in Figure 33, exist for the large R condition, they are only shown explicitly in that figure.

The α_1, β_1, α_2, β_2 streamlines and the cross hatched section of the jet represent conjectural estimates of the flow behavior. The forme are to show the presence of a sharp division between jet and cross stream fluid and the formation of the bound vortex from the interaction of these two streams.

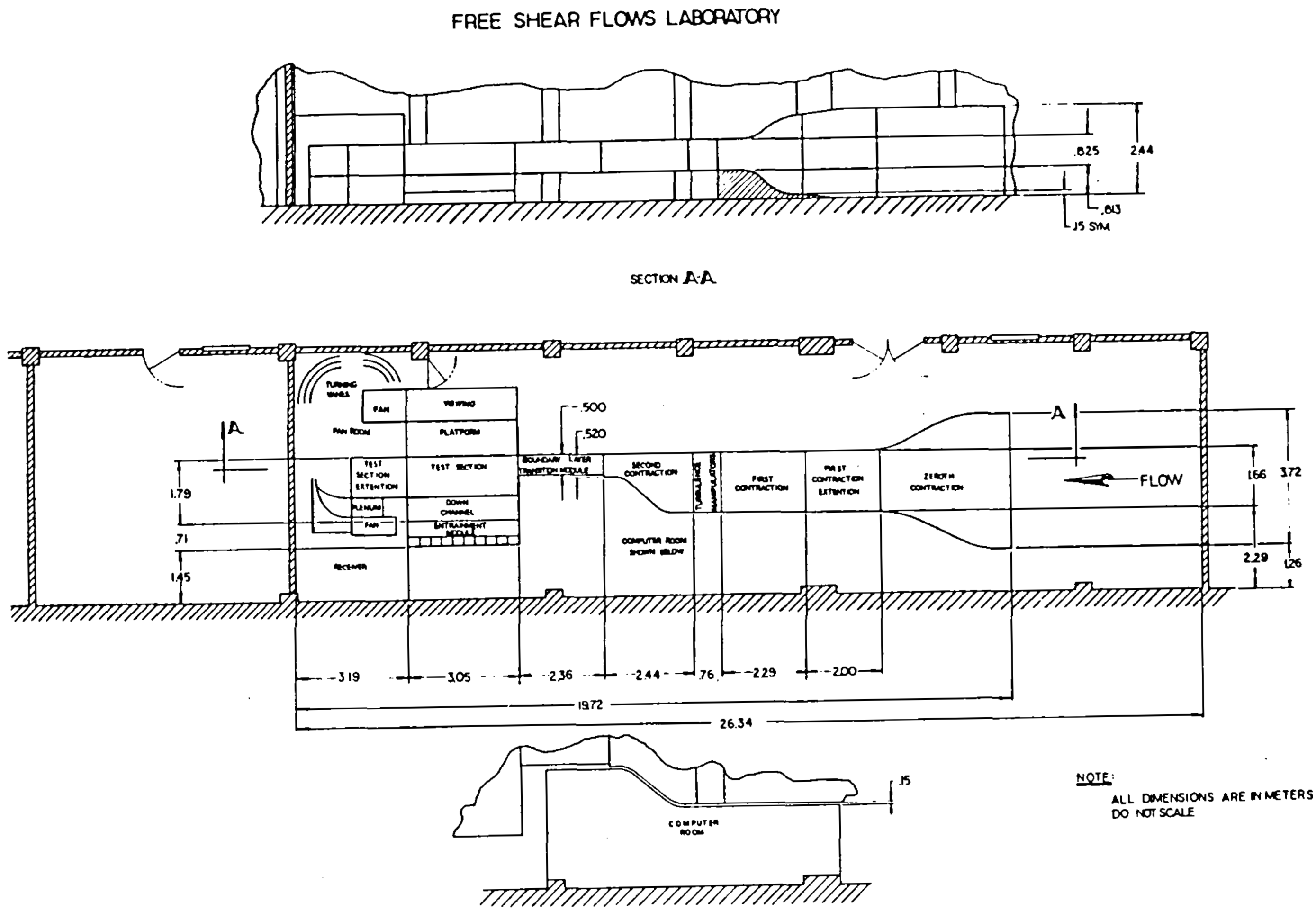

Figure 2. Flow facility; MSU free Shear Flows Laboratory

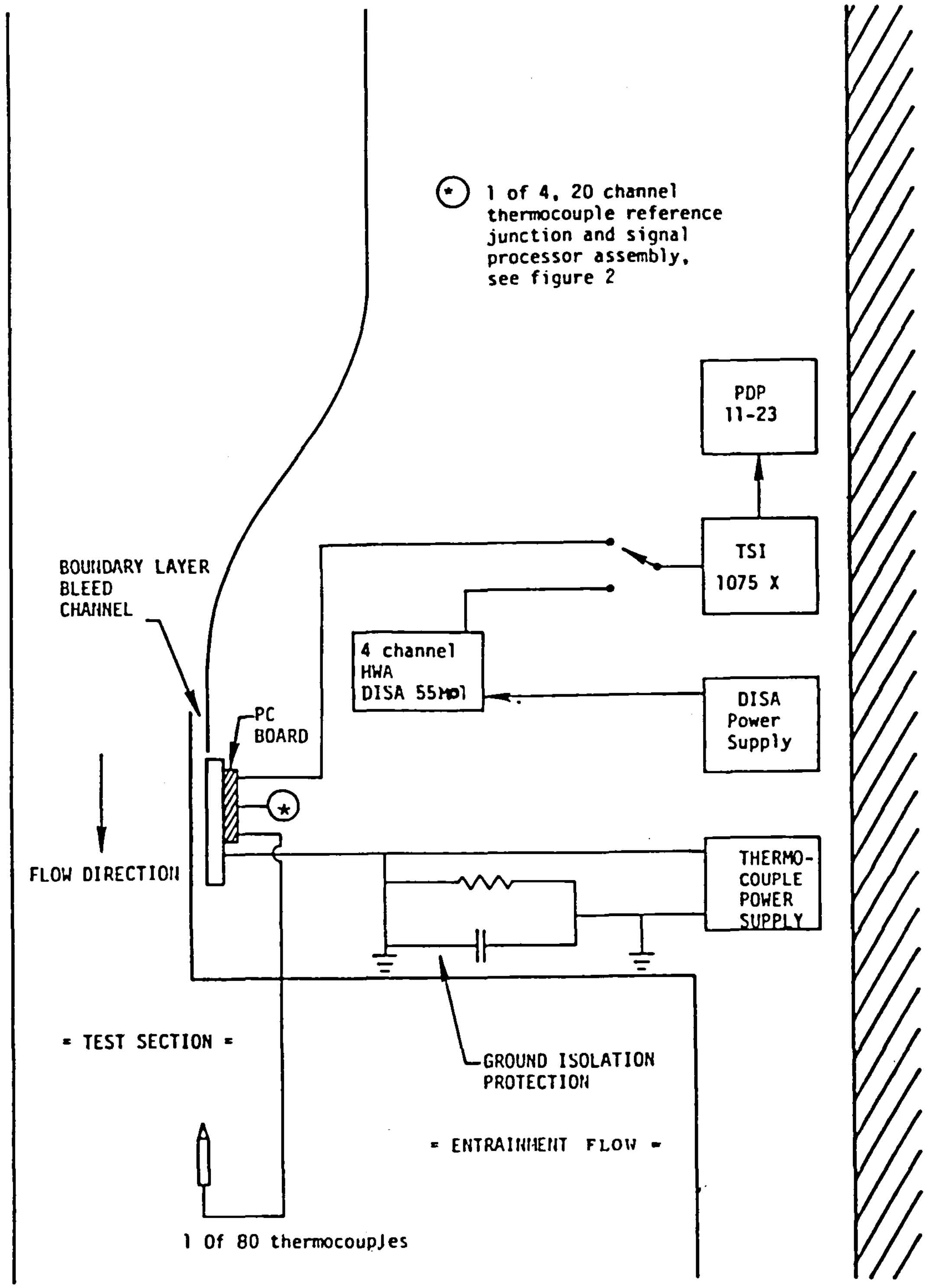

Figure 3. Schematic representation of the flow field, the Thermocouple Sampler, and Instrumentation

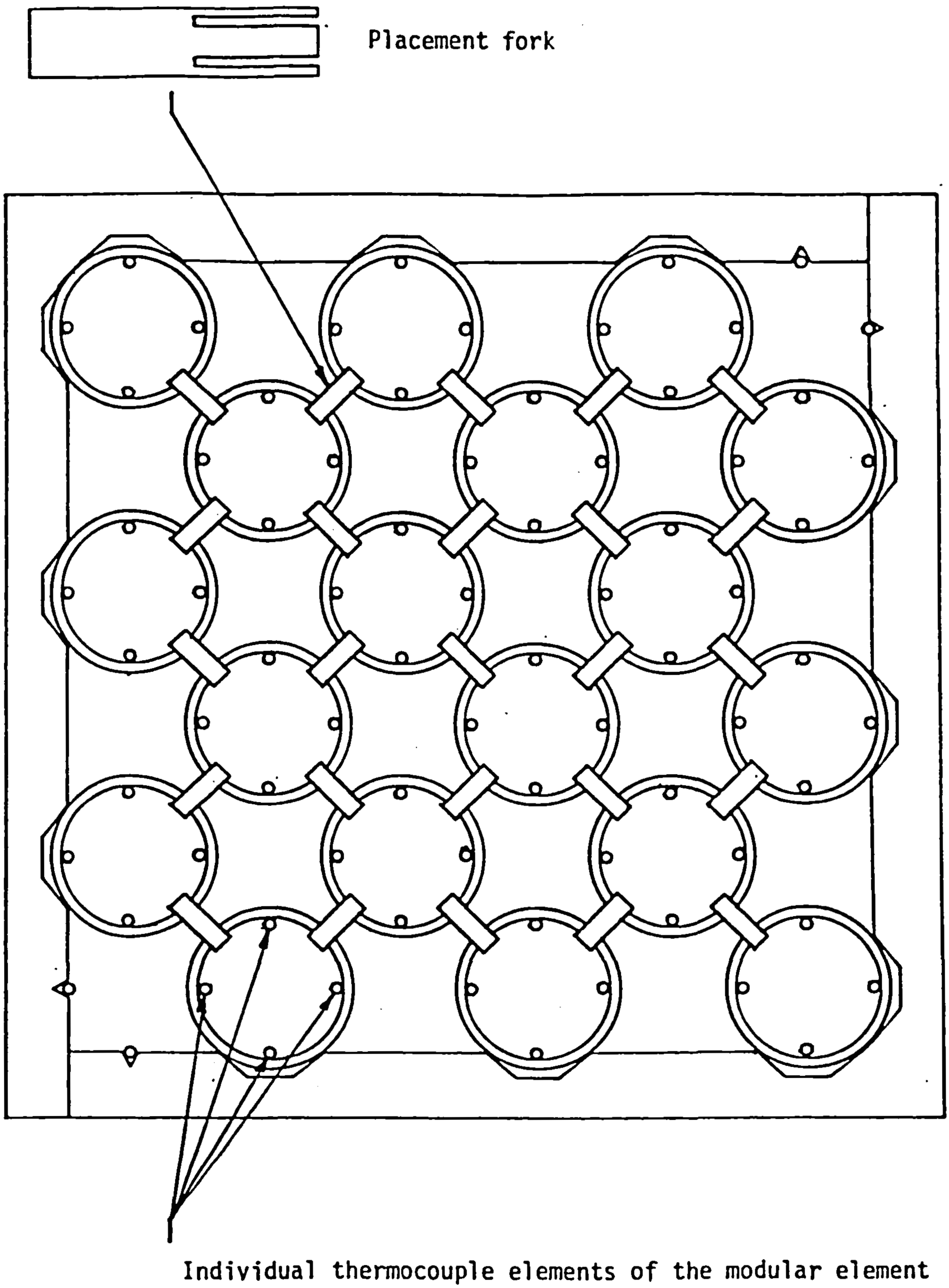

Figure 4 The thermocouple array support member.

Notes: All elements shown to correct physical size.