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

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The thesis titled "**STUDY OF NATURAL CONVECTION HEAT TRANSFER IN A RECTANGULAR ENCLOSURE FROM ONE COOLED SIDE WALL**", submitted by Md. Mostafa Hossain, Roll No. M.Sc. 9610061P, Session 1995-96-97 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Master of Science in Mechanical Engineering** on 09 August 2003.

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MD. MOSTOFA HOSSAIN

Dedicated
To
My Beloved and Respected
Father Amiruddin Pramanik

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ABSTRACT

An experimental investigation of natural convection heat transfer in rectangular enclosure from one cooled vertical side wall is carried out. In the experiment the side wall is cooled by a thermoelectric module (TEM). The measurements cover the temperatures of the cold plate and air in the enclosures at different interval of time at 14 different locations which are measured and recorded by data acquisition system. The power consumed by a thermoelectric module (TEM) during the transient and steady state conditions is also recorded. In an experiment lasting 1 hour, the enclosure air is cooled down to a minimum of 5°C, when the cold wall temperature is –4°C. With time, temperatures of both cold wall and air within the enclosure decrease asymptotically to a steady state value.

From the temperature distribution data, stratification within the enclosure is observed. The stratification indicator γ is 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 be decreased with the time.

Heat transfer rate, heat transfer coefficient, Nusselt number and Rayleigh number are calculated from the measured experimental data during transient and steady state regime. The Rayleigh number and Nusselt number cover the range, 1.47×10^6 to 3.08×10^7 and 18.55 to 33.50 respectively.

From the experimental results a correlation is developed in terms of Nusselt number and Rayleigh number which is found to be capable of correlating all experimental data within ± 15%.

NOMENCLATURE

Symbols	Meaning	Units
g	gravitational acceleration	m/s^2
h	heat transfer coefficient	$w/m^2 K$
H	enclosure height	m
k	thermal conductivity	w/m K
L	enclosure length	m
N_u	Nusselt number	dimensionless number
P	Pressure	N/m^2
p_o	minimum density	
P_r	Prandtl number	dimensionless number
G_r	Grashof number	dimensionless number
R_{ah}	Rayleigh number	dimensionless number
T	Temperature	K
T_c	temperature of the cold plate	K
T_o	initial temperature of air	K
T_α	average temperature of the last column of the air	K
$T_{\alpha a}$	average temperature of twelve thermocouples	K
T_h	adiabatic temperature wall temperature of enclosures	K
T_1	Temperature of heated surface	K
T_2	Temperature of cold surface	
τ	Tilt angle	
ΔT	temperature difference, $T_h - T_c$	K
u	velocity vector, $\{u, v\}$	
U	dimensionless velocity vector $\{U, V\}$	
U, V	dimensionless velocities in X and Y coordinates	
x, y	Coordinates	
θ	dimensionless temperature	
μ	dynamic viscosity	Kg/s m
ν	kinematic viscosity	m^2/s
γ	Temperature gradient	$^oC/m$
ρ	Density	Kg/m^3
ρ_o	maximum density	
ψ	stream function	m^2/s
Ψ	dimensionless stream function	
α	thermal diffusivity	m^2/s
β	Coefficient of thermal expansion	K^{-1}
C_p	Specific heat at constant pressure	$J/kg\ ^oK$
m	Mass	Kg
Q	Heat transfer	W
q''	Heat flux	W/m^2
A	Area of cold plate	m^2
t	Time	S

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CHAPTER-ONE

INTRODUCTION

1.1 Introduction of natural convection and its physical consideration

Natural or free convection is observed as a result of the motion of fluid due to density changes arising from heating or cooling processes. In natural convection flows, the fluid velocities are highly dependent on the thermal field and variable properties can have strong effects on both velocities and temperature. The movement of the fluid in free convection whether it is a gas or a liquid, results from buoyancy forces imposed on the fluid when its density in the proximity of heat transfer surface is decreased or increased as a result of heating or cooling process. Buoyancy forces will not be present if the fluid is not acted upon by some external force fields such as gravity, although gravity is not the only type of force field which can produce the free convection currents. A centrifugal force field can create convection currents. A fluid enclosed in a rotating machine is acted upon by a centrifugal force field if one or more surfaces in contact with the fluid are heated or cooled. Among all properties the temperature gradient has been found to be the most common situation in which a density gradient may arise in a fluid. For gases, density depends on temperature.

Situations for which there is no forced velocity, and yet convection currents exist within the fluid are referred to as free or natural convection. They originate when a body force acts on a fluid in which there are density gradients. The net effect is a buoyancy force, which induces free convection currents. In the most common case, the density gradient is due to a temperature gradient, and the body force is due to the gravitational field. Since free convection flow velocities are generally much smaller than those associated with forced convection, the corresponding convection transfer rates are also smaller. It is perhaps tempting therefore to attach less significance to free convection processes. This temptation should be resisted. In many systems involving multi-mode heat transfer effects, free convection provides the largest resistance to heat transfer and therefore plays an important role in the design or performance of the system. Moreover, when it is desirable to minimize heat transfer rates or to minimize operating costs, free convection is often preferred to forced convection.

There are, of course, many applications. Free convection strongly influences heat transfer from pipes and transmission lines, as well as from various electronic devices. It is important in transferring heat from electric baseboard heaters or steam radiators to room air and in dissipating heat from the coil of a refrigeration unit to the surrounding air. It is also relevant to the environmental sciences, where it is responsible for oceanic and atmospheric motions, as well as related heat transfer processes.

Physical considerations :

In free convection, fluid motion is due to buoyancy forces within the fluid, while in forced convection it is externally imposed. Buoyancy is due to the combined presence of a fluid density gradient and a body force that is proportional to density. In practice the body force is usually gravitational, although it may be a centrifugal force in rotating fluid machinery or a Coriolis force in atmospheric and oceanic rotational motions. There are several ways in which a mass density gradient may arise in a fluid, but in the most common situation it is due to the presence of a temperature gradient. We know that the density of gases and liquids depends on temperature, generally decreasing (due to fluid expansion) with increasing temperature ($\delta\rho / \delta T < 0$).

In this topic we focus on free convection problems in which the density gradient is due to temperature gradient and the body force is gravitational. However, the presence of a fluid density gradient in a gravitational field does not ensure the existence of free convection currents. Consider the conditions of Figure 1.1. A fluid is enclosed by two large, horizontal plates at different temperatures ($T_1 \neq T_2$). In case (a) the temperature of the lower plate exceeds that of the upper plate, and the density decreases in the direction of the gravitational force. This condition is unstable, and free convection currents will exist. The gravitational force on the denser fluid in the upper layers exceeds that acting on the lighter fluid in the lower layers, and the designated circulation flow pattern will commence. The heavier fluid will descend, being warmed in the process, the lighter fluid will rise and will be cooled by descending cold fluid. However, this condition does not characterize case (b), for which $T_1 > T_2$ and the density no longer decreases in the direction of the gravitational force. Conditions are now stable, and there is no bulk fluid motion. In case (a) heat transfer occurs from the bottom to the top surface by free convection; for case (b) heat transfer (from top to bottom) occurs by conduction.

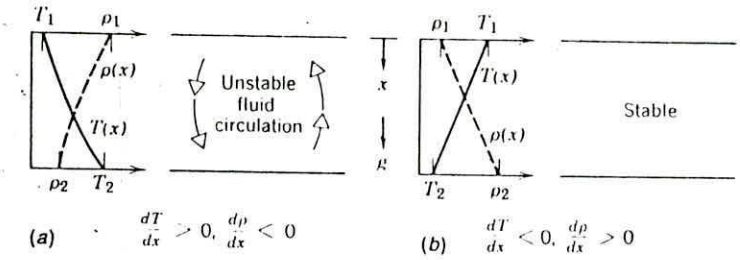
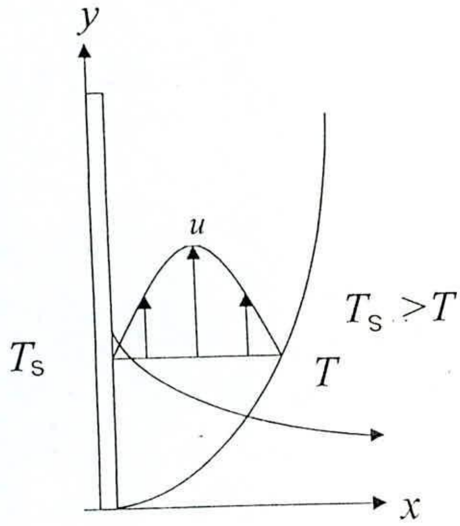
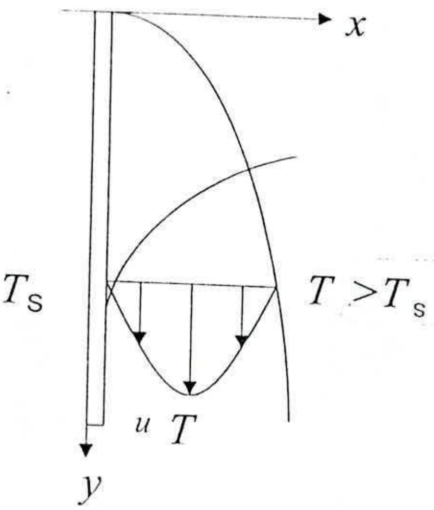


Fig. 1.1: Conditions in a fluid between large horizontal plates at different temperatures (a) Unstable temperature gradient (b) Stable temperature gradient.

In this text we focus on free convection flows bounded by a surface, and a classical example relates to boundary layer development on a heated vertical plate (Figure 1.2a). The plate is immersed in an extensive, quiescent fluid, and with $T_s > T$, the density of fluid close to the plate is less than that of fluid at a distance from the plate. Buoyancy forces therefore induce a free convection boundary layer in which the heated fluid rises vertically, entraining fluid from the quiescent region. The resulting velocity distribution is unlike that associated with forced convection boundary layers. In particular the velocity is zero as $y \to \infty$, as well as at $y = 0$. A free convection boundary layer also develops if $T_s < T$. In this case, however, fluid motion is downward (Fig. 1.2b).



a



b

Fig. 1.2a: Boundary layer development on a heated vertical plate.

Fig. 1.2b: Boundary layer development on a cooled vertical plate.

1.2 Natural convection in an enclosure

In many engineering applications natural convection plays an important role as a dominating mechanism of heat transfer. 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 and air conditioning system with chilled ceiling etc . There are two elementary classes of natural convection 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. The enclosure may be horizontal, vertical or inclined. The determination of the on-set of 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. But the natural convection in enclosure with one side cold and other sides adiabatic is relatively unknown. The natural convection heat transfer depends on boundary layer thickness. Hence the development of the flow is often strongly influenced by the shape of the boundaries. Therefore the heat transfer rate and heat transfer coefficient are also dependent on the boundary conditions of enclosure.

1.3 Effect of thermal stratification

Natural convection along a vertical cold wall is the simplest model possible, heat transfer inter action between a vertical wall and an isothermal semi infinite fluid reservoir is shown in Fig. 1.3. We take a closer look at the problems of modeling a heat transfer situation involving natural convection. Vertical walls are rarely in communication with semi infinite 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 into 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.

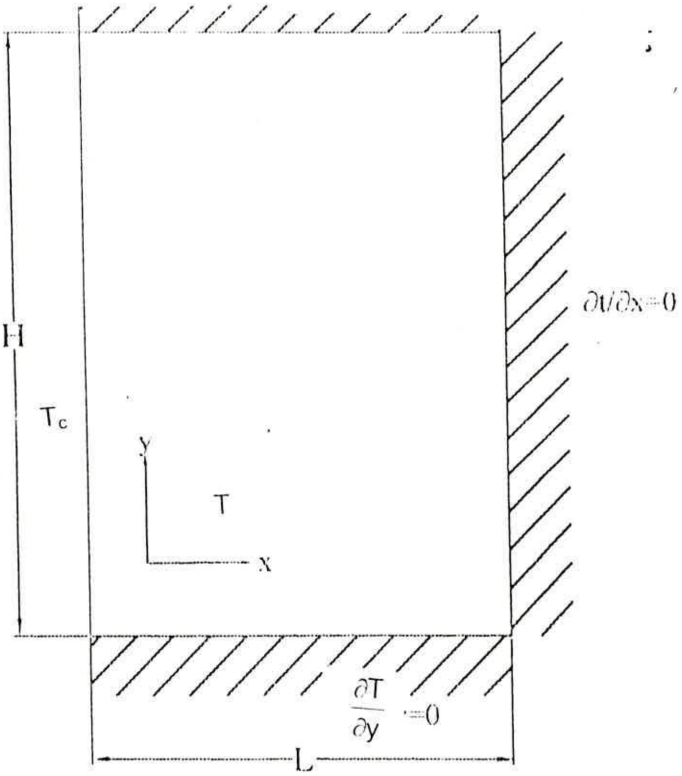


Fig. 1.3: Natural convection along a cold vertical wall environment.

1.4 Motivation behind the selection of present work

In many engineering applications natural convection plays an important role as a dominating mechanism of heat transfer [1]. The phenomenon of natural convection in fluid-filled enclosure has received considerable attention in recent years. This is mainly because of the this fact that phenomenon substantially influence the thermal performance of heat transfer equipment used for cooling of electronic components, refrigeration and air-conditioning system etc. [2-4]. Many studies have been done regarding natural convection in an enclosure. Most of the studies on natural convection in an enclosure are related to either vertical wall heating or bottom surface heating [5-8]. The present work deals with the natural convection in rectangular enclosure where one of its side walls will be cooled and the top and bottom surfaces will be adiabatic.

1.5 The Present study

An experimental investigation on the natural convection heat transfer in a rectangular enclosure from one cooled side wall is conducted with 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 natural convection in the rectangular enclosure cooled from one of its vertical walls.

CHAPTER-TWO

LITERATURE REVIEW

2.1 Introduction

Fluid motions and transport processes due to buoyancy effect plays an important role in various field of science and technology. As a result, this subject is currently discussed in conferences and journals covering such diverse areas of meteorology, geophysics, astrophysics, nuclear reactor systems, materials processing, solar energy systems, energy storage and conservation fire control, and chemical, food, and metallurgical industries, as well as in the more conventional fields of fluid and thermal sciences.

Buoyancy-induced flows are complex because of the essential coupling between the flow and transport. The problems can be classified as either external ones (free convection) or internal ones (natural convection). The first unified and comprehensive review of this subject was made by Ostrach[9]. Later, summaries of free convection were presented by Ede[10] and Gebhart[11] and other reviews of natural convection were complied by Ostrach[12], Catton[13], Ostrach[14] and Hogendoorn[15]. Each of the last three emphasize essentially on different aspects of the subject.

It was first pointed out by Ostrach[16] that internal problems are considerably more complex than the external ones. This is because at large Rayleigh numbers (the product of Prandtl and Grashof numbers) classical boundary layer theory yields the same simplifications for external problems that are so helpful in other fluid-flow problems, viz., the region exterior to the boundary layer is unaffected by the boundary layer. For confined natural convection, on the other hand, boundary layer forms near the walls but the region exterior to them is enclosed by the boundary layers and forms a core region. Since the core is partially or fully encircled by the boundary layers, the core flow is not readily determined from the boundary conditions but depends on the boundary layers, which, in turn, is influenced by the core. The interactions between the boundary layer and the core constitute a central problem that has remained unsolved and is inherent to all confined convection configurations, namely, the flow pattern cannot be predicted a priori from the given boundary conditions and geometry. In fact, the situation is even more intricate because it often appears that more than one global core flow is possible and flow subregions, such as cells and layers, may be embedded in the core. This matter, which has been discussed more fully by Ostrach[12-14], and Ostrach and Hantman[17], is not merely a subtlety for analysis, but has equal significance for numerical and experimental studies, as will be indicated later.

It is distressing to note that this crucial aspect of natural convection seems to be essentially ignored in most existing literature or is treated in a cavalier manner. The core flow is often merely assumed, estimated in an adhoc manner, or specified from seemingly similar problems. However, experience has shown that natural convection is extremely sensitive to changes in the container configuration and the imposed boundary conditions so the use of results from similar problems is dangerous. In numerical studies, the entire matter generally is ignored and, as a consequence, there have been no truly reliable predictive result of velocity and temperature distributions. Until the problem is resolved, numerical studies must be guided and closely coupled with experiments.

Lack of progress on this crucial aspect of natural convection can be attributed to two reasons, one old and one relatively new. The first is related to proper normalization of equations, sometimes referred to as dimensional or scaling analysis. As was pointed out by Ostrach, it is disturbing to note that despite the existence of clear and explicit delineations of how to normalize natural-convection problems, they are scaled in many different inappropriate ways (even for identical problems) in the literature. This can lead to errors in analysis and to considerable numerical problems (see de Vahl Davis, 1986), some of which even lead to misrepresentation of the physics. Scaling analysis is also essential or indicating the resolution required in both numerical and experimental studies. The disregard or lack of appreciation of such vital aspects, which are well documented, is hard to understand. The second aspect alluded to above concerns inherent coupling between the flow and the buoyacy-driving force. This was first indicated by Hantman[18] (1969) and later noted more specifically by Cormack et al. [19], but was not fully appreciated until relatively recently. In essence, this coupling causes the principal driving force to act in different regions of the enclosure, depending on conditions. This unusual physical characteristic of natural convection must be properly accounted for if meaningful results are to be obtained.

To add to all the complexity it should be recalled that there are essentially two basic modes of flow generated by buoyancy. The first, usually referred to as conventional convection, occurs whenever a density gradient (due to thermal and/or concentration effects) is normal to the gravity vector. In such a case a flow ensues immediately. The second mode, called unstable convection, occurs when the density gradient is parallel but opposed to the gravity vector. In this situation the fluid remains in a state of unstable equilibrium (due to heavier fluid being above the lighter) until a critical density gradient is exceeded. A spontaneous flow then results that eventually becomes steady and cellular-like. If the density gradient is parallel but in the same direction as gravity the fluid is stably stratified. As if all this were not sufficiently difficult to deal with, both conventional and unstable (or stratified) modes can interact in a given configuration.

For many years research on natural convection in enclosures centered around two basic configurations, viz., horizontal cylinders and rectangular cavities. The height-to-width (aspect) ratio of the rectangular cavities ranged from values equal to or greater than unity. Most attention has been given to each mode of convection separately, i.e., where the density gradients in a gravitational field were either horizontal or vertical with the gradient increasing upward. Most density variations were considered to be the result of temperature gradients. Less attention has been given to situations in which the buoyancy is due to concentration differences. Catton[13] reviewed work done when both modes occurred simultaneously, as, in tilted rectangular enclosure.

More recently, due to motivations from diverse applications, the research scope has expanded in many ways. The configurations now being considered are low-aspect-ratio rectangles, parallelograms, annuli, and three-dimensional enclosures. The fluids now may be radiation participating media, or be changing phase, or be in porous media. Some problems are now being considered with heat flow in more than a single direction, either by direct imposition or by inclination of the cavity. Problems are being considered in which the imposed thermal conditions are not specified but must be determined from the interaction between the enclosure heat transfer and the environment or cover only part of the surface. Increasing attention is being given to situations in which the buoyancy is due to the combined effects of temperature and concentration gradients, which have various orientations relative to themselves and to gravity.

Clearly, with the limited space allotted to this paper, it is impossible to present a comprehensive review of all ongoing research. Because many physical and mathematical questions remain unresolved and others are introduced by some new works, emphasis will be given to refocusing on the crucial aspects of the conventional convection problem and on presenting insights on how to deal with them. In this way, some other older work will be revisited and some of the most recent work will be discussed.

2.2 Overview of Early Work

The early work done on fully developed flows in channels and tubes, closed-end tubes, and in a shallow right circular cylinder that rotate about its axis and is heated at its lower surface was reviewed by Ostrach[11-12].

The earliest investigation of natural convection in a completely confined configuration seems to have been made by Lewis[20], who considered the heat transfer of foam type commercial insulating materials, which consist of gas filled cells dispersed throughout a solid material. The natural convection in the cells was of particular interest. To simplify the analysis a spherical cell was treated as a horizontal cylinder of circular cross section and infinite length.

A cosine wall temperature was specified, with the maximum and minimum wall temperatures on opposite ends of the horizontal diameter. This temperature corresponds to that which would occur in the solid without gas bubbles. Since the cells were very small, Lewis considered only the case of Rayleigh number less than unity for which no boundary-layer phenomena are encountered. A similar problem was treated by Zhukovitd[21]. An excellent survey of low Rayleigh number problems is presented by Ostroumov[22]. Low Rayleigh number convection in a spherical cavity was investigated to Drakhin[23].

The heat transfer through gas layer confined in rectangular cavities composed of isothermal vertical walls and either perfectly conducting or perfectly insulating horizontal surfaces was investigated by Batchelor[24] for the cases of height-to-width ratios of layers between 5 and 200. It was reasoned that several different flow regimes could occur within the cavity depending on the values of the height-to-width ratio l/d and the Rayleigh number Ra. For small Ra Batchelor[24] used a perturbation scheme similar to that of Lewis[25] and, as expected, concluded that convection was unimportant compared to conduction. Conduction was also found to be the sole means of heat transfer in the asymptotic case of $l/d\ \alpha$ and general Ra. In such cases, the temperature distribution in the air was found to vary linearly between the walls and fluid flow was entirely vertical. Conduction was restricted to the upper and lower ends of the cavity and as Ra approached values appropriate for boundary layers, these effects propagated into the rest of the cavity. This asymptotic case of infinite aspect ratio had been investigated earlier by Ostrach[26] who treated it as a special case in a general analysis of natural convection between parallel and vertical isothermal plate.

None of the aforementioned difficulties were encountered in those problems because the flows were not of the boundary layer type.

2.3 Empirical Correlations: Enclosures

Many engineering applications frequently involve heat transfer surfaces that are at different temperatures and are separated by an enclosed fluid. Now we present correlations that are pertinent to the most common geometries.

2.3.1 Rectangular Cavities

The rectangular cavity, shown schematically in Fig. 2.1, has been studied extensively and comprehensive reviews of both experimental and theoretical results are available in the literature [27, 28]. The tilt angle τ between the heated and cooled surfaces of the cavity and the horizontal plane strongly influences the heat flux across the cavity. This flux may be expressed as

$$q'' = h\,(T_1 - T_2) \qquad \ldots\ldots 2.1$$

The horizontal cavity heated from below (τ = 0) has been considered by many investigators. It is known that when

$$Ra \equiv \frac{g\beta(T_1 - T_2)L^3}{\alpha\nu} > 1708$$

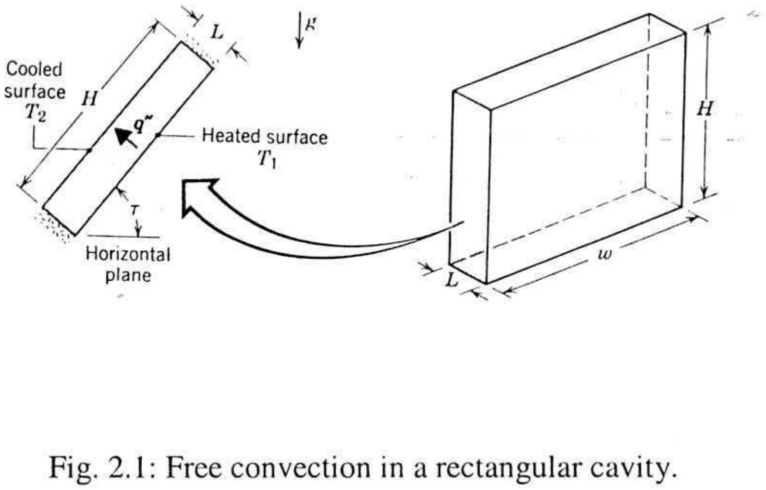


Fig. 2.1: Free convection in a rectangular cavity.

conditions are thermally unstable and there is heat transfer by free convection. As a first approximation, the convection coefficient may be obtained from a correlation proposed by Globe and Dropkin [29].

$$\overline{\mathrm{Nu}}_L = \frac{\bar{h}L}{k} = 0.069\mathrm{Ra}_L^{1/3}\,\mathrm{Pr}^{0.074} \qquad 3\mathrm{x}10^5 < \mathrm{Ra}_L < 7\mathrm{x}10^9 \qquad .....2.2$$

where all properties are evaluated at the average temperature, $\overline{T} \equiv (T_1 + T_2)/2$. More detailed correlations, which apply over a wider range of Ra_L, have been proposed [30-31]. In each case, however, the ratios L/H and L/w were small, and the effects of lateral boundaries on heat transfer were negligible. For $\mathrm{Ra}_L < 1708$ or for $\tau = 180^o$, heat transfer between the surfaces occurs by conduction and $\mathrm{Nu}_L = 1$.

In the vertical rectangular cavity ($\tau = 90^o$) the vertical surfaces are heated and cooled, whereas the horizontal surfaces are adiabatic. For aspect ratios in the range $1 < (H/L) < 10$, the following correlations have been suggested [28].

$$\overline{\mathrm{Nu}}_L = 0.22\left(\frac{\mathrm{Pr}}{0.2+\mathrm{Pr}}\mathrm{Ra}_L\right)^{0.28}\left(\frac{H}{L}\right)^{-1/4} \qquad .....2.3$$

$$\begin{bmatrix} 2 < (H/L) < 10 \\ \mathrm{Pr} < 10^5 \\ \mathrm{Ra}_L < 10^{10} \end{bmatrix}$$

$$\overline{\mathrm{Nu}}_L = 0.18\left(\frac{\mathrm{Pr}}{0.2+\mathrm{Pr}}\mathrm{Ra}_L\right)^{0.29} \qquad .....2.4$$

$$\begin{bmatrix} 1 < (H/L) < 2 \\ 10^{-3} < \mathrm{Pr} < 10^{-5} \\ 10^{-3} > (\mathrm{Ra}_L\,\mathrm{Pr})/(0.2+\mathrm{Pr}) \end{bmatrix}$$

For larger aspect ratios, the following correlations have been proposed [27]:

$$\overline{Nu}_L = 0.42Ra_L^{1/4}\,Pr^{0.012(H/L)^{-0.3}} \begin{bmatrix} 10 < (H/L) < 40 \\ 1 < Pr < 2x10^4 \\ 10^4 > Ra_L < 10^7 \end{bmatrix} \qquad .....2.5$$

$$\overline{Nu}_L = 0.46Ra_L^{1/3} \begin{bmatrix} 1 < (H/L) < 40 \\ 1 < Pr < 20 \\ 10^6 > Ra_L < 10^9 \end{bmatrix} \qquad .....2.6$$

Convection coefficients computed from the foregoing expressions are to be used with Equation 2.1. Again, all properties are evaluated at the mean temperature, $(T_1 + T_2)/2$.

Many publications have appeared in recent years concerning free convection heat transfer in inclined, rectangular spaces, with particular attention given to solar collector applications. For large aspect ratios, (H/L)>12, and tilt angles less than the critical value τ* given in Table 6 the following correlation due to Hollands et al. [33] is in excellent agreement with available data.

$$\begin{aligned} \overline{Nu}_L = 1 + 1.44\left[1 - \frac{1708}{Ra_L \cos\tau}\right]^{*} \left[1 - \frac{1708(\sin 1.8\tau)^{1.6}}{Ra_L \cos\tau}\right] \\ + \left[\left(\frac{Ra_L \cos\tau}{5830}\right)^{1/3} - 1\right]^{*} \begin{bmatrix} (H/L) > 12 \\ 0 < \tau \le \tau^{*} \end{bmatrix} \end{aligned} \qquad .....2.7$$

The notation [ ]* implies that, if the quantity in brackets is negative, it must be set equal to zero. For small aspect ratios Catton [28] suggests that reasonable results may be obtained from a correlation of the form

$$\overline{Nu}_L = \overline{Nu}_L(\tau = 0)\left[\frac{\overline{Nu}_L = (\tau = 90)}{\overline{Nu}_L = (\tau = 0)}\right]^{\tau/\tau^{*}} (\sin\tau^{*})^{(\tau/4\tau^{*})} \begin{bmatrix} (H/L) < 12 \\ 0 < \tau \le \tau^{*} \end{bmatrix} \qquad .....2.8$$

Beyond the critical tilt angle, the following correlations due to Ayyaswamy and Cartton and Arnold et al. [31], respectively , have been recommended [28] for all aspect ratios (H/L).

$$\overline{\mathrm{Nu}}_L = 1 + \overline{\mathrm{Nu}}_L(\tau = 90^\circ)(\sin\tau)^{1/4} \qquad \tau^* < \tau < 90^\circ \qquad \text{.....2.9}$$

$$\overline{\mathrm{Nu}}_L = 1 + [\overline{\mathrm{Nu}}_L(\tau = 90^\circ) - 1]\sin\tau \qquad 90^\circ < \tau < 180^\circ \qquad \text{.....2.10}$$

CHAPTER-THREE

MATHEMATICAL MODELING OF THE PROBLEM

3.1 Description of the Problem

The natural convection heat transfer in a rectangular enclosure is a complex problem of temperature, boundary conditions, position of the enclosure and the properties of the confined fluid. The rectangular enclosure of the present investigation has a cold side wall. The other side walls, bottom surface and ceiling are adiabatic as shown Fig. 3.1. The convective fluid is air. The flow, temperature and concentration fields are taken as two dimensional. At time less than or equal to zero, the fluid in the enclosure is quiescent and the temperature is uniform. For time $t>0$ cold plate absorbs heat from the air. The fluid comes in contact with the cold plate, the temperature of the cold plate is gradually decreasing and finally reaches a steady state value. During transient and steady state condition the heat flux q'' was transferred to the cold plate by convection.

3.2 Governing Equation

The geometry considered is a two-dimensional air layer confined by two horizontal impermeable and adiabatic rigid walls and two vertical walls. The air of the enclosure is initially at rest and isothermal at room temperature T_α at which the density of air is minimum. The back side is cooled gradually in lower temperature.

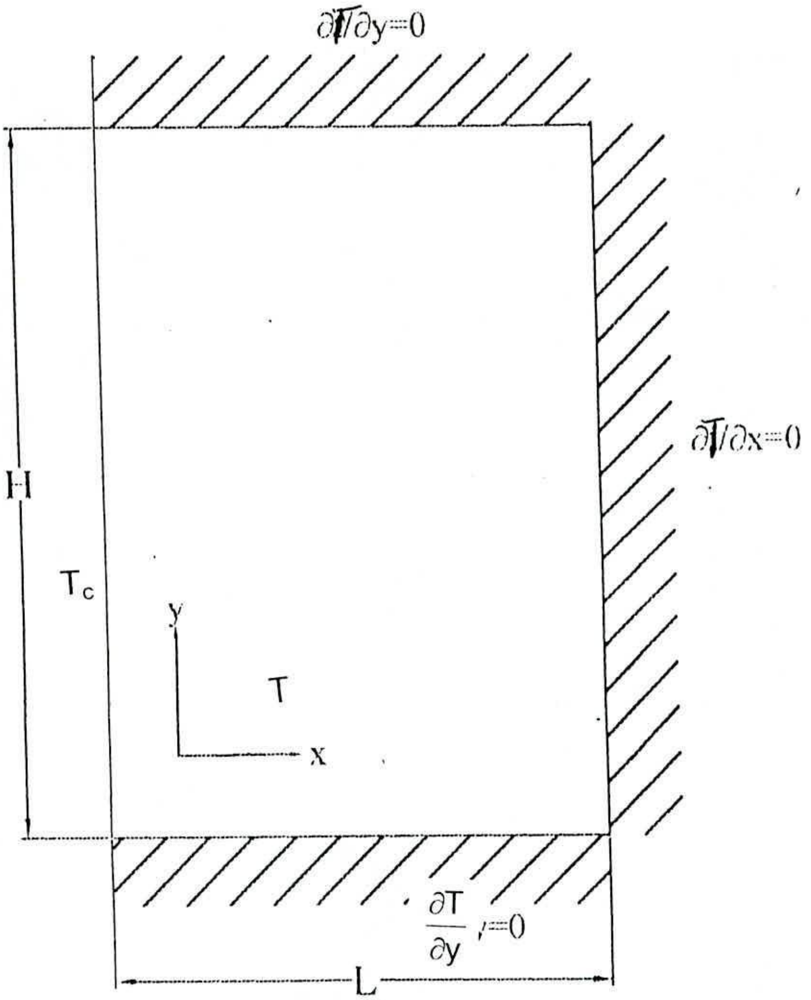


Fig. 3.1: Schematic configuration of the problem and coordinate system.

For measuring temperature of air in the enclosure at different locations, twelve thermocouples are placed in three columns and four rows, thus, four vertical air sub-layers are formed with various density gradients. The flow is assumed to be Newtonian, two dimensional buoyancy induced flow with negligible viscous dissipation. The governing equations are the continuity, momentum and energy equations:

$$\nabla . u = 0 \qquad \text{-------- (1)}$$

$$\frac{\partial u}{\partial t} + u.\nabla u = -\frac{1}{\rho_o}\nabla p + \nu \nabla^2 u + \frac{\rho}{\rho_o} g \qquad \text{-------- (2)}$$

$$\frac{\partial t}{\partial \tau} + u.\nabla T = k \nabla^2 T \qquad \text{-------- (3)}$$

where u is the velocity vector, ν the kinetic viscosity, T the temperature, p the pressure, t the time, ρ_o the minimum density at T_α and g is the acceleration due to gravity.

There are several models for predicting the density-temperature behavior of air around the maximum density region. A parabolic density temperature relationship is given by Debler[34].

$$\frac{\rho}{\rho_o} = 1.0 - \nu\left(T_o - T\right)^2 \qquad \text{--------------------(4)}$$

Later, by adding cubic term in equation (4) this model can be expanded to decrease the temperature in the range 27 and -7°C.

$$\frac{\rho}{\rho_o} = 1.0 - \nu_1\left(T_o - T\right)^2 + \nu_2\left(T_o - T\right)^3 \qquad \text{--------------------(5)}$$

The non-slip boundary condition is imposed at all rigid walls. The initial and boundary conditions are specified as follows:

(i) for time $T < 0$

$u = 0; T = T_o \ \forall x, \forall y$ ----------------- (6)

(ii) for $T > 0$

$u = 0; T = T_o$ at $x = 0$

$u = 0; T = T_h$ at $x = L$

$u = 0; \dfrac{\partial T}{\partial y} = 0$ at $y = 0; y = H.$ - -----------------(7)

The dimensionless variables (geometry, velocity, temperature, pressure and time) are introduced as follows:

$$X = \frac{x}{L} \qquad Y = \frac{y}{L}$$

$$U = \frac{u}{\frac{k}{L}\sqrt{(\mathrm{Ra\,Pr})}};\theta = \frac{T_o - T}{T_h - T_c}$$

$$P = \frac{p}{\frac{\mu k}{L^2}\sqrt{(\mathrm{Ra\,Pr})}};t = \frac{T}{\frac{L^2}{k}\sqrt{(\mathrm{Ra\,Pr})}} \qquad \text{-------------} \; (8)$$

where L is the enclosure length, k the thermal diffusivity, and μ the dynamic viscosity. The Rayleigh number, Ra, and the Prandtl number, Pr, are defined as

$$\mathrm{Ra} = \frac{g\gamma(T - T_c)^2 L^3}{k\nu} \qquad \text{---------------} \; (9)$$

$$\mathrm{Pr} = \frac{\nu}{k} \qquad \text{--------------} \; (10)$$

Thus, with the definitions in (8) the dimensionless governing equations expressing conservation of mass, momentum, and energy are written as:

$$\nabla.U = 0 \qquad \text{-----------} \; (11)$$

$$\sqrt{\frac{\mathrm{Ra}}{p_r}}\left(\frac{\partial U}{\partial t} + U.\nabla.U\right) = -\nabla P + \nabla^2 U - \sqrt{\frac{\mathrm{Ra}}{p_r}}\theta^2 \qquad \text{----------}(12)$$

$$\sqrt{(\mathrm{Ra}\,p_r}\left(\frac{\partial \theta}{\partial t} + U.\nabla.\theta\right) = \nabla^2\theta \qquad \text{-----------}(13)$$

From equation (12) it can be seen that the buoyancy effect is characterized by the ratio of two dimensionless parameters: Ra and Pr. In this study, Pr is kept fixed at 0.7 .

The heat transfer rate at the vertical walls is described by the Nusselt number, which is a function of both time and space. In terms of dimensionless parameters the local Nusselt number is defined as:

$$\mathrm{Nu} = \left|\frac{\partial \theta}{\partial X}\right|_{x=0.1} \qquad \text{--------} \ (14)$$

The average Nusselt number is the integral of the local Nusselt number over the length of the vertical wall

$$\overline{\mathrm{Nu}} = \frac{1}{A}\int_{o}^{H} \left|\frac{\partial \theta}{\partial X}\right|_{x=0.1} dY \qquad \text{-----------}(15)$$

3.3 Mathematical Equations

A two dimensional (2D), steady state and transient incompressible laminar flow model is considered in the present study. All properties are assumed to be constant except the effect of density.

The mathematical equations that are used to calculate the natural convection heat transfer co-efficient, Nusselt number, and Rayleigh number are given below:

$$Q \quad = \quad -k_f A \frac{\partial T}{\partial x} = hA\left(T_\alpha - T_c\right)$$

$$N_{uH} \quad = \quad h_t L / K$$

$$R_{aH} \quad = \quad g\beta \Delta T l^3 / v^2 \ x \ P_r$$

$$\gamma \quad = \quad \frac{\Delta T}{H}$$

CHAPTER-FOUR

EXPERIMENTAL SETUP

4.1 General Description of the Experimental Facility

This chapter describes the experimental aspects of the investigation and includes a detailed description of the experimental facility. Fig. 4.1 presents 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.

The dimensions of the rectangular enclosure are: base 40 cm x 35 cm and height 50 cm. Internal space of the rectangular enclosure is: base 32cm x 32cm and height 45cm. The enclosure is made of mild steel sheet. Each of the walls is thermally insulated with styrofoam. A thermoelectric module of size 9x4x7cm is placed at the center of one of the vertical walls of the enclosure. An aluminum plate of size 22cm x 22cm and of thickness 5mm is screwed to the thermoelectric module. In course of the experiment, cooling of the aluminum plate is accomplished by the thermoelectric module (TEM). In first setting, 14 thermocouples are used out of which 12 thermocouples, are used to measure the temperature of air within the enclosure at different locations along and from the cold plate (Fig. 4.2). The other two thermocouples are used to measure cold plate temperature and room temperature. The input current is measured by a precision ammeter. Forced convection heat sink (fins) of area 1080 cm^2 are used on the hot side of the heat exchanger to give off the heat to the surrounding air. For forced convection 220 volt (AC), 50hz, ¼ hp fan is used over the sink. For supplying 10 volt (DC) to the thermoelectric module a rectifier is used. A data acquisition system is used to record the data from the thermocouples.

4.2 Test Section

The test section consist of :

- i. Rectangular enclosure
- ii. Thermoelectric module
- iii. Data acquisition system
- iv. Fan
- v. Fins
- vi. Rectifier
- vii. Thermocouples

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

4.2.1 Rectangular enclosure

All walls of the enclosure are made of mild steel. The thickness of the mild steel sheet is 1mm. All walls are thermally insulated with styrofoam. The thickness of the styrofoam is 2.54cm. There is a door on the front side of the enclosure. The provision of the door is kept for placing the thermocouple at different locations in the enclosure and also for screwing up the aluminum plate with the thermoelectric module. The thermoelectric module is placed at the centre of one of the vertical walls. Heat sink (fin) is used on the hot side of the heat exchanger to give off the heat to the surrounding air. For force a convection low capacity fan is used over the sink Fig. 4.1.

4.2.2 Thermoelectric module

For cooling the internal space of the enclosure a thermoelectric module is used (Fig. 4.3). The dimension of thermoelectric module is of 9cm x 4cm and height 7cm. The thermoelectric module has 11 couples. The module is composed of two ceramic substrates that serve as a foundation and electric insulation for P-type and N-type bismuth telluride dice that are connected electrically in series and thermally parallel between the ceramics. The ceramics also serve as insulation between modules, internal electric elements and a heat sink that must be in contact with the hot side as an object against the cold side surface. An electrically conductive material, copper pads attached to the ceramics, maintain electric connections inside the module. Solder is used at the joints to enhance the electric connection and hold the module together.

Most modules have even number of P-type and N-type dice and one of each sharing has an electrical interconnection and is known as, "a couple." The above module would be described as an 11-couple module.

While both P-type and N-type materials are alloys of bismuth and tellurium, both have different free electrical densities at the same temperature. P-type dice are composed of material having a deficiency of electrons and N-type has an excess of electrons. As current (amperage) flows up and down through the module it attempts to establish a new equilibrium within the materials. The current treats the P-type material as a hot junction needing to be cooled and the N-type as a cold junction needing to be heated. Since the material is actually at the same temperature, the result is that hot side becomes hotter while the cold side becomes colder The direct current will determine if a particular die will cool down or heat up.

4.2.3 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 is the component number 2 as shown in Fig. 4.1. The acquisitor model is COLE-PARMER PCA-14. From the certifications of construction the resolution and accuracy are found to be 16 bits and ±0.02% respectively. The dimension is height 35cm, width 10cm and depth 22.5 cm.

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

4.2.4 Rectifier

To supply the DC power to the thermoelectric module and data aquisitor two rectifiers are used. The input and output of the rectifiers are 200-250v A.C ,50 Hz and 10v D.C,3A respectively . Out put voltage variation is ± 0.1 %(max).

4.2.5 Thermocouples

T type thermocouple are employed in this experiment.

a. Position of the thermocouples in the enclosure:

To measure the temperature of air within the enclosure at different height and different locations along and from the cold plate 12 thermocouples are used as shown in Fig. 4.2. Thermocouples are placed in three columns and four rows. The position of three columns are 30mm, 150mm and 300mm apart from the cold plate and the position of rows are 20mm, 150mm 300 mm and 400 mm apart from the bottom surface of the enclosure. Two thermocouples are used to measure cold plate temperature and room temperature.

4.3 Details of the cold plate assembly

To receive heat from air in the enclosure cold plate assembly is placed on the back vertical wall of the enclosure .To make all walls adiabatic, 2.54 cm thick styrofoam is used. A rectangular hole of size 9 x 4 cm is made at the middle of the back vertical wall of the enclosure . Then a thermoelectric module of 9cm x 4cm and height 7cm is placed in the rectangular hole. An alumininim (cold) plate of size 23cm x 25cm and of thickness 5mm is screwed to the inside (cold side) of the thermoelectric module. Heat sink (fins) about 1080-square cm is used on the outside (hot side) of the thermoelectric module to give off the heat to the surrounding air. For forced convection a fan is placed against the sink (fig. 4.4).

CHAPTER-FIVE

EXPERIMENTAL MEASUREMENT AND TEST PROCEDURE

5.1 Instrumentation

In the present investigation provision are made for measuring temperature of air within the enclosure at different locations and the temperature of the cold plate. AC to DC converter is used to supply the necessary voltage at different sections of the experimental set up. A data acquisition system is used to record the data from thermocouples. Details of the instrumentation and measurement procedure are as follows.

5.2 Calibration of Thermocouple

Calibration of one of the thermocouples is done with the help of a J-type thermocouple. At first, leads of both the thermocouples are connected with respective meters. The junctions of both thermocouples are put into a bowl containing tap water. At the steady state condition, both the meters read 27^{o}C temperature which are recorded. Then some ice chips is mixed with the water of the bowl. After stirring for some time, both the thermocouple meters become static and their readings are recorded. Again, some more ice chips are added to the water until a steady temperature of –2^{o}C is reached. The calibration curve is shown in Fig. 5.1.

5.3 Temperature Measurement

Fourteen 36 SWG T-type thermocouples are used in this experiment. Twelve thermocouples are placed at different locations within the enclosure [Fig. (4.1)] to measure the temperature of air. Other two thermocouples are used to measure the room and cold plate temperature. Data acquisition system is used to record the data from the thermocouples at every fiveminute interval until steady state condition is reached. Recorded data is stored in the computer.

5.4 Current and Voltage Measurement.

Power is measured indirectly by using a digital volt meter and a precision ammeter. The digital volt meter of model LEADER LDM-853A is employed to measure the voltage across the thermoelectric module which absorbs the necessary heat to from the air within the enclosure. The volt meter has the accuracy of ±0.3% and the range of the voltmeter is 0.2 – 1000 v.

A precision ammeter of model WESTING HOUSE 936234E is used to measure the current supplied to the experimental thermoelectric module. It has the sensitivity of ±0.01 amp.

5.5 Experimental Procedure and Data Analysis

A rectangular enclosure having a height of 450 mm and length 320 mm is used. The experimental fluid is air at atmospheric pressure. The experiment is carried out under transient as well as steady state conditions.

The overall test procedure is as follows:

1. First one end of the fourteen thermocouples are placed at different locations in the enclosure. Other ends of the thermocouples are connected to the aquisitor.

2. Then aquisitor is connected to the CPU of the computer.

3. Electric power is supplied to the aquisitor through a rectifier.

4. Electric power is also supplied to the thermoelectric module through another rectifier.

5. The computer is then started and PCA-14 is run.

6. From main menu fourteen channels are selected.

7. Then data are recorded till steady state condition is reached.

8. Then recorded data are analyzed for finding out heat transfer co-efficient, Nusselt number and Rayleigh number.

CHAPTER-SIX

RESULT AND DISCUSSION

6.1 Discussion on the Results and Finding

Figures 6.1 to 6.5 show 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 are calculated.

For finding out heat transfer rate Q temperature data and distance are plotted in sigma plot-2000, and curve fitting is done. It is found that the single rectangular hyperbola fitted the data very well and the nature of the equation can be given as:

$$T = T_c + ax / (b + x)$$

Where

T_c = cold wall temperature

T = Air temperature of the enclosure

From the above equation dT/dx is calculated for each curve and the average dT/dx was also calculated for each interval and Q is calculated by using the following equation

$$Q = -k_f A \, dT/dx = hA (T - T_c)$$

Where Q is the total heat transfer from the air to the cold plate during that time.

It is found that the value of heat transfer rate Q increases with the interval of time.

For calculating temperature gradient γ, a general model for gravitational force driven flow near the cold vertical wall is considered as shown in Fig. 6.0. Now the fluid of enclosure is linearly stratified.

$$T(y) = T.0 + \gamma y$$

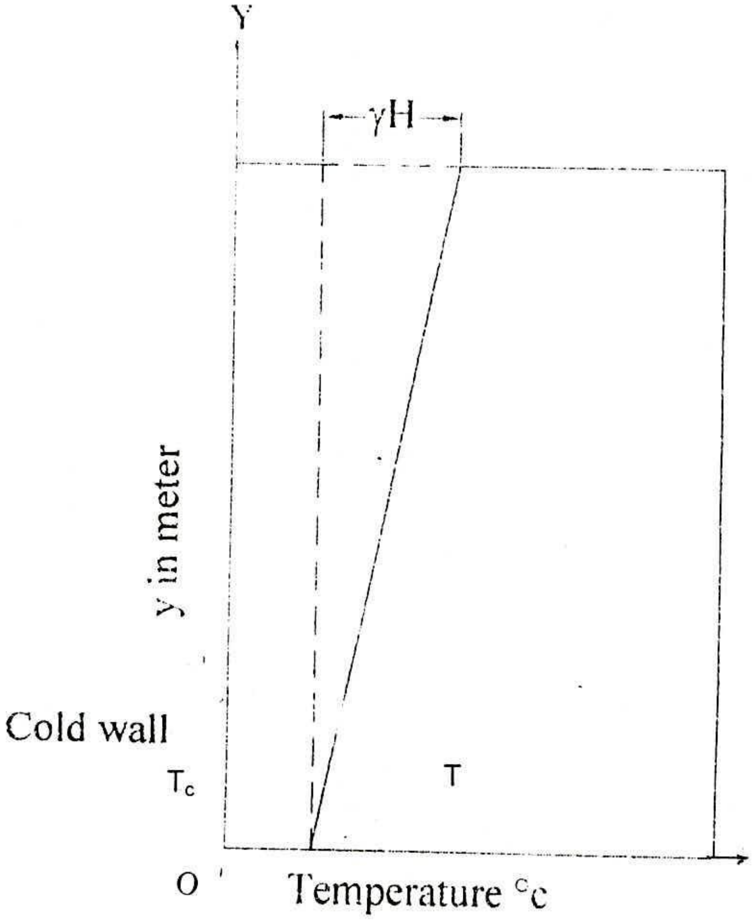


Fig. 6.0: The effect of stratification in a cold vertical wall enclosure.

T.0 being the lowest temperature in the arrangement and γ is constant temperature gradient. The dashed line shown in the figure the location of the isothermal reservoir model employed so far ($\gamma = {}^{o}C / m$).

Now γ is calculated by the following equation.

$$\gamma = \Delta t / H \ {}^{o}C/m$$

where Δt is the temperature difference between the lowest and highest temperature of fluid line.

For calculating Rayleigh number, the average temperature of last column i.e. ($x = 0.3m$) is calculated then the temperature difference between the average temperature and cold plate is calculated. And vertical height of cold plate is considered for calculating Rayleigh number.

$$Ra_H \quad = \quad g\beta H^3 (T_\alpha - T_c) / \nu^2 \ x \ \rho_2$$

where

H is the height of the cold plate
T_c is the cold plate temperature
T_α is the average air temperature of the last column

For calculating Nusselt number, vertical height of the cold plate is considered and the value of heat transfer coefficient is considered for particular interval.

$$Nu_H = \frac{h(\tau)L}{k_f}$$

For finding out the value of heat transfer coefficient "h" for each interval the average temperature of twelve thermocouples which have been recorded through data acquisition is calculated. Then temperature difference between the average temperature and cold plate is calculated and the following equation is used.

$$Q = hA\,(\Delta t) \qquad \text{where } \Delta t = (T_{\infty a} - T_c)$$

Findings of the experimental investigation are discussed below. The rectangular enclosure has an adiabatic surrounding, therefore, it is expected that the heat transfer rate from air to the cold plate would be unaffected by the presence of surrounding from the enclosure.

Fig. 6.1 to 6.5 show the temperature distribution of the air within the enclosure at different intervals. It is found from the figures that the temperature of air at any point gradually decreases with time and air is colder closer to the cold wall and near the bottom of the enclosure.

Again from Fig. 6.1 to 6.5 it is found that fluid layers developed with interval of time which floats on top of increasingly colder layers. It is 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 has no choice but discharge horizontally from air of the enclosure. So, the direction of discharge is horizontal because the cold boundary layer contains fluid colder than the rest of the enclosure. In this way thermal stratification is developed in the enclosure.

From Fig. 6.6 to 6.10 it is found that the effect of the enclosure stratification on the heat transfer from air to the gradually decreasing cold wall temperature with interval of time. It is found that the value of temperature gradient, decreases with the interval of time. (Fig. 6.11). It means the temperature difference between the adjacent layer decreases with the interval of time i.e. the temperature difference among the warm fluid layers floating on top and of increasingly colder layers is decreasing and γ value is decreasing with time and approaching a constant value at each section in the enclosure.

Fig. 6.12 shows the average Nusselt number increases with the interval of time, so heat transfer coefficient also increases with the interval of time. This argument holds that heat transfer rate in the enclosure increases with time until steady state condition was reached.

The experimental data of Nusselt number and Rayleigh number is plotted in Fig. 6.13. The plots are given in term of Nusselt number versus Rayleigh number for different time of interval and for constant aspect ratio. From the graph it is found out that the relation between Nusselt number and Rayliegh number are linear. Fig. 14 shows the Rayleigh number also increases with the interval of time.

Fig. 6.15 shows the variation of temperature with respect to time. It can be seen from this graph that the temperature decreases rapidly initially. The rate of variation then decreases and finally the temperature stabilized at a steady value.

Fig. 6.16 shows air temperature difference between top most and bottom most layer of air at different x axis distance with respect to time. It can be seen from the graph that the temperature difference after some time almost same. This argument holds there is no significant change of heat transfer coefficient is established.

Fig. 6.17 shows average temperature difference of top most and bottom most layer versus time. It can be seen that after some time there is no significant change of average temperature difference with time.

Fig. 6.18 is found that the value of γ is decreasing with time. It shows that at any distance from the cold plate temperature of the stratified layers is approaching a steady state value.

CHAPTER-SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions:

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

1. The temperature of air at different parts of the enclosure decreases asymptotically to the steady state value.

2. Temperature difference between top most and bottom most layer of air at different x value increases initially and then remains constant.

3. The result shows that the air in a part of the enclosure is substantially stratified.

4. Stratification indicator γ decreases with the increase of time.

5. The natural convection heat transfer coefficient, Nusselt number and Rayleigh number increase with the increase of time.

6. The experimental data are well correlated with the following correlation

$$Nu_H = 0.5 \times Ra_H^{0.25}$$

7.2 Recommendations

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

1. Further investigation can be carried out with fluid filled rectangular enclosure driven by a single vertical wall with warm and cold regions:

2. A numerical model may be developed for the study of natural convection heat transfer in a rectangular enclosure from one cooled side wall.

3. 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 may be helpful. For finding out the effect of Prandtl number experiments may be carried out with different fluids.

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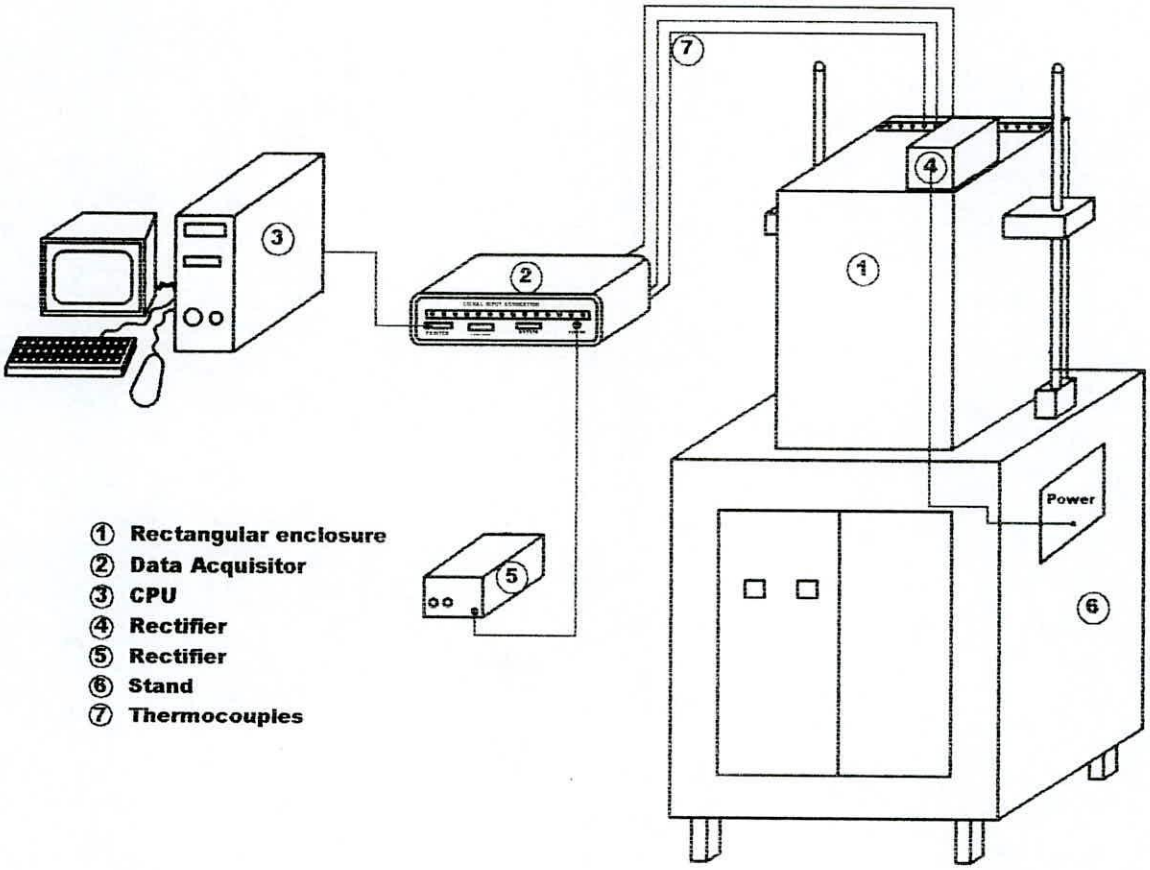

Figure 4.1 : Schematic diagram of the experimental facility

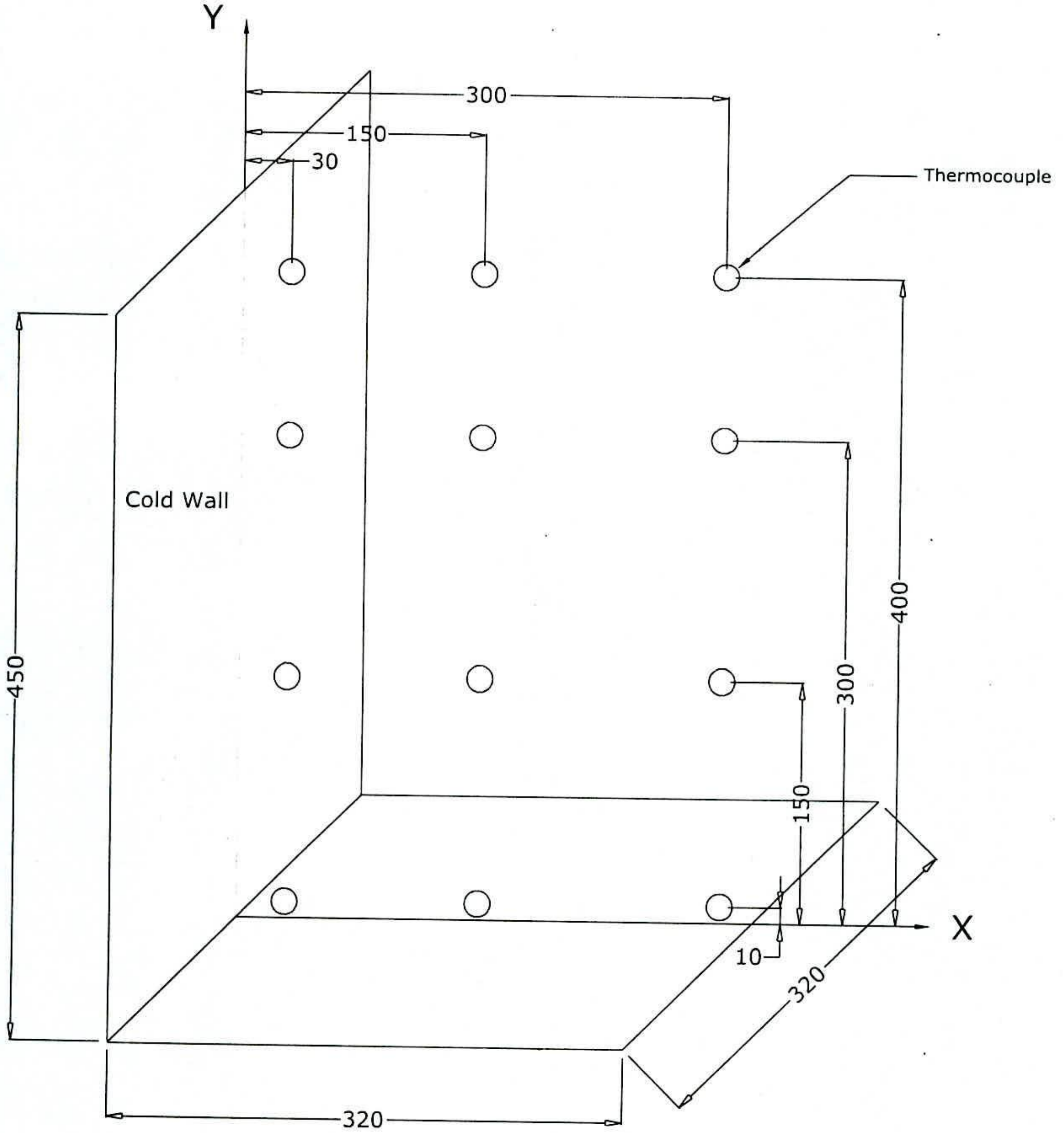

Figure 4.2: Position of the thermocouples in the enclosure

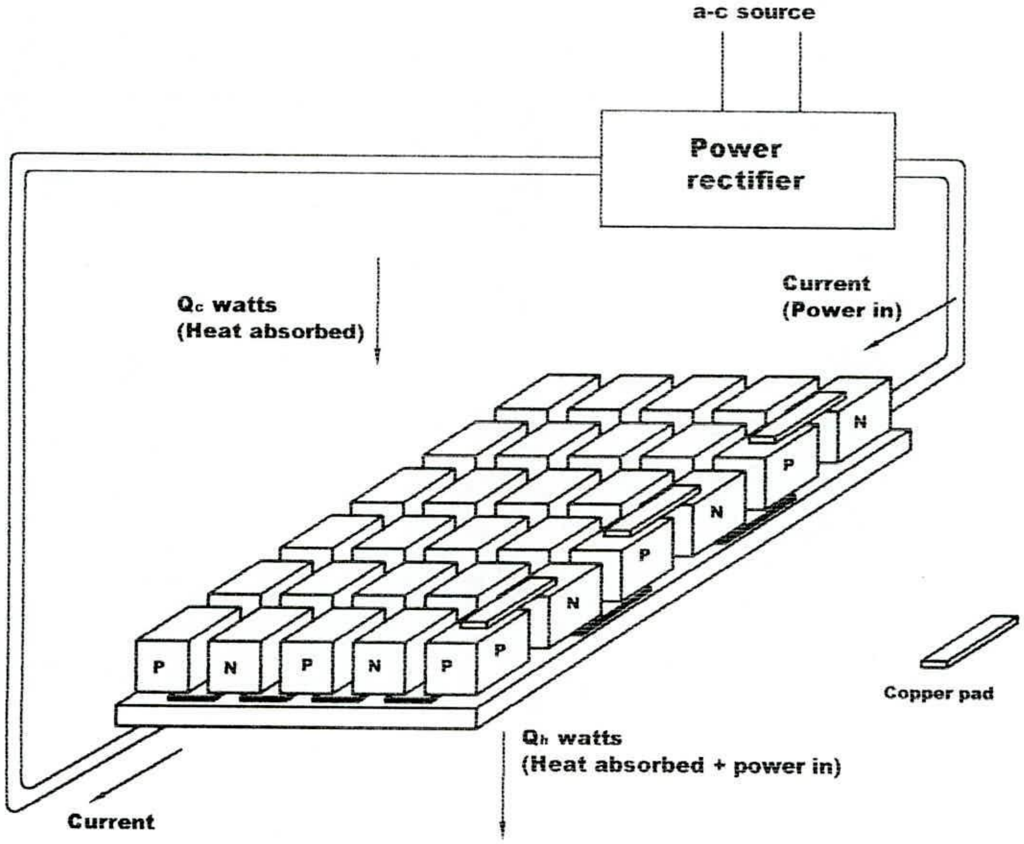

Fig. 4.3: Schematic Diagram of Thermoelectric Module with Power Supply

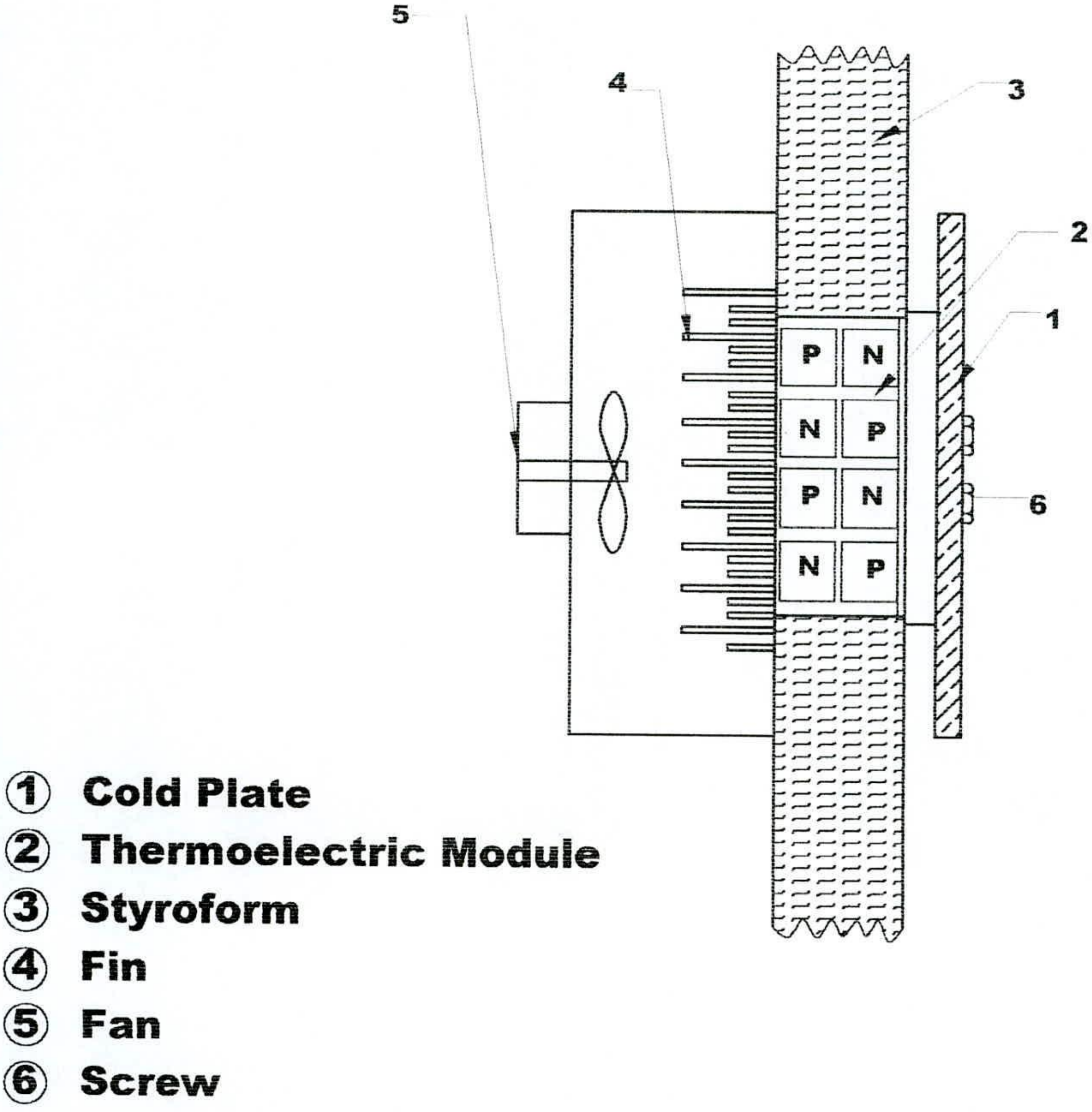

Fig. 4.4: Details of cold plate assembly

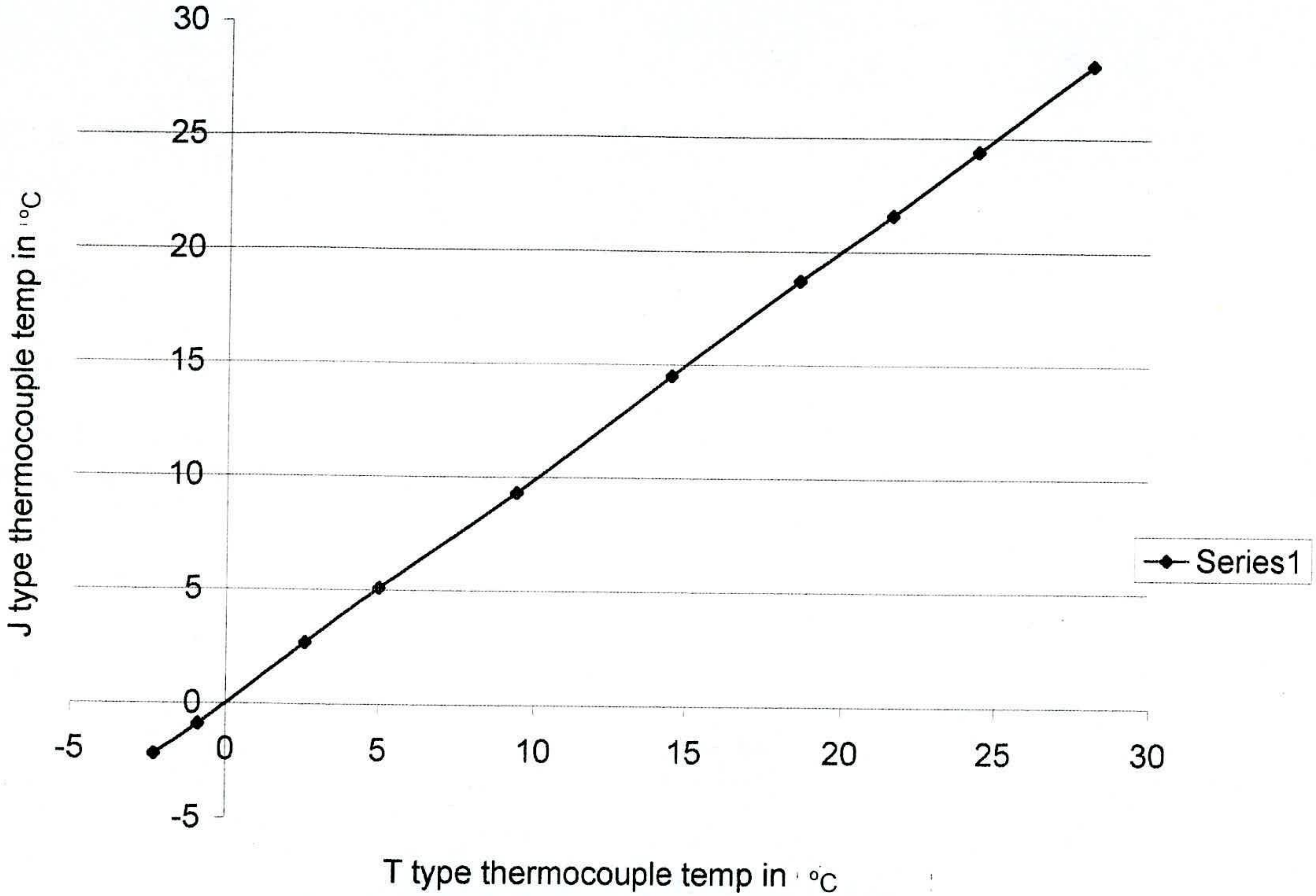

Fig: 5.1Calibration of thermocouple

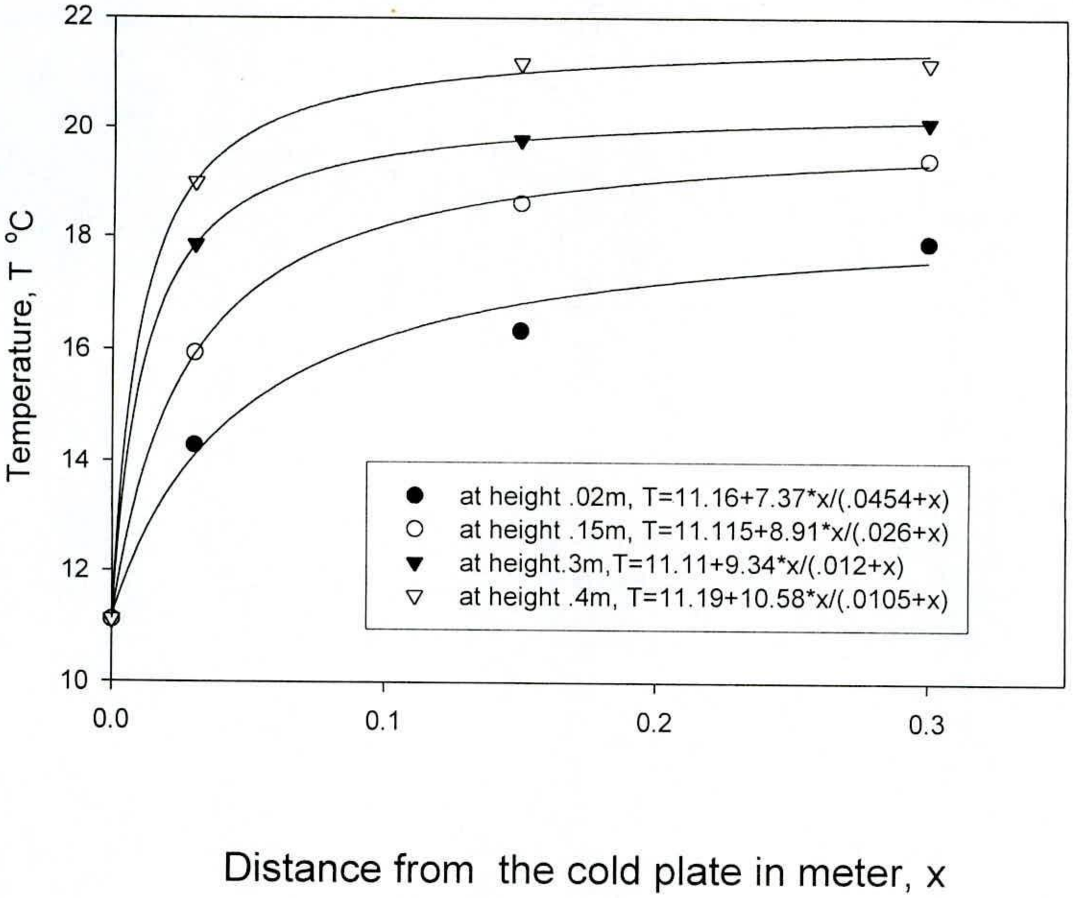

Fig. 6.1 Temperature at different height ' y ' in the enclosure at different distance ' x ' from cold plateafter 15 minutes.

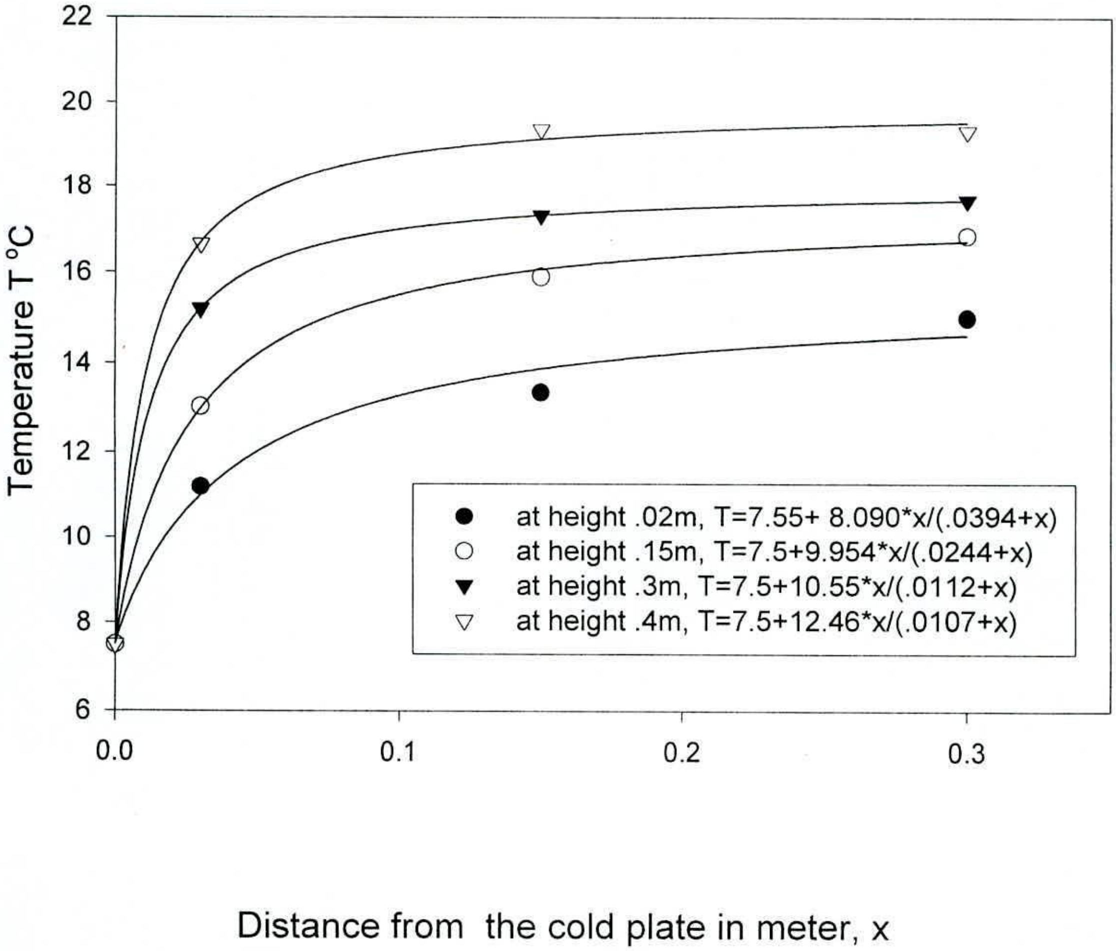

Fig. 6.2 Temperature at different height ' y ' in the enclosure at different distance ' x ' from cold plate after 25 minutes.

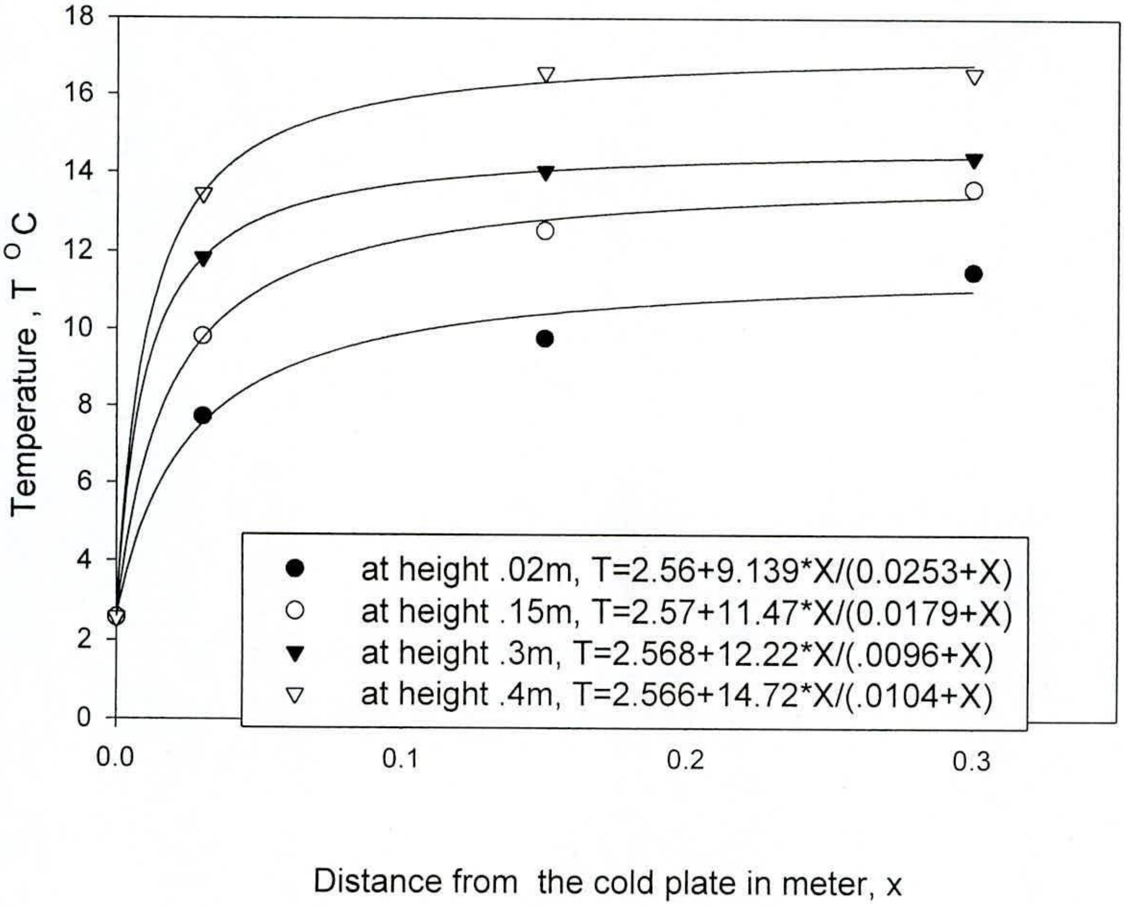

Fig. 6.3 Temperature at different height ' y ' in the enclosure at different distance ' x ' from cold plateafter 50 minutes.

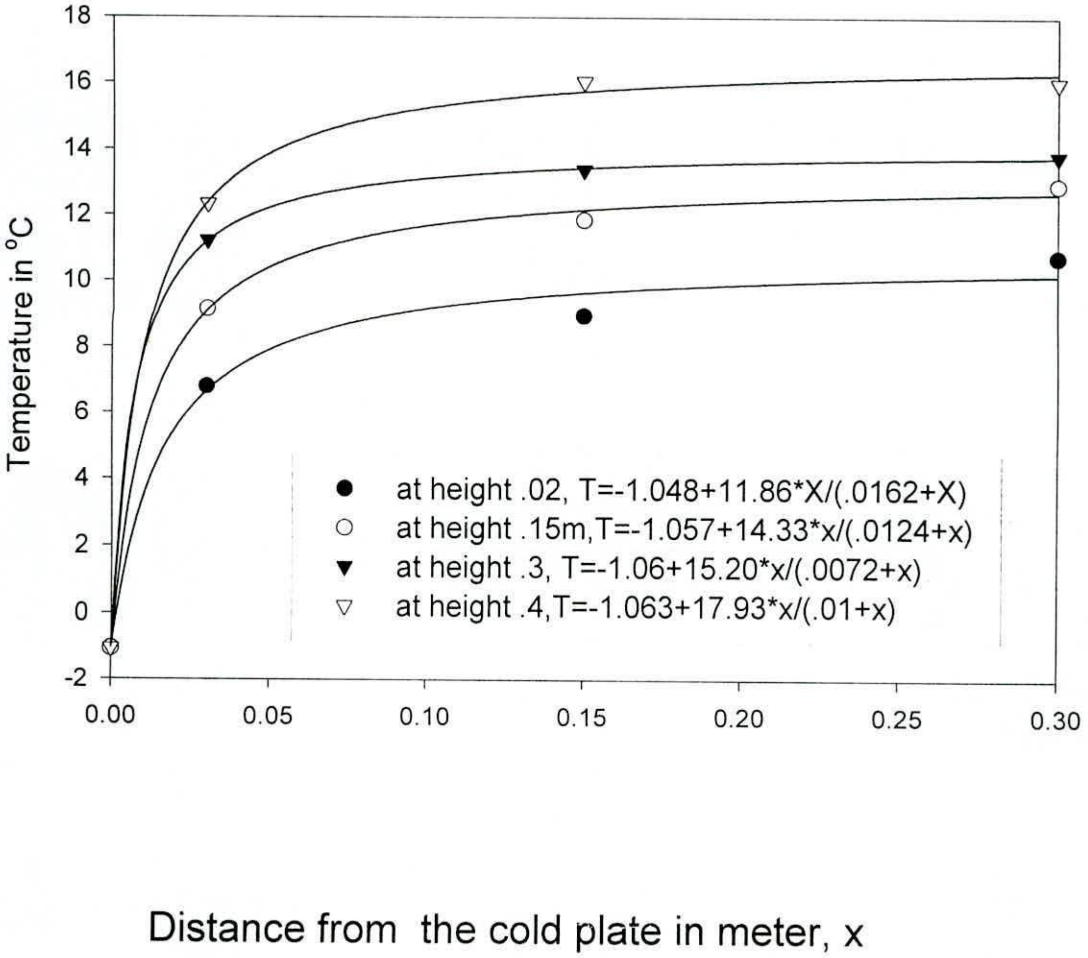

Fig. 6.4 Temperature at different height ' y ' in the enclosure at different distance ' x ' from cold plateafter 60 minutes.

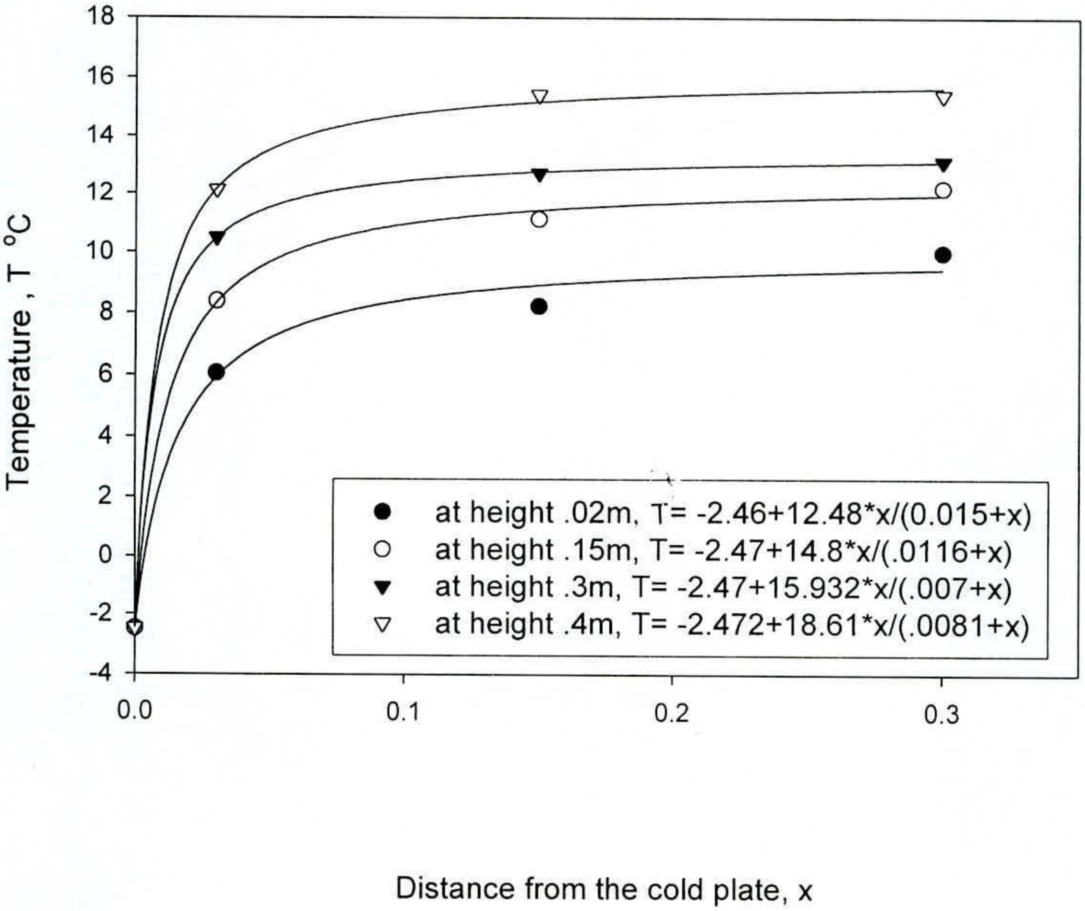

Fig.6.5Temperature at different height ' y ' in the enclosure at different distance ' x ' from the cold plate after 80 minutes.

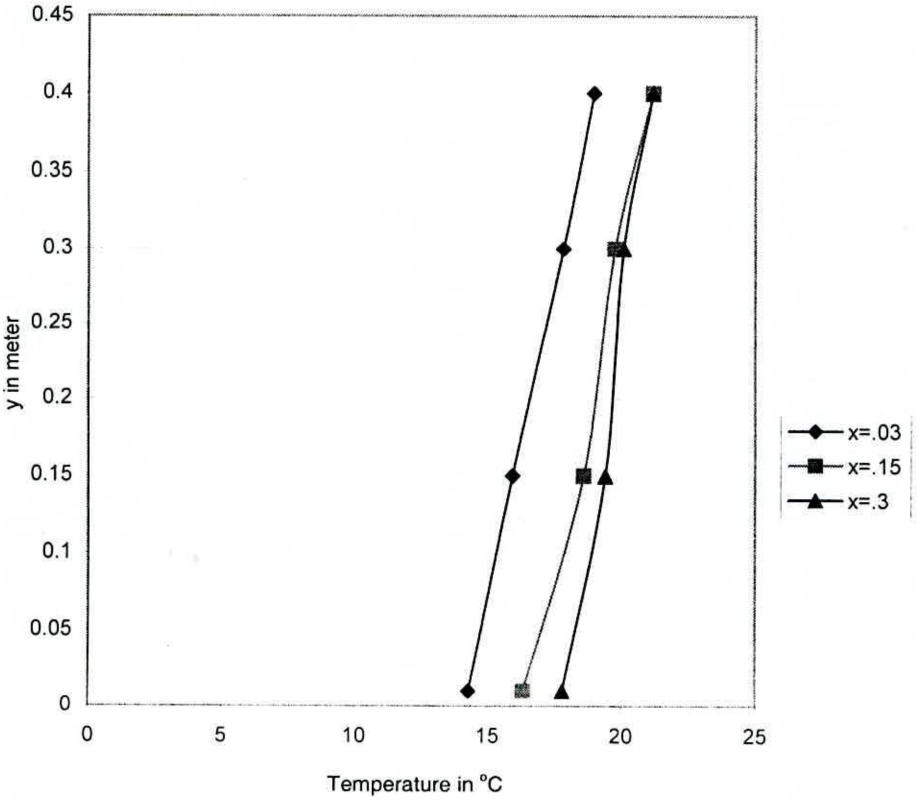

Fig. 6.6: Effect of the enclosure stratification on heat transfer from air to the cold vertical wall (after 15 mins)

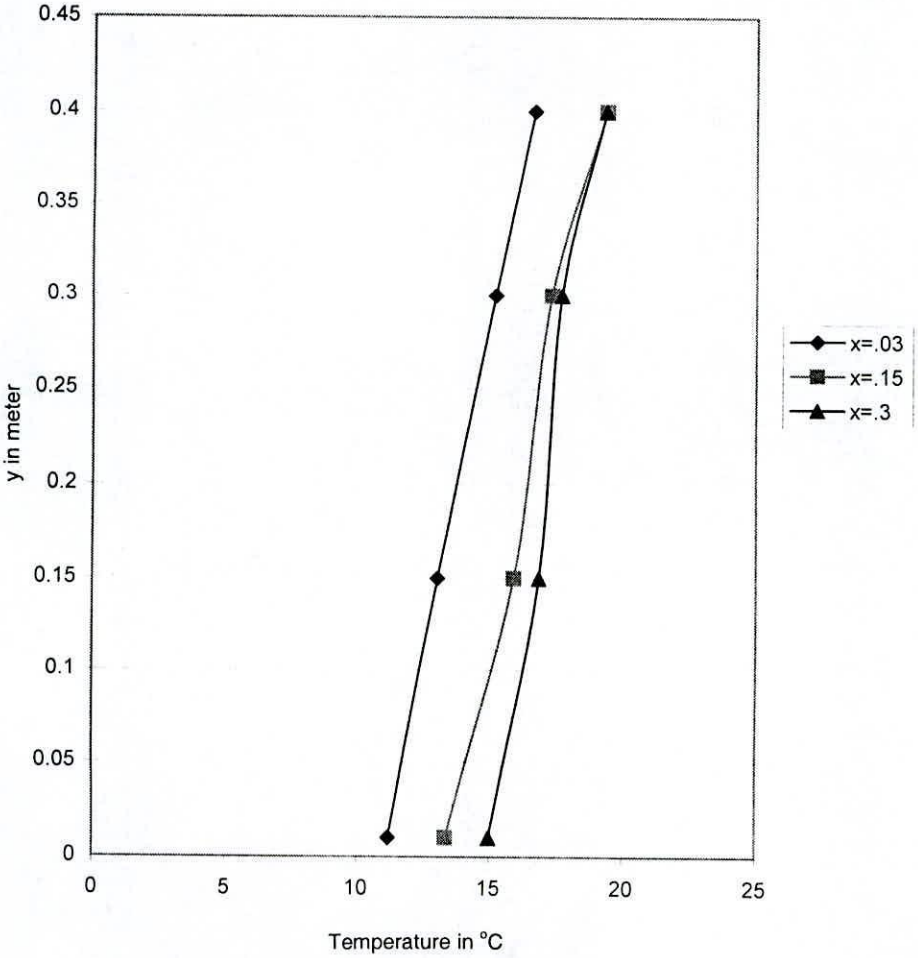

Fig. 6.7: Effect of the enclosure stratification on heat transfer from air to the cold vertical wall (after 25 mins)

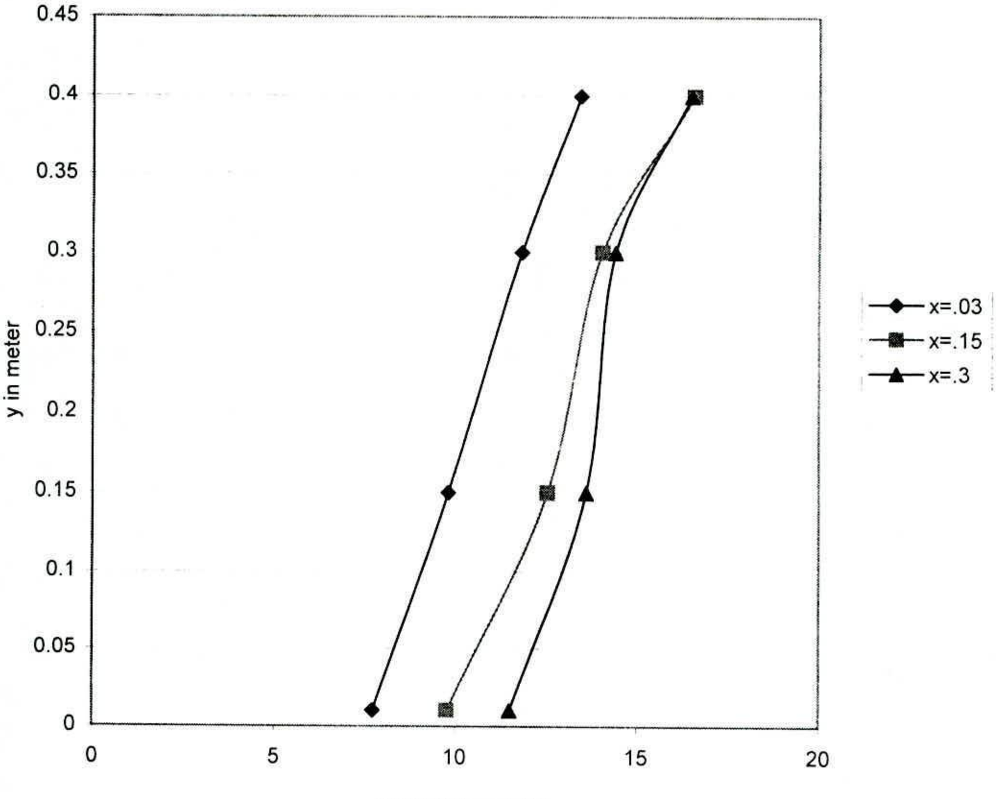

Fig. 6.8: Effect of the enclosure stratification on heat transfer from air to the cold vertical wall (after 50 mins)

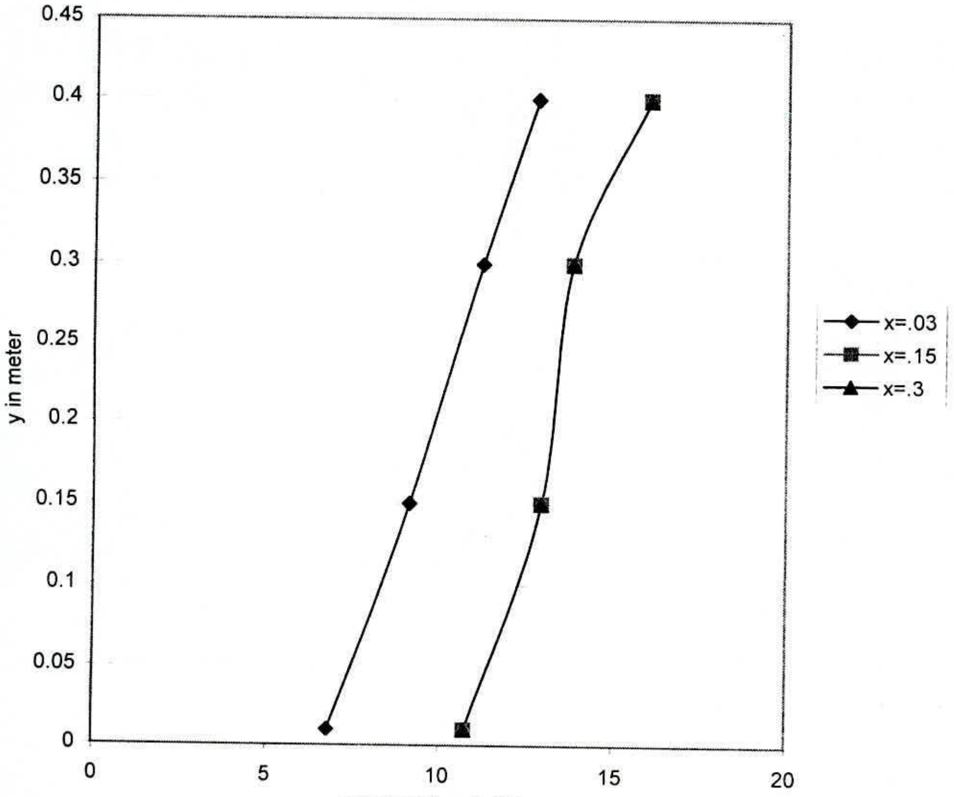

Fig. 6.9: Effect of the enclosure stratification on heat transfer from air to the cold vertical wall (after 60 mins)

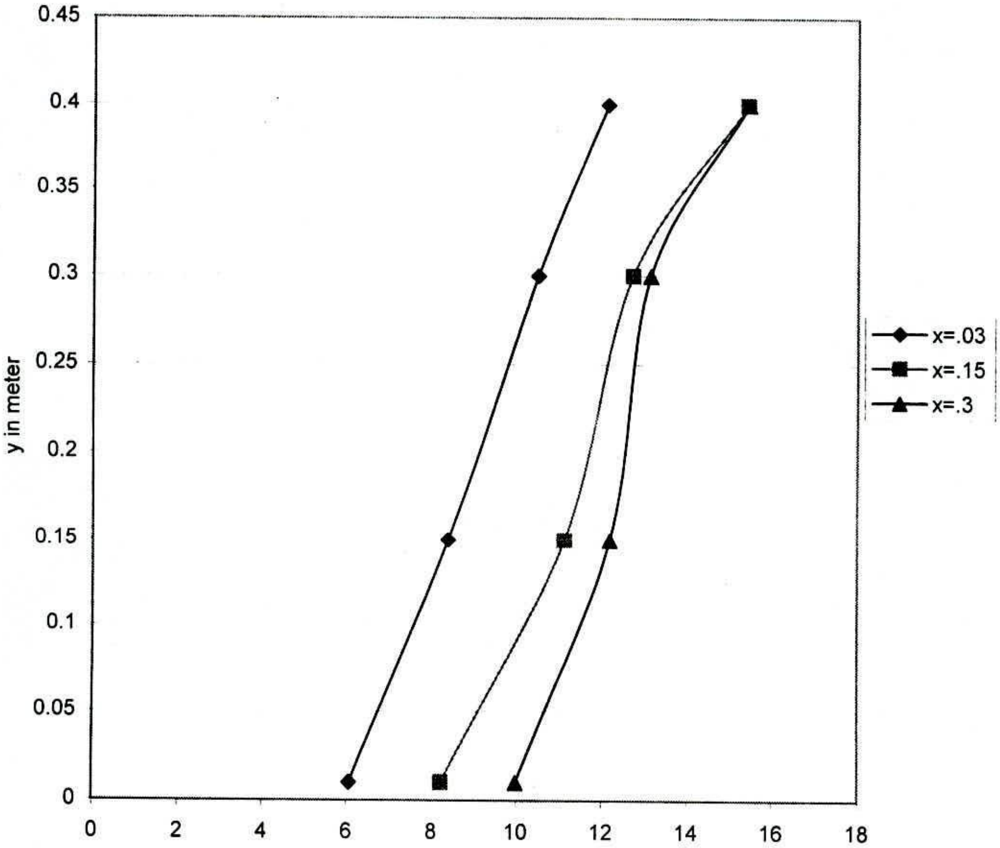

Fig. 6.10: Effect of the enclosure stratification on heat transfer from air to the cold vertical wall (after 80 mins)

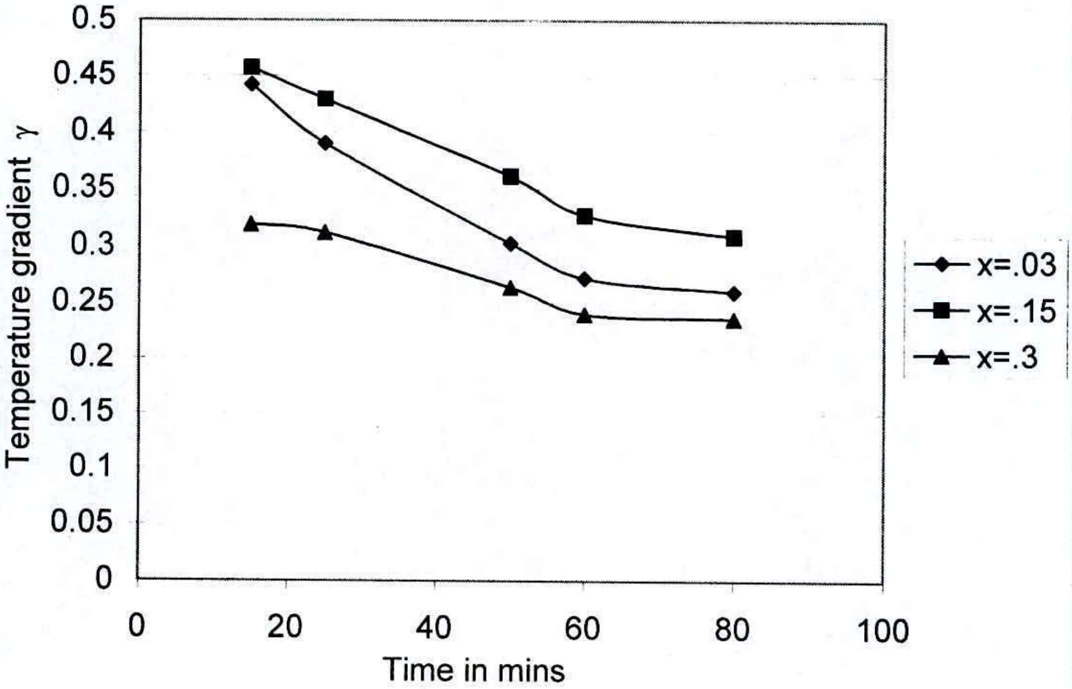

Fig 6.11 γ versus time

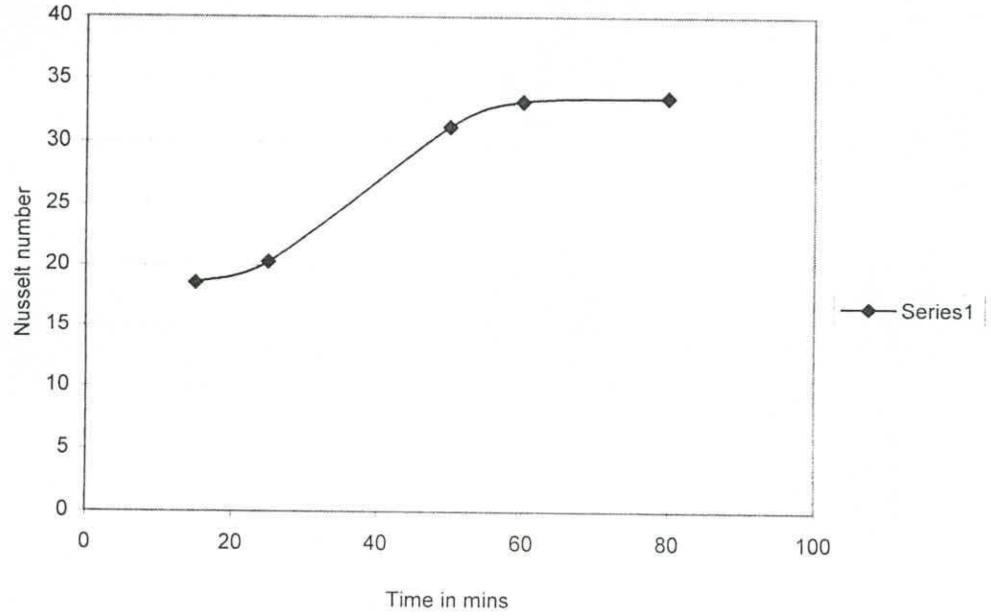

Fig: 6.12 Nusselt number versus time

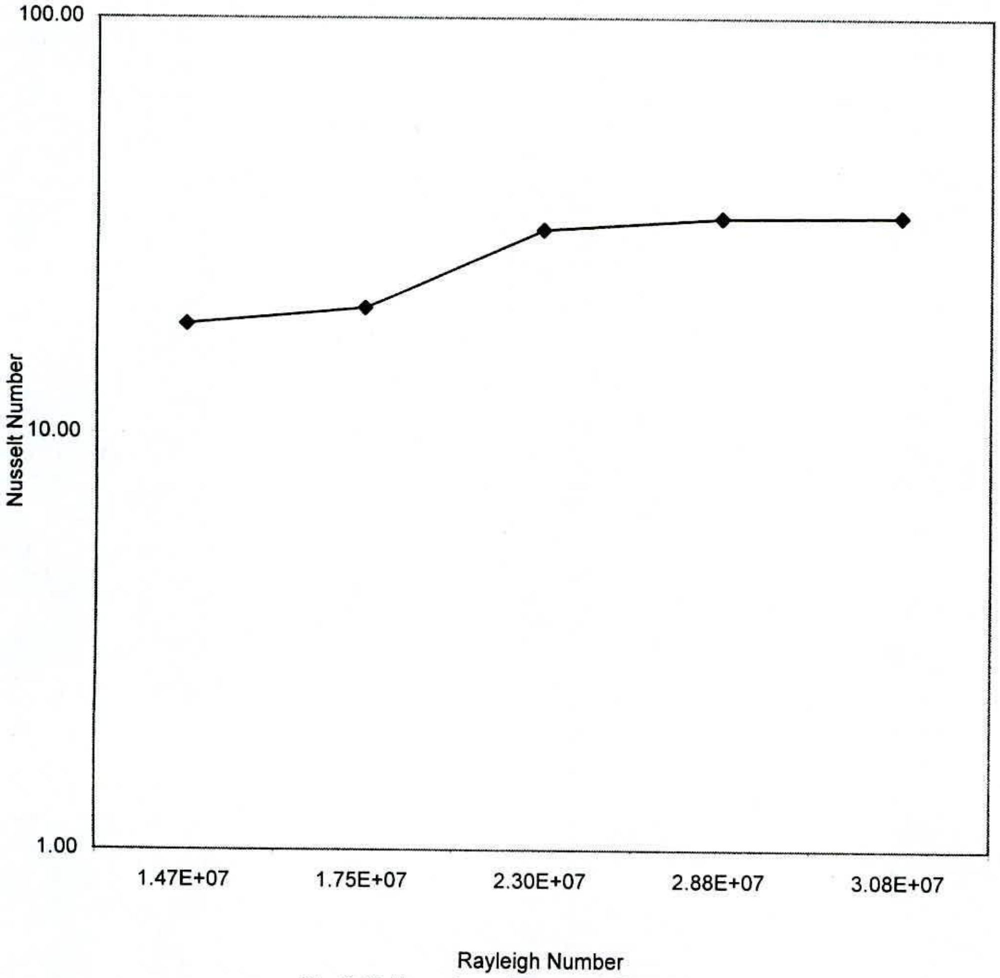

Fig. 6.13 Nusselt number versus Rayleigh number

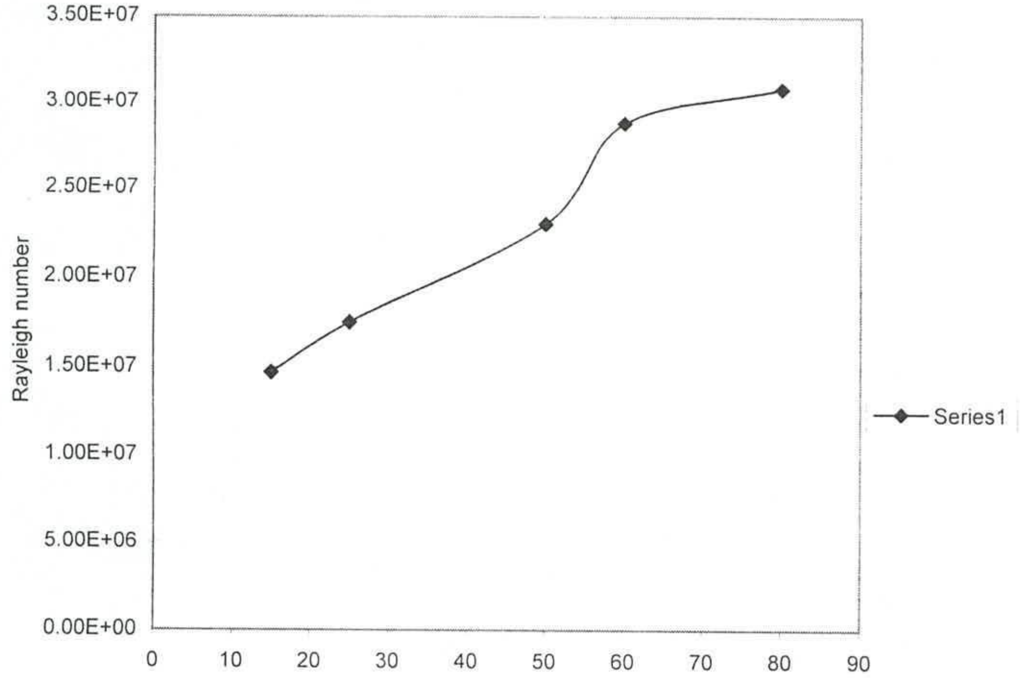

Fig:6.14 Rayleigh number versus time

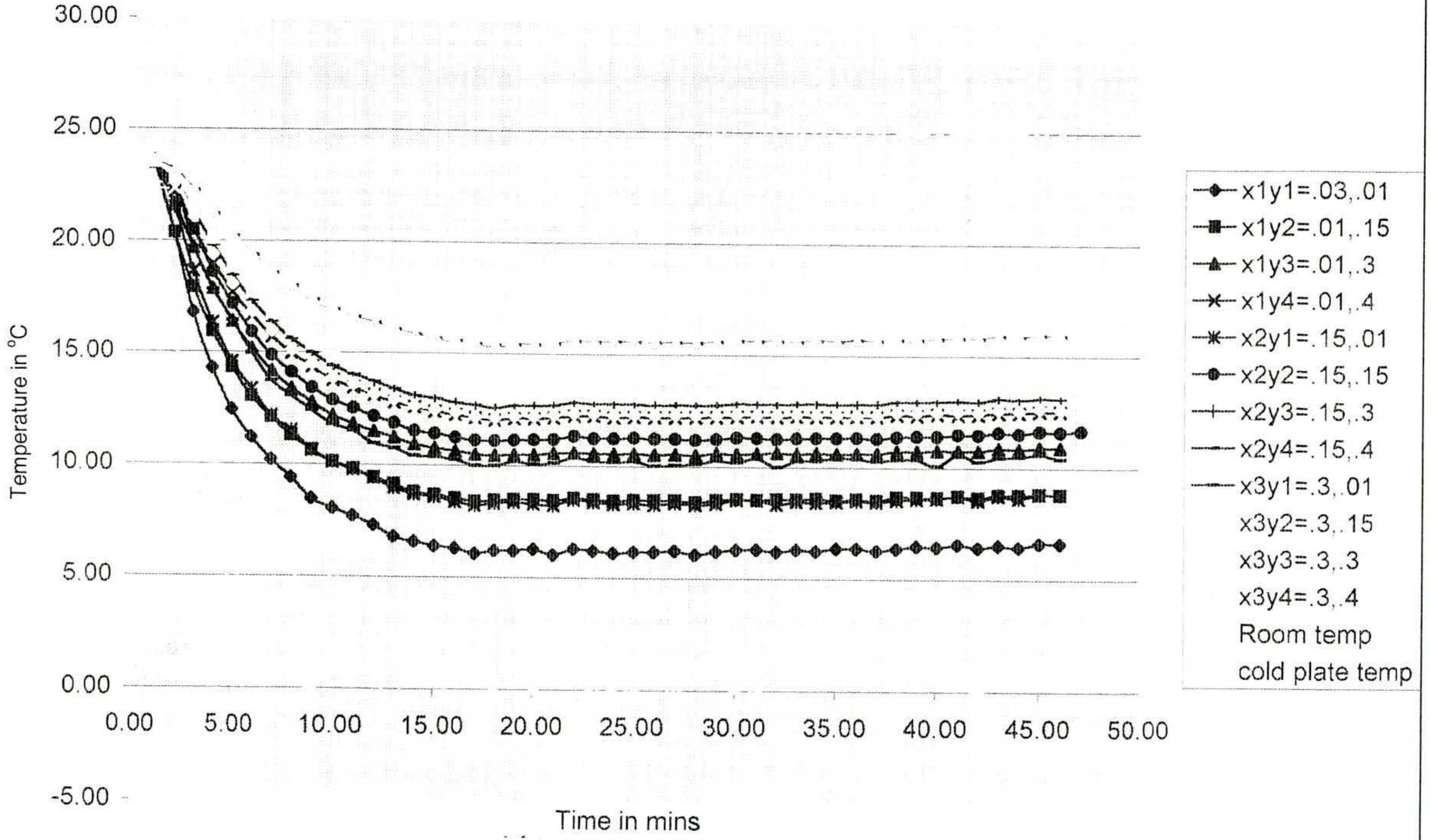

Fig. 6.15 Temperature versus time

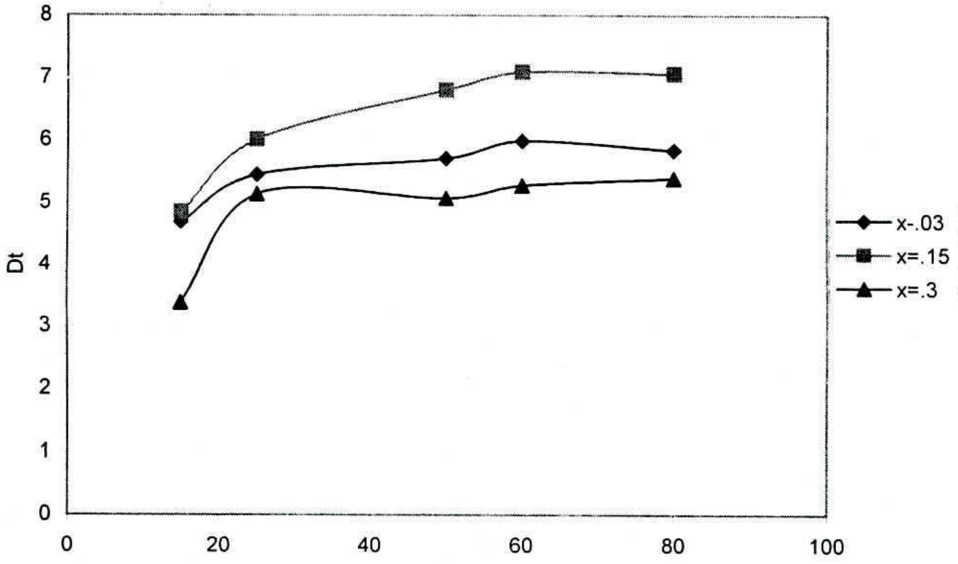

Fig:6.16 Air temperature difference between top most and bottom layerof airat different x distance with time

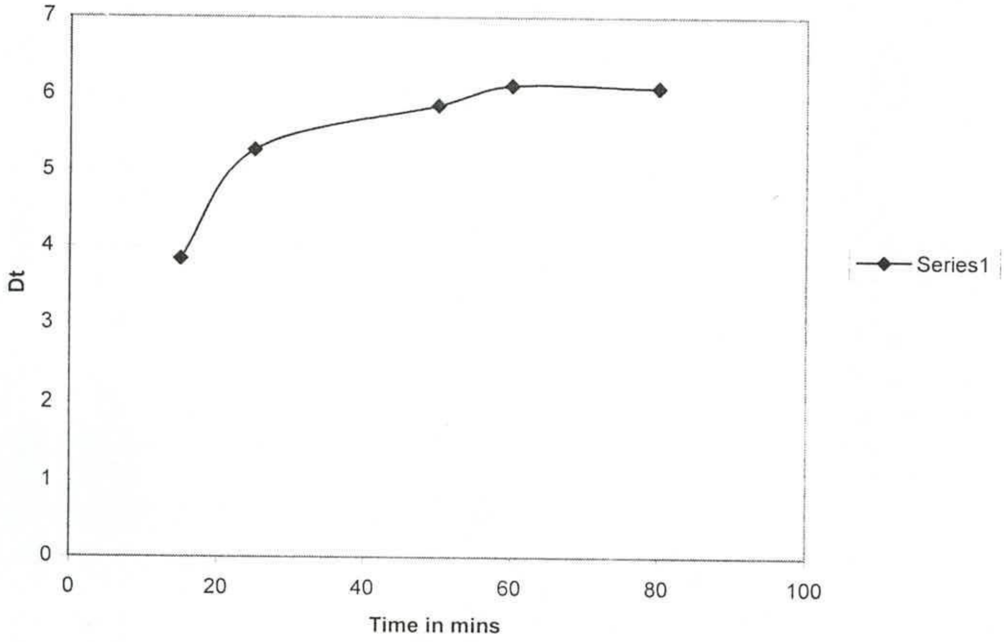

Fig:6.17 Average highest and lowest temperature difference Dt versus time

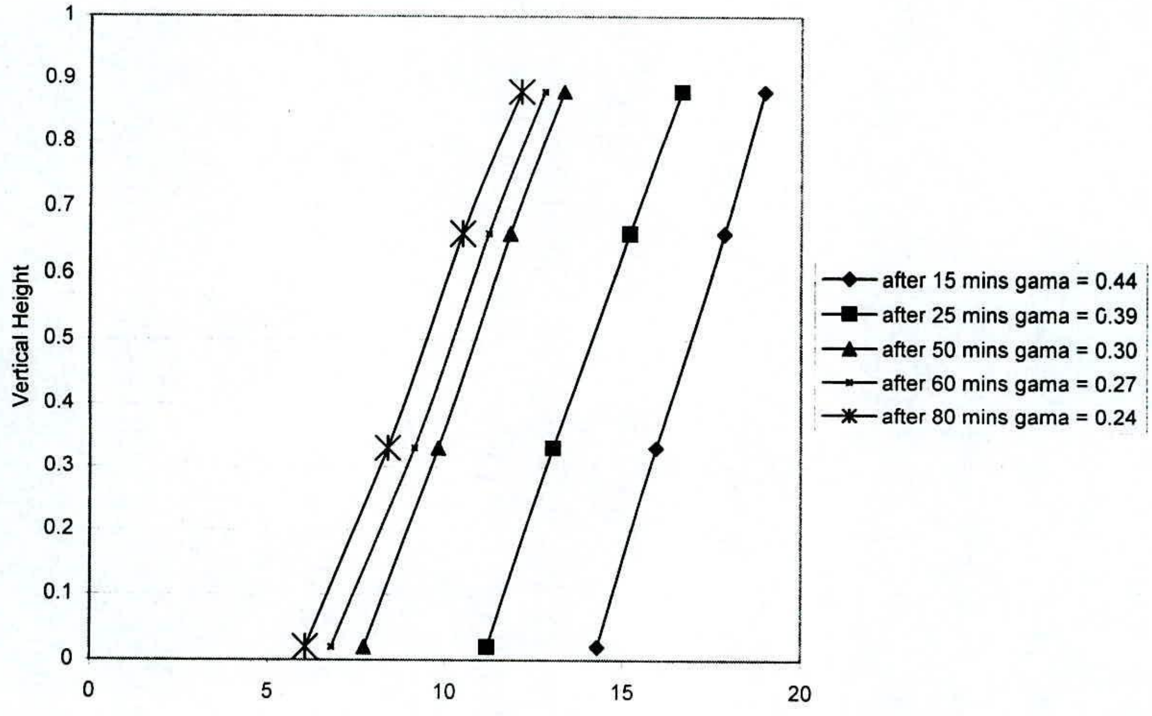

Fig. 6.18: Effect of the enclosure stratfication on heat transfer from air to the cold vertica wall
(x=0.03 m)

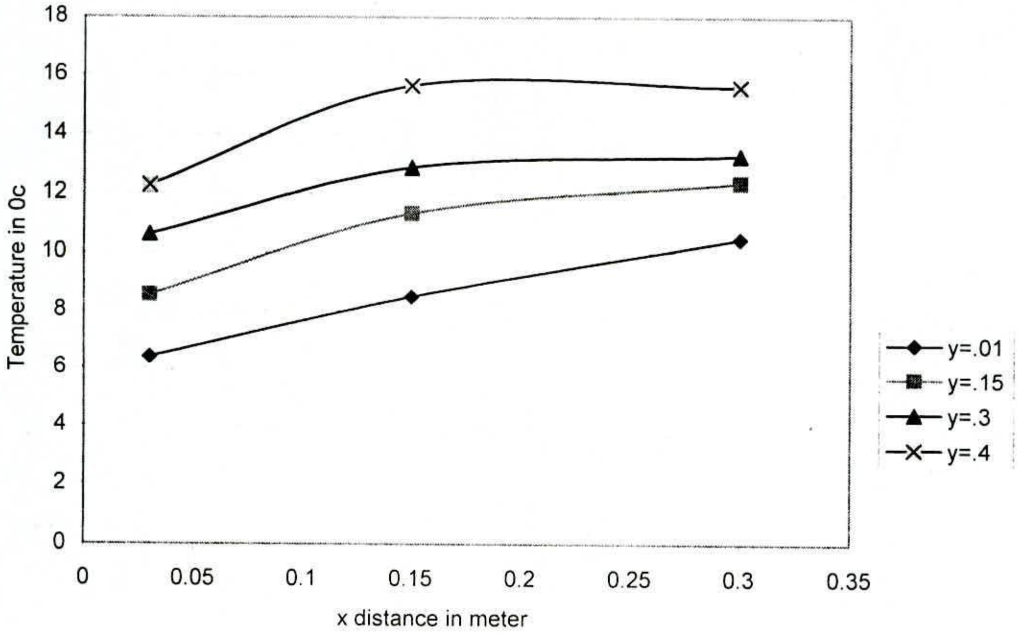

Fig:6.19 Temperature distribution of air in the enclosure at steady state condition

APPENDIX-A

Table-1 Temperature T ° C at different height from the base and at different distance from the cold plate after 15 minutes

Dist.from cold plate meter, x	Height from the base of the enclosure y in meter / Temperature				
	0.02/T °C	0.15/T °C	0.3/T °C	0.4/T °C	
0	11.11	11.11	11.11	11.11	
0.03	14.29	15.94	17.85	18.98	
0.15	16.34	18.61	19.78	21.19	
0.3	17.89	19.41	20.1	21.19	

Table-2 Temperature T ° C at different height from the base and at different distance from the cold plate after 25 minutes

Dist.from cold plate meter, x	Height from the base of the enclosure y in meter / Temperature				
	0.02/T °C	0.15/T °C	0.3/T °C	0.4/T °C	
0	7.5	7.5	7.5	7.5	
0.03	11.2	13.04	15.19	16.65	
0.15	13.36	15.9	17.31	19.37	
0.3	14.99	16.84	17.68	19.34	

Table-3 Temperature T ° C at different height from the base
and at different distance from the cold plate after 50 minutes

Dist.from cold plate meter, x	Height from the base of the enclosure y in meter / Temperature				
	0.02/T °C	0.15/T °C	0.3/T °C	0.4/T °C	
0.00	2.57	2.57	2.57	2.57	
0.03	7.73	9.81	11.83	13.44	
0.15	9.78	12.54	14.04	16.58	
0.30	11.51	13.61	14.41	16.58	

Table-4 Temperature T ° C at different height from the base
and at different distance from the cold plate after 60 minutes

Dist.from cold plate meter, x	Height from the base of the enclosure y in meter / Temperature				
	0.02/T °C	0.15/T °C	0.3/T °C	0.4/T °C	
0	-1.06	-1.06	-1.06	-1.06	
0.03	6.8	9.14	11.22	12.34	
0.15	8.96	11.88	13.4	16.05	
0.3	10.76	12.95	13.83	16.04	

Table-5 Temperature T ° C at different height from the base and at different distance from the cold plate after 80 minutes

Dist.from	Height from the base of the enclosure y in meter / Temperature				
cold plate	0.02/T °C	0.15/T °C	0.3/T °C	0.4/T °C	
meter, x					
0	-2.471195	-2.471195	-2.471195	-2.471195	
0.03	6.067409	8.392873	10.49329	12.13401	
0.15	8.23096	11.13024	12.71549	15.43087	
0.3	9.993936	12.19525	13.14354	15.43848	

Table-6 Critical angle for inclined rectangular cavities

(H/L)	1	3	6	12	>12
t*	25	53	60	67	70

APPENDIX-B

02-24-2003 #### 14 CHAN 0 MINS

CHANNEL	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Time	adj b	12 cm	24 cm	36 cm	mid b	12 cm	24 cm	36 cm	door b	12 cm	24 cm	36 cm	room	plate
HH:MM:SS	deg c	deg c	deg	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c
07:47:42	23.52	23.50	23.50	23.51	23.55	23.57	23.60	23.52	23.55	23.55	23.57	23.54	22.37	21.38
07:52:42	20.37	20.37	21.65	22.19	21.50	22.43	22.90	23.13	22.61	22.73	22.92	23.09	22.35	15.72
07:57:42	16.80	17.92	19.68	20.53	18.65	20.50	21.32	22.23	19.73	21.08	21.54	22.21	22.92	13.11
08:02:42	14.29	15.94	17.85	18.98	16.34	18.61	19.78	21.19	17.81	19.41	20.10	21.19	23.15	11.11
08:07:42	12.44	14.32	16.40	17.70	14.58	17.18	18.46	20.22	16.43	18.06	18.82	20.22	23.21	4.24
08:12:42	11.20	13.04	15.19	16.65	13.36	15.90	17.31	19.37	14.99	16.84	17.68	19.34	23.35	7.51
08:17:42	10.21	12.11	14.18	15.70	12.17	14.87	16.38	18.54	13.74	15.96	16.75	18.55	23.47	5.83
08:22:42	9.42	11.31	13.41	14.97	11.51	14.13	15.61	17.97	13.05	15.12	16.00	17.96	23.52	6.59
08:27:42	8.48	10.65	12.78	14.37	10.64	13.42	14.98	17.36	12.42	14.51	15.38	17.37	23.64	-0.21
08:32:42	8.06	10.13	12.18	13.78	10.11	12.88	14.41	16.94	11.79	13.88	14.80	16.93	23.84	5.34
08:37:42	7.73	9.81	11.83	13.44	9.78	12.54	14.04	16.58	11.51	13.61	14.41	16.58	23.81	2.57
08:42:42	7.32	9.44	11.50	13.11	9.43	12.18	13.73	16.33	10.95	13.18	14.11	16.30	23.98	1.67
08:47:42	6.80	9.14	11.22	12.79	8.96	11.88	13.40	16.05	10.76	12.95	13.83	16.04	23.88	-1.06
08:52:42	6.58	8.80	10.94	12.60	8.71	11.53	13.11	15.83	10.43	12.66	13.55	15.80	23.79	2.72
08:57:42	6.39	8.69	10.76	12.40	8.59	11.43	13.00	15.66	10.36	12.51	13.42	15.67	23.85	2.81
09:02:42	6.29	8.52	10.64	12.28	8.37	11.24	12.80	15.57	10.24	12.38	13.29	15.56	23.86	-2.21
09:07:42	6.07	8.39	10.49	12.13	8.23	11.13	12.72	15.43	9.99	12.20	13.14	15.44	24.10	-2.47
09:12:42	6.20	8.45	10.46	12.04	8.31	11.12	12.57	15.37	10.00	12.15	13.06	15.39	24.10	-0.11
09:17:42	6.20	8.50	10.50	12.12	8.38	11.15	12.69	15.41	10.19	12.23	13.10	15.40	24.25	1.98
09:22:42	6.27	8.49	10.50	12.12	8.30	11.17	12.70	15.41	10.07	12.23	13.16	15.41	24.32	0.07
09:27:42	6.03	8.45	10.57	12.16	8.24	11.19	12.71	15.44	10.14	12.29	13.18	15.45	24.41	0.64
09:32:42	6.29	8.57	10.59	12.25	8.49	11.35	12.84	15.58	10.39	12.36	13.25	15.57	24.56	1.33
09:37:42	6.21	8.51	10.58	12.24	8.40	11.24	12.79	15.54	10.22	12.37	13.20	15.52	24.50	-0.28
09:42:42	6.12	8.46	10.55	12.19	8.33	11.24	12.78	15.56	10.19	12.30	13.20	15.53	24.44	-0.12
09:47:42	6.19	8.50	10.57	12.21	8.36	11.28	12.79	15.54	10.22	12.32	13.18	15.52	24.39	-0.29
09:52:42	6.18	8.50	10.53	12.19	8.30	11.24	12.76	15.52	10.03	12.31	13.22	15.51	24.51	1.40
09:57:42	6.24	8.48	10.55	12.19	8.38	11.24	12.77	15.54	10.08	12.32	13.20	15.51	24.61	-0.30
10:02:42	6.06	8.41	10.51	12.21	8.30	11.21	12.74	15.53	10.13	12.32	13.20	15.50	24.69	1.20
10:07:42	6.22	8.50	10.62	12.22	8.36	11.24	12.76	15.58	10.29	12.34	13.21	15.57	24.75	1.52
10:12:42	6.29	8.56	10.58	12.25	8.53	11.33	12.85	15.61	10.21	12.36	13.26	15.63	24.67	0.15
10:17:42	6.32	8.52	10.61	12.26	8.53	11.30	12.82	15.62	10.39	12.35	13.26	15.59	24.72	-0.24
10:22:42	6.21	8.56	10.64	12.25	8.33	11.27	12.82	15.62	10.01	12.35	13.22	15.63	24.77	2.08
10:27:42	6.31	8.57	10.62	12.28	8.47	11.31	12.84	15.61	10.29	12.38	13.26	15.59	24.81	0.38
10:32:42	6.26	8.60	10.65	12.27	8.44	11.32	12.87	15.65	10.30	12.36	13.31	15.66	24.78	1.17
10:37:42	6.37	8.54	10.62	12.28	8.47	11.33	12.83	15.63	10.47	12.37	13.28	15.60	24.77	2.02
10:42:42	6.38	8.59	10.64	12.29	8.51	11.34	12.84	15.70	10.41	12.35	13.33	15.64	24.77	1.70
10:47:42	6.28	8.53	10.62	12.29	8.47	11.30	12.85	15.65	10.31	12.36	13.30	15.67	24.86	2.00
10:52:42	6.37	8.68	10.74	12.37	8.55	11.39	12.96	15.71	10.37	12.50	13.34	15.71	24.97	1.85
10:57:42	6.48	8.68	10.75	12.34	8.61	11.41	12.96	15.73	10.38	12.50	13.39	15.75	25.02	0.89
11:02:42	6.45	8.67	10.79	12.40	8.62	11.42	12.98	15.75	10.09	12.51	13.40	15.71	24.95	0.91
11:07:42	6.57	8.73	10.76	12.39	8.75	11.50	13.00	15.80	10.62	12.55	13.44	15.80	25.00	0.36
11:12:42	6.43	8.67	10.76	12.37	8.54	11.47	12.96	15.77	10.27	12.53	13.42	15.76	25.01	-0.01
11:17:42	6.52	8.79	10.88	12.48	8.76	11.60	13.11	15.89	10.48	12.64	13.54	15.86	25.06	0.34
11:22:42	6.45	8.79	10.87	12.49	8.65	11.53	13.07	15.86	10.52	12.58	13.47	15.85	25.00	1.34
11:27:42	6.62	8.85	10.91	12.55	8.84	11.65	13.13	15.94	10.61	12.70	13.57	15.91	25.25	0.38
11:32:42	6.63	8.83	10.92	12.53	8.82	11.61	13.12	15.90	10.42	12.63	13.54	15.90	25.05	2.12

11:37:42	6.64	8.89	10.97	12.57	8.84	11.66	13.20	15.98	10.62	12.77	13.57	15.97	25.14	1.33
11:42:42	6.59	8.81	10.93	12.57	8.78	11.62	13.16	15.95	10.59	12.69	13.58	15.95	25.17	1.71
11:47:42	6.64	8.90	10.94	12.60	8.79	11.62	13.15	15.98	10.57	12.64	13.61	15.96	25.42	2.01
11:52:42	6.72	8.93	11.01	12.67	8.85	11.70	13.22	16.03	10.60	12.78	13.70	16.05	25.26	2.35
11:57:42	6.72	8.95	11.04	12.72	8.80	11.74	13.28	16.11	10.52	12.78	13.74	16.07	25.39	2.12
12:02:42	6.85	9.04	11.11	12.77	9.02	11.81	13.31	16.11	10.82	12.86	13.75	16.15	25.36	2.48
12:07:42	6.76	9.08	11.12	12.77	8.90	11.83	13.34	16.10	10.49	12.84	13.77	16.14	25.32	1.54
12:12:42	6.86	9.08	11.16	12.78	9.02	11.83	13.37	16.14	10.76	12.88	13.82	16.16	25.43	0.48
12:17:42	6.84	8.99	11.14	12.79	9.00	11.83	13.35	16.19	10.89	12.89	13.85	16.18	25.39	1.24
12:22:42	6.77	9.09	11.20	12.87	8.98	11.89	13.40	16.20	10.76	12.93	13.84	16.18	25.43	2.05
12:27:42	6.90	9.10	11.24	12.87	9.06	11.92	13.44	16.25	10.74	12.96	13.87	16.25	25.44	0.38
12:32:42	6.89	9.06	11.21	12.81	9.12	11.88	13.40	16.20	10.77	12.93	13.84	16.20	25.43	0.37
12:37:42	6.91	9.08	11.21	12.88	9.07	11.89	13.43	16.22	10.79	12.97	13.86	16.25	25.62	1.63
12:42:42	6.74	9.08	11.25	12.90	8.95	11.92	13.50	16.32	10.87	13.02	13.90	16.29	25.51	1.90
12:47:42	6.93	9.14	11.30	12.93	9.17	11.97	13.48	16.33	10.93	13.06	13.94	16.29	25.53	2.45
12:52:42	6.94	9.19	11.30	12.92	9.12	12.01	13.54	16.41	10.90	13.02	13.97	16.35	25.53	1.51
12:57:42	6.91	9.17	11.30	12.96	9.08	11.99	13.53	16.37	10.71	13.10	14.01	16.36	25.54	1.53
13:02:42	7.05	9.19	11.30	12.97	9.26	12.01	13.57	16.37	11.20	13.09	13.96	16.37	25.68	0.45
13:07:42	7.03	9.22	11.34	13.01	9.22	12.03	13.61	16.44	11.08	13.12	14.04	16.41	25.57	1.37
13:12:42	7.15	9.26	11.41	13.02	9.23	12.14	13.67	16.51	10.96	13.19	14.09	16.48	25.72	2.63
13:17:42	7.01	9.21	11.37	13.07	9.24	12.07	13.66	16.42	10.97	13.13	14.09	16.45	25.75	1.39
13:22:42	7.11	9.32	11.42	13.08	9.22	12.11	13.69	16.52	10.88	13.25	14.13	16.54	25.73	0.64
13:27:42	7.10	9.29	11.44	13.10	9.23	12.10	13.67	16.54	10.73	13.17	14.13	16.54	25.85	2.67
13:32:42	7.16	9.39	11.47	13.09	9.32	12.19	13.72	16.60	11.21	13.33	14.14	16.58	25.77	0.78
13:37:42	7.09	9.39	11.49	13.19	9.34	12.26	13.76	16.60	11.17	13.29	14.21	16.64	25.76	0.82
13:42:42	7.23	9.40	11.50	13.16	9.43	12.20	13.75	16.57	11.28	13.31	14.20	16.63	25.67	2.51
13:47:42	7.21	9.47	11.54	13.19	9.42	12.22	13.81	16.64	11.36	13.30	14.25	16.67	25.86	1.22
13:52:42	7.26	9.38	11.54	13.20	9.44	12.28	13.79	16.67	11.16	13.31	14.24	16.63	25.78	2.58
13:57:42	7.23	9.46	11.58	13.26	9.37	12.31	13.82	16.67	10.97	13.36	14.25	16.64	25.95	1.67
14:02:42	7.31	9.55	11.65	13.29	9.43	12.35	13.91	16.71	11.22	13.37	14.32	16.71	25.87	1.19
14:07:42	7.18	9.51	11.67	13.28	9.34	12.39	13.91	16.72	11.34	13.43	14.36	16.75	25.84	2.83
14:12:42	7.30	9.58	11.64	13.31	9.40	12.35	13.91	16.72	11.24	13.46	14.32	16.72	25.98	2.74
14:17:42	7.39	9.51	11.69	13.30	9.56	12.39	13.95	16.72	11.17	13.46	14.37	16.72	25.79	1.94
14:22:42	7.53	9.65	11.73	13.35	9.63	12.45	13.98	16.78	11.25	13.52	14.38	16.77	25.99	2.10
14:27:42	7.44	9.57	11.69	13.35	9.62	12.38	13.96	16.75	11.39	13.50	14.41	16.74	25.71	0.76
14:32:42	7.46	9.71	11.71	13.39	9.66	12.45	13.98	16.82	11.57	13.58	14.37	16.81	25.77	2.04
14:37:42	7.32	9.63	11.72	13.39	9.50	12.41	14.01	16.88	11.23	13.57	14.42	16.87	25.87	2.82
14:42:42	7.55	9.67	11.76	13.47	9.66	12.47	14.02	16.89	11.28	13.48	14.45	16.89	25.96	3.08

02-26-2003		0.29				14.00	CHANN	0.00	MINS					
CHANNEL	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00
Time	2mm	150mm	300mm	400mm	2mm	150mm	300mm	400mm	2mm	150mm	300mm	400mm	room	plate
HH:MM:SS	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c	deg c
07:02:25	25.30	25.31	25.26	25.30	25.25	25.29	25.32	25.24	25.25	25.24	25.26	25.19	23.06	28.06
07:07:25	22.13	22.14	23.28	23.79	23.15	24.10	24.56	24.71	24.27	24.38	24.57	24.71	23.52	16.27
07:12:25	18.42	19.46	21.15	21.94	20.27	21.99	22.85	23.68	21.80	22.62	22.98	23.67	23.54	15.15
07:17:25	15.79	17.23	19.18	20.34	18.01	19.96	21.12	22.51	19.50	20.77	21.41	22.50	24.09	12.57
07:22:25	13.78	15.52	17.60	18.97	16.03	18.35	19.67	21.48	17.70	19.22	20.04	21.45	23.92	10.23
07:27:25	12.28	14.25	16.30	17.73	14.54	17.09	18.44	20.51	16.06	18.05	18.86	20.51	24.08	9.43
07:32:25	11.21	13.11	15.24	16.77	13.47	15.93	17.45	19.62	15.06	16.97	17.85	19.61	24.08	4.79
07:37:25	10.30	12.26	14.34	15.91	12.62	15.12	16.58	18.94	14.48	16.13	16.98	18.92	24.12	7.21
07:42:25	9.53	11.58	13.68	15.25	11.78	14.34	15.91	18.33	13.49	15.38	16.30	18.30	24.06	3.07
07:47:25	8.81	11.00	13.11	14.71	11.05	13.80	15.31	17.83	12.80	14.82	15.76	17.81	24.27	0.80
07:52:25	8.25	10.49	12.65	14.23	10.62	13.26	14.84	17.44	12.63	14.35	15.29	17.39	24.32	0.26
07:57:25	8.02	10.20	12.31	13.92	10.31	12.96	14.54	17.14	12.03	13.98	14.97	17.16	24.60	-0.62
08:02:25	7.74	9.90	12.01	13.63	9.99	12.68	14.21	16.92	11.76	13.80	14.66	16.90	24.71	5.01
08:07:25	7.51	9.80	11.81	13.47	9.84	12.60	14.07	16.75	11.33	13.60	14.51	16.75	24.83	4.91
08:12:25	7.45	9.64	11.66	13.30	9.70	12.37	13.86	16.63	11.32	13.40	14.37	16.65	24.99	4.29
08:17:25	7.32	9.58	11.62	13.27	9.50	12.27	13.83	16.62	11.19	13.41	14.29	16.58	25.00	-0.96
08:22:25	7.17	9.51	11.58	13.18	9.40	12.25	13.78	16.53	10.76	13.27	14.21	16.52	25.02	3.96
08:27:25	7.14	9.52	11.51	13.14	9.41	12.28	13.77	16.51	11.40	13.25	14.17	16.49	24.85	5.01
08:32:25	7.16	9.43	11.45	13.07	9.47	12.17	13.67	16.43	11.24	13.14	14.08	16.40	25.13	5.01
08:37:25	6.95	9.37	11.39	13.04	9.27	12.14	13.62	16.41	11.12	13.18	14.07	16.41	25.29	4.11
08:42:25	7.07	9.29	11.41	13.07	9.32	12.09	13.63	16.43	10.88	13.12	14.07	16.40	24.98	3.15
08:47:25	6.88	9.21	11.36	13.07	9.29	12.14	13.63	16.37	11.16	13.18	14.06	16.38	25.33	-1.80
08:52:25	6.76	9.19	11.36	13.01	9.21	12.02	13.56	16.36	10.98	13.07	14.01	16.33	25.29	-1.62
08:57:25	6.90	9.28	11.35	12.98	9.28	12.10	13.56	16.43	10.93	13.12	14.05	16.41	25.54	4.52
09:02:25	6.96	9.32	11.35	13.01	9.36	12.03	13.61	16.46	11.21	13.04	14.09	16.43	25.59	4.38
09:07:25	7.02	9.35	11.47	13.07	9.48	12.18	13.71	16.44	11.32	13.23	14.17	16.46	25.68	-1.15
09:12:25	7.08	9.36	11.51	13.15	9.39	12.20	13.72	16.54	11.03	13.26	14.16	16.54	25.46	-1.08
09:17:25	6.97	9.47	11.57	13.15	9.41	12.27	13.80	16.56	11.29	13.37	14.23	16.53	25.64	4.74
09:22:25	7.18	9.49	11.57	13.22	9.46	12.27	13.81	16.62	11.22	13.39	14.24	16.55	25.78	-1.11
09:27:25	7.11	9.48	11.64	13.25	9.46	12.35	13.86	16.63	11.35	13.37	14.31	16.66	25.89	-1.15
09:32:25	7.33	9.61	11.71	13.38	9.71	12.44	13.95	16.76	11.52	13.47	14.44	16.77	25.98	4.54
09:37:25	7.21	9.65	11.76	13.37	9.57	12.47	13.96	16.78	11.38	13.52	14.40	16.77	26.04	2.99
09:42:25	7.26	9.67	11.75	13.37	9.69	12.53	14.02	16.82	11.48	13.56	14.44	16.81	26.12	-0.45
09:47:25	7.47	9.74	11.85	13.48	9.77	12.51	14.09	16.89	11.51	13.59	14.56	16.86	26.18	0.11
09:52:25	7.49	9.83	11.96	13.56	9.83	12.60	14.18	16.97	11.49	13.67	14.61	16.96	26.29	-0.29
09:57:25	7.50	9.81	11.92	13.60	9.86	12.61	14.18	17.00	11.68	13.66	14.65	16.96	26.33	1.97
10:02:25	7.64	9.88	11.97	13.63	9.92	12.69	14.24	17.00	11.42	13.81	14.69	17.00	26.31	-0.70
10:07:25	7.56	9.97	12.07	13.70	9.81	12.77	14.30	17.08	11.47	13.87	14.74	17.08	26.20	4.31
10:12:25	7.65	10.07	12.15	13.75	10.04	12.90	14.38	17.17	11.81	13.89	14.80	17.15	26.42	2.64
10:17:25	7.73	9.99	12.06	13.76	10.02	12.78	14.32	17.13	11.71	13.81	14.79	17.10	26.28	2.09
10:22:25	7.61	10.01	12.11	13.80	9.89	12.78	14.34	17.18	11.65	13.87	14.84	17.16	26.36	4.86
10:27:25	7.83	10.09	12.14	13.78	10.12	12.91	14.42	17.18	11.96	13.94	14.83	17.18	26.55	2.48
10:32:25	7.76	10.06	12.21	13.84	10.10	12.90	14.45	17.22	11.76	13.97	14.91	17.24	26.43	1.49
10:37:25	7.81	10.18	12.27	13.87	10.17	13.05	14.52	17.29	11.84	14.02	14.99	17.27	26.46	2.57
10:42:25	7.77	10.11	12.24	13.93	10.09	12.94	14.52	17.31	11.69	14.03	14.99	17.30	26.46	3.56
10:47:25	7.88	10.29	12.34	13.96	10.28	13.01	14.57	17.38	12.06	14.08	15.05	17.36	26.59	5.62

10:52:25	7.82	10.24	12.34	14.00	10.16	13.08	14.58	17.38	12.08	14.10	15.06	17.37	26.62	3.68
10:57:25	7.92	10.29	12.39	14.03	10.28	13.13	14.64	17.44	11.93	14.21	15.07	17.44	26.68	2.75
11:02:25	8.10	10.42	12.46	14.08	10.41	13.14	14.73	17.48	12.15	14.24	15.12	17.47	26.63	5.77
11:07:25	8.06	10.37	12.50	14.08	10.38	13.22	14.71	17.49	12.15	14.26	15.14	17.49	26.75	2.82
11:12:25	8.07	10.45	12.53	14.11	10.40	13.21	14.73	17.53	12.26	14.31	15.20	17.53	26.82	3.38
11:17:25	8.09	10.50	12.57	14.22	10.46	13.25	14.78	17.58	12.26	14.36	15.27	17.54	26.64	3.76
11:22:25	8.33	10.61	12.63	14.26	10.66	13.36	14.90	17.63	12.37	14.42	15.32	17.63	26.89	4.36
11:27:25	8.37	10.65	12.70	14.35	10.67	13.45	14.94	17.71	12.37	14.45	15.39	17.70	26.88	1.98
11:32:25	8.32	10.60	12.72	14.33	10.63	13.40	14.93	17.70	12.36	14.46	15.39	17.70	26.66	3.83
11:37:25	8.39	10.60	12.74	14.31	10.66	13.43	14.94	17.72	12.32	14.51	15.41	17.71	26.89	2.99
11:42:25	8.48	10.75	12.83	14.39	10.81	13.53	15.02	17.77	12.66	14.59	15.45	17.76	26.80	2.08
11:47:25	8.35	10.78	12.78	14.39	10.64	13.53	14.99	17.82	12.42	14.56	15.45	17.79	26.92	2.61
11:52:25	8.59	10.74	12.85	14.43	10.85	13.59	15.06	17.81	12.49	14.65	15.48	17.81	27.02	2.17
11:57:25	8.57	10.78	12.86	14.45	10.84	13.57	15.07	17.85	12.50	14.63	15.54	17.85	26.96	4.17
12:02:25	8.50	10.79	12.92	14.53	10.76	13.64	15.15	17.90	12.69	14.70	15.60	17.90	27.03	4.21
12:07:25	8.55	10.87	12.91	14.54	10.86	13.68	15.16	17.94	12.79	14.73	15.63	17.94	26.92	4.60
12:12:25	8.68	10.97	13.00	14.61	10.97	13.68	15.21	17.99	12.70	14.79	15.70	17.99	27.18	3.94
12:17:25	8.65	10.93	12.97	14.61	10.97	13.70	15.21	18.05	12.64	14.80	15.66	18.00	27.36	2.27
12:22:25	8.57	10.95	13.03	14.67	10.90	13.71	15.27	18.05	12.82	14.82	15.72	18.00	26.89	3.84
12:27:25	8.48	10.95	13.07	14.68	10.86	13.80	15.32	18.06	12.55	14.85	15.74	18.05	27.09	2.28
12:32:25	8.63	10.97	13.05	14.67	10.96	13.85	15.31	18.07	12.86	14.82	15.78	18.05	27.12	2.43
12:37:25	8.64	10.98	13.08	14.68	10.92	13.79	15.33	18.13	12.41	14.83	15.81	18.11	27.07	3.62
12:42:25	8.66	10.95	13.13	14.75	11.06	13.79	15.37	18.14	12.64	14.92	15.82	18.14	27.17	4.27
12:47:25	8.54	10.96	13.06	14.70	10.94	13.79	15.34	18.13	12.78	14.90	15.78	18.13	27.21	3.58
12:52:25	8.66	11.03	13.10	14.74	11.03	13.81	15.37	18.17	13.03	14.95	15.83	18.17	27.45	2.81
12:57:25	8.79	11.05	13.18	14.80	11.10	13.82	15.42	18.21	12.81	14.98	15.88	18.19	27.11	4.08
13:02:25	8.75	11.09	13.18	14.83	11.10	13.91	15.43	18.27	12.76	15.02	15.93	18.26	27.74	2.82
13:07:25	8.71	11.06	13.13	14.83	11.07	13.85	15.39	18.28	12.75	14.95	15.86	18.26	27.41	3.99
13:12:25	8.85	11.08	13.22	14.89	11.20	13.94	15.49	18.34	13.01	15.04	15.95	18.32	27.40	2.16
13:17:25	8.97	11.14	13.25	14.93	11.34	14.01	15.57	18.36	13.30	15.06	16.01	18.36	27.35	2.11
13:22:25	8.74	11.13	13.27	14.88	11.06	13.99	15.56	18.39	12.79	15.09	16.03	18.39	27.30	3.03
13:27:25	8.73	11.06	13.19	14.89	11.10	13.96	15.52	18.38	12.83	15.02	16.04	18.36	27.67	4.64
13:32:25	8.79	11.08	13.25	14.89	11.21	13.99	15.56	18.35	12.80	15.06	16.02	18.40	27.28	2.32
13:37:25	8.82	11.20	13.29	14.95	11.22	14.00	15.62	18.45	13.05	15.06	16.04	18.46	27.49	4.67
13:42:25	8.74	11.10	13.27	14.97	11.13	14.04	15.60	18.44	13.08	15.11	16.07	18.40	27.69	3.09
13:47:25	9.00	11.31	13.38	15.02	11.28	14.12	15.69	18.48	13.12	15.24	16.10	18.50	27.85	3.16
13:52:25	8.85	11.28	13.40	15.07	11.31	14.09	15.67	18.52	13.14	15.21	16.13	18.51	27.40	3.17
13:57:25	8.82	11.21	13.37	15.09	11.18	14.10	15.67	18.53	13.00	15.22	16.20	18.53	27.32	4.17
14:02:25	8.88	11.28	13.45	15.06	11.24	14.20	15.77	18.52	13.08	15.31	16.20	18.56	27.51	2.48

```
Nonlinear Regression                                    (15 Mins)

 [Variables]
 x = col(1)
 y = col(2)
 [Parameters]
 y0 = min(y) "Auto {{previous: 11.1611}}
 a = max(y)-min(y) "Auto {{previous: 7.36488}}
 b = x50(x,y-min(y)) "Auto {{previous: 0.0453455}}
 [Equation]
 f=y0+a*x/(b+x)
 fit f to y
 [Options]
 tolerance=0.000100
 stepsize=100
 iterations=100
 [Constraints]

 R = 0.99263805        Rsqr = 0.98533029    Adj Rsqr = 0.95599088

 Standard Error of Estimate = 0.6146

                Coefficient    Std. Error        t                  P
 y0             11.1611        0.6125            18.2229            0.0349
 a              7.3649         1.0373            7.1000             0.0891
 b              0.0453         0.0246            1.8456             0.3161

 Analysis of Variance:
                DF             SS                MS                 F                  P
 Regression     2              25.3719           12.6860            33.5838            0.1211
 Residual       1              0.3777            0.3777
 Total          3              25.7497           8.5832

 PRESS = 60.2294

 Durbin-Watson Statistic = 3.0866

 Normality Test:        Passed     (P = 0.5987)

 Constant Variance Test:        Failed      (P = <0.0001)

 Power of performed test with alpha = 0.0500: 0.7997

 The power of the performed test (0.7997) is below the desired power of 0.8000
 You should interpret the negative findings cautiously.

 Regression Diagnostics:
 Row            Predicted      Residual          Std. Res.          Stud. Res.         Stud. Del. Res.
 1              11.1611        -0.0511           -0.0832            -1.0000            0.0000
 2              14.0936        0.1964            0.3196             0.9999             0.0000
 3              16.8164        -0.4764           -0.7751            -1.0000            (+inf)
 4              17.5589        0.3311            0.5386             1.0000             (+inf)

 Influence Diagnostics:
 Row            Cook'sDist     Leverage          DFFITS
 1              47.8496        0.9931            0.0000
 2              2.9289         0.8978            0.0000
 3              0.2215         0.3992            (+inf)
 4              0.8156         0.7099            (+inf)

 95% Confidence:
 Row            Predicted      Regr. 5%          Regr. 95%          Pop. 5%            Pop. 95%
 1              11.1611        3.3789            18.9434            0.1362             22.1860
 2              14.0936        6.6939            21.4932            3.3353             24.8518
 3              16.8164        11.8822           21.7506            7.5789             26.0539
 4              17.5589        10.9793           24.1386            7.3473             27.7706
```

```
Nonlinear Regression                    (15 Mins)

[Variables]
x = col(1)
y = col(3)
[Parameters]
y0 = min(y) "Auto {{previous: 11.1148}}
a = max(y)-min(y) "Auto {{previous: 8.91542}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0257932}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99975150        Rsqr = 0.99950306    Adj Rsqr = 0.99850917

Standard Error of Estimate = 0.1446

            Coefficient   Std. Error      t             P
y0          11.1148       0.1445          76.9140       0.0083
a           8.9154        0.2144          41.5805       0.0153
b           0.0258        0.0025          10.3749       0.0612

Analysis of Variance:
            DF            SS              MS            F             P
Regression  2             42.0488         21.0244       1005.6476     0.0223
Residual    1             0.0209          0.0209
Total       3             42.0697         14.0232

PRESS = 19.3334

Durbin-Watson Statistic = 2.9175

Normality Test:       Passed     (P = 0.5324)

Constant Variance Test:          Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9944

Regression Diagnostics:
Row         Predicted     Residual        Std. Res.     Stud. Res.    Stud. Del. Res.
1           11.1148       -0.0048         -0.0333       -0.9999       0.0000
2           15.9086       0.0314          0.2169        0.9999        0.0000
3           18.7221       -0.1121         -0.7755       -1.0000       0.0000
4           19.3244       0.0856          0.5920        1.0000        (+inf)

Influence Diagnostics:
Row         Cook'sDist    Leverage        DFFITS
1           299.3310      0.9989          0.0000
2           6.7512        0.9530          0.0000
3           0.2209        0.3986          0.0000
4           0.6179        0.6496          (+inf)

95% Confidence:
Row         Predicted     Regr. 5%        Regr. 95%     Pop. 5%       Pop. 95%
1           11.1148       9.2787          12.9510       8.5174        13.7123
2           15.9086       14.1152         17.7021       13.3412       18.4761
3           18.7221       17.5623         19.8820       16.5494       20.8948
4           19.3244       17.8437         20.8051       16.9648       21.6840
```

```
Nonlinear Regression                    (15 Mins)

[Variables]
x = col(1)
y = col(4)
[Parameters]
y0 = min(y) "Auto {{previous: 11.9099}}
a = max(y)-min(y) "Auto {{previous: 8.55589}}
b = x50(x,y-min(y)) "Auto {{previous: 0.013202}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99999921      Rsqr = 0.99999843    Adj Rsqr = 0.99999529

Standard Error of Estimate = 0.0082

              Coefficient    Std. Error        t                P
y0            11.9099        0.0082            1444.5532        0.0004
a             8.5559         0.0115            744.4935         0.0009
b             0.0132         0.0001            154.4846         0.0041

Analysis of Variance:
              DF             SS                MS               F                 P
Regression    2              43.2965           21.6483          318441.1082       0.0013
Residual      1              0.0001            0.0001
Total         3              43.2966           14.4322

PRESS = 0.6811

Durbin-Watson Statistic = 2.7970

Normality Test:       Passed      (P = 0.4628)

Constant Variance Test:           Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:
Row           Predicted      Residual          Std. Res.        Stud. Res.        Stud. Del. Res.
1             11.9099        0.0001            0.0100           1.0000            0.0000
2             17.8512        -0.0012           -0.1489          -1.0000           (+inf)
3             19.7737        0.0063            0.7652           1.0000            (+inf)
4             20.1052        -0.0052           -0.6263          -1.0000           0.0000

Influence Diagnostics:
Row           Cook'sDist     Leverage          DFFITS
1             3322.7035      0.9999            0.0000
2             14.6918        0.9778            (+inf)
3             0.2360         0.4145            (+inf)
4             0.5166         0.6078            0.0000

95% Confidence:
Row           Predicted      Regr. 5%          Regr. 95%        Pop. 5%           Pop. 95%
1             11.9099        11.8052           12.0147          11.7618           12.0581
2             17.8512        17.7476           17.9548          17.7039           17.9986
3             19.7737        19.7062           19.8411          19.6491           19.8983
4             20.1052        20.0235           20.1868          19.9723           20.2380
```

```
Nonlinear Regression                          (15 Mins)

[Variables]
x = col(1)
y = col(5)
[Parameters]
y0 = min(y) "Auto {{previous: 11.1086}}
a = max(y)-min(y) "Auto {{previous: 10.5746}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0101452}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99960800        Rsqr = 0.99921616    Adj Rsqr = 0.99764847

Standard Error of Estimate = 0.2321

            Coefficient     Std. Error      t               P
y0          11.1086         0.2321          47.8609         0.0133
a           10.5746         0.3191          33.1434         0.0192
b           0.0101          0.0017          6.0714          0.1039

Analysis of Variance:
            DF              SS              MS              F               P
Regression  2               68.6756         34.3378         637.3838        0.0280
Residual    1               0.0539          0.0539
Total       3               68.7295         22.9098

PRESS = 1443.7697

Durbin-Watson Statistic = 2.7675

Normality Test:        Passed     (P = 0.4508)

Constant Variance Test:          Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9895

Regression Diagnostics:
Row         Predicted       Residual        Std. Res.       Stud. Res.      Stud. Del. Res.
1           11.1086         0.0014          0.0061          0.9993          0.0000
2           19.0108         -0.0308         -0.1329         -1.0000         (+inf)
3           21.0133         0.1767          0.7613          1.0000          (+inf)
4           21.3373         -0.1473         -0.6346         -1.0000         0.0000

Influence Diagnostics:
Row         Cook'sDist      Leverage        DFFITS
1           8912.5534       1.0000          0.0000
2           18.5401         0.9823          (+inf)
3           0.2417          0.4204          (+inf)
4           0.4945          0.5973          0.0000

95% Confidence:
Row         Predicted       Regr. 5%        Regr. 95%       Pop. 5%         Pop. 95%
1           11.1086         8.1595          14.0577         6.9378          15.2793
2           19.0108         16.0878         21.9339         14.8585         23.1632
3           21.0133         19.1012         22.9254         17.4985         24.5281
4           21.3373         19.0579         23.6166         17.6099         25.0646
```

```
Nonlinear Regression                          (25 Mins)

[Variables]
x = col(1)
y = col(5)
[Parameters]
y0 = min(y) "Auto {{previous: 7.49793}}
a = max(y)-min(y) "Auto {{previous: 12.4655}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0106754}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99949946        Rsqr = 0.99899917    Adj Rsqr = 0.99699751

Standard Error of Estimate = 0.3081

              Coefficient     Std. Error        t               P
y0            7.4979          0.3081            24.3349         0.0261
a             12.4655         0.4246            29.3604         0.0217
b             0.0107          0.0019            5.5214          0.1141

Analysis of Variance:
              DF              SS                MS              F               P
Regression    2               94.7652           47.3826         499.0853        0.0316
Residual      1               0.0949            0.0949
Total         3               94.8601           31.6200

PRESS = 2101.9952

Durbin-Watson Statistic = 2.7726

Normality Test:        Passed     (P = 0.4527)

Constant Variance Test:          Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9856

Regression Diagnostics:
Row           Predicted       Residual          Std. Res.       Stud. Res.      Stud. Del. Res.
1             7.4979          0.0021            0.0067          1.0000          0.0000
2             16.6918         -0.0418           -0.1357         -1.0000         0.0000
3             19.1352         0.2348            0.7620          1.0000          0.0000
4             19.5351         -0.1951           -0.6331         -1.0000         (+inf)

Influence Diagnostics:
Row           Cook'sDist      Leverage          DFFITS
1             7360.3221       1.0000            0.0000
2             17.7780         0.9816            0.0000
3             0.2407          0.4193            0.0000
4             0.4983          0.5992            (+inf)

95% Confidence:
Row           Predicted       Regr. 5%          Regr. 95%       Pop. 5%         Pop. 95%
1             7.4979          3.5830            11.4129         1.9613          13.0346
2             16.6918         12.8129           20.5707         11.1806         22.2030
3             19.1352         16.6001           21.6703         14.4710         23.7993
4             19.5351         16.5046           22.5656         14.5842         24.4860
```

```
Nonlinear Regression                    (25 Mins)

[Variables]
x = col(1)
y = col(4)
[Parameters]
y0 = min(y) "Auto {{previous: 7.50009}}
a = max(y)-min(y) "Auto {{previous: 10.5507}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0111699}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99999883       Rsqr = 0.99999766    Adj Rsqr = 0.99999298

Standard Error of Estimate = 0.0126

            Coefficient    Std. Error       t               P
y0          7.5001         0.0126           597.1227        0.0011
a           10.5507        0.0173           608.2348        0.0010
b           0.0112         0.0001           116.9870        0.0054

Analysis of Variance:
            DF             SS               MS              F                P
Regression  2              67.4588          33.7294         213786.1478      0.0015
Residual    1              0.0002           0.0002
Total       3              67.4590          22.4863

PRESS = 2.9475

Durbin-Watson Statistic = 2.7774

Normality Test:        Passed     (P = 0.4545)

Constant Variance Test:           Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:
Row         Predicted      Residual         Std. Res.       Stud. Res.       Stud. Del. Res.
1           7.5001         -0.0001          -0.0073         -1.0000          (+inf)
2           15.1883        0.0017           0.1382          1.0000           0.0000
3           17.3196        -0.0096          -0.7627         -1.0000          0.0000
4           17.6721        0.0079           0.6318          1.0000           (+inf)

Influence Diagnostics:
Row         Cook'sDist     Leverage         DFFITS
1           6208.0909      0.9999           (+inf)
2           17.1083        0.9809           0.0000
3           0.2397         0.4183           0.0000
4           0.5018         0.6009           (+inf)

95% Confidence:
Row         Predicted      Regr. 5%         Regr. 95%       Pop. 5%          Pop. 95%
1           7.5001         7.3405           7.6597          7.2744           7.7258
2           15.1883        15.0302          15.3463         14.9636          15.4129
3           17.3196        17.2164          17.4228         17.1295          17.5097
4           17.6721        17.5484          17.7958         17.4701          17.8740
```

```
Nonlinear Regression                        (25 Mins)

[Variables]
x = col(1)
y = col(3)
[Parameters]
y0 = min(y) "Auto {{previous: 7.50653}}
a = max(y)-min(y) "Auto {{previous: 9.95378}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0244091}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99956026        Rsqr = 0.99912071    Adj Rsqr = 0.99736213

Standard Error of Estimate = 0.2159

             Coefficient    Std. Error      t              P
y0           7.5065         0.2158          34.7892        0.0183
a            9.9538         0.3177          31.3297        0.0203
b            0.0244         0.0031          7.7589         0.0816

Analysis of Variance:
             DF             SS              MS             F              P
Regression   2              52.9510         26.4755        568.1401       0.0297
Residual     1              0.0466          0.0466
Total        3              52.9976         17.6659

PRESS = 52.1053

Durbin-Watson Statistic = 2.9042

Normality Test:       Passed     (P = 0.5235)

Constant Variance Test:        Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9878

Regression Diagnostics:
Row          Predicted      Residual        Std. Res.      Stud. Res.     Stud. Del. Res.
1            7.5065         -0.0065         -0.0303        -0.9999        0.0000
2            12.9948        0.0452          0.2092         0.9999         0.0000
3            16.0673        -0.1673         -0.7748        -1.0000        0.0000
4            16.7114        0.1286          0.5958         1.0000         (+inf)

Influence Diagnostics:
Row          Cook'sDist     Leverage        DFFITS
1            363.2736       0.9991          0.0000
2            7.2764         0.9562          0.0000
3            0.2219         0.3997          0.0000
4            0.6057         0.6450          (+inf)

95% Confidence:
Row          Predicted      Regr. 5%        Regr. 95%      Pop. 5%        Pop. 95%
1            7.5065         4.7649          10.2482        3.6284         11.3847
2            12.9948        10.3127         15.6770        9.1585         16.8312
3            16.0673        14.3332         17.8014        12.8222        19.3123
4            16.7114        14.5085         18.9143        13.1934        20.2294
```

```
Nonlinear Regression                    (25 Mins)

[Variables]
x = col(1)
y = col(2)
[Parameters]
y0 = min(y) "Auto {{previous: 7.54504}}
a = max(y)-min(y) "Auto {{previous: 7.99981}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0393529}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99279497        Rsqr = 0.98564185    Adj Rsqr = 0.95692555

Standard Error of Estimate = 0.6720

            Coefficient    Std. Error      t            P
y0          7.5450         0.6705          11.2526      0.0564
a           7.9998         1.0849          7.3740       0.0858
b           0.0394         0.0207          1.9018       0.3082

Analysis of Variance:
            DF             SS              MS           F            P
Regression  2              31.0025         15.5012      34.3234      0.1198
Residual    1              0.4516          0.4516
Total       3              31.4541         10.4847

PRESS = 108.1224

Durbin-Watson Statistic = 3.0386

Normality Test:      Passed      (P = 0.6206)

Constant Variance Test:       Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.8027

Regression Diagnostics:
Row         Predicted      Residual        Std. Res.    Stud. Res.   Stud. Del. Res.
1           7.5450         -0.0450         -0.0670      -1.0000      0.0000
2           11.0055        0.1945          0.2894       1.0000       0.0000
3           13.8823        -0.5223         -0.7772      -1.0000      (+inf)
4           14.6172        0.3728          0.5548       1.0000       (+inf)

Influence Diagnostics:
Row         Cook'sDist     Leverage        DFFITS
1           73.8545        0.9955          0.0000
2           3.6469         0.9163          0.0000
3           0.2186         0.3960          (+inf)
4           0.7496         0.6922          (+inf)

95% Confidence:
Row         Predicted      Regr. 5%        Regr. 95%    Pop. 5%      Pop. 95%
1           7.5450         -0.9747         16.0648      -4.5173      19.6073
2           11.0055        2.8320          19.1791      -0.8148      22.8259
3           13.8823        8.5086          19.2559      3.7932       23.9714
4           14.6172        7.5129          21.7214      3.5093       25.7250
```

```
Nonlinear Regression                    (50 Mins)

[Variables]
x = col(1)
y = col(2)
[Parameters]
y0 = min(y) "Auto {{previous: -2.45934}}
a = max(y)-min(y) "Auto {{previous: 12.4765}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0146078}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99569050        Rsqr = 0.99139958    Adj Rsqr = 0.97419873

Standard Error of Estimate = 0.8869

            Coefficient    Std. Error        t              P
y0          -2.4593        0.8868           -2.7733         0.2203
a           12.4765        1.2439           10.0303         0.0633
b           0.0146         0.0067           2.1701          0.2749

Analysis of Variance:
            DF             SS               MS              F              P
Regression  2              90.6642          45.3321         57.6367        0.0927
Residual    1              0.7865           0.7865
Total       3              91.4507          30.4836

PRESS = 5482.5542

Durbin-Watson Statistic = 2.8102

Normality Test:        Passed     (P = 0.4689)

Constant Variance Test:           Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.8663

Regression Diagnostics:
Row         Predicted      Residual         Std. Res.       Stud. Res.     Stud. Del. Res.
1           -2.4593        -0.0107          -0.0120         -1.0000        0.0000
2           5.9315         0.1385           0.1562          0.9999         0.0000
3           8.9100         -0.6800          -0.7667         -1.0000        0.0000
4           9.4379         0.5521           0.6226          1.0000         (+inf)

Influence Diagnostics:
Row         Cook'sDist     Leverage         DFFITS
1           2308.1446      0.9999           0.0000
2           13.3262        0.9756           0.0000
3           0.2337         0.4121           0.0000
4           0.5267         0.6124           (+inf)

95% Confidence:
Row         Predicted      Regr. 5%         Regr. 95%       Pop. 5%        Pop. 95%
1           -2.4593        -13.7271         8.8084          -18.3950       13.4763
2           5.9315         -5.1988          17.0617         -9.9072        21.7702
3           8.9100         1.6760           16.1440         -4.4807        22.3007
4           9.4379         0.6193           18.2565         -4.8711        23.7469
```

```
Nonlinear Regression                          580 Mins)

[Variables]
x = col(1)
y = col(3)
[Parameters]
y0 = min(y) "Auto {{previous: -2.46679}}
a = max(y)-min(y) "Auto {{previous: 14.9996}}
b = x50(x,y-min(y)) "Auto {{previous: 0.011969}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99945020        Rsqr = 0.99890071     Adj Rsqr = 0.99670212

Standard Error of Estimate = 0.3854

              Coefficient    Std. Error       t               P
y0            -2.4668        0.3854           -6.4000         0.0987
a             14.9996        0.5342           28.0767         0.0227
b             0.0120         0.0021           5.5806          0.1129

Analysis of Variance:
              DF             SS               MS              F               P
Regression    2              135.0031         67.5016         454.3377        0.0332
Residual      1              0.1486           0.1486
Total         3              135.1517         45.0506

PRESS = 2144.6482

Durbin-Watson Statistic = 2.7851

Normality Test:      Passed      (P = 0.4576)

Constant Variance Test:         Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9838

Regression Diagnostics:
Row           Predicted      Residual         Std. Res.       Stud. Res.      Stud. Del. Res.
1             -2.4668        -0.0032          -0.0083         -1.0000         (+inf)
2             8.2551         0.0549           0.1424          1.0000          0.0000
3             11.4244        -0.2944          -0.7637         -1.0000         0.0000
4             11.9573        0.2427           0.6296          1.0000          (+inf)

Influence Diagnostics:
Row           Cook'sDist     Leverage         DFFITS
1             4793.5366      0.9999           (+inf)
2             16.0991        0.9797           0.0000
3             0.2382         0.4168           0.0000
4             0.5075         0.6036           (+inf)

95% Confidence:
Row           Predicted      Regr. 5%         Regr. 95%       Pop. 5%         Pop. 95%
1             -2.4668        -7.3642          2.4306          -9.3929         4.4593
2             8.2551         3.4074           13.1028         1.3641          15.1461
3             11.4244        8.2626           14.5861         5.5949          17.2539
4             11.9573        8.1523           15.7623         5.7553          18.1593
```

```
Nonlinear Regression                    (50 Mins)

[Variables]
x = col(1)
y = col(4)
[Parameters]
y0 = min(y) "Auto {{previous: -2.46983}}
a = max(y)-min(y) "Auto {{previous: 15.9323}}
b = x50(x,y-min(y)) "Auto {{previous: 0.00689925}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99999062        Rsqr = 0.99998123    Adj Rsqr = 0.99994370

Standard Error of Estimate = 0.0554

              Coefficient    Std. Error        t              P
y0            -2.4698        0.0554            -44.5706       0.0143
a             15.9323        0.0751            212.2593       0.0030
b             0.0069         0.0002            30.9332        0.0206

Analysis of Variance:
              DF             SS                MS             F              P
Regression    2              163.6323          81.8162        26643.8937     0.0043
Residual      1              0.0031            0.0031
Total         3              163.6354          54.5451

PRESS = 386.6743

Durbin-Watson Statistic = 2.7363

Normality Test:       Passed      (P = 0.4413)

Constant Variance Test:        Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:
Row           Predicted      Residual          Std. Res.      Stud. Res.     Stud. Del. Res.
1             -2.4698        -0.0002           -0.0030        -1.0382        (+inf)
2             10.4836        0.0064            0.1162         0.9999         0.0000
3             12.7619        -0.0419           -0.7567        -1.0000        0.0000
4             13.1043        0.0357            0.6434         1.0001         (+inf)

Influence Diagnostics:
Row           Cook'sDist     Leverage          DFFITS
1             41947.8179     1.0000            (+inf)
2             24.3255        0.9865            0.0000
3             0.2488         0.4274            0.0000
4             0.4721         0.5861            (+inf)

95% Confidence:
Row           Predicted      Regr. 5%          Regr. 95%      Pop. 5%        Pop. 95%
1             -2.4698        -3.1739           -1.7657        -3.4656        -1.4741
2             10.4836        9.7842            11.1829        9.4912         11.4759
3             12.7619        12.3016           13.2223        11.9207        13.6032
4             13.1043        12.5653           13.6434        12.2176        13.9911
```

```
Nonlinear Regression                        (50 Mins)

[Variables]
x = col(1)
y = col(5)
[Parameters]
y0 = min(y) "Auto {{previous: -2.47128}}
a = max(y)-min(y) "Auto {{previous: 18.6087}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0081038}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99975910        Rsqr = 0.99951825    Adj Rsqr = 0.99855475

Standard Error of Estimate = 0.3249

              Coefficient     Std. Error        t                P
y0            -2.4713         0.3249            -7.6069          0.0832
a             18.6087         0.4425            42.0560          0.0151
b             0.0081          0.0012            6.7839           0.0932

Analysis of Variance:
              DF              SS                MS               F               P
Regression    2               218.9806          109.4903         1037.3857       0.0219
Residual      1               0.1055            0.1055
Total         3               219.0861          73.0287

PRESS = 6529.4791

Durbin-Watson Statistic = 2.7479

Normality Test:         Passed     (P = 0.4442)

Constant Variance Test:            Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9946

Regression Diagnostics:
Row           Predicted       Residual          Std. Res.        Stud. Res.      Stud. Del. Res.
1             -2.4713         0.0013            0.0039           0.9908          0.0000
2             12.1798         -0.0398           -0.1224          -1.0000         (+inf)
3             15.1836         0.2464            0.7585           1.0000          (+inf)
4             15.6479         -0.2079           -0.6401          -1.0000         0.0000

Influence Diagnostics:
Row           Cook'sDist      Leverage          DFFITS
1             20597.6015      1.0000            0.0000
2             21.9265         0.9850            (+inf)
3             0.2461          0.4247            (+inf)
4             0.4802          0.5903            0.0000

95% Confidence:
Row           Predicted       Regr. 5%          Regr. 95%        Pop. 5%         Pop. 95%
1             -2.4713         -6.5992           1.6566           -8.3091         3.3665
2             12.1798         8.0828            16.2767          6.3639          17.9957
3             15.1836         12.4934           17.8737          10.2564         20.1107
4             15.6479         12.4764           18.8194          10.4423         20.8535
```

```
Nonlinear Regression                    (60 Mins)

[Variables]
x = col(1)
y = col(2)
[Parameters]
y0 = min(y) "Auto {{previous: -1.04685}}
a = max(y)-min(y) "Auto {{previous: 11.8565}}
b = x50(x,y-min(y)) "Auto {{previous: 0.016206}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99498097        Rsqr = 0.98998712    Adj Rsqr = 0.96996137

Standard Error of Estimate = 0.9026

              Coefficient    Std. Error       t              P
y0            -1.0468        0.9025           -1.1599        0.4530
a             11.8565        1.2755           9.2953         0.0682
b             0.0162         0.0078           2.0849         0.2847

Analysis of Variance:
              DF             SS               MS             F              P
Regression    2              80.5552          40.2776        49.4357        0.1001
Residual      1              0.8147           0.8147
Total         3              81.3699          27.1233

PRESS = 3870.2242

Durbin-Watson Statistic = 2.8258

Normality Test:        Passed     (P = 0.4767)

Constant Variance Test:           Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.8491

Regression Diagnostics:
Row           Predicted      Residual         Std. Res.      Stud. Res.     Stud. Del. Res.
1             -1.0468        -0.0132          -0.0146        -1.0000        0.0000
2             6.6512         0.1488           0.1648         1.0000         0.0000
3             9.6536         -0.6936          -0.7684        -1.0000        0.0000
4             10.2020        0.5580           0.6182         1.0000         (+inf)

Influence Diagnostics:
Row           Cook'sDist     Leverage         DFFITS
1             1569.3698      0.9998           0.0000
2             11.9327        0.9728           0.0000
3             0.2312         0.4095           0.0000
4             0.5390         0.6179           (+inf)

95% Confidence:
Row           Predicted      Regr. 5%         Regr. 95%      Pop. 5%        Pop. 95%
1             -1.0468        -12.5147         10.4210        -17.2657       15.1720
2             6.6512         -4.6609          17.9633        -9.4579        22.7603
3             9.6536         2.3142           16.9930        -3.9627        23.2700
4             10.2020        1.1868           19.2173        -4.3861        24.7902
```

```
Nonlinear Regression                    (60 Mins)

[Variables]
x = col(1)
y = col(3)
[Parameters]
y0 = min(y) "Auto {{previous: -1.05652}}
a = max(y)-min(y) "Auto {{previous: 14.3291}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0123943}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99937620        Rsqr = 0.99875279    Adj Rsqr = 0.99625838

Standard Error of Estimate = 0.3912

            Coefficient    Std. Error     t              P
y0          -1.0565        0.3912         -2.7005        0.2258
a           14.3291        0.5433         26.3734        0.0241
b           0.0124         0.0023         5.3255         0.1182

Analysis of Variance:
            DF             SS             MS             F              P
Regression  2              122.5800       61.2900        400.3962       0.0353
Residual    1              0.1531         0.1531
Total       3              122.7331       40.9110

PRESS = 1939.7578

Durbin-Watson Statistic = 2.7892

Normality Test:       Passed     (P = 0.4594)

Constant Variance Test:          Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9811

Regression Diagnostics:
Row         Predicted      Residual       Std. Res.      Stud. Res.     Stud. Del. Res.
1           -1.0565        -0.0035        -0.0089        -1.0000        0.0000
2           9.0834         0.0566         0.1447         1.0000         0.0000
3           12.1790        -0.2990        -0.7642        -1.0000        0.0000
4           12.7041        0.2459         0.6285         1.0000         (+inf)

Influence Diagnostics:
Row         Cook'sDist     Leverage       DFFITS
1           4206.3503      0.9999         0.0000
2           15.5937        0.9791         0.0000
3           0.2374         0.4160         0.0000
4           0.5106         0.6050         (+inf)

95% Confidence:
Row         Predicted      Regr. 5%       Regr. 95%      Pop. 5%        Pop. 95%
1           -1.0565        -6.0276        3.9145         -8.0868        5.9738
2           9.0834         4.1644         14.0024        2.0899         16.0769
3           12.1790        8.9728         15.3852        6.2635         18.0945
4           12.7041        8.8373         16.5710        6.4060         19.0022
```

```
Nonlinear Regression                    (60 Mins)

[Variables]
x = col(1)
y = col(4)
[Parameters]
y0 = min(y) "Auto {{previous: -1.05979}}
a = max(y)-min(y) "Auto {{previous: 15.2022}}
b = x50(x,y-min(y)) "Auto {{previous: 0.00716291}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99998555        Rsqr = 0.99997110    Adj Rsqr = 0.99991330

Standard Error of Estimate = 0.0655

            Coefficient    Std. Error        t              P
y0          -1.0598        0.0655            -16.1861       0.0393
a           15.2022        0.0888            171.2043       0.0037
b           0.0072         0.0003            25.5660        0.0249

Analysis of Variance:
            DF             SS                MS             F              P
Regression  2              148.3336          74.1668        17300.2647     0.0054
Residual    1              0.0043            0.0043
Total       3              148.3379          49.4460

PRESS = 458.5315

Durbin-Watson Statistic = 2.7388

Normality Test:       Passed    (P = 0.4419)

Constant Variance Test:         Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:
Row         Predicted      Residual          Std. Res.      Stud. Res.     Stud. Del. Res.
1           -1.0598        -0.0002           -0.0032        -1.0284        (+inf)
2           11.2123        0.0077            0.1176         0.9999         0.0000
3           13.4496        -0.0496           -0.7571        -1.0000        0.0000
4           13.7879        0.0421            0.6427         1.0000         (+inf)

Influence Diagnostics:
Row         Cook'sDist     Leverage          DFFITS
1           35626.7491     1.0000            (+inf)
2           23.7702        0.9862            0.0000
3           0.2482         0.4268            0.0000
4           0.4738         0.5870            (+inf)

95% Confidence:
Row         Predicted      Regr. 5%          Regr. 95%      Pop. 5%        Pop. 95%
1           -1.0598        -1.8917           -0.2278        -2.2363        0.1168
2           11.2123        10.3861           12.0385        10.0398        12.3848
3           13.4496        12.9060           13.9931        12.4558        14.4433
4           13.7879        13.1505           14.4253        12.7399        14.8360
```

```
Nonlinear Regression                    (60 Mins)

[Variables]
x = col(1)
y = col(5)
[Parameters]
y0 = min(y) "Auto {{previous: -1.06234}}
a = max(y)-min(y) "Auto {{previous: 17.9304}}
b = x50(x,y-min(y)) "Auto {{previous: 0.00998006}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99960629        Rsqr = 0.99921274    Adj Rsqr = 0.99763821

Standard Error of Estimate = 0.3949

              Coefficient    Std. Error       t              P
y0            -1.0623        0.3949           -2.6905        0.2265
a             17.9304        0.5424           33.0592        0.0193
b             0.0100         0.0017           6.0037         0.1051

Analysis of Variance:
              DF             SS               MS             F              P
Regression    2              197.8882         98.9441        634.6120       0.0281
Residual      1              0.1559           0.1559
Total         3              198.0441         66.0147

PRESS = 4445.2773

Durbin-Watson Statistic = 2.7659

Normality Test:        Passed      (P = 0.4502)

Constant Variance Test:         Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9895

Regression Diagnostics:
Row           Predicted      Residual         Std. Res.      Stud. Res.     Stud. Del. Res.
1             -1.0623        0.0023           0.0059         0.9992         0.0000
2             12.3921        -0.0521          -0.1320        -1.0000        (+inf)
3             15.7495        0.3005           0.7611         1.0000         (+inf)
4             16.2907        -0.2507          -0.6350        -1.0000        0.0000

Influence Diagnostics:
Row           Cook'sDist     Leverage         DFFITS
1             9482.9187      1.0000           0.0000
2             18.7864        0.9826           (+inf)
3             0.2421         0.4207           (+inf)
4             0.4933         0.5968           0.0000

95% Confidence:
Row           Predicted      Regr. 5%         Regr. 95%      Pop. 5%        Pop. 95%
1             -1.0623        -6.0794          3.9547         -8.1576        6.0329
2             12.3921        7.4189           17.3654        5.3278         19.4565
3             15.7495        12.4953          19.0036        9.7694         21.7296
4             16.2907        12.4149          20.1665        9.9509         22.6306
```

```
Nonlinear Regression                            (80 Mins)

[Variables]
x = col(1)
y = col(2)
[Parameters]
y0 = min(y) "Auto {{previous: -2.45934}}
a = max(y)-min(y) "Auto {{previous: 12.4765}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0146078}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99569050      Rsqr = 0.99139958    Adj Rsqr = 0.97419873

Standard Error of Estimate = 0.8869

               Coefficient    Std. Error         t                 P
y0             -2.4593        0.8868             -2.7733           0.2203
a              12.4765        1.2439             10.0303           0.0633
b              0.0146         0.0067             2.1701            0.2749

Analysis of Variance:
               DF             SS                 MS                F                 P
Regression     2              90.6642            45.3321           57.6367           0.0927
Residual       1              0.7865             0.7865
Total          3              91.4507            30.4836

PRESS = 5482.5542

Durbin-Watson Statistic = 2.8102

Normality Test:        Passed     (P = 0.4689)

Constant Variance Test:           Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.8663

Regression Diagnostics:
Row            Predicted      Residual           Std. Res.         Stud. Res.        Stud. Del. Res.
1              -2.4593        -0.0107            -0.0120           -1.0000           0.0000
2              5.9315         0.1385             0.1562            0.9999            0.0000
3              8.9100         -0.6800            -0.7667           -1.0000           0.0000
4              9.4379         0.5521             0.6226            1.0000            (+inf)

Influence Diagnostics:
Row            Cook'sDist     Leverage           DFFITS
1              2308.1446      0.9999             0.0000
2              13.3262        0.9756             0.0000
3              0.2337         0.4121             0.0000
4              0.5267         0.6124             (+inf)

95% Confidence:
Row            Predicted      Regr. 5%           Regr. 95%         Pop. 5%           Pop. 95%
1              -2.4593        -13.7271           8.8084            -18.3950          13.4763
2              5.9315         -5.1988            17.0617           -9.9072           21.7702
3              8.9100         1.6760             16.1440           -4.4807           22.3007
4              9.4379         0.6193             18.2565           -4.8711           23.7469
```

```
Nonlinear Regression                    (80 Mins)

[Variables]
x = col(1)
y = col(3)
[Parameters]
y0 = min(y) "Auto {{previous: -2.46679}}
a = max(y)-min(y) "Auto {{previous: 14.9996}}
b = x50(x,y-min(y)) "Auto {{previous: 0.011969}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99945020        Rsqr = 0.99890071    Adj Rsqr = 0.99670212

Standard Error of Estimate = 0.3854

             Coefficient    Std. Error        t              P
y0           -2.4668        0.3854            -6.4000        0.0987
a            14.9996        0.5342            28.0767        0.0227
b            0.0120         0.0021            5.5806         0.1129

Analysis of Variance:
             DF             SS                MS             F              P
Regression   2              135.0031          67.5016        454.3377       0.0332
Residual     1              0.1486            0.1486
Total        3              135.1517          45.0506

PRESS = 2144.6482

Durbin-Watson Statistic = 2.7851

Normality Test:       Passed      (P = 0.4576)

Constant Variance Test:           Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9838

Regression Diagnostics:
Row          Predicted      Residual          Std. Res.      Stud. Res.     Stud. Del. Res.
1            -2.4668        -0.0032           -0.0083        -1.0000        (+inf)
2            8.2551         0.0549            0.1424         1.0000         0.0000
3            11.4244        -0.2944           -0.7637        -1.0000        0.0000
4            11.9573        0.2427            0.6296         1.0000         (+inf)

Influence Diagnostics:
Row          Cook'sDist     Leverage          DFFITS
1            4793.5366      0.9999            (+inf)
2            16.0991        0.9797            0.0000
3            0.2382         0.4168            0.0000
4            0.5075         0.6036            (+inf)

95% Confidence:
Row          Predicted      Regr. 5%          Regr. 95%      Pop. 5%        Pop. 95%
1            -2.4668        -7.3642           2.4306         -9.3929        4.4593
2            8.2551         3.4074            13.1028        1.3641         15.1461
3            11.4244        8.2626            14.5861        5.5949         17.2539
4            11.9573        8.1523            15.7623        5.7553         18.1593
```

```
Nonlinear Regression                    (80 Mins)

[Variables]
x = col(1)
y = col(4)
[Parameters]
y0 = min(y) "Auto {{previous: -2.46983}}
a = max(y)-min(y) "Auto {{previous: 15.9323}}
b = x50(x,y-min(y)) "Auto {{previous: 0.00689925}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99999062       Rsqr = 0.99998123    Adj Rsqr = 0.99994370

Standard Error of Estimate = 0.0554

            Coefficient     Std. Error       t               P
y0          -2.4698         0.0554           -44.5706        0.0143
a           15.9323         0.0751           212.2593        0.0030
b           0.0069          0.0002           30.9332         0.0206

Analysis of Variance:
            DF              SS               MS              F               P
Regression  2               163.6323         81.8162         26643.8937      0.0043
Residual    1               0.0031           0.0031
Total       3               163.6354         54.5451

PRESS = 386.6743

Durbin-Watson Statistic = 2.7363

Normality Test:       Passed      (P = 0.4413)

Constant Variance Test:           Failed      (P = <0.0001)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:
Row         Predicted       Residual         Std. Res.       Stud. Res.      Stud. Del. Res.
1           -2.4698         -0.0002          -0.0030         -1.0382         (+inf)
2           10.4836         0.0064           0.1162          0.9999          0.0000
3           12.7619         -0.0419          -0.7567         -1.0000         0.0000
4           13.1043         0.0357           0.6434          1.0001          (+inf)

Influence Diagnostics:
Row         Cook'sDist      Leverage         DFFITS
1           41947.8179      1.0000           (+inf)
2           24.3255         0.9865           0.0000
3           0.2488          0.4274           0.0000
4           0.4721          0.5861           (+inf)

95% Confidence:
Row         Predicted       Regr. 5%         Regr. 95%       Pop. 5%         Pop. 95%
1           -2.4698         -3.1739          -1.7657         -3.4656         -1.4741
2           10.4836         9.7842           11.1829         9.4912          11.4759
3           12.7619         12.3016          13.2223         11.9207         13.6032
4           13.1043         12.5653          13.6434         12.2176         13.9911
```

```
Nonlinear Regression                    (80 Mins)

[Variables]
x = col(1)
y = col(5)
[Parameters]
y0 = min(y) "Auto {{previous: -2.47128}}
a = max(y)-min(y) "Auto {{previous: 18.6087}}
b = x50(x,y-min(y)) "Auto {{previous: 0.0081038}}
[Equation]
f=y0+a*x/(b+x)
fit f to y
[Options]
tolerance=0.000100
stepsize=100
iterations=100
[Constraints]

R = 0.99975910        Rsqr = 0.99951825    Adj Rsqr = 0.99855475

Standard Error of Estimate = 0.3249

              Coefficient    Std. Error       t              P
y0            -2.4713        0.3249           -7.6069        0.0832
a             18.6087        0.4425           42.0560        0.0151
b             0.0081         0.0012           6.7839         0.0932

Analysis of Variance:
              DF             SS               MS             F              P
Regression    2              218.9806         109.4903       1037.3857      0.0219
Residual      1              0.1055           0.1055
Total         3              219.0861         73.0287

PRESS = 6529.4791

Durbin-Watson Statistic = 2.7479

Normality Test:        Passed      (P = 0.4442)

Constant Variance Test:        Failed     (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9946

Regression Diagnostics:
Row           Predicted      Residual         Std. Res.      Stud. Res.     Stud. Del. Res.
1             -2.4713        0.0013           0.0039         0.9908         0.0000
2             12.1798        -0.0398          -0.1224        -1.0000        (+inf)
3             15.1836        0.2464           0.7585         1.0000         (+inf)
4             15.6479        -0.2079          -0.6401        -1.0000        0.0000

Influence Diagnostics:
Row           Cook'sDist     Leverage         DFFITS
1             20597.6015     1.0000           0.0000
2             21.9265        0.9850           (+inf)
3             0.2461         0.4247           (+inf)
4             0.4802         0.5903           0.0000

95% Confidence:
Row           Predicted      Regr. 5%         Regr. 95%      Pop. 5%        Pop. 95%
1             -2.4713        -6.5992          1.6566         -8.3091        3.3665
2             12.1798        8.0828           16.2767        6.3639         17.9957
3             15.1836        12.4934          17.8737        10.2564        20.1107
4             15.6479        12.4764          18.8194        10.4423        20.8535
```