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STUDY OF NATURAL CONVECTION HEAT TRANSFER IN A RECTANGULAR ENCLOSURE FROM ONE COOLED SIDE WALL

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ABSTRACT

An experimental investigation of natural convection heat transfer in rectangular enclosure from one cooled vertical side wall was carried out. In the experiment the side wall was cooled by a thermoelectric module (TEM). The measurements covered the temperatures of the cold plate and air in the enclosures at different interval of time at 14 different locations. From the temperature distribution data, stratification within the enclosure was observed. The stratification indicator γ was estimated at three different horizontal distances from the cold plate for the time interval of 15, 25, 50, 60 and 80 minutes and found to decrease with time in the enclosure. Heat transfer rate, heat transfer coefficient, Nusselt number and Rayleigh number were calculated from the measured experimental data during transient and steady state regime.

Keywords: Template, Typing Instruction, Double column.

INTRODUCTION

Natural convection in an enclosure

In many engineering applications natural convection plays important role as a dominating mechanism of heat transfer[1]. Heat transfer by free convection in enclosed spaces has numerous engineering applications. For example, double glazing, nuclear insulation, ventilation room , solar energy collector, crystal growth in liquid , the periodic energizing of electronic devices by the on and off heating and cooling mode, effective cooling of microelectronic equipment, refrigeration air conditioning system with chilled ceiling etc[2]. There are two elementary classes of nature convocation flows in enclosure, namely, those in vertical enclosures with two differentially heated vertical walls and those in horizontal enclosures with two differentially heated horizontal walls. With the ultimate aim to simulate realistic flows found in engineering applications. The surfaces may be plane horizontal or vertical or inclined. The determination of the on set free convection and the heat transfer coefficient in an enclosure associated with free convection has been the subject of numerous investigations. Despite the vast number of experimental and analytical studies of free convection in enclosed spaces, the heat transfer correlation covering all ranges of parameters are not available. Numerous studies on natural convection in enclosure related to either side heating or bottom heating have been reported[3]. But the natural convection in enclosure with one side cold and other sides adiabatic is relatively unknown. The main features of these types of natural convection heat transfer problem is that the boundary layer thickness. Hence the development of the flow is often strongly influenced by the shape of the boundaries[7]. Therefore the heat transfer rate and heat transfer coefficient are also dependent on the boundary conditions of enclosure.

For the discussion of basics of natural convection along a vertical cold wall what it considered so for the simplest model possible, that is the heat transfer inter action between a vertical wall and an isothermal fluid reservoir proceeding now on the road from the simple to the complex. We take a closer look at the problems of modeling a heat transfer situation involving natural convection. Vertical walls are rarely in communication with in finite isothermal pools of fluid. More often their height is finite and the cold boundary layer eventually hits the bottom. At that point the cold stream has no choice but to discharge horizontally intos the fluid reservoir. The direction of this discharge is horizontal because the discharge contains fluid colder than the rest of the reservoir. The long time effect of the discharge process is the thermal stratification characterized by warm fluid layers floating on top of colder layers. At this point it is sufficient to recognize that the air in any room with the door closed is thermally stratified in such a way that the lower layers assume the temperature of the coldest wall and the highest layer near the ceiling approach the temperature of the warmest wall.

The Present study

An experimental investigation on the natural convection heat transfer in a rectangular enclosure from one cooled side wall will be conducted which consist of the following objectives:

i. To measure temperatures of the cold vertical wall and air at different locations within the enclosure during transient period .

ii. To measure temperatures of the cold vertical wall and of air at different locations within the enclosure during steady state condition.

iii. To study the variation of average natural convection heat transfer coefficient h at different thermal potentials, ΔT.

iv. To understand thermal stratification phenomenon for this enclosure.

v. To determine the Rayleigh number at different locations within the enclosure for both transient and steady state conditions.

vi. To develop a correlation which will be recommended for estimation of heat transfer coefficient for the natural convection in the rectangular enclosure cooled from one of its vertical walls.

EXPERIMENTAL SETUP

General Description of the Experimental Facility

This section describes the experimental aspects of the investigation and includes a detailed description of the experimental facility. Fig. 1 present schematically the experimental set up and test section respectively. Major components of test apparatus are, rectangular enclosure, thermoelectric module, fan, rectifier converter heat sink, cold plate and data acquisition System.

- Details of the test section is shown in the Fig. 4.1

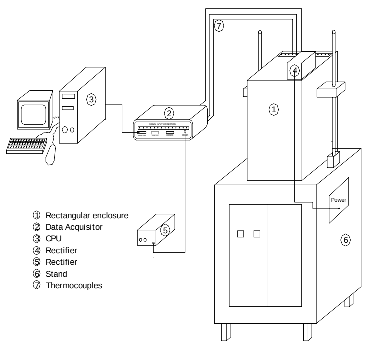

Figure 4.1 : Schematic diagram of the experimental facility

and the position of rows were 20mm, 150mm 300 mm and 400 mm apart respectively from the bottom surface of the enclosure. Another more two thermocouples were used to measured cold plate temperature and room temperature.

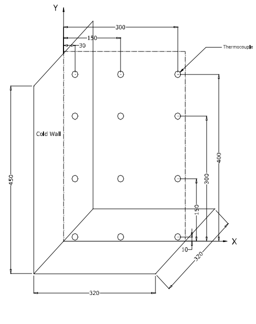

Figure 4.2: Position of the thermocouples in the enclosure

Data acquisition system

The system consist of (1) data acquisitor (2) UPS (3) CPU (4) Monitor

Data acquisitor

The data acquisitor used to measure temperature at different locations was the component number 2 as shown in Fig. 1. The acquisitor model is COLE-PARMER PCA-14. From the certifications of construction the resolution and accuracy were found to be 16 bits and ±0.02% respectively. The dimension was of height 35cm width 10cm and depth 22.5 cm.

The software supplied was menu driven and very easy to use with BASIC interpreter supplied with any computer. The menu appeared on the monitor and enabled to identify each channel. Set up the name of data file, varied the time between storing sets of data on disk, display disk directories etc. No knowledge of programming was needed.

RESULT AND DISCUSSION

Discussion on the Results and Finding

Fig. 2 to 4 shows the temperature distribution of the air within the enclosure. The data are presented at different height 'Y' in the enclosure at different distance 'X' from the cold plate at different interval. The data at the interval of 15, 25, 50, 60 and 80 minutes are analyzed. From the temperature distribution profile in the enclosure the heat transfer rate Q, heat transfer coefficient "h" and average Nusselt number was calculated.

Fig. 2 to 4 show the temperature distribution of the air within the enclosure at different intervals. It was found from the figure that the temperature of air at any point gradually decreases with time and air was more cold closer to the cold wall and the bottom of the enclosure.

Again from Fig. 2 to 4 it was found that fluid layers developed with interval of time which were floating on top of increasingly colder layers. It was due to the finite height of the enclosure and eventually cold boundary layer hits the bottom of the enclosure. At that point the colder stream had no choice but discharge horizontally from air of the enclosure. So, the direction of discharge was horizontal because the cold boundary layer contains fluid colder than the rest of the enclosure. In this way thermal stratification was developed in the enclosure.

From Fig. 6 it was found that the value of γ is decreasing with time. His shows that at any distance from the cold plate temperature of the stratified layers is approaching a steady state value.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The important conclusions as a consequence of the present investigation are enumerated below:

- The temperature of air at the different parts of the enclosure decreases asymptotically to the steady state value.
- Temperature difference between top most and bottom most layer of air at different x value increases initially and then remains constant.
- The result shows that the air in a part of the enclosure is substantially stratified.
- Stratification indicator γ decreases with the increase of time.
- The natural convection of heat transfer coefficient, Nusselt number and Rayleigh number increase with the increase of time.
- The experimental data are well correlated with the following correlation

  $Nu_H = (0.394\ Ra_H^{0.25})$

Recommendations

The following recommendations are put forward as future extension of the present investigations:

- Further investigation can be carried out with fluid filled rectangular enclosure driven by a single vertical wall with warm and cold regions:
- The entire investigation can also be repeated with a square enclosure.
- The entire investigation may be carried out employing interferometric technique. The flow field may also be studied with the help of a Laser Doppler Anemometer.
- For comprehensive investigation of natural convection heat transfer of the similar type, a test rig consisting of a pressure as well as a vacuum vessel will be helpful. For finding out the effect of Prandtl number experiments may be carried out with different fluids.

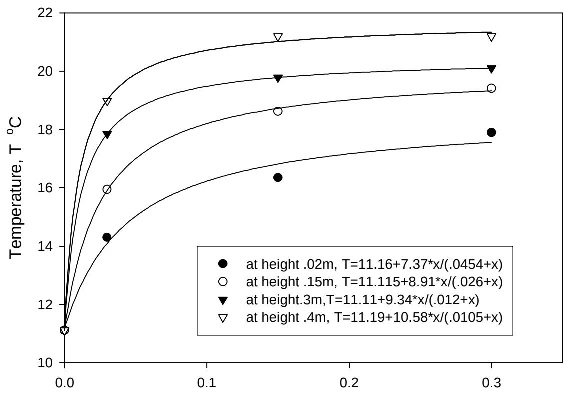

Fig. Temperature at different height ' y ' in the enclosure at different distance ' x ' from cold plateafter 15 minutes. Table-

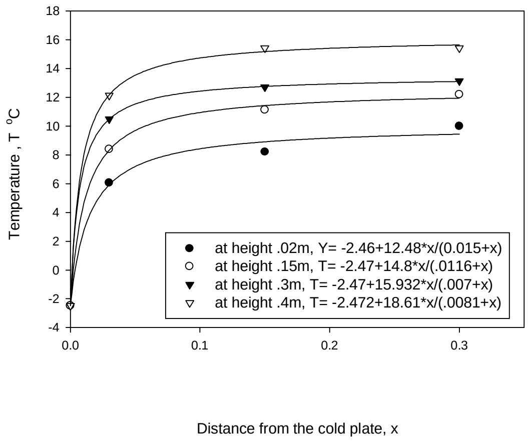

Fig. Temperature at different height ' y ' in the enclosure at different distance ' x ' from the cold plate after 80 minutes. Table -

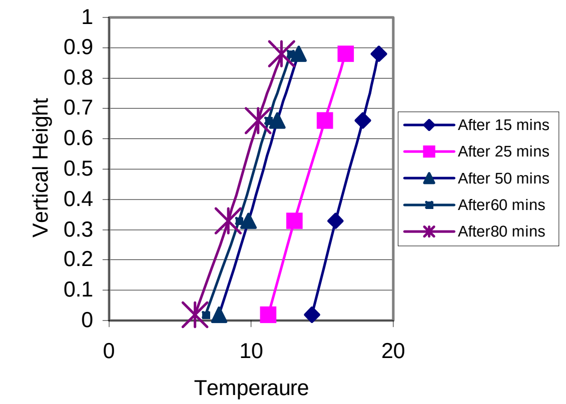

Fig. 6: Effect of the enclosure stratfication on heat transfer from air to the cold vertica wall (x=0.03 m)

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NOMENCLATURE

Symbol	Meaning
T	Temperature
Nu_H	Nusselt number
Ra_H	Rayleigh number
γ	Stratification factor
X, y	Coordinate