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## VISUALIZATION OF MIXED CONVECTION FLOWS IN VERTICAL, HORIZONTAL, AND INCLINED PIPES

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### ABSTRACT

An experimental apparatus for visualization of natural mixed convection flows in vertical, horizontal, and inclined pipes is described. Two key elements of the design allowed for the first time, flow visualization over the entire heated portion of the test section. A thin, horizontally conductive, gold-plated heater was attached to the outside surface of a Plexiglas pipe, and about 80% transparent to light, and a camera of the pipe within a large concentric Plexiglas tube, and evacuation of the air in the annular space active in a secondary transparent and recirculating medium. The flow visualization photographs revealed the following: (i) a weak recirculating flow pattern which was followed by laminar flow instability in the vertical tubes, and (ii) dual, secondary convective, and weakly recirculating flow patterns in the inclined and horizontal tubes. Some of these results were qualitatively similar to earlier numerical predictions in the published literature. The results are presented and discussed in this paper.

### INTRODUCTION

Mixed convection heat transfer is commonly encountered in engineering equipment and in the environment. One example is closed-loop thermophotovoltaic systems for solar energy conversion. Other examples include flow inside tubes used as fire-damper valve actuators and in emergency cooling systems for nuclear reactors. The design of such equipment is a multi-parameter problem that is best solved using an accurate combination of computer simulations and focused experiments before the building and refining of prototypes. Experimental apparatus and procedures for visualization of natural mixed convection flows in vertical, horizontal, and inclined pipes are presented in this paper. They are intended to facilitate the development of computational, experimental, and numerical approaches to the design of heat transfer equipment. The study of mixed convection heat transfer in vertical, horizontal, and inclined pipes, subjected to a uniform wall heat flux, has been given considerable attention in the literature. A

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