1. Publication Nº	2. Version	3. Date	5. Distribution
INPE-2512-PRE/191		*Aug., 1982*	☐ Internal ☒ External
4. Origin *DMC/DEC*	Program *TERM*		☐ Restricted

6. Key words - selected by the author(s)

THERMAL RESISTANCE
CONDUCTIVE HEAT TRANSFER

7. U.D.C.: *536.2*

8. Title *INPE-2512-PRE/191*

DETERMINATION OF CONDUCTIVE THERMAL RESISTANCE OF PLATES WITH NONUNIFORM INTERNAL HEAT GENERATION AND UNDER VARIOUS BOUNDARY CONDITIONS

10. Nº of pages: *22*

11. Last page: *21*

12. Revised by

A.V. Krishna Murty

13. Authorized by

Nelson de Jesus Parada
Diretor

9. Authorship *Olavo Bueno de Oliveira Filho*
Santiago Alves Tavares
Nellore S. Venkataraman

Responsible author

14. Abstract/Notes

The conductive resistance of thin rectangular plates with internal heat generation in two regions, with one end subject to an internal flux is determined using the finite element method. The dependance of the thermal resistance on various parameters is discussed. A comparison is made with the one dimensional resistance.

15. Remarks

For presentation at the First Latin American Congress an Heat and Mass Transfer, La Plata, Argentina, 1982.

DETERMINATION OF CONDUCTIVE THERMAL RESISTANCE OF PLATES WITH NONUNIFORM INTERNAL HEAT GENERATION AND UNDER VARIOUS BOUNDARY CONDITIONS

Olavo B. Oliveira Filho; Santiago A. Tavares; Nellore S. Vankataraman
Instituto de Pesquisas Espaciais - INPE/CNPq
São José dos Campos, S.P. - Brazil

ABSTRACT

The conductive resistance of thin rectangular plates with internal heat generation in two regions, with one end subject to an internal flux is determined using the finite element method. The dependance of the thermal resistance on various parameters is discussed. A comparison is made with the one dimensional resistance.

INTRODUCTION

The motivation for this work arose while trying to make a thermal analysis of the first Brazilian satellite. The thermal analysis of satellite is done by dividing the satellite into many isothermal nodes and the knowledge of the internodal conductive resistance or conductive coupling coefficients is essential for the thermal design and analysis. The calculation of these coupling coefficients is often difficult because of geometrical complexities and uncertainties about the contact resistance. Often in satellite thermal control design, for lack of information, a one-dimensional approximation is made.

Oliveira and Forslund (1974) considered a convectively cooled plate with constant heat flux and no internal heat generation. Schneider et al. (1980) extended the same to include the case of nonuniform heat flux, but again with no internal heat generation. Venkataraman et al. (1981) extended the problem to include internal heat generation. Three different internal heat generation cases were considered and thermal resistance was calculated for the various cases. The objective of this work is to find the thermal resistance between two heat generating boxes (which may be the heat dissipation by electronic components) mounted on a thin rectangular plate as shown in Figure 1. One of the sides is subjected to an external heat flux, the adjacent side is at a constant temperature and all other sides are maintained at zero temperature. If the other sides are at a non-zero constant temperature, the problem can be reduced to the present one by using superposition.

FORMULATION

The geometry is shown in Figure 1. We consider a thin rectangular plate of length a and width b, with the coordinate axes as shown. The plate is subjected to a constant internal heat generation g_1 per unit volume confined to the region $x_1 \leqq x \leqq x_2$, $y_1 \leqq y \leqq y_2$ and constant heat generation of g_2 per unit volume confined to $x_3 \leqq x \leqq x_4$, $y_3 \leqq y \leqq y_4$. The bottom side is subjected to constant heat flux q_0. The side $x = 0$ is maintained at a constant temperature. The problem is to find the thermal resistance between the two heat generating boxes. The governing differential equation for the temperature $\theta(x,y)$ is the Poisson equation given by

$$\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} = - \frac{g(x,y)}{k} \tag{1}$$

where k is the plate thermal conductivity, g(x,y) is the internal heat generation per unit volume:

$$\theta(0,y) = \theta_0 \tag{1-a}$$

$$\theta(x,b) = 0 \tag{1-b}$$

$$\theta(a,y) = 0 \tag{1-c}$$

$$-k\left(\frac{\partial\theta}{\partial x}\right)_{y=0} = q_0 \tag{1-d}$$

THE SOLUTION

The finite element method (Chung, 1978) has been used because it offers flexibility in choosing various types of internal generation and boundary conditions, and there is better control an error propagation.

The functional corresponding to the Euler's Equation (1) is (Heuser, 1973)

$$I = k\ell \int_S \left[\frac{1}{2}\left(\frac{\partial\theta}{\partial x}\right)^2 + \frac{1}{2}\left(\frac{\partial\theta}{\partial y}\right)^2\right] ds - \ell\int_S g(x,y)\theta ds + \ell\int_F q(x)\theta dF \tag{2}$$

Here $q(x)$ is the external heat flux and ℓ is the plate thickness. The first two integrals are over the plate area and the last one is on the plate boundary. The problem has been solved starting from this function using the method of finite elements based on the method of Ritz. A triangular element with six nodes and quadratic interpolation have been used. The interpolation function was selected such that the second derivatives of the temperature with respect to x and y are constant. The condition of the temperature continuity along the boundaries of the triangle was imposed, with no restriction on the normal derivatives. One could presumably obtain better results by using the Hermite interpolation polynomials with continuous first derivatives across the interelement boundaries.

The solution of the problem in terms of the shape functions N_j are

$$\theta(x,y) = \sum_{j=1}^{6} N_j \ (x,y)\theta_j \tag{3}$$

The shape functions in terms of the area coordinates ξ_1, ξ_2 and ξ_3 are

$$\begin{aligned} &N_1 = \xi_1(2\xi_1 - 1), \quad &&N_2 = \xi_2(2\xi_2 - 1), \quad &&N_3 = \xi_3(2\xi_3 - 1) \\ &N_4 = 4\xi_1\xi_2, &&N_5 = 4\xi_2\xi_3, &&N_6 = 4\xi_3\xi_1. \end{aligned} \tag{4}$$

By dividing the domain and the boundaries into finite subdonains, we can write the function as

$$I = \sum_{e=1}^{n} I^e \tag{5}$$

where the superscript e corresponds to the element and n the number of elements. Substituting Equations (2) and (3) in Equation (5) transforms the problem from function space to R^N space, where the variables are θ_1, θ_2, ..., θ_N. The problem of finding the function that makes the functional stationary is reduced to the problem of obtaining the points of R^N that will make the function a minimum. Thus:

$$\frac{\partial I}{\partial \theta_k} \delta\theta_k = 0, \qquad k = 1,\ldots,N \tag{6}$$

from which we obtain a system of n equations

$$\frac{\partial I}{\partial \theta_k} = 0 \qquad k = 1,\ldots,N \tag{7}$$

Solving this equation, we obtain the solution in each element (subdomain), in the form

$$\theta^E(x,y) = \sum_{j=1}^{6} N_i(\xi_1,\xi_2,\xi_3)\theta_j^e \tag{8}$$

where θ_j^e are the values of θ_k at the nodal element e.

Substituting from Equation (5) into Equation (6) we get

$$\frac{\partial}{\partial\theta_k} = \sum_e I^e = 0 \qquad \text{ou} \quad \sum_e \frac{\partial I^e}{\partial\theta_i} = 0 \tag{9}$$

where $\partial I^e/\partial\theta_i$ for each i corresponds to the nodes of the elements and forms the matrix of element e.

θ_i^e (i=1,...,6) being the nodal parameter of element e, we have, for the problem considered, six expressions of the type

$$\frac{\partial I^e}{\partial\theta_i^e} \qquad i=1,\ldots,6 \tag{10}$$

Substituting Equation (2) in Equation (10)

$$\frac{\partial I^e}{\partial\theta_i} = k\ell\int_S\left[\frac{\partial\theta}{\partial x}\,\frac{\partial}{\partial\theta_i}\left(\frac{\partial\theta}{\partial x}\right) + \frac{\partial\theta}{\partial y}\,\frac{\partial}{\partial\theta_i}\left(\frac{\partial\theta}{\partial y}\right)\right] ds -$$

$$- \ell\int_S g(x,y)\,\frac{\partial\theta}{\partial\theta_i}\,ds + \ell\int_F q(x)\,\frac{\partial\theta}{\partial\theta_i}\,dF \tag{11}$$

Using Equation (8), the first term of Equation (11) becomes

$$\frac{\partial\theta}{\partial x}\,\frac{\partial}{\partial\theta_i}\left(\frac{\partial\theta}{\partial x}\right) = \sum_{j=1}^{6}\frac{\partial N_j}{\partial x} =$$

$$= \sum_{j=1}^{6}\left(\sum_{\ell=1}^{3}\frac{\partial N_i}{\partial\xi_\ell}\,\frac{\partial\xi_\ell}{\partial x}\,\sum_{m=1}^{3}\frac{\partial N_j}{\partial\xi_m}\,\frac{\partial\xi_m}{\partial x}\right)\theta_j \tag{12}$$

and similarly for y. From the relation between the cartesian and natural coordinates

$$\begin{bmatrix} 1 \\ x \\ y \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \end{bmatrix}\begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} \tag{13}$$

which can be writeen as

$$\begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{bmatrix}\begin{bmatrix} 1 \\ x \\ y \end{bmatrix} \tag{14}$$

we obtain

$$\frac{\partial \xi_\ell}{\partial x} = \frac{g_{\ell 2}}{\Delta} \quad , \qquad \frac{\partial \xi_m}{\partial x} = \frac{g_{m2}}{\Delta}$$
$$\frac{\partial \xi_\ell}{\partial y} = \frac{g_{\ell 3}}{\Delta} \quad , \qquad \frac{\partial \xi_m}{\partial y} = \frac{g_{m3}}{\Delta} \tag{15}$$

where Δ is the determinant of the matrix of Equation (13) .

Using Equations (10), (11) and (15) we get

$$\frac{\partial I^e}{\partial \theta_i} = \frac{k\ell}{\Delta^2} \sum_{j=1}^{6} \left[\sum_\ell \sum_m (g_{\ell 2}\ g_{m2} + g_{\ell 3}\ g_{m3}) \int_S \frac{\partial N_i}{\partial \xi_\ell} \frac{\partial N_j}{\partial \xi_m} \right] \theta_j -$$
$$- \ell \int_S g(x,y) N_i ds + \ell \int_F q(x) N_i dF \qquad i=1,2,\ldots,6 \tag{16}$$

The above six equation can be written in matrix notation as

$$[K^e]\ \{\theta^e\} + \{F^e\} = 0 \tag{17}$$

where

$$K^e_{ij} = \frac{k\ell}{\Delta^2} \sum_\ell \sum_m (g_{\ell 2} g_{m2} + g_{\ell 3} g_{m3}) \int_S \frac{\partial N_i}{\partial \xi_\ell} \frac{\partial N_j}{\partial \xi_m} \ ds \tag{18}$$

$$F^e_i = F^e_{q_i} + F^e_{g_i} \tag{19}$$

$$F^e_{q_i} = + \ell \int_F q(x)\ N_i\ dF \tag{20}$$

$$F^e_{g_i} = - \ell \int_S g(x,y)\ N_i\ dS \tag{21}$$

The value of the matrix elements are shown in appendix A.

Following an analogous approach for the remaining nodes and using Equation (7), we have the following final system of matrix equations.

$$[K]\{\theta\} + \{F\} = 0 \tag{22}$$

where the matrices K, θ and F correspond to the entire plate.

NONDIMENSIONALIZATION

To have more generality, the variables are nondimensionalized as follows.

Non dimensional lengths $\bar{x} = \frac{x}{a}$, $\bar{y} = \frac{y}{a}$, $\varepsilon = \frac{b}{a}$, $\bar{x}_1 = \frac{x_1}{a}$,

$\bar{y}_1 = \frac{y_1}{a}$, $\bar{x}_2 = \frac{x_2}{a}$, ... etc.

Non dimensional temperature $\theta^* = \frac{k\ell\theta}{Q+Q_V}$

where

$Q = q_0 a\ell$ is the total external heat flow

$$Q_V = \ell\int_{x_1}^{x_2}\int_{y_1}^{y_2} g_1\,dx\,dy + \ell\int_{x_2}^{x_3}\int_{y_2}^{y_3} g_2\,dx\,dy$$

is the total internal heat generation.

Ratio of internal heat generarion to external heat flux, $G_1 = ag_1/q_0$, $G_2 = ag_2/q_0$.

Boundary condition parameter $C = k\theta_0/aq_0$.

The matrix {F} can be written as

$$\{F\} = \{F_{g_1}\} + \{F_{g_2}\} + \{F_q\} \tag{23}$$

where F_{g_1} and F_{g_2} are source matries due to g_1 and g_2, and F_q is the matrix due to the heat flux, for the entire plate.

Substituting in Equation (22), we have the nondimensional form of the matrix equation

$$[K^*]\{\theta^*\} + G\{F^*_q\} + G_1G\{F^*_{q_1}\} + G_2G\{F^*_{q_2}\} = 0 \tag{24}$$

where

$$G = \frac{1}{1 + G_1(\bar{x}_2 - \bar{x}_1)(\bar{y}_2 - \bar{y}_1) + G_2(\bar{x}_4 - \bar{x}_3)(\bar{y}_4 - \bar{y}_3)} \tag{25}$$

and the asterisks represent the nondimensionalized matries.

NONDIMENSIONAL THERMAL RESISTANCE

The nondimensional thermal resistance R is defined as

$$R = \frac{\bar{\theta}^*_1 - \bar{\theta}^*_2}{|\vec{Q}_{12}|} \tag{26}$$

where $\bar{\theta}^*_1$ and $\bar{\theta}^*_2$ are the average temperatures of the zones of heat generation g_1 and g_2, and Q_{12} is the nondimensional heat flow from region 1 to region 2.

$$Q_{12} = \left[\left\{ \int_{\bar{y}_A}^{\bar{y}_B} \frac{\partial\theta^*}{\partial\bar{x}}\, d\bar{y} \right\}^2 + \left\{ \int_{\bar{x}_A}^{\bar{x}_B} \frac{\partial\theta^*}{\partial\bar{y}}\, d\bar{x} \right\}^2 \right]^{1/2} \tag{27}$$

$$\left[\left\{ \int_{\bar{y}_C}^{\bar{y}_D} \frac{\partial\theta^*}{\partial\bar{x}}\, d\bar{y} \right\}^2 + \left\{ \int_{\bar{x}_A}^{\bar{x}_D} \frac{\partial\theta^*}{\partial\bar{y}}\, d\bar{x} \right\}^2 \right]^{1/2} \tag{28}$$

where $(\bar{x}_A,\bar{y}_A)$, $(\bar{x}_B,\bar{y}_B)$, $(\bar{x}_C,\bar{y}_C)$, $(\bar{x}_D,\bar{y}_D)$ are the coordinates of the limiting lines of heat flux. These limiting lines are obtained graphically as shown in Figure 2 for a typical case. The isotherms are normalized between 0 and 100 and are plotted by a Calcomp plotter. The limiting flux lines (perpendicular to the isotherms) between the two regions are then drawn and thus the coordiantes of the points A, B, C and D, on the boundaries of these heat generating regions are determined.

RESULTS AND DISCUSSIONS

Equation (22) was solved by the method of Crout and Banachiewicz (Crandall, 1956) by dividing the plate into 400 elements. For confirmation purposes the problem was also solved by the finite difference method and the comparison has been very good. The nondimensional thermal resistance has been calculated as a function of the parameters C, G_1, G_2, ε, size and position of the heat generating regions. For simplicity, the size of these regions, the value of ε and their relative position in the y direction are fixed, and analysis is made by varying G_1, G_2, ε and their relative position in x direction. For comparison purposes the nondimensional one dimensional resistance R_{1D} between the two regions is also calculated. Figures 3, 4 and 5 show the behabiour of R and the percetage difference between R_{1D} and R against G_1/G_2 for various values of C with ε and $\bar{x}_3 - \bar{x}_2$ fixed. Figures 6 and 7 show the variation of these resistances and the percentage difference against $\bar{x}_3 - \bar{x}_2$ with G_1/G_2 fixed but for different values of C. Figure 2 shows isotherms for a typical case. For small values of G_1/G_2 the resistance is considerably larger than the one dimensional resistance, but rapidly decreases to a constant value whichis less than the one dimensional resistance. The resistance tends to increase with C, because an increase in C implies a higher temperature gradient along the plate. The resistance increases as the regions of heat generation are moved apart, steeply incresting to infinity at some separation distance. The one dimensional resistance as expected increases lineary with the separation distance.

In conclusion, the nondimensional resistance can considerably differ from the nondimensional one dimensional resistance depending upor plate geometry and the boundary conditions.

APPENDIX A

From Equation (18) we have for the elements of the matrix $[K^e]$

$$K^e_{11} = \frac{1}{2\Delta}(g^2_{12} + g^2_{13})$$

$$K^e_{12} = K^e_{21} = -\frac{1}{6\Delta}(g_{12}g_{22} + g_{13}g_{23})$$

$$K^e_{13} = K^e_{31} = -\frac{1}{6\Delta}(g_{12}g_{32} + g_{13}g_{33})$$

$$K^e_{14} = K^e_{41} = \frac{2}{3\Delta}(g_{12}g_{22} + g_{13}g_{23})$$

$$K^e_{15} = K^e_{51} = 0$$

$$K^e_{16} = K^e_{61} = \frac{2}{3\Delta}(g_{12}g_{32} + g_{13}g_{33})$$

$$K^e_{22} = \frac{1}{2\Delta}(g^2_{22} + g^2_{23})$$

$$K^e_{23} = K^e_{32} = -\frac{1}{6\Delta}(g_{22}g_{32} + g_{23}g_{33})$$

$$K^e_{24} = K^e_{42} = -\frac{2}{3\Delta}(g_{12}g_{22} + g_{13}g_{23})$$

$$K^e_{25} = K^e_{52} = -\frac{2}{3\Delta}(g_{22}g_{32} + g_{23}g_{33})$$

$$K^e_{26} = K^e_{62} = 0$$

$$K^e_{33} = \frac{1}{2\Delta}(g^2_{32} + g^2_{33})$$

$$K^e_{34} = K^e_{43} = 0$$

$$K^e_{35} = K^e_{53} = \frac{2}{3\Delta}(g_{22}g_{32} + g_{23}g_{33})$$

$$K_{36}^{e} = K_{63}^{e} = \frac{2}{3\Delta}(g_{12}g_{32} + g_{13}g_{33})$$

$$K_{44}^{e} = \frac{4}{3\Delta}(g_{12}^{2} + g_{13}^{2} + g_{12}g_{22} + g_{13}g_{23} + g_{22}^{2} + g_{23}^{2})$$

$$K_{45}^{e} = K_{54}^{e} = -8\,K_{13}$$

$$K_{46}^{e} = K_{64}^{e} = -8\,K_{23}$$

$$K_{55}^{e} = \frac{4}{3\Delta}(g_{22}^{2} + g_{23}^{2} + g_{22}g_{32} + g_{23}g_{33} + g_{32}^{2} + g_{33}^{2})$$

$$K_{56}^{e} = -8\,K_{12}$$

$$K_{66}^{e} = \frac{4}{3\Delta}(g_{12}^{2} + g_{13}^{2} + g_{12}g_{32} + g_{13}g_{33} + g_{32}^{2} + g_{33}^{2})$$

Considering that $g(x,y)$ is defined in two regions, we have the following elements for the matrix $\{F^{e}\}$

$$F_{g1}^{e} = 0\ ,\ F_{g2}^{e} = 0\ ,\ F_{g3}^{e} = 0\ ,\ F_{g4}^{e} = F_{g5}^{e} = F_{g6}^{e} = -\frac{g_i\Delta}{6}$$

where $g_i = g_1$ for region 1 and $g_i = g_2$ for region 2.

From Equation (20) we obtain the matrix elements of $\{F_q^{e}\}$ as

$$F_{q1}^{e} = \frac{q_0 L}{6}\ ,\ F_{q2}^{e} = \frac{q_0 L}{6}\ ,\ F_{q3}^{e} = 0\ ,\ F_{q4}^{e} = \frac{2q_0 L}{3}\ ,$$

$$F_{q5}^{e} = F_{q6}^{e} = 0.$$

where L is the characteristic dimension of the element perpendicular to the direction of the specified flux q_0.

LIST OF SYMBOLS

θ	: Plate temperature.
θ_0	: Temperature of one side of plate.
$\theta_1,\ldots,\theta_N$	: Temperature parameter in R^N space.
$\theta,\theta_1^*,\theta_2^*$	: Nondimensional temperature.
ε	: Plate geometric parameter.
ξ_1,ξ_2,ξ_3	: Area coordinates.
a,b	: Plate dimensions.
C	: Boundary condition parameter.
$g(x,y)$	: Internal heat generation.
g_1,g_2	: Internal heat generation in the two regions.
$g_{11},g_{12},\ldots,g_{66}$	: Matrix elements of Eq.(14).
G_1,G_2	: Nondimensional heat generation parameter.
i,j,k	: Suffixes.
$K^e_{ij},F^e_{qi},F^e_{gi}$	: Elements of the generalized matrices K^e, F^e_q and F^e_g.
ℓ	: Plate thickness.
N	: Total number of nodes.
n	: Total of number of elements.
$N_1,\ldots,N_6$	: Shape functions.
$q(x)$	: External heat flux.
q_0	: Constant external heat flux.
Q	: Total external heat flux.
Q_V	: Total internal heat generation.
R	: Nondimensional thermal resistance.
R_{1D}	: Nondimensional one dimensional thermal resistance.
x,y	: Rectangular coordinates.
$\bar{x},\bar{y}$	: Nondimensional coordinates.

$(\bar{x}_1,\bar{y}_1),(\bar{x}_2,\bar{y}_2)$: Nondimensional coordinates of region 1.

$(\bar{x}_3,\bar{y}_3),(\bar{x}_4,\bar{y}_4)$: Nondimensional coordinates of region 2.

$(\bar{x}_A,\bar{y}_A)$........ : Coordiantes of limiting heat flux lines.

REFERENCES

Chung, T.T. "Finite Element Analysis in Fluid Dynamics". McGraw-Hill Book Company, Inc., New York, 1978.

Crandall, S.H. "Engineering Analysis". Mc Graw-Hill Book Company, Inc., New York, p. 27, 1956.

Heuser, J. "Finite Element Method for Thermal Analysis". NASA TN D-7274, Nov. 1973.

Oliveira, H.Q.; Forslund, R.P. "The Effect of Thermal Constriction Resistance in the Design of Channel Plate Heat Exchangers". ASME Journal of Heat Transfer, 96, Ser C, 292-295 (1974).

Schneider, G.E.; Yovanovick, M.M.; Cane, R.L.D. "Thermal Resistance of a Convectively Cooled Plate With Nonuniform Applied Flux". Journal of Spacecraft and Rockets, 17, 372-376 (1980).

Venkataraman, N.S.; Cardoso, H.P.; Oliveira Filho, O.B. de. "Thermal Resistance of Convectively Cooled Plates With Applied Heat Flux and Internal Heat Generation". Report nº INPE-2291-PRE/066, Instituto de Pesquisas Espaciais, São José dos Campos, SP, Brazil, Dec. 1981. (To be published in ACTA ASTRONAUTICA).

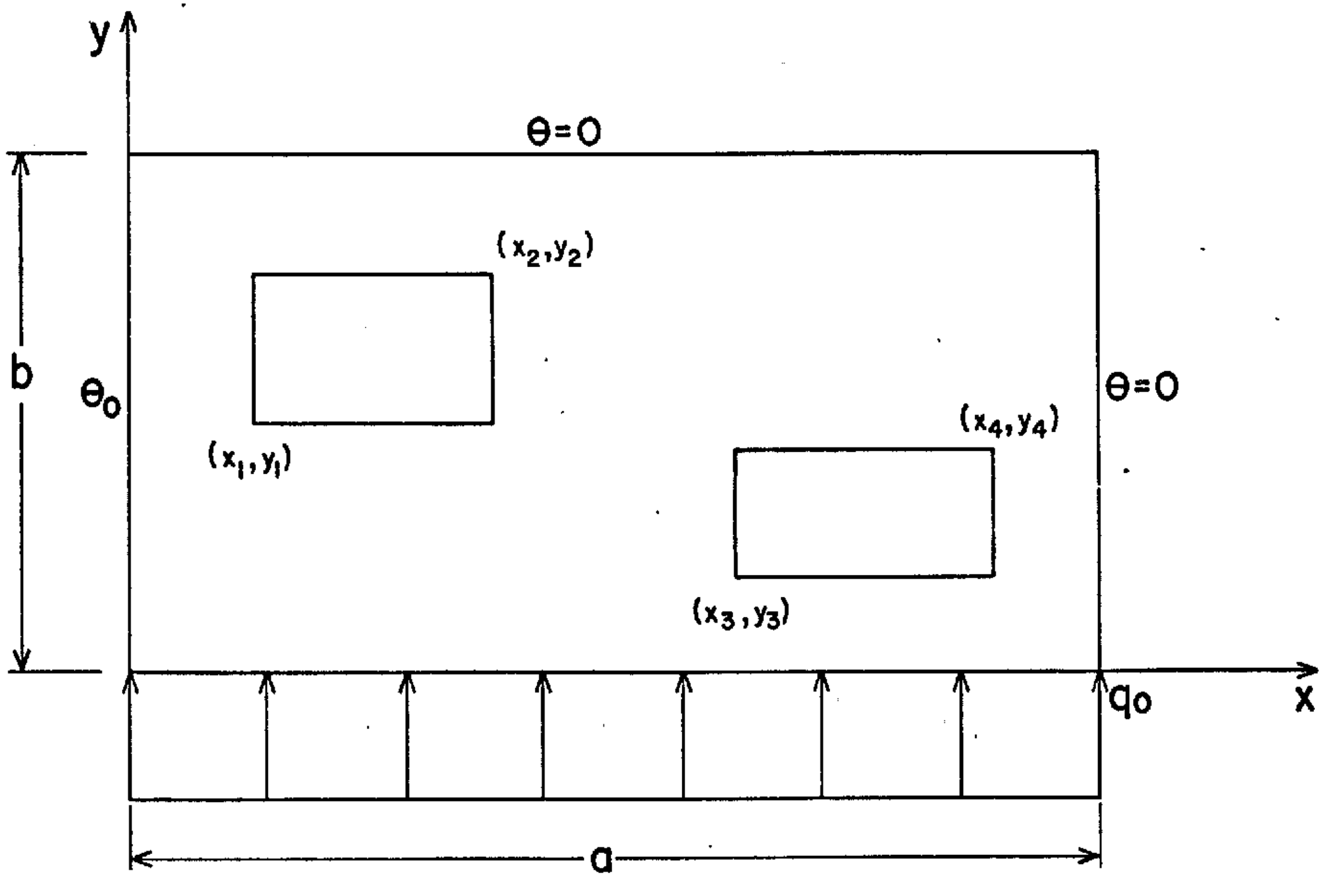

FIGURE 1 - THE GEOMETRY

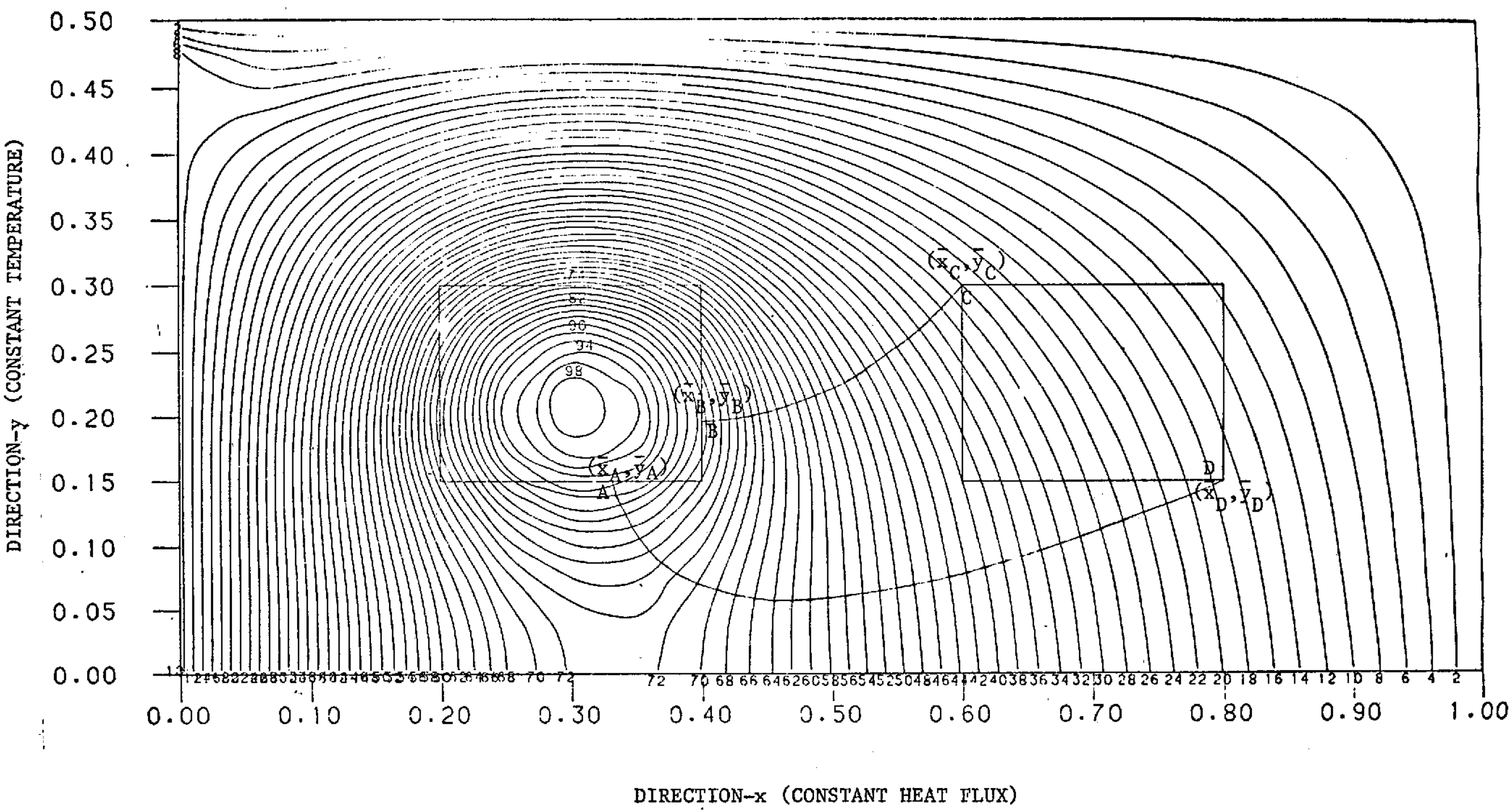

FIGURE 2 - THE DISTRIBUTION OF NORMALIZED TEMPERATURE

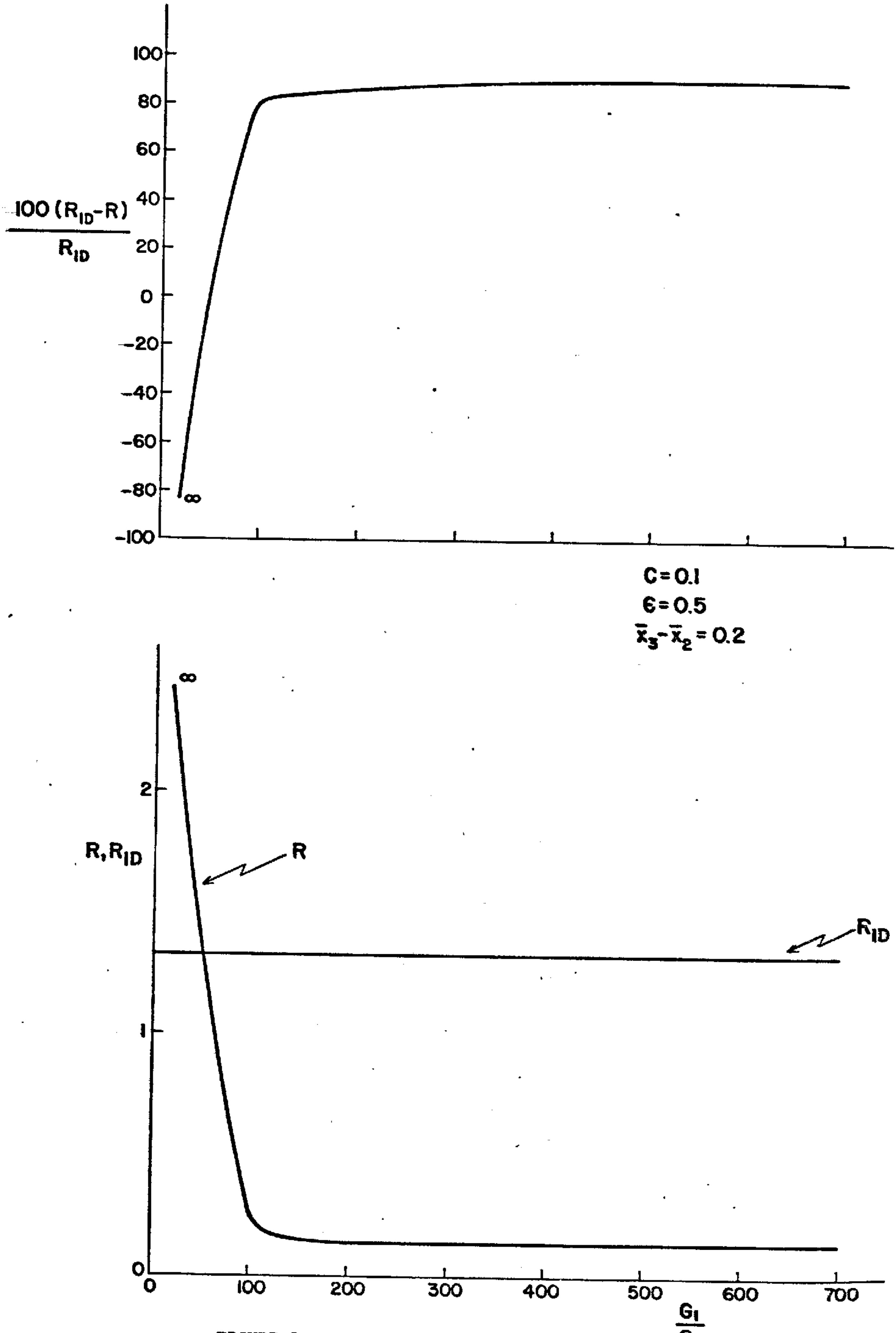

FIGURE 3 - THERMAL RESISTANCE VARIATION WITH $\frac{G_1}{G_2}$

G_1/G_2, $C = 0.1$

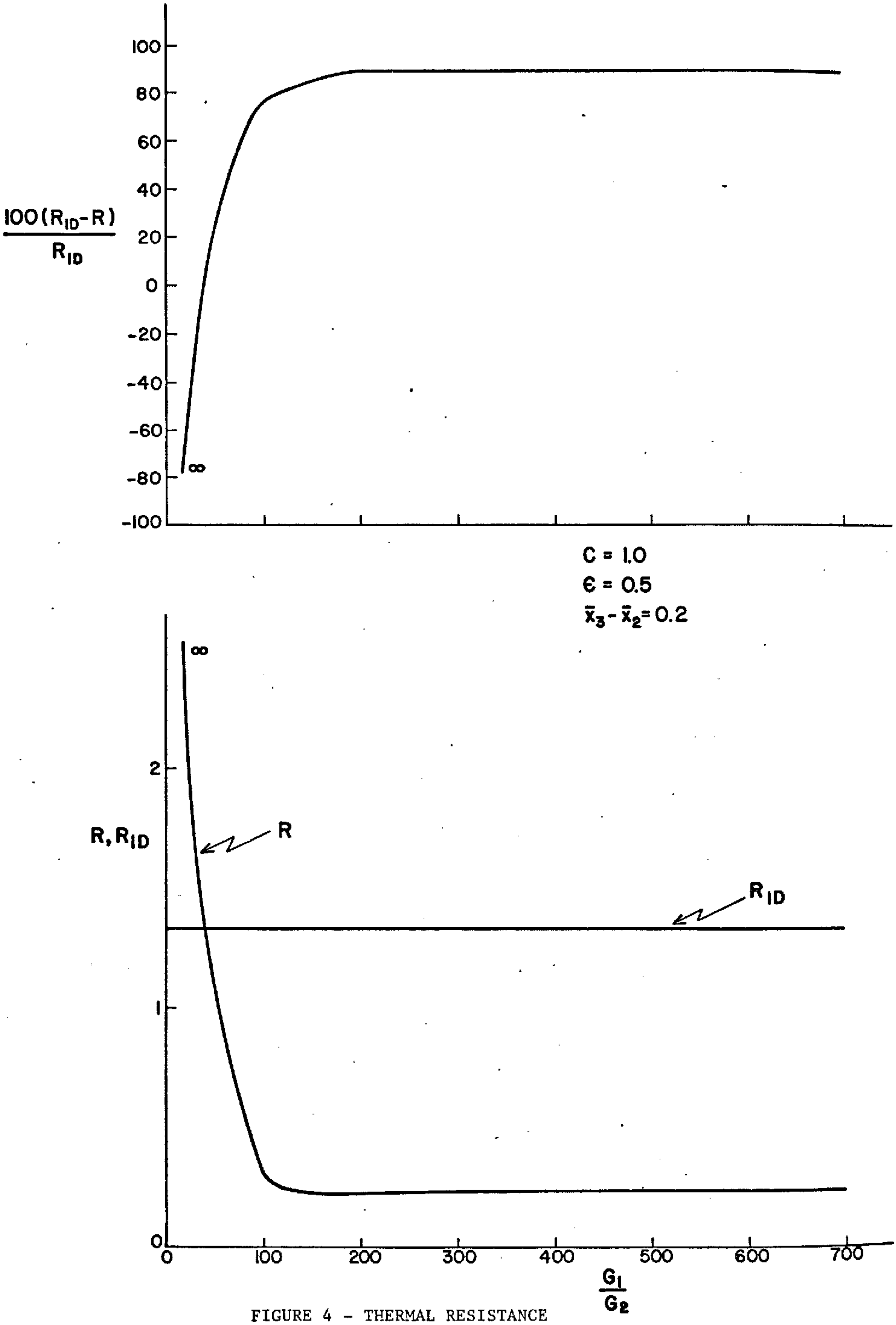

FIGURE 4 - THERMAL RESISTANCE VARIATION WITH G_1/G_2, C = 1.0

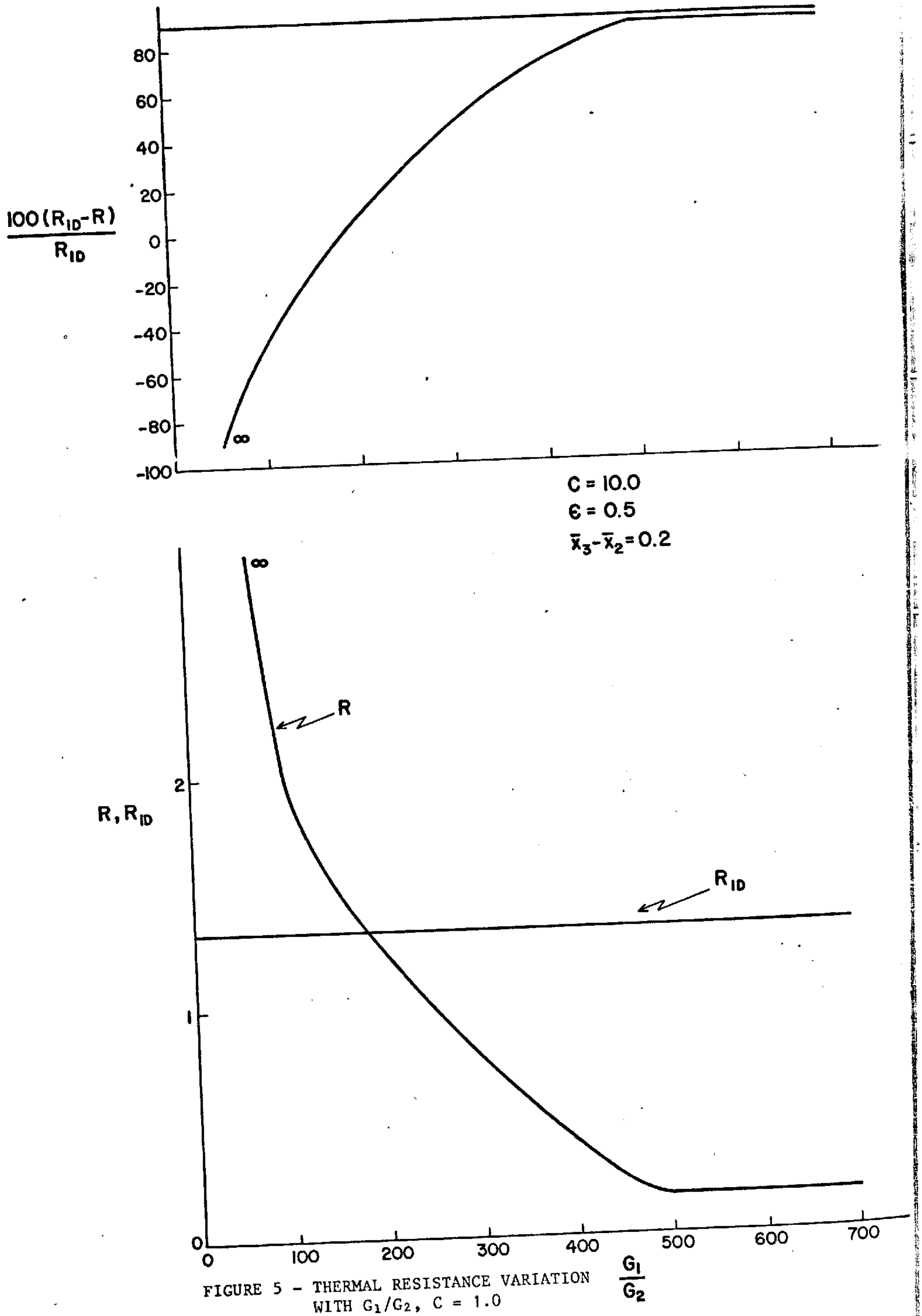

FIGURE 5 - THERMAL RESISTANCE VARIATION WITH G_1/G_2, C = 1.0

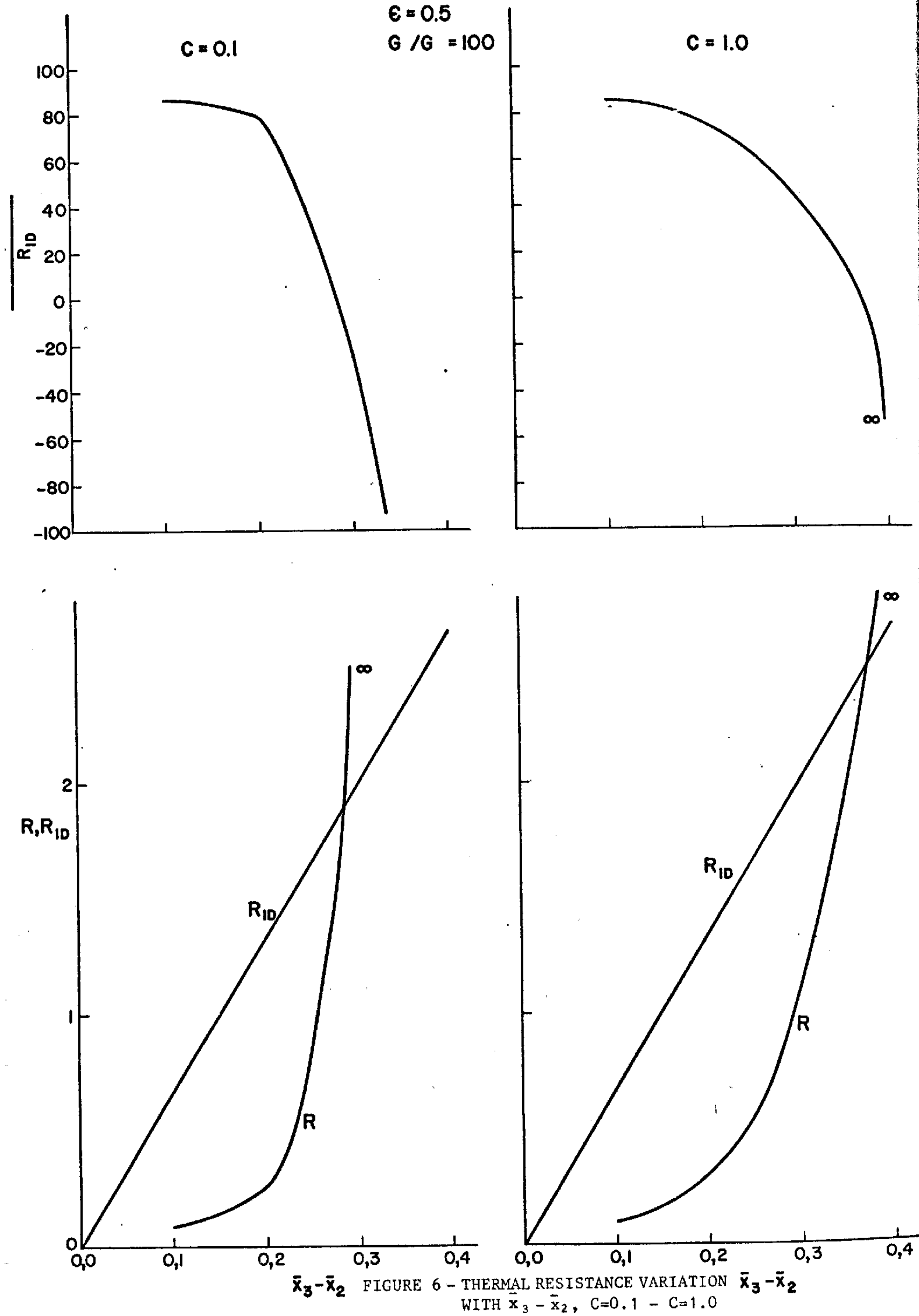

FIGURE 6 – THERMAL RESISTANCE VARIATION WITH $\bar{x}_3 - \bar{x}_2$, C=0.1 – C=1.0

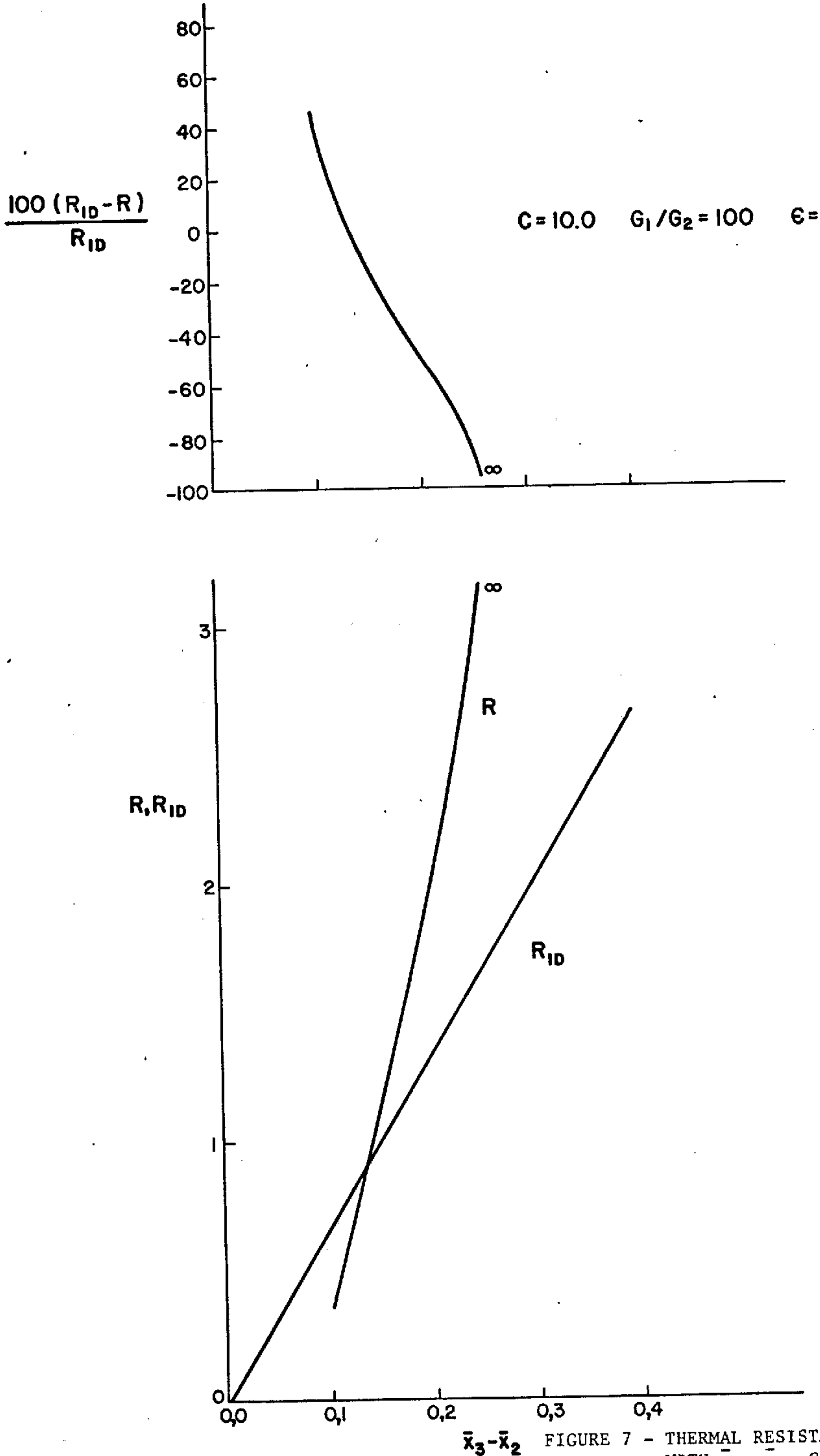

FIGURE 7 - THERMAL RESISTANCE VARIATION WITH $\bar{x}_3 - \bar{x}_2$, C=10.0

I CONGRESO LATINOAMERICANO DE TRANSFERENCIA DE CALOR Y MATERIA
I CONGRESSO LATINO AMERICANO DE TRANSFERÊNCIA DE CALOR E MATERIA
Ist. LATIN AMERICAN CONGRESS ON HEAT AND MASS TRANSFER

CL/597/82

La Plata - República Argentina - 31 de Octubre al 4 de Noviembre de 1982 22.205

NPE-2512

SANTA FE, Setiembre 13 de 1982

Doctor
Nelson de Jesús Parada
INPE
Caixa Postal 515
12200 - Sao José dos Campos
<u>BRASIL</u>

Por la presente acuso recibo del manuscrito final del trabajo: "DETERMINATION OF CONDUCTIVE THERMAL RESISTANCE OF PLATES WITH NONUNIFORM INTERNAL HEAT GENERATION AND UNDER VARIOUS BOUNDARY CONDITIONS". O.B.Oliveira Filho, S.A.Tavares y N.S.Venkataraman.

el cual ha de ser publicado en las "Actas" del I Congreso Latinoamericano de Transferencia de Calor y Materia.

Agradeciéndole su envío hago propicia la oportunidad para saludarlo muy atentamente.

p/

DR. JUAN ALBERTO BRESSAN
SECRETARIO EJECUTIVO

JAB:eg/ez

CNPq

CONSELHO NACIONAL
DE DESENVOLVIMENTO
CIENTÍFICO E TECNOLÓGICO

26 July, 1982.

Dr. Juan Alberto Bressan
Secretario Ejecutivo
Comite Argentino de Transferencia
de Calor y Materia
Casilla de Correo nº 91
3000, Santa Fé
República Argentina

Ref.: 30.650.200.006/82

Dear Dr. Bressan:

I thank you for informing that our papers, 1) Determination of Conductive Thermal Resistance of Plates With Non-uniform Internal Heat Generation and Under Various Boundary Conditions and 2) Wall Temperature Distribuition in a Cylindrical Thermo-vacuum Chamber, have been accepted for presentation in the congress.

I am sending again the abstracts of these two papers prepared as per your format.

Thanking you once again.

Sincerely yours

N S Venkataraman
Nellore S. Venkataraman

NSV/abg

Mailing address:

INPE - C.P. 515
12200 São José dos Campos - SP
Brazil

DETERMINATION OF CONDUCTIVE THERMAL RESISTANCE OF PLATES WITH NON-UNIFORM INTERNAL HEAT GENERATION AND UNDER VARIOUS BOUNDARY CONDITIONS

Olavo B. Oliveira Filho, Santiago A. Tavares and Nellore S. Venkataraman

Instituto de Pesquisas Espaciais - INPE, Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq, C.P. 515, 12200 São José dos Campos, SP, Brasil.

ABSTRACT

The determination of the equivalent thermal resistance is important in thermal analysis and has many engineering applications. For example, in satellite thermal analysis the structure is divided into a large number of isothermal nodes and the knowledge of internodal thermal resistance is necessary for thermal analysis as well as thermal simulation. Often many of these nodes may include sources of heat dissipation like electronic components and this can be approximated as internal heat generation. This work determines the thermal conductive resistance of rectangular plates with non-uniform internal heat generation with one end subject to an external heat flux and with temperature specified on the other ends. The internal heat generation is considered in two regions, which represent thermal dissipation by two electronic boxes on the mounting plate. We are interested in determining the thermal resistance between these boxes. The governing differential equation for the temperature distribuition is solved numerically by finite difference and finite element methods and the results are compared. The nondimensional thermal resistance is a function of the plate geometry, the ratio of total internal heat generation to total heat flux, their relative positions and a parameter which relates the temperature boundary condition to the heat flux boundary condition. The influence of these parameters is discussed. A comparison is also made with the one dimensional resistance which is sometimes used for quick estimates.