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INVERSE AXISYMMETRIC BODY STUDY. (U)

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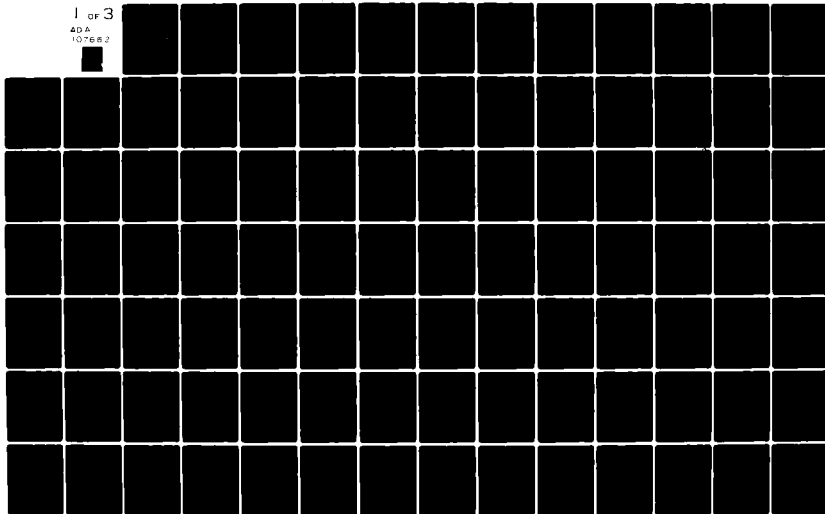
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J. J. Eisenhuth, G. H. Hoffman

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## List of Symbols

$C_p$	pressure coefficient = $\frac{p^* - p_\infty^*}{\frac{1}{2} \rho_\infty^* V_\infty^{*2}}$
$C_v$	prismatic coefficient = $\frac{\text{volume of body}}{\text{volume of cylinder}}$
$L^*$	axial length of body
$M$	pressure gradient parameter = $\frac{x}{u_e} \frac{du_e}{dx}$
$n$	exponent in conical flow formulation
$p^*$	local pressure
$p_\infty^*$	pressure in the free stream
$r_o^*$	local body radius
$r_o$	nondimensional local body radius = $\frac{r_o^*}{L^*}$
$R_\delta^*$	Reynolds number = $\frac{u_e^* \delta^*}{\nu_\infty^*}$
$S$	slope of $C_p$ curve in mid-body region = $\frac{C_{p2} - C_{p1}}{x_2 - x_1}$
$u_e^*$	velocity at the edge of boundary layer
$u_e$	nondimensional velocity at the edge of boundary layer = $\frac{u_e^*}{U_\infty^*}$
$U_\infty^*, V_\infty$	free-stream velocity
$x^*$	length along body axis—also, arc length distance along body surface
$x$	nondimensional distance = $\frac{x^*}{L^*}$
$\alpha$	constant = $\left[ (n+1)(1 - C_{p2}) - \frac{\eta_2}{2} S \right]$ [See Eq. (8)]
$\beta$	pressure gradient parameter = $\frac{2M}{M + \lambda + 1}$ , also constant = $\left[ n(1 - C_{p2}) - \frac{\eta_2}{2} S \right]$ [See Eq. (8)]
$\delta^*$	boundary layer displacement thickness

- $\eta$  relative axial distance =  $1 - x$
- $\lambda$  radius gradient parameter =  $\frac{2x}{r_o} \frac{dr_o}{dx}$
- $v_\infty^*$  kinematic viscosity in free stream
- $\xi$  normalized axial distance =  $\frac{x}{x_1}$
- $\xi_m$  value of  $\xi$  where Segments I and II of  $C_p$  curve meet

Subscripts

- 1 end location of the  $C_p$  distribution's Segment I
- 2 beginning location of the  $C_p$  distribution's Segment III
- I refers to Segment I of  $C_p$  distribution
- II refers to Segment II of  $C_p$  distribution
- III refers to Segment III of  $C_p$  distribution
- c cone
- crit critical value

Introduction

Inverse methods permit the specification of certain performance properties of a body and from this specification the generation of a compatible body profile. A potential flow inverse method, in which the pressure distribution of an axisymmetric body operating in water is specified, was developed at the Applied Research Laboratory, The Pennsylvania State University (ARL/PSU) and was reported in Reference 1. This method employs a higher order surface singularity technique using parabolic surface elements with linearly varying sources. The body shape is obtained through an iterative scheme which is rapidly convergent.

There is at present a strong need to exercise such a method in establishing some bounds on a class of bodies that lend themselves to extensive laminar flow in the forebody region, either by the shape alone or by a combination of shape and surface heat. This class of bodies requires that the pressure distribution change gradually over a major portion of the body extent and be free of abrupt peaks in the nose region. This insures the best possible environment for laminar flow.

In answer to this need, a study was undertaken in which the pressure distribution was specified in parametric form. Bodies were generated for a range of parameters and then analyzed with respect to surface heat requirements for a specific body diameter and a specific speed of operation. In the interest of presenting the data generated to date, no analysis of the turbulent boundary layer flow portion of the body nor the estimation of the overall drag is included in this report. This will be reported in a subsequent memorandum.

Pressure Distribution Specification

The approach that was used was to divide the pressure coefficient distribution into three segments as shown in Figure 1. Segment II, the largest of the three, has a constant pressure gradient and its limits are indicated by points (1) and (2). Segments I and III provide a transition from the  $C_p$  values at (1) and (2) to a value of  $C_p = 1.0$  at the nose and tail, respectively. Four parameters that can, therefore, be specified are  $x_1$ ,  $C_{p1}$ ,  $x_2$ , and  $C_{p2}$ . If these are specified, so is the slope of Segment II,

$$S = \frac{C_{p2} - C_{p1}}{x_2 - x_1} \quad (1)$$

If  $S$  is chosen, only three of the original four parameters need be specified.

Other parameters that might enter the picture would be those associated with the type of curve that is used in either Segment I or Segment III. In this study, only one type of curve definition was used in each of these two segments. Therefore, as far as this study is concerned, only four parameters were used.

Segment I: After trying a number of defining curves, the one one that was used in this study was a portion of an ellipse. The semiminor axis is the value,  $x_1$ , and the semimajor axis is approximately  $C_{p1}$ . The semimajor axis is exactly equal to  $C_{p1}$  when  $S = 0$ , but is slightly different for other  $S$  values because of a built-in requirement that curve Segments I and II meet with the same slope.

The defining equation for the  $C_p$  distribution curve in Segment I is given by:

$$C_{pI} = 1 - \left\{ \left( 1 - C_{p1}' \right)^2 \left[ 1 - (1 - \xi)^2 \right] \right\}^{\frac{1}{2}} \quad (2)$$

where

$$\xi = \frac{x}{x_1}$$

and

$$(1 - C_{p1}')^2 = \frac{\left[ (1 - C_{p1}) - \frac{x_1^2 S^2}{(1 - C_{p1})} \right]}{\left[ 1 - \left( \frac{S x_1}{1 - C_{p1}} \right)^2 \right]}$$

The  $C_p$  calculations for Segment I should be made only to the point:

$$\xi = \xi_m = 1 + \frac{S x_1}{(1 - C_{p1})} \quad (3)$$

This type of defining curve produces rather blunt noses when the  $x_1$  choices are relatively small. These noses do not have flat faces, but in some cases come fairly close to that type of shape.

Another type of defining curve that was tried, but not used in this study, was a parabolic one. The defining equation for this type can be written as:

$$C_{pI} = C_{p1}' + (1 - C_{p1}') (1 - \xi)^2 \quad (4)$$

where

$$\xi = \frac{x}{x_1}$$

and

$$C_{p1}' = -\frac{(1 + C_{p1})}{2} - \left[ \frac{(1 + C_{p1})^2}{4} - \left( \frac{x_1^2 S}{4} - C_{p1} \right) \right]^{\frac{1}{2}}$$

Again the  $C_p$  calculations for Segment I should be made only to a point  $\xi_m$ . In this case,  $\xi_m$  is given by:

$$\xi_m = 1 + \frac{x_1 S}{2 (1 - C_{p1}')} \quad (5)$$

The noses that result from this description are more pointed, even when the chosen  $x_1$  value is relatively small.

Segment II: A great deal more need not be said about this segment. The slope of the  $C_p$  curve is constant and is given by Equation (1). The equation for  $C_p$  in Segment II then becomes

$$C_{pII} = C_{p1} + x_1 (1 - \xi) S \quad (6)$$

with the calculations beginning at  $\xi = \xi_m$ .  $\xi$  is defined the same as it has been previously.

Segment III: The third segment was formulated by attempting to fair into the local potential flow of a cone. The local conical solution, originally derived by Mangler (see Reference 2), shows that:

$$u_c \sim \eta^n$$

from which

$$C_{p_c} = 1 - a \eta^{2n}$$

where

$$0 \leq 2n \leq 1$$

and

$$\eta = 1 - x$$

So that there will be continuity of  $C_p$  and  $(dC_p/dx)$  at point (2), the pressure coefficient can be written as:

$$C_p = 1 - a \eta^{2n} + b \eta^{(2n + 2)} \quad (7)$$

Imposing these continuity conditions, the final equation that results is:

$$C_{p_{III}} = 1 - \alpha \bar{\eta}^{-2n} + \beta \bar{\eta}^{(2n + 2)} \quad (8)$$

where

$$\alpha = \left[ (n + 1) (1 - C_{p_2}) - \frac{\eta_2}{2} s \right] \quad (9)$$

$$\beta = + \left[ n(1 - C_{p_2}) - \frac{\eta_2}{2} s \right] \quad (10)$$

and

$$\bar{\eta} = \frac{\eta}{\eta_2} = \frac{1 - x}{1 - x_2} \quad (11)$$

The choice of  $n = 0.1$  was made in this study. This was somewhat arbitrary, but it was felt that what happens from a potential flow point of view in the tail region is not as important as it is in the nose portion. On reflection, it would probably have been just as good or better to use a different value of  $n$  or to formulate the distribution by use of a parabola as discussed in the Segment I description. In an extension of this work, when we pay more attention to the shaping of the aft part of the body, more care will be taken with this aspect.

#### Body Generation Procedure and Results

Bodies were generated by choosing combinations of  $x_2$  and  $S$  as fixed parameters and then systematically varying  $x_1$  and  $C_{p1}$  to see what ranges of values of these latter parameters would permit the generation of possible bodies. When these ranges are exceeded, a body consistent with the prescribed pressure distribution is not possible.

In order to show graphically the ranges in question, contours enclosing the  $x_1 - C_{p1}$  combinations for possible body shapes are shown in Figures 2-10.  $x_2$  values of 0.7, 0.8, and 0.9 were chosen for each  $S$  value. The  $S$  values were chosen to be -0.075, 0.0, and +0.075. The  $n$  value in all cases was 0.1. Superimposed on the contour curves are lines of constant length-to-diameter ratio,  $L/D$ , and lines of constant prismatic coefficient,  $C_v$  (volume of body/volume of cylinder of same  $L/D$ ).

The numbered points, shown in Figures 2-10, represent the calculations used to determine the contours. As can be seen, these points do not lie exactly on the faired contours.

In determining the right-hand portion of a contour, successive runs were made for increments of  $\Delta x_1 = 0.01$  and a faired curve drawn through the results. Thus, the possible error in the location of the right-hand part of the contour is  $\pm 0.01$ .

Points on the left portion of the contour were restricted to  $x_1 \geq 0.01$ . The value  $x_1 = 0.01$  represents a practical lower limit for possible body shapes which conform acceptably to the present  $C_p$  parameterization. For  $x_1 < 0.01$  the direct program predicts an unacceptable overshoot in  $C_p$  in the vicinity of  $x_1$ .

This brings us then to the display of the specified  $C_p$  curves and the corresponding generated bodies for the cases shown with the contour curves. These cases will represent the extremes in body shape that can be generated within the range of fixed parameters that were chosen and are shown in Figures 11-87. In addition to the specified  $C_p$  curves and the body shapes,  $C_p$  values generated by a direct program are also shown. One can see that the direct program points match the specified distributions very well with the possible exception of the slight overshoot in the  $x_1 = 0.01$  cases.

Temperature Distribution Calculations and Results

The type of body generated in this study is amenable to the use of wall heating as a means of extending the length of its stable boundary layer region. A procedure for estimating the distribution of wall temperature and heat flux necessary to attain this objective was developed at ARL/PSU and is reported in Reference 3. The procedure makes use of two criteria, the "minimum heat" and the "maximum heat" conditions. The minimum heat criterion implies that, for a particular free-stream velocity, enough heat is added to make the local operating Reynolds number  $R_{\delta^*}$ , equal to the critical value of that Reynolds number. This should insure that there will never be any amplification of waves in the laminar boundary layer. The maximum heat criterion fixes the  $R_{\delta^*_{crit}}$  at its maximum value. Whether there is amplification depends upon the free-stream velocity and the local thickness  $\delta^*$  being high enough to have the local operating  $R_{\delta^*}$  exceed the maximum  $R_{\delta^*_{crit}}$ .

A code embodying these criteria was used in this study to provide the temperature and heat flux information for the chosen body cases. The procedure is based on the laminar characteristics resulting from similar solution of the axisymmetric boundary layer equations for water with wall heat addition. The major parameters in this procedure are the pressure gradient parameter  $\beta$  and the differential temperature between the wall and the ambient temperature. It was shown in Reference 3 that the parameter  $\beta$  can be related to two other parameters, the pressure gradient parameter  $M$  and the radius gradient parameter  $\lambda$  through the equation:

$$\beta = \frac{2M}{M + \lambda + 1} \tag{12}$$

where

$$M = \frac{x}{u_e} \frac{du_e}{dx} \tag{13}$$

and

$$\lambda = \frac{2x}{r_o} \frac{dr_o}{dx} \tag{14}$$

x here is the arc length distance along the body surface,  $u_e$  is the velocity at the edge of the boundary layer (equivalent to the tangential velocity at the body surface via potential flow theory), and  $r$  is the local body radius. Therefore, from the  $C_p$  distributions and corresponding body shapes of this study, the local values of  $\beta$  can be calculated directly from the local values of  $M$  and  $\lambda$ .

Although not used in the calculations of this study, a recently developed reformulation permits  $\beta$  to be calculated somewhat more simply by:

$$\beta = 2 \times r_o^2 \frac{du_e}{d\zeta} \quad (15)$$

where

$$\zeta = x r_o^2 u_e \quad (16)$$

The development of this alternative formulation appears in the Appendix.

The specified  $C_p$  distributions and the derived body shapes were used as inputs to the temperature and heat flux estimating procedure. The results are shown in Figures 88-241 for a vehicle velocity,  $U_\infty = 50$  fps and a maximum body diameter of 21 inches.

One of the first observations is that the temperature and heat flux distributions in the forward nose regions (Segment I) are never smooth. This is the result of the nature of the  $C_p$  and radius distributions at the nose. Although the curves of  $C_p$  (therefore  $u_e$ ) and radius versus axial distance are both smoothly varying,  $u_e$  versus arc length curves have localized changes in slope that ultimately cause irregularities in the temperature and heat flux curves. The cause of these irregularities was studied in great detail to make sure they were not a function of numerical noise by way of the spline routines used in curve fitting or the number of points that were used. The conclusion was reached that the irregularities were the result of the combination of velocity and body radius distributions and is, therefore, a phenomenon that exists for this family of bodies. The temperature and heat flux curves were drawn by using straight line segments between points. Attempts to draw these as curves with continuous slopes were not at all successful.

Given along with the graphs are values of total heating power for the extent of arc length distance along which heat is added. As can be seen, the temperature and heat flux curves stop at distances less than the full length of the body. For the minimum heat, this is an indication that the operating displacement thickness Reynolds number has exceeded the peak critical Reynolds number beyond the point where the curves end.

This further indicates that the boundary layer is unstable beyond this point and that transition is imminent. The ends of these minimum heat curves can thus be used as a conservative estimate of the transition location on each body.

One other part of the temperature heat flux study is shown in Figures 242-251. In order to show the effects of free-stream velocity on the heating requirements, values of  $V_\infty$  of 30, 40, and 60 fps were used and are shown in Figures 242-247. Along with the computations at 50 fps already shown, these give the reader some idea of the effects of forward speed. The effects of body diameter (and therefore body length) are shown in the results displayed in Figures 248-251 along with the original results of Case 22 with a body diameter of 21 inches.

#### Discussion of Results

This study provides a basis for determining the range of body shapes that are possible for one type of parameterized pressure distribution. This type of distribution permits the maintenance of laminar flow over a major portion of the body by the addition of heat to the body wall. The results that are presented are intended to be used as a catalog for quickly making a preliminary choice of a body to fit some specific requirement.

To carry the range of parameters beyond those chosen is also possible, but time and the overwhelming bulk of data did not permit this. For instance, other values of the slope  $S$  could certainly have been used. A more negative value of  $S$  would provide a greater hedge against transition. The positive  $S$  value was used primarily to show that a small adverse pressure gradient could be used without disastrous results. The value of  $x_2$  could also have been made larger, thus pushing aft the location of the body maximum diameter and again improving the chances of moving the transition location farther back on the body.

With regard to the temperature and heat flux distributions, one would certainly not provide heat in the irregular manner displayed near the nose for most of the cases. These curves could be smoothed making sure that the resulting distributions lie somewhere between the original maximum and minimum curves.

It is hoped that the presentation of these results will provide the designer with a practical means for making preliminary choices of body shapes. It should not be viewed as a final tool for the complete hydrodynamic design of an underwater body. Overall drag estimation,

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including the contribution of the aft portion of the body with its own difficult computational problems must still enter the picture and eventually be included in a completely inverse design approach. Then too, the approximate similarity considerations used in the heating calculations should be checked by the use of more sophisticated nonsimilar procedures.

References

1. Fernandez, J., "A Higher Order Surface Singularity Method for the Axisymmetric Inverse Problem," ARL/PSU Technical Memorandum, File No. 79-125, June 25, 1979.
2. Rosenhead, L., Laminar Boundary Layers, Oxford at the Clarendon Press, 1963, pp. 428-430.
3. Eisenhuth, J. J. and Hoffman, G. H., "A Simplified Method for Predicting Body Temperature Distribution in the Preliminary Design of Heated Underwater Vehicles," ARL/PSU Technical Memorandum, File No. 79-02, January 4, 1979.

Appendix

Calculation of  $\beta$

By definition

$$\beta = \frac{2M}{M + \lambda + 1} \tag{A-1}$$

where

$$M = \frac{x}{u_e} \frac{du_e}{dx} \tag{A-2}$$

$$\lambda = \frac{2x}{r_o} \frac{dr_o}{dx} \tag{A-3}$$

A single expression for  $\beta$  can be found in which it is not necessary to perform the intermediate steps of calculating  $M$  and  $\lambda$ . This expression can be derived as follows:

$$\frac{M + \lambda}{x} = \frac{1}{u_e} \frac{du_e}{dx} + \frac{2}{r_o} \frac{dr_o}{dx} = \frac{1}{u_e r_o^2} \frac{d}{dx} (u_e r_o^2) \tag{A-4}$$

Therefore, the denominator of Equation (A-1) becomes:

$$M + \lambda + 1 = \frac{x}{u_e r_o^2} \frac{d}{dx} (u_e r_o^2) + 1 \tag{A-4}$$

$$M + \lambda + 1 = \frac{1}{u_e r_o^2} \left[ x \frac{d}{dx} (u_e r_o^2) + u_e r_o^2 \right] \tag{A-4}$$

$$M + \lambda + 1 = \frac{1}{u_e r_o^2} \frac{d}{dx} (x r_o^2 u_e) \tag{A-5}$$

Substituting Equation (A-2) and Equation (A-5) in Equation (A-1):

$$\beta = \frac{\frac{2x}{u_e} \frac{du_e}{dx}}{\frac{1}{u_e r_o^2} \frac{d}{dx} (x r_o^2 u_e)} = \frac{2x r_o^2 \frac{du_e}{dx}}{\frac{d}{dx} (x r_o^2 u_e)}$$

or finally,

$$\beta = 2x r_o^2 \frac{du_e}{d\zeta} \tag{A-6}$$

where

$$\zeta = x r_o^2 u_e \tag{A-7}$$

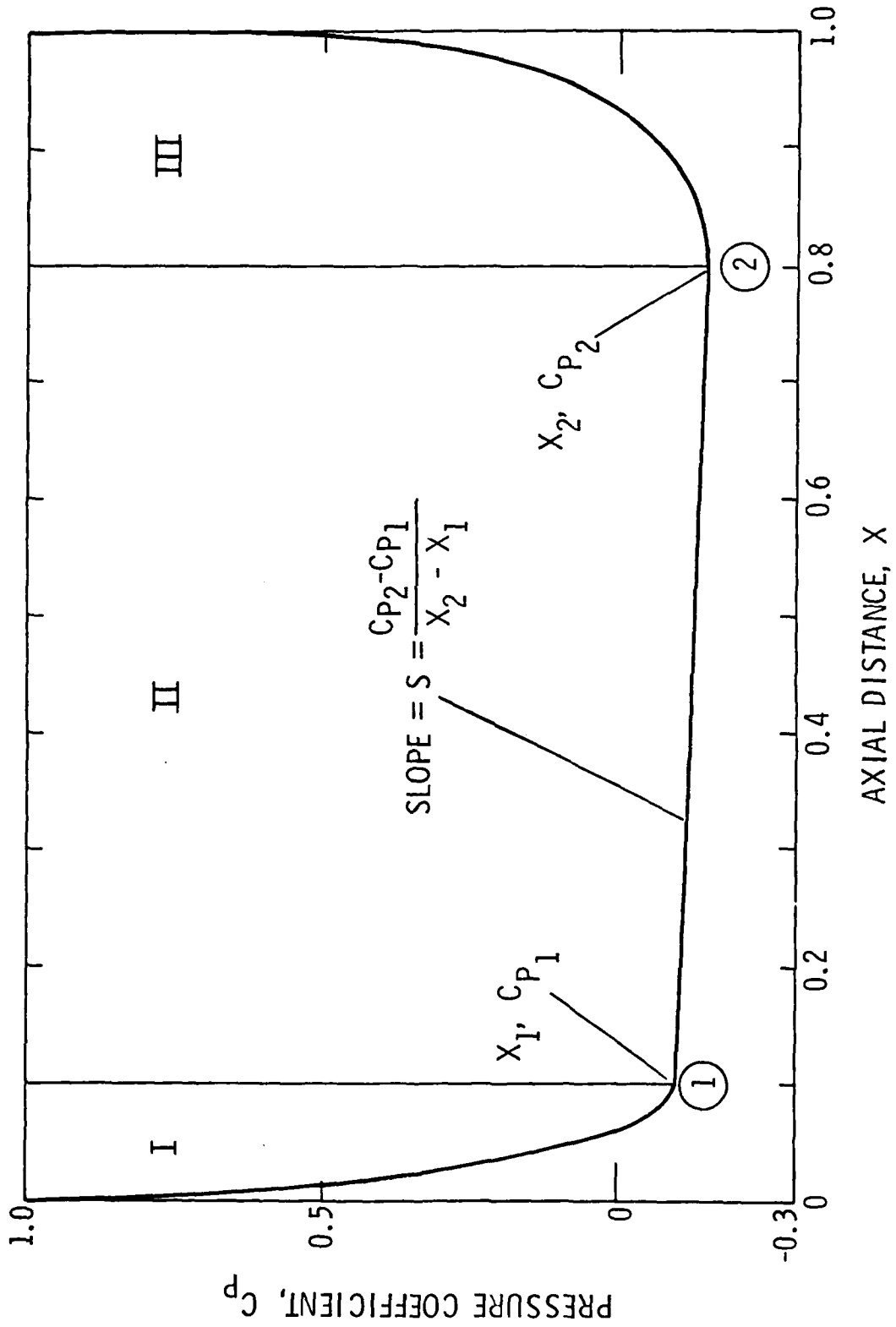


Figure 1. Parameterized Pressure Distribution.

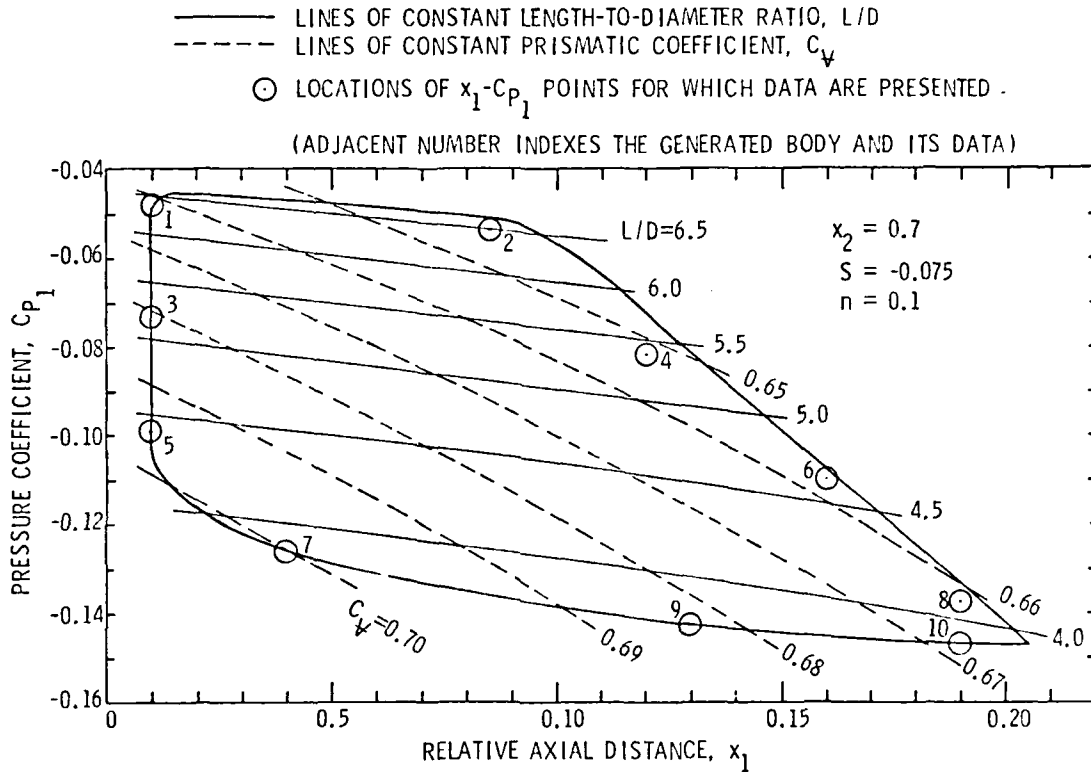


Figure 2. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.7$ ,  $S = -0.075$ ).

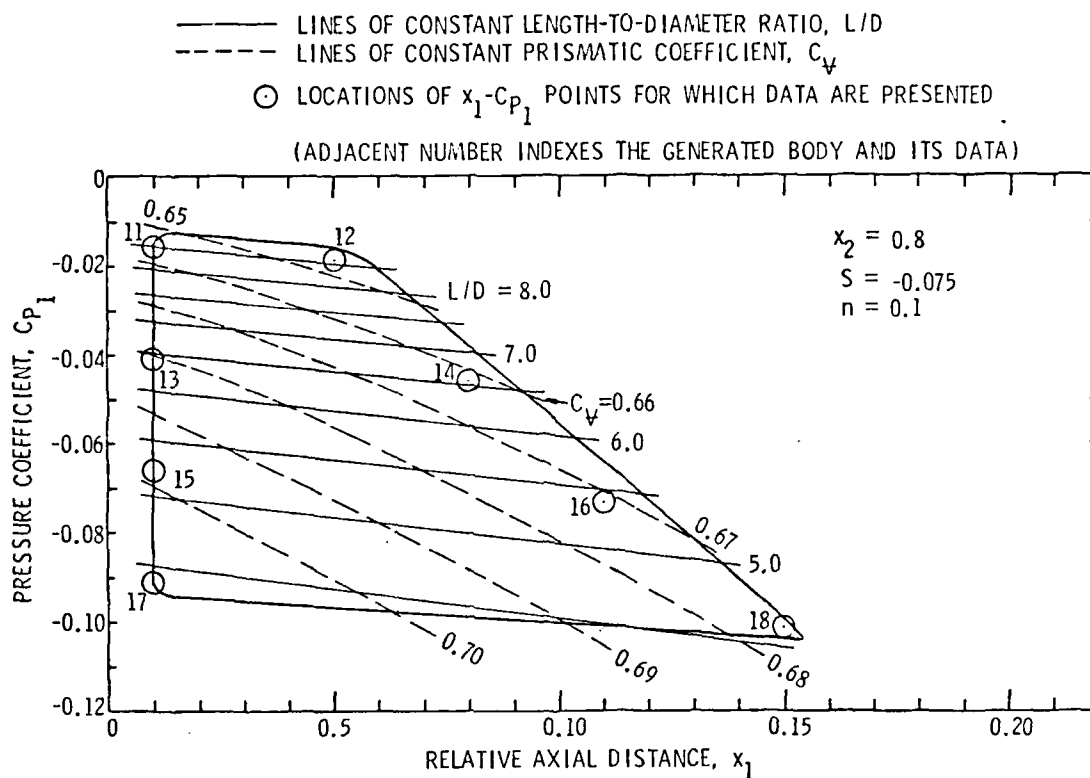


Figure 3. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.8$ ,  $S = -0.075$ ).

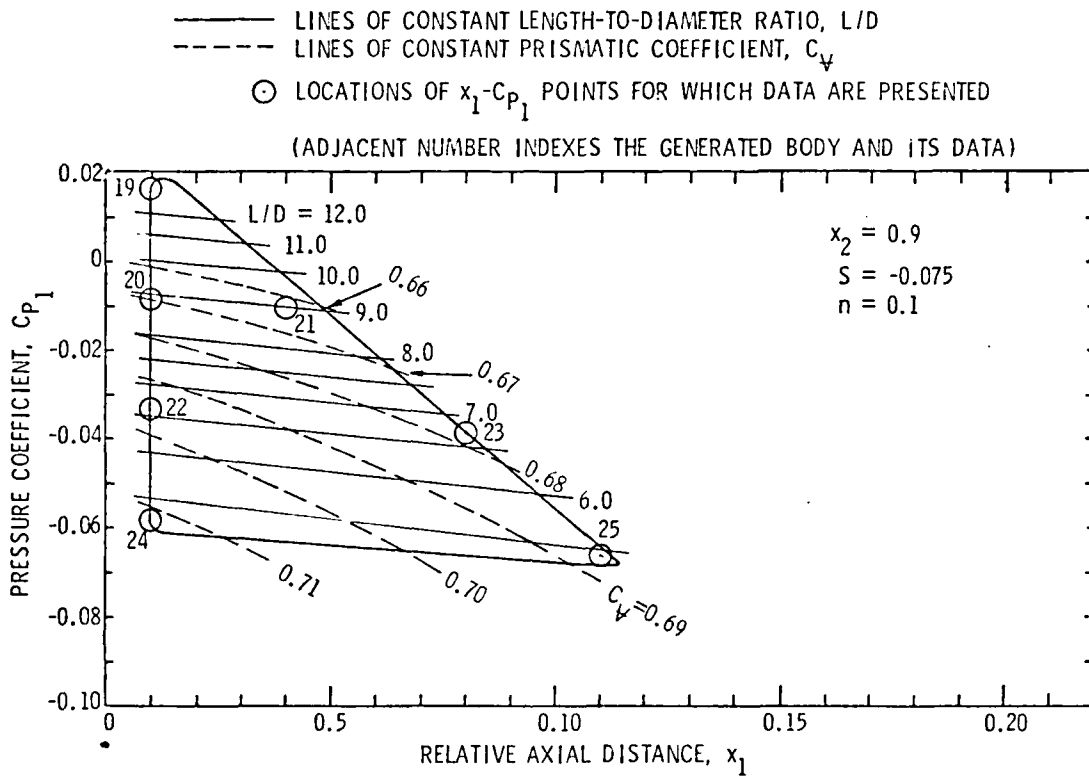


Figure 4. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.9$ ,  $S = -0.075$ ).

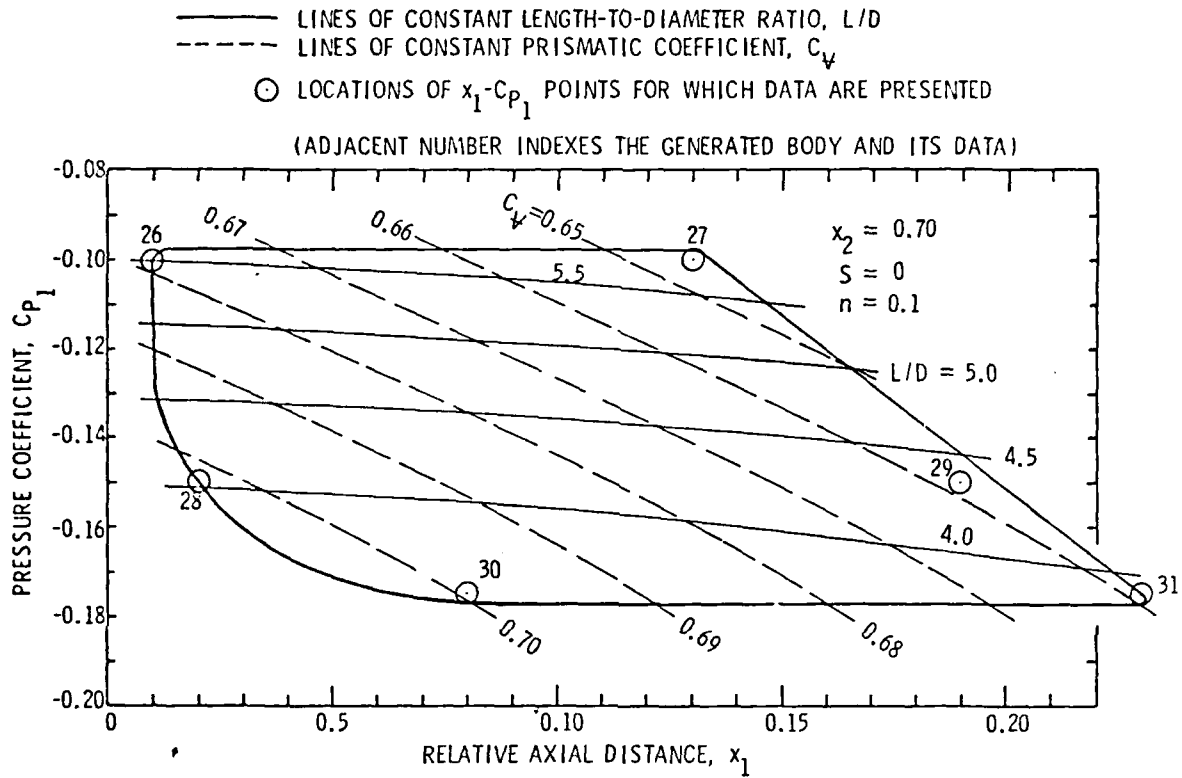


Figure 5. Parameter Contour for Possible Body Shapes ( $x_2 = 0.7$ ,  $S = 0.0$ ).

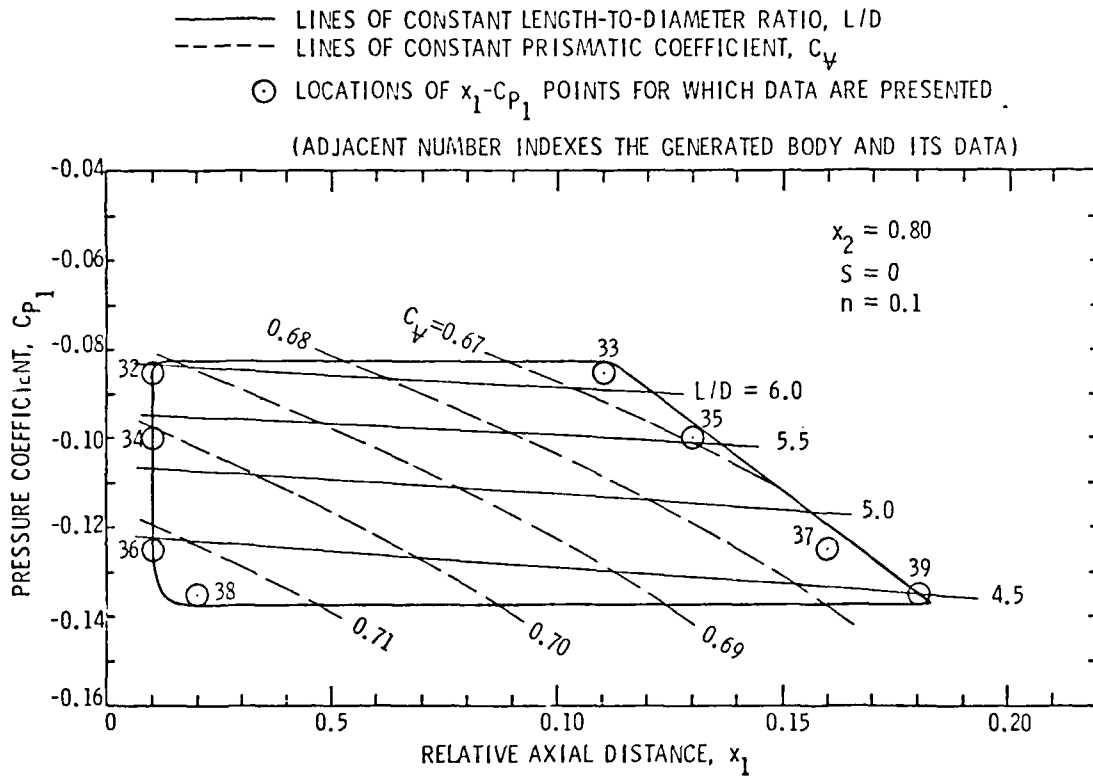


Figure 6. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.8$ ,  $S = 0.0$ ).

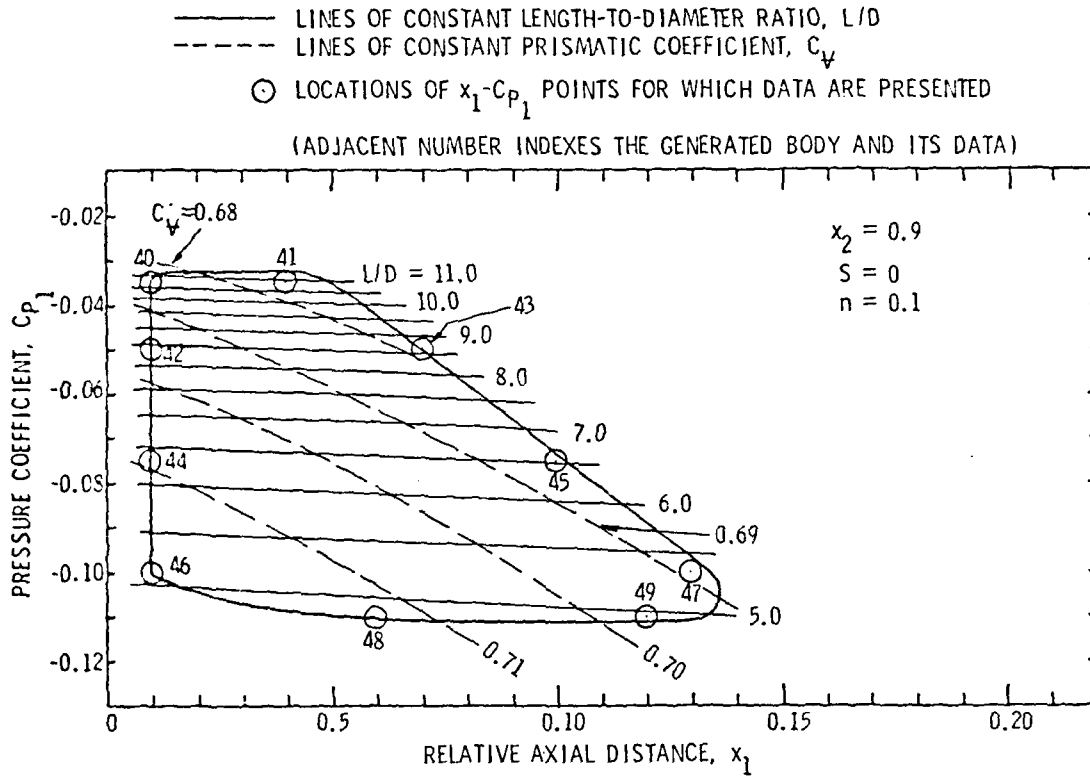


Figure 7. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.9$ ,  $S = 0.0$ ).

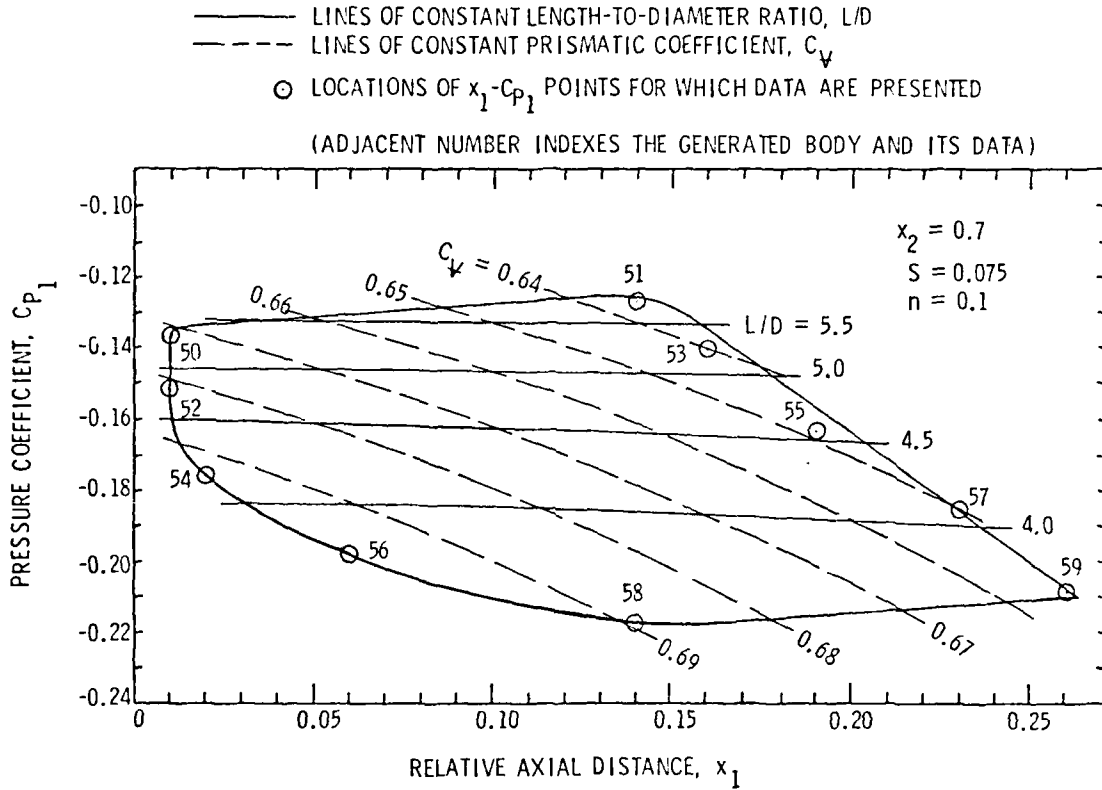


Figure 8. Parameter Contour for Possible Body Shapes ( $x_2 = 0.7$ ,  $S = 0.075$ ).

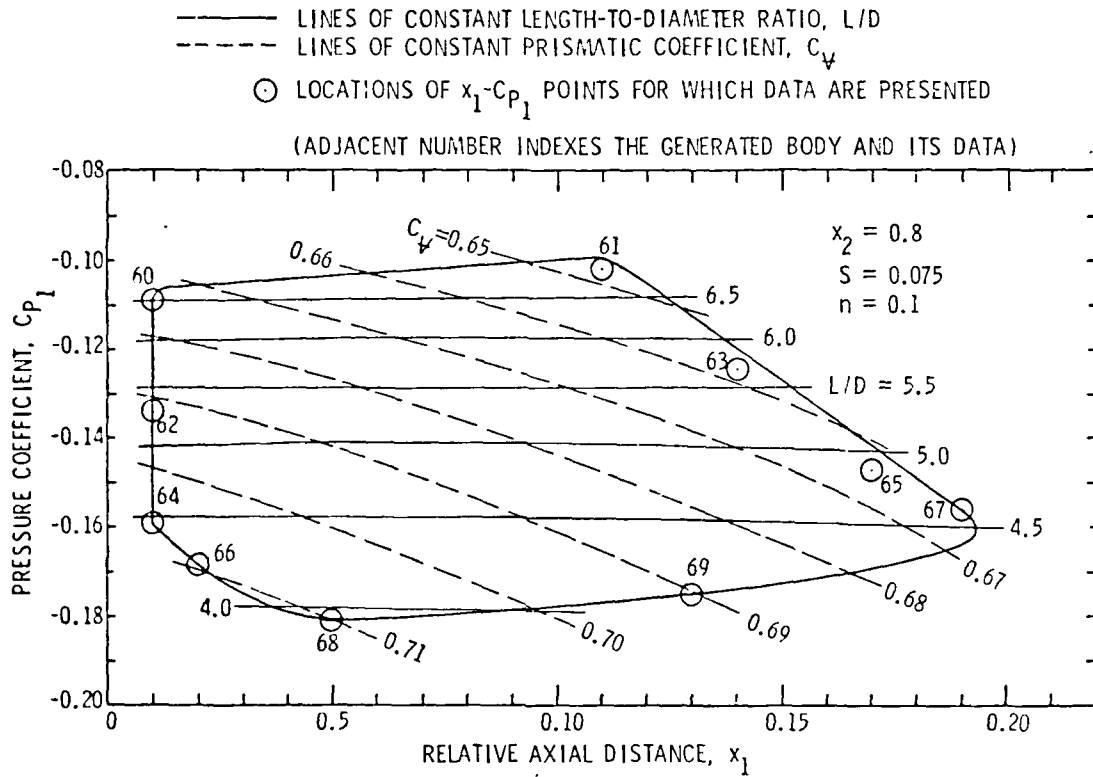


Figure 9. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.8$ ,  $S = 0.075$ ).

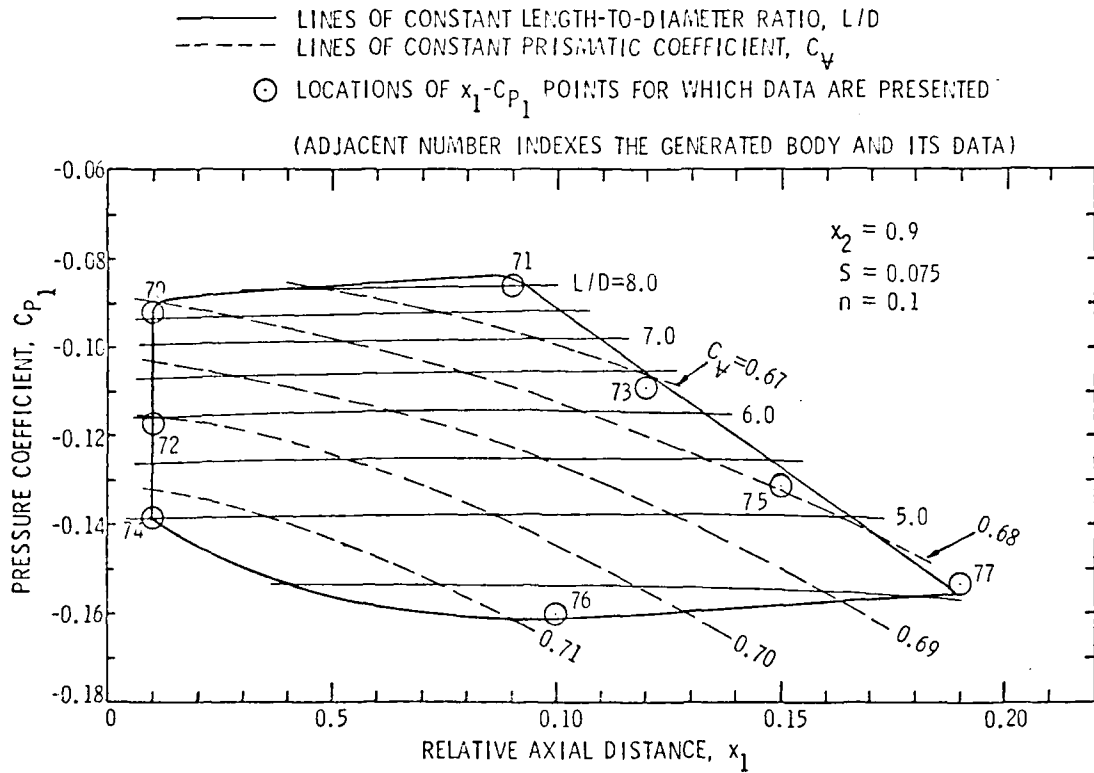


Figure 10. Parameter Contour for Possible Body Shapes  
( $x_2 = 0.9$ ,  $S = 0.075$ ).

# INVERSE BODY CASE 1

X1= 0.010  
CP1= -0.048250  
X2= 0.700  
CP2= -0.106000  
S= -0.075  
N= 0.10

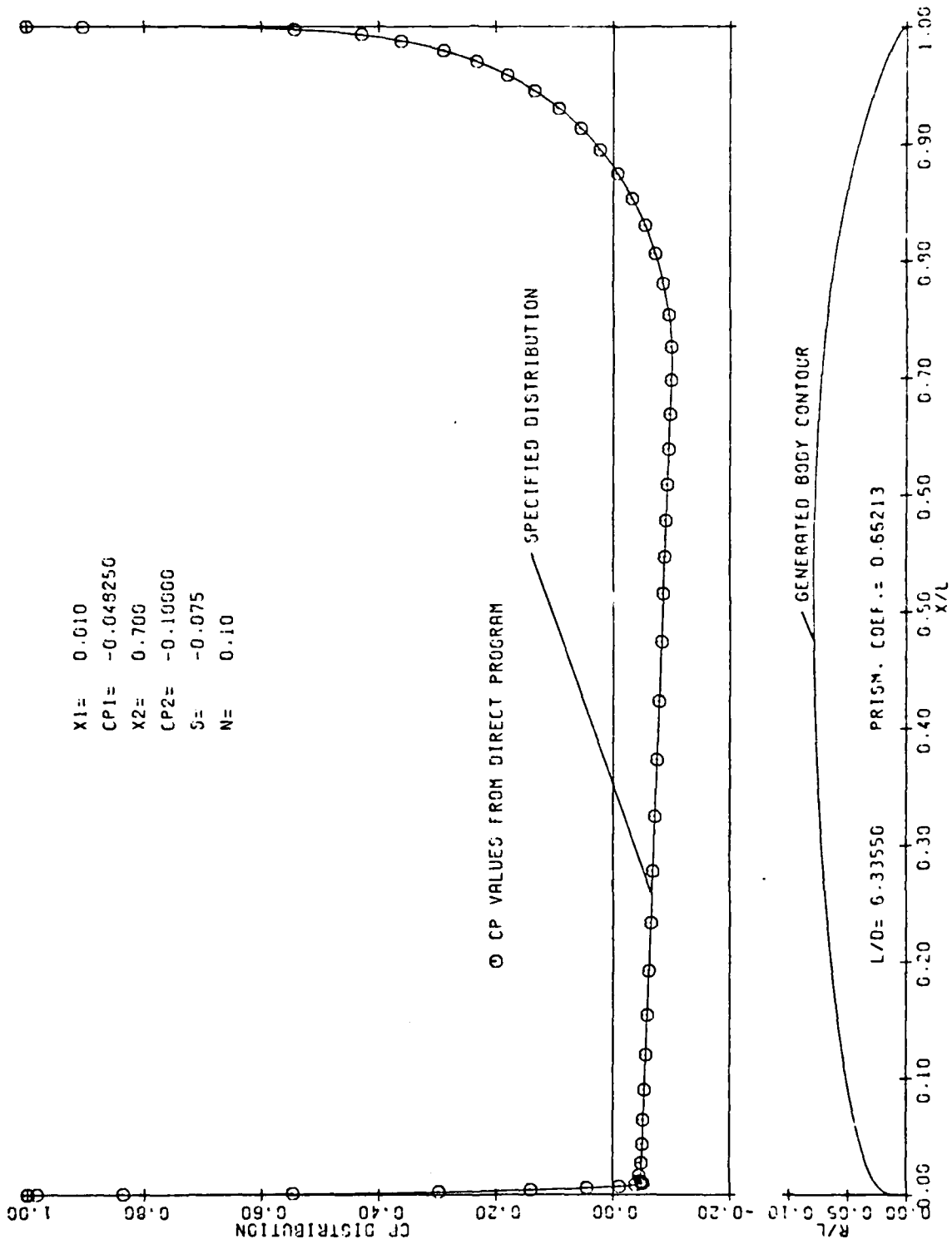


Figure 11. Pressure Distribution and Body Contour, Case No. 1.

# INVERSE BODY CASE 2

X1= 0.095  
CP1= -0.053370  
X2= 0.700  
CP2= -0.10000  
S= -0.075  
N= 0.10

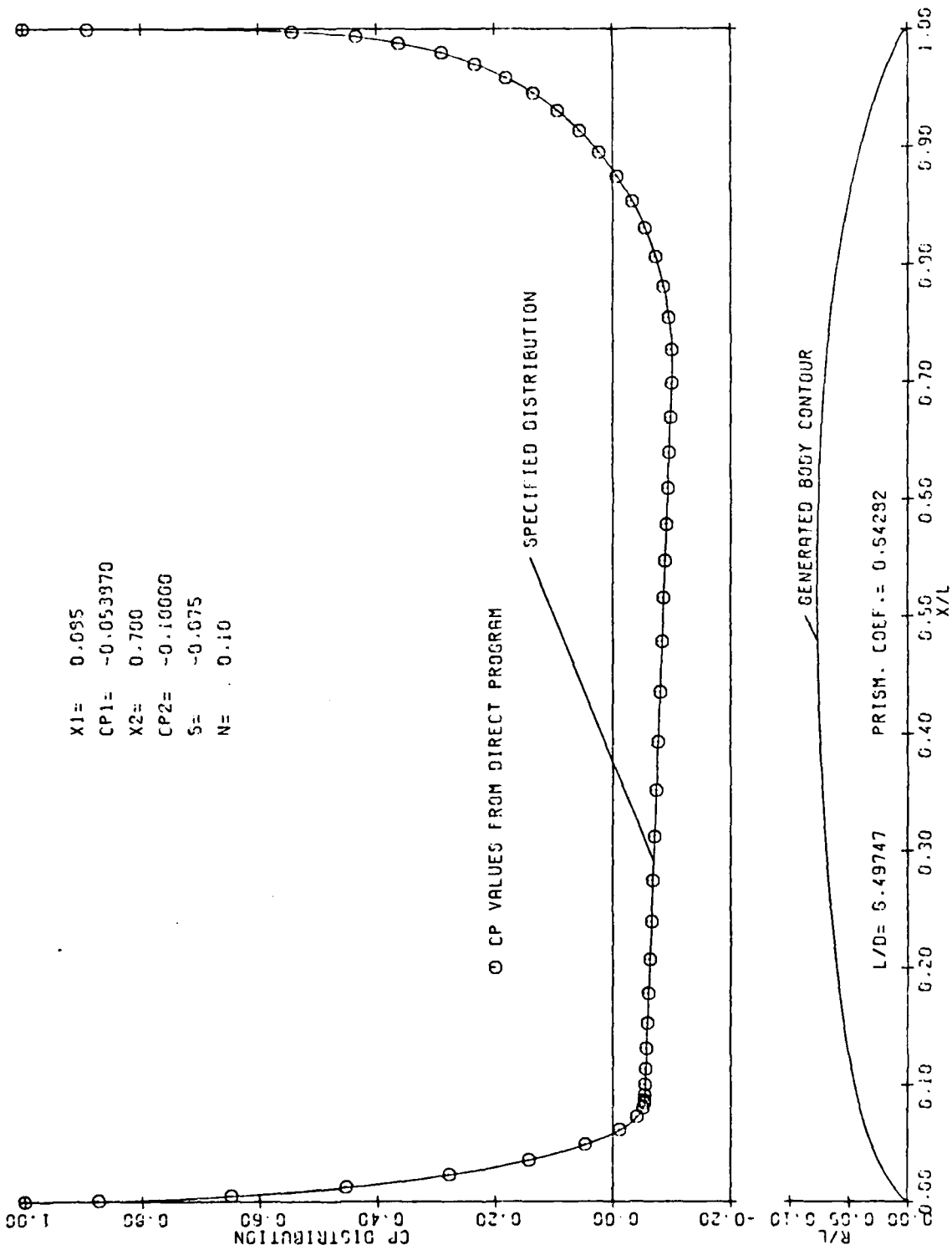


Figure 12. Pressure Distribution and Body Contour, Case No. 2.

# INVERSE BODY CASE 3

X1= 0.010  
CP1= -0.073250  
X2= 0.700  
CP2= -0.12500  
S= -0.075  
N= 0.10

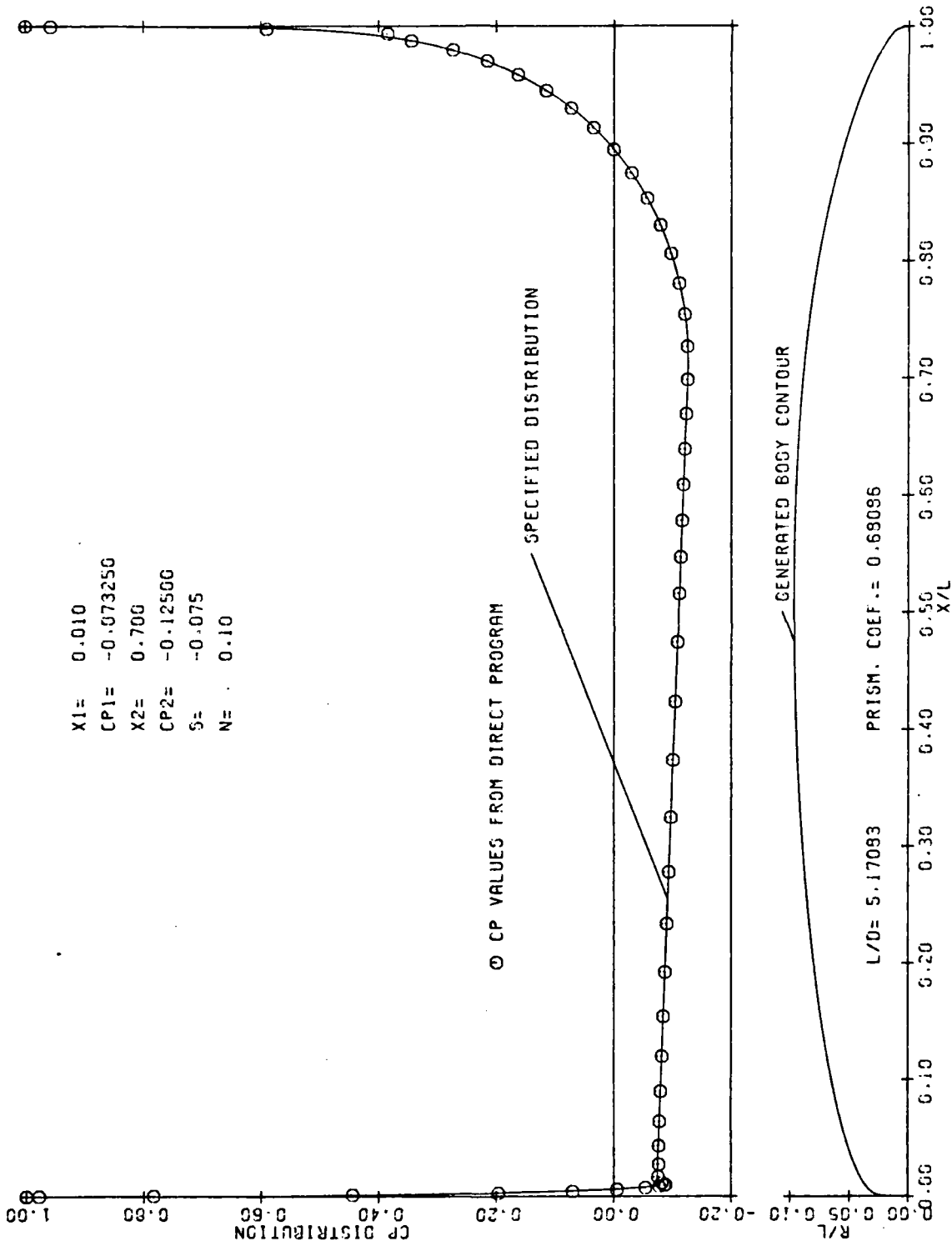


Figure 13. Pressure Distribution and Body Contour, Case No. 3.

# INVERSE BODY CASE 4

X1= 0.120  
CP1= -0.091500  
X2= 0.706  
CP2= -0.12500  
S= -0.075  
N= 0.10

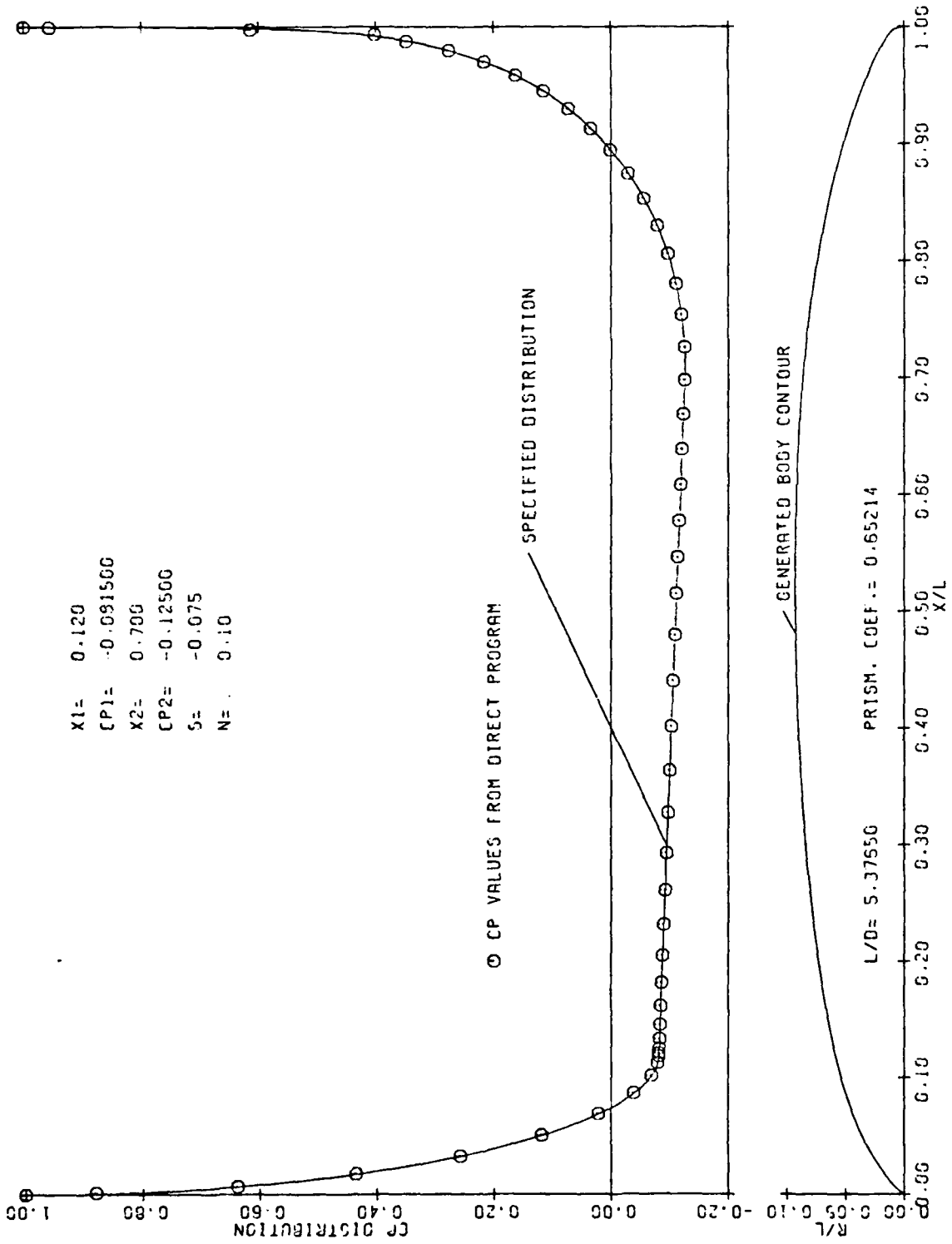


Figure 14. Pressure Distribution and Body Contour, Case No. 4.

# INVERSE BODY CASE 5

X1= 0.010  
 CP1= -0.09250  
 X2= 0.700  
 CP2= -0.15000  
 S= -0.075  
 N= 0.10

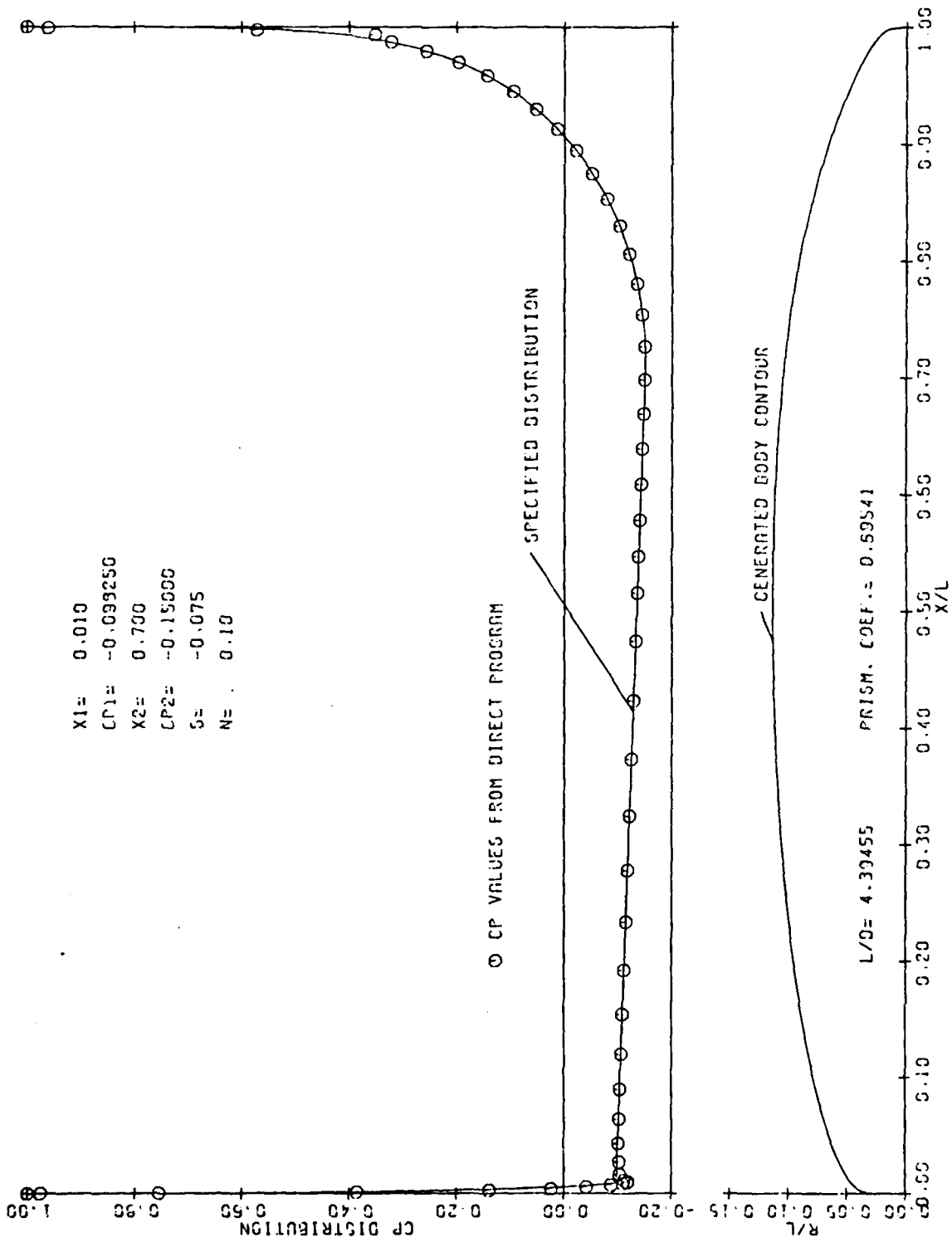


Figure 15. Pressure Distribution and Body Contour, Case No. 5.

# INVERSE BODY CASE 6

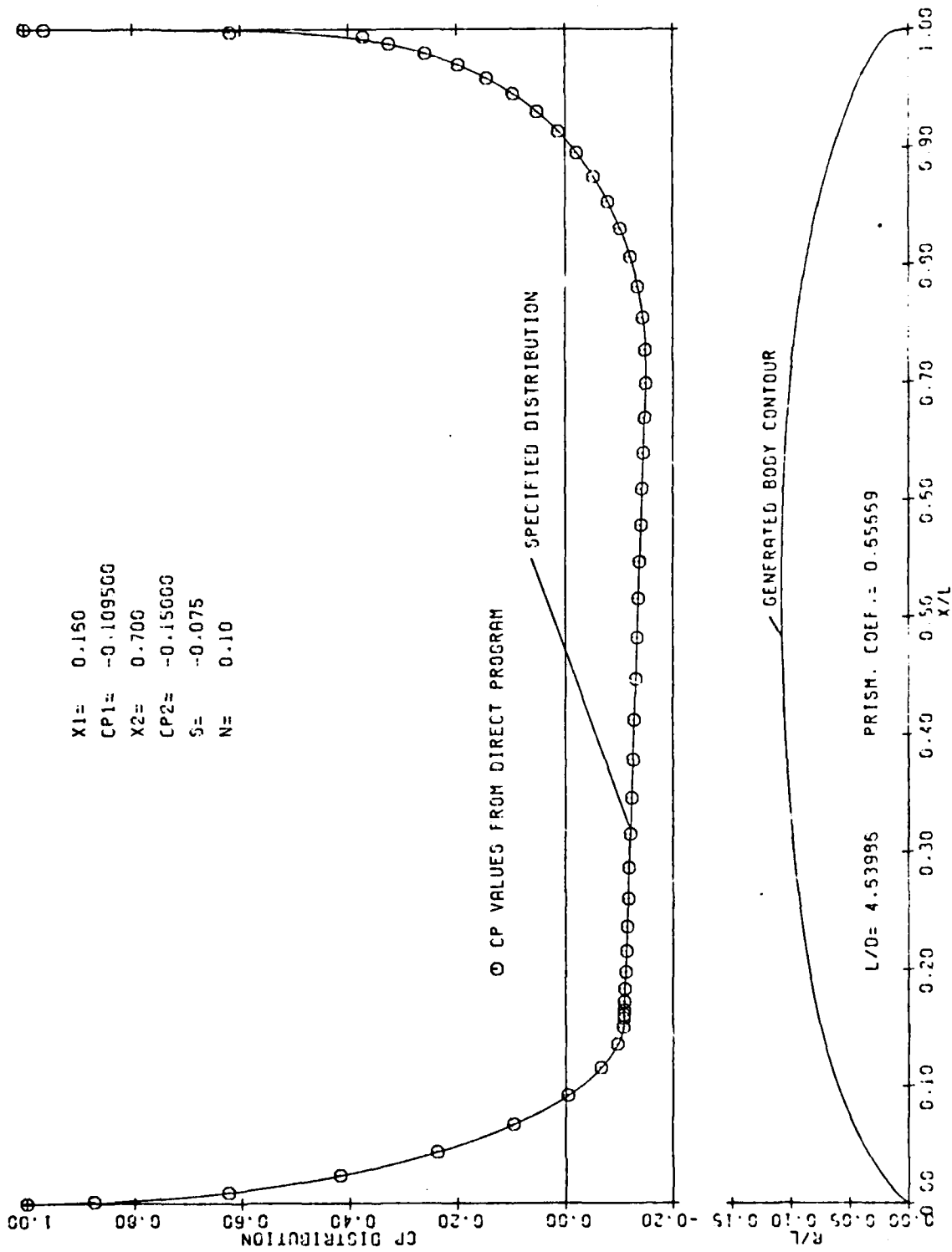


Figure 16. Pressure Distribution and Body Contour, Case No. 6.

# INVERSE BODY CASE 7

X1= 0.040  
CP1= -0.125500  
X2= 0.700  
CP2= -0.17500  
S= -0.075  
N= 0.10

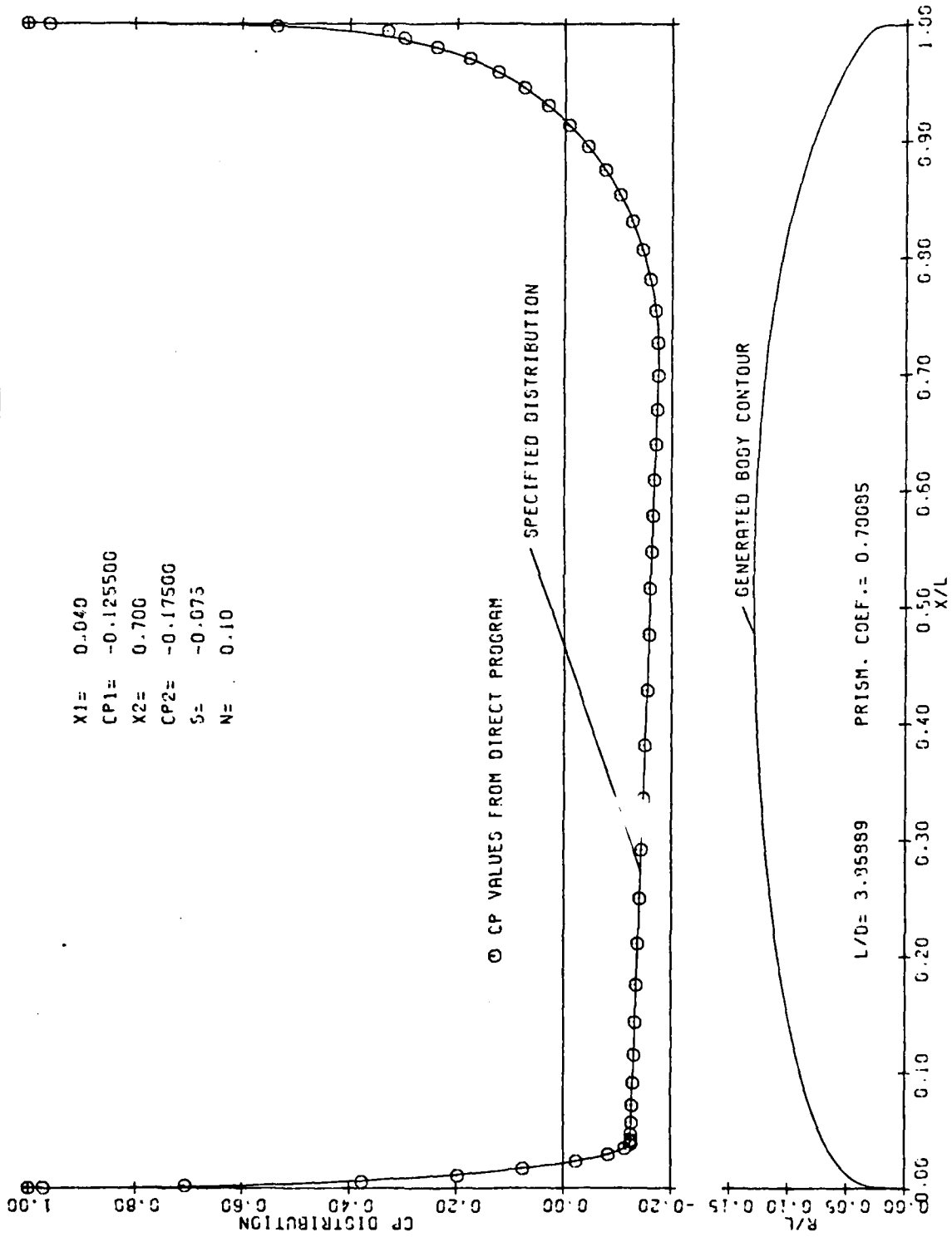


Figure 17. Pressure Distribution and Body Contour, Case No. 7.

# INVERSE BODY CASE 8

X1= 0.190  
CP1= -0.136750  
X2= 0.700  
CP2= -0.17500  
S= -0.075  
N= 0.10

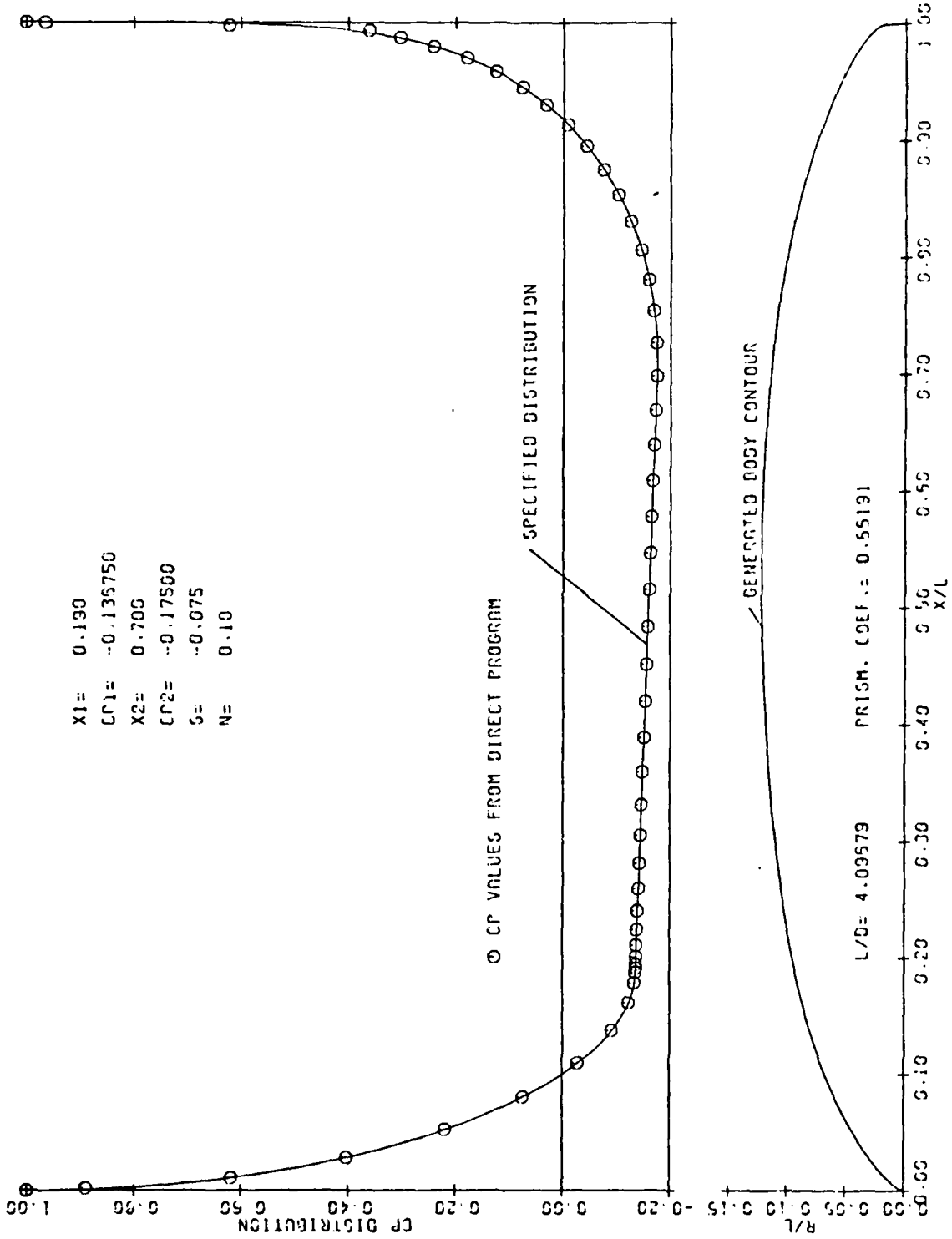


Figure 18. Pressure Distribution and Body Contour, Case No. 8.

# INVERSE BODY CASE 9

X1= 0.130  
CP1= -0.142250  
X2= 0.700  
CP2= -0.19500  
S= -0.075  
N= 0.10

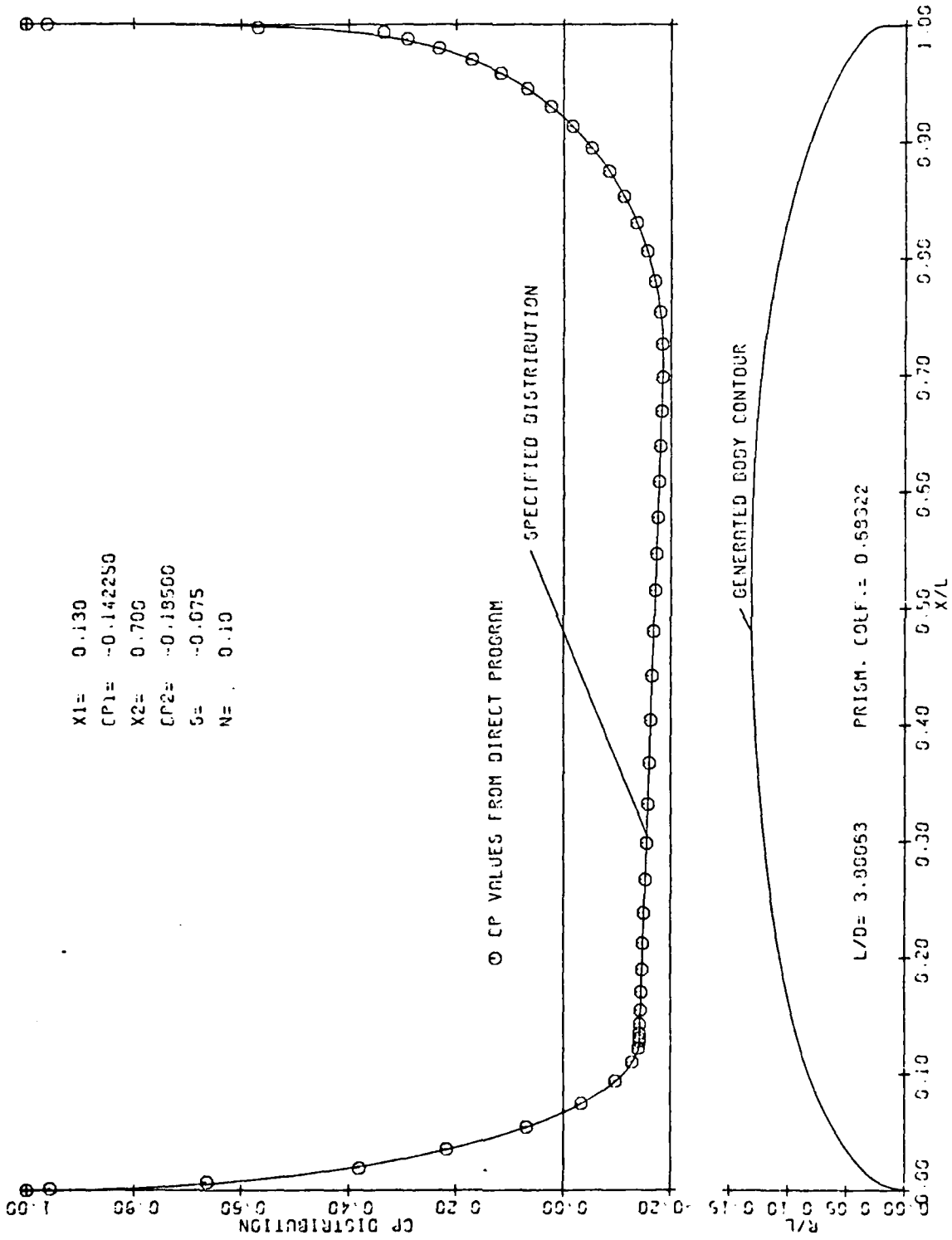


Figure 19. Pressure Distribution and Body Contour, Case No. 9.

# INVERSE BODY CASE 10

X1= 0.190  
CP1= -0.145750  
X2= 0.700  
CP2= -0.18500  
S= -0.075  
N= 0.10

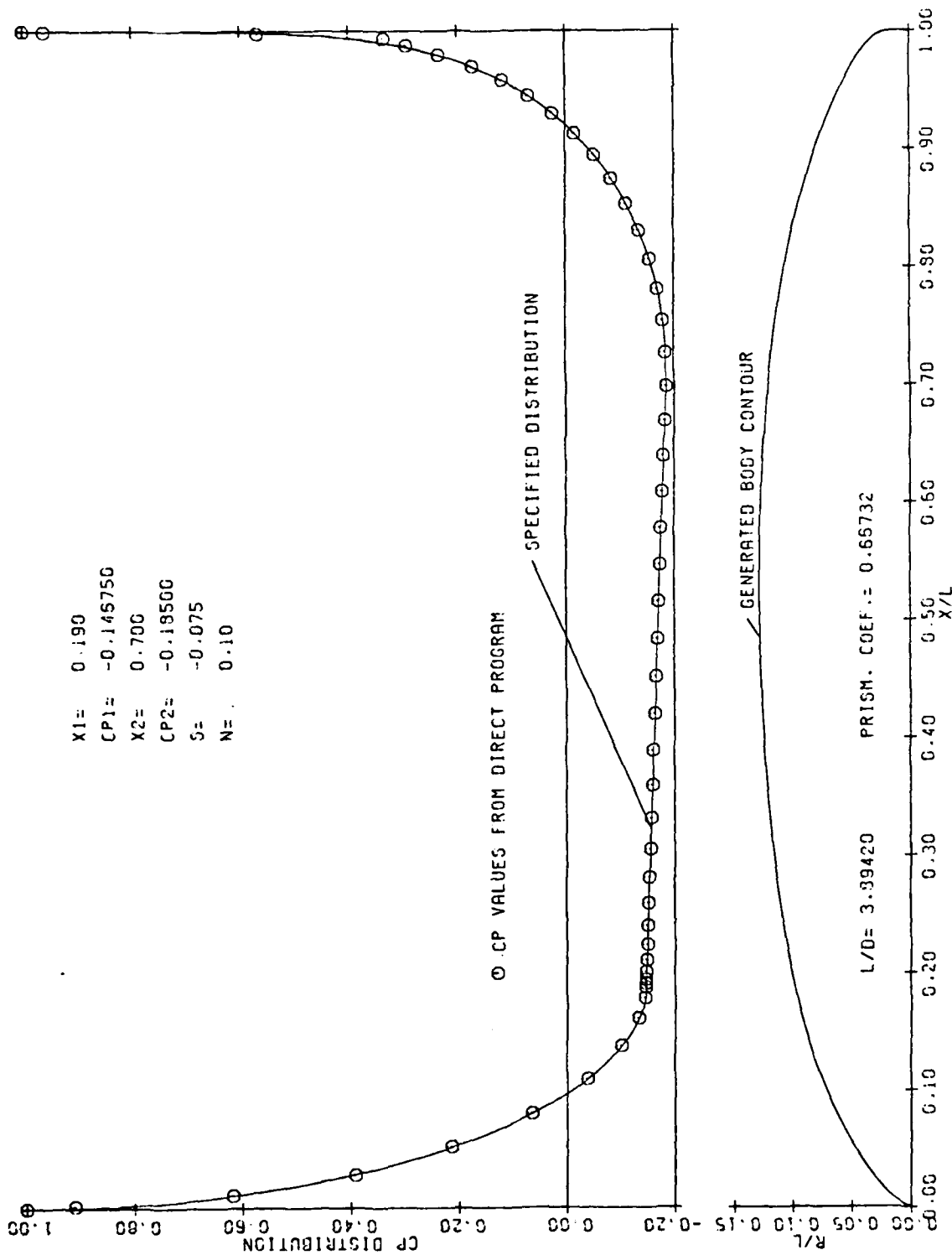


Figure 20. Pressure Distribution and Body Contour, Case No. 10.

# INVERSE BODY CASE 11

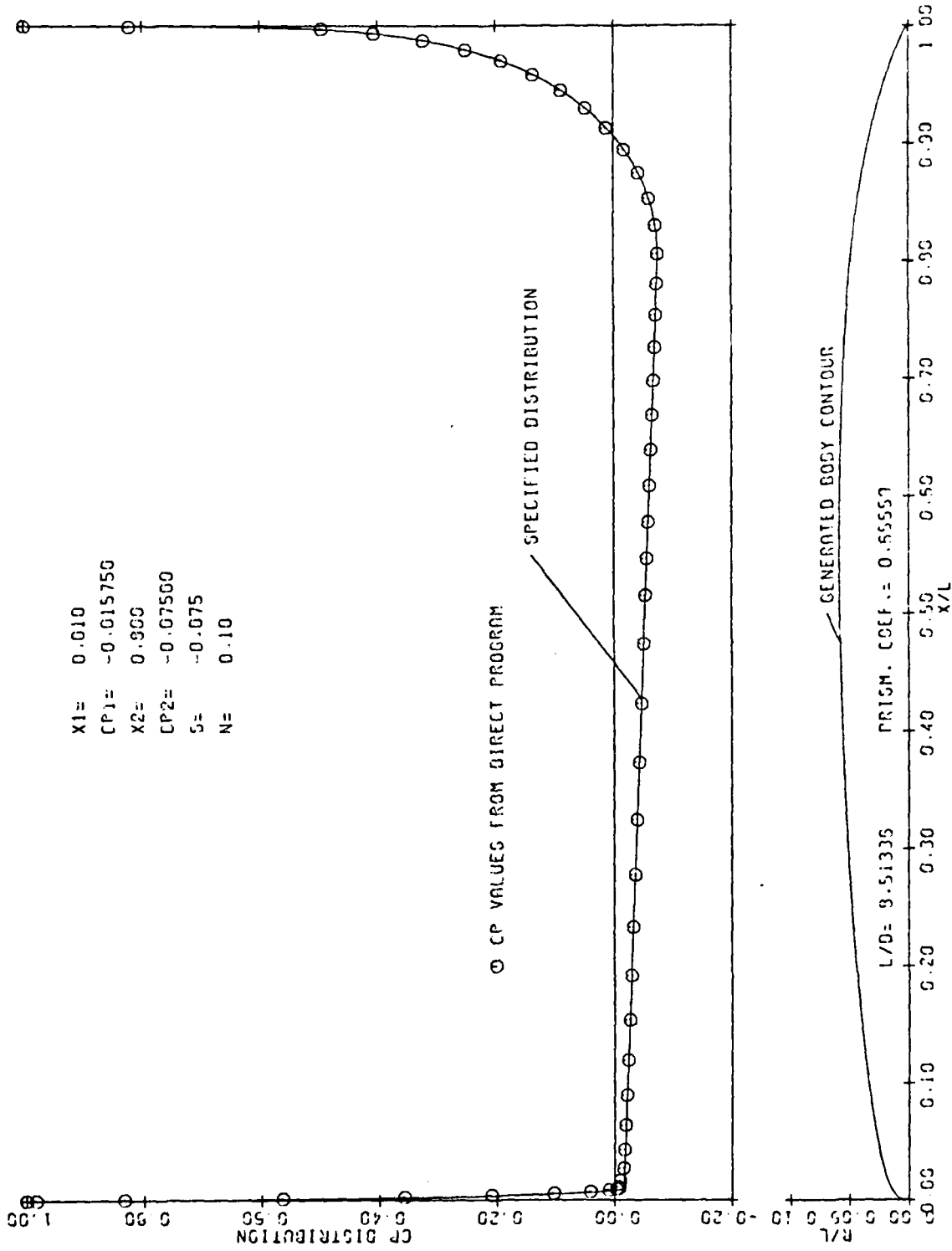


Figure 21. Pressure Distribution and Body Contour, Case No. 11.

# INVERSE BODY CASE 12

X1= 0.050  
 CP1= -0.018750  
 X2= 0.800  
 CP2= -0.07500  
 S= -0.075  
 N= 0.10

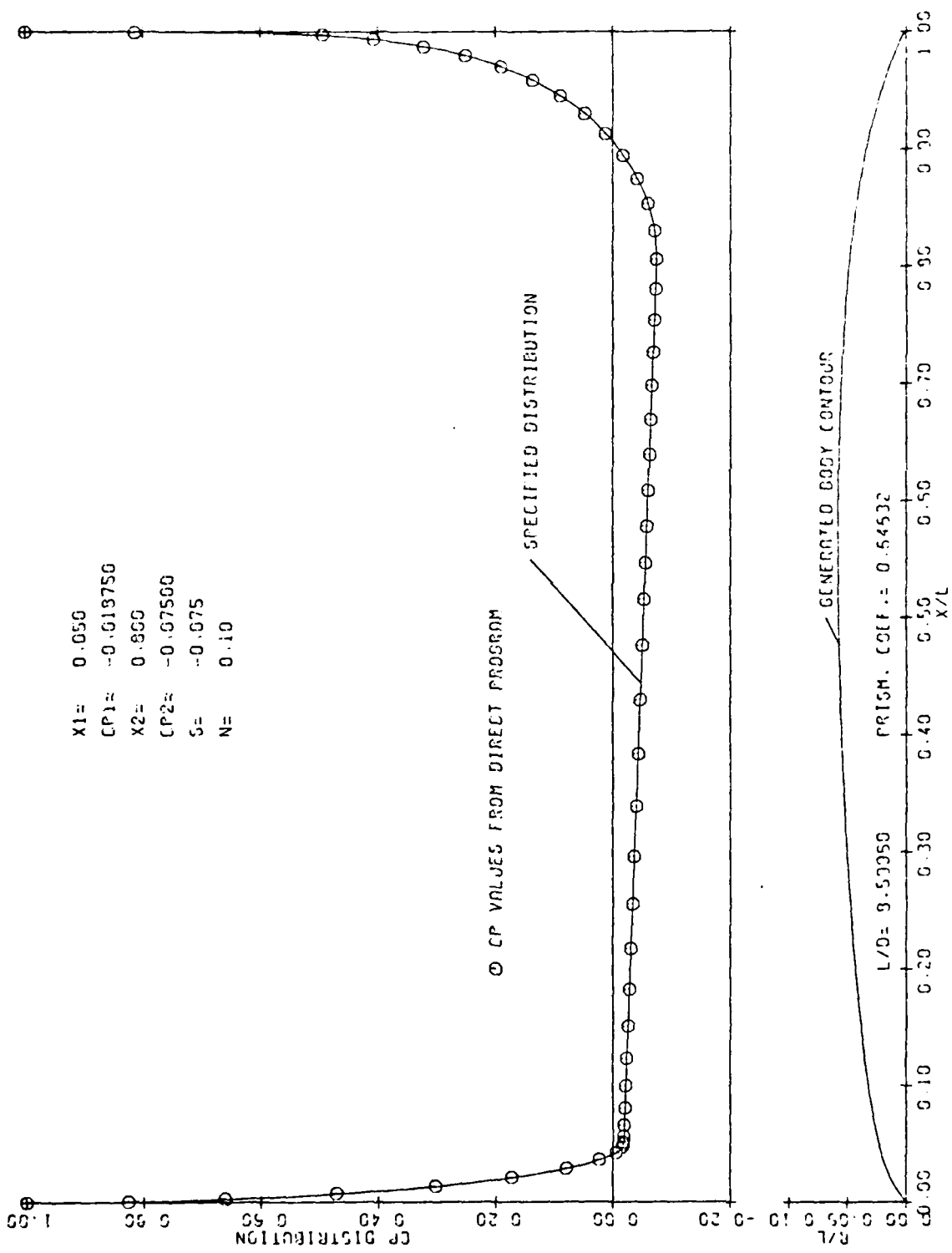


Figure 22. Pressure Distribution and Body Contour, Case No. 12.

# INVERSE BODY CASE 13

X1= 0.010  
 CP1= -0.040750  
 X2= 0.860  
 CP2= -0.100000  
 S= -0.075  
 N= 0.10

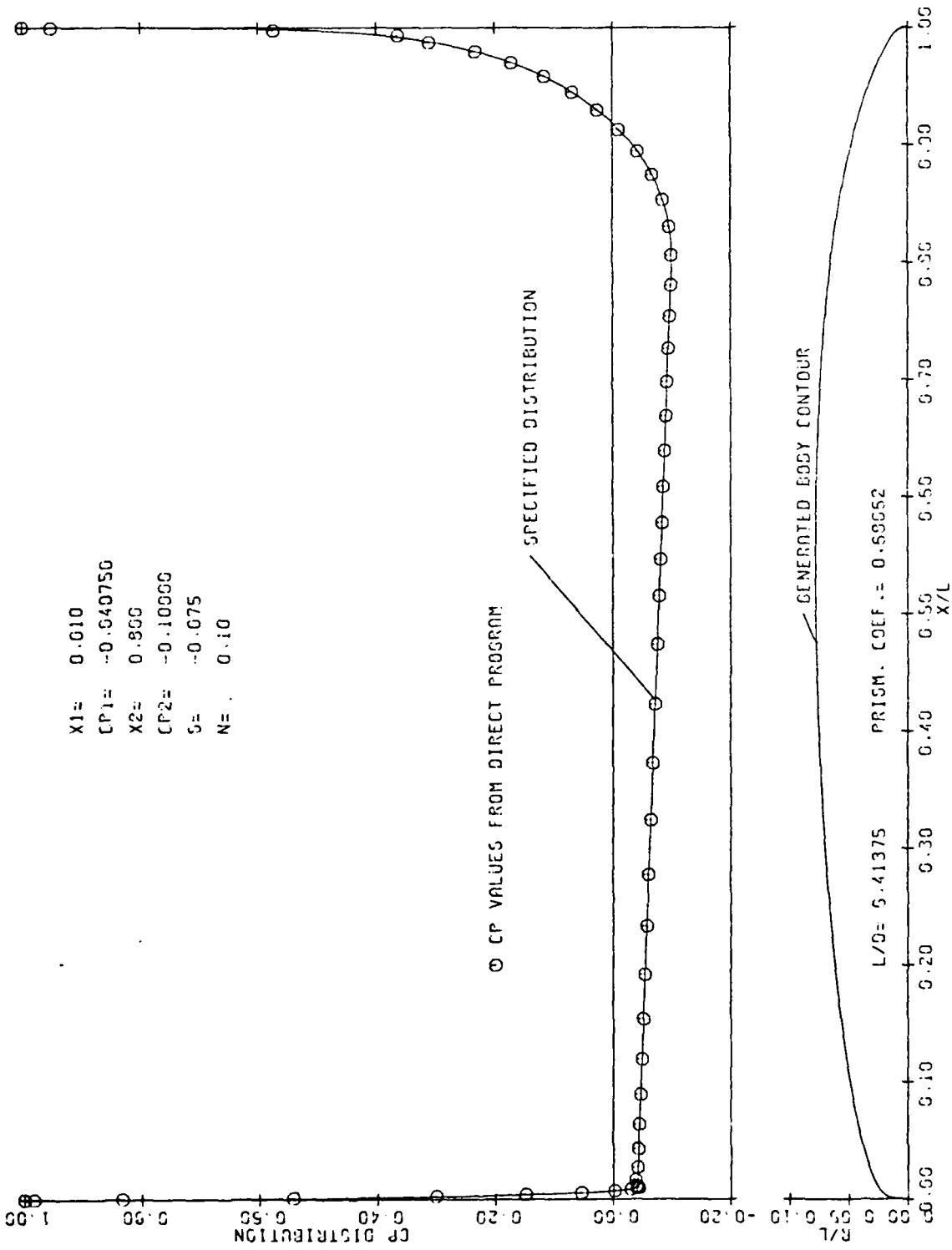


Figure 23. Pressure Distribution and Body Contour, Case No. 13.

# INVERSE BODY CASE 14

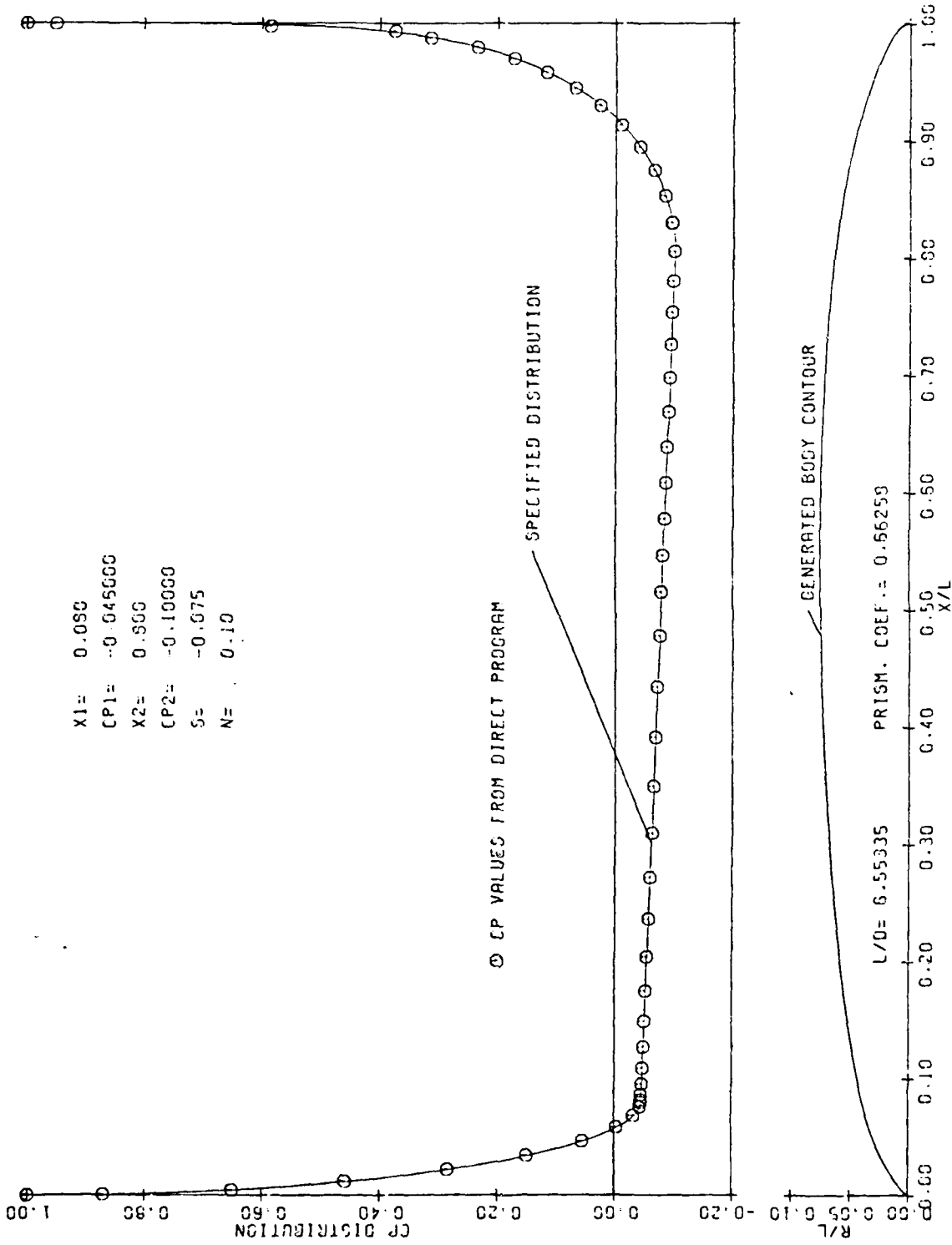


Figure 24. Pressure Distribution and Body Contour, Case No. 14.

# INVERSE BODY CASE 15

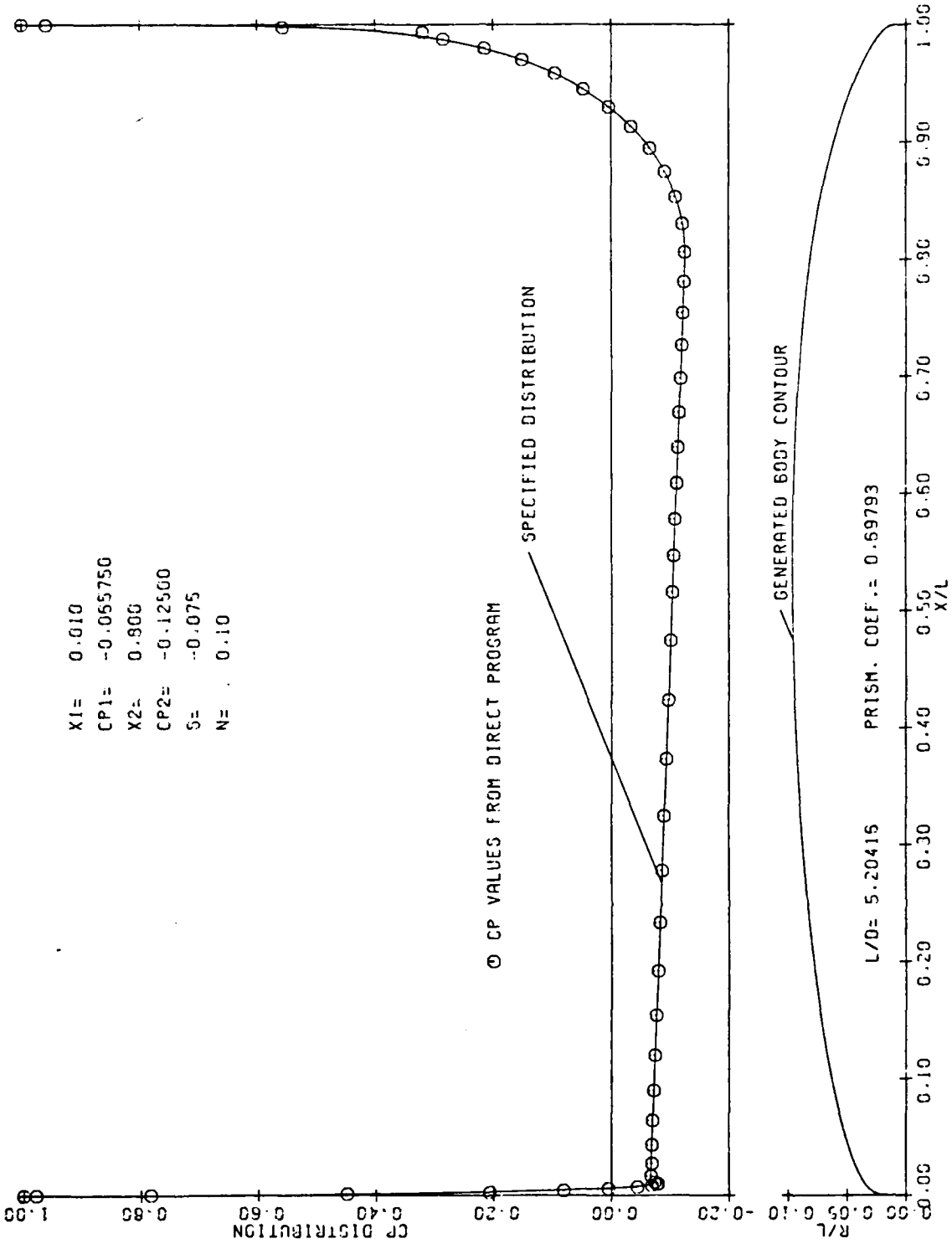


Figure 25. Pressure Distribution and Body Contour, Case No. 15.

# INVERSE BODY CASE 16

X1= 0.110  
CP1= -0.073250  
X2= 0.800  
CP2= -0.12500  
S= -0.075  
N= 0.10

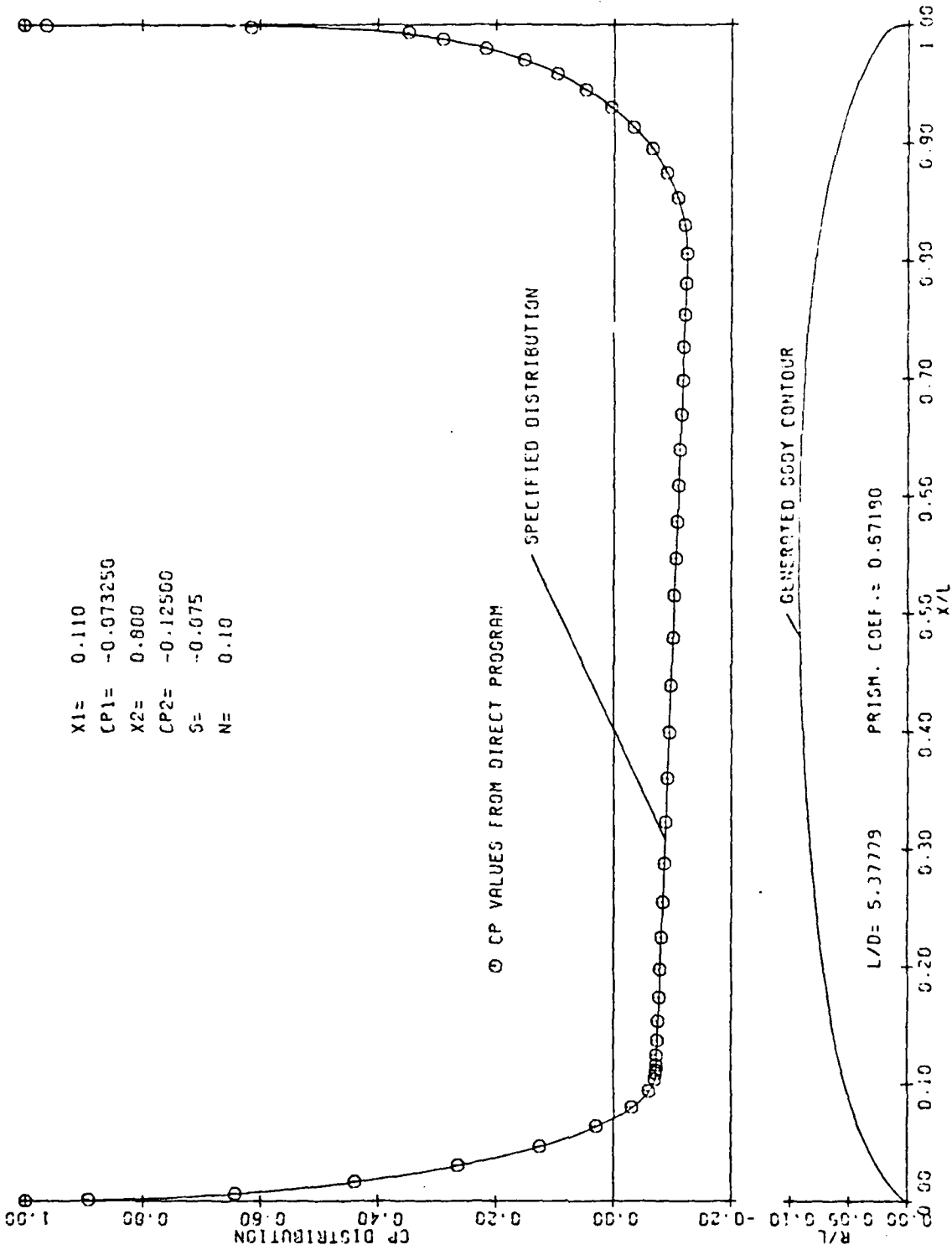


Figure 26. Pressure Distribution and Body Contour, Case No. 16.

# INVERSE BODY CASE 17

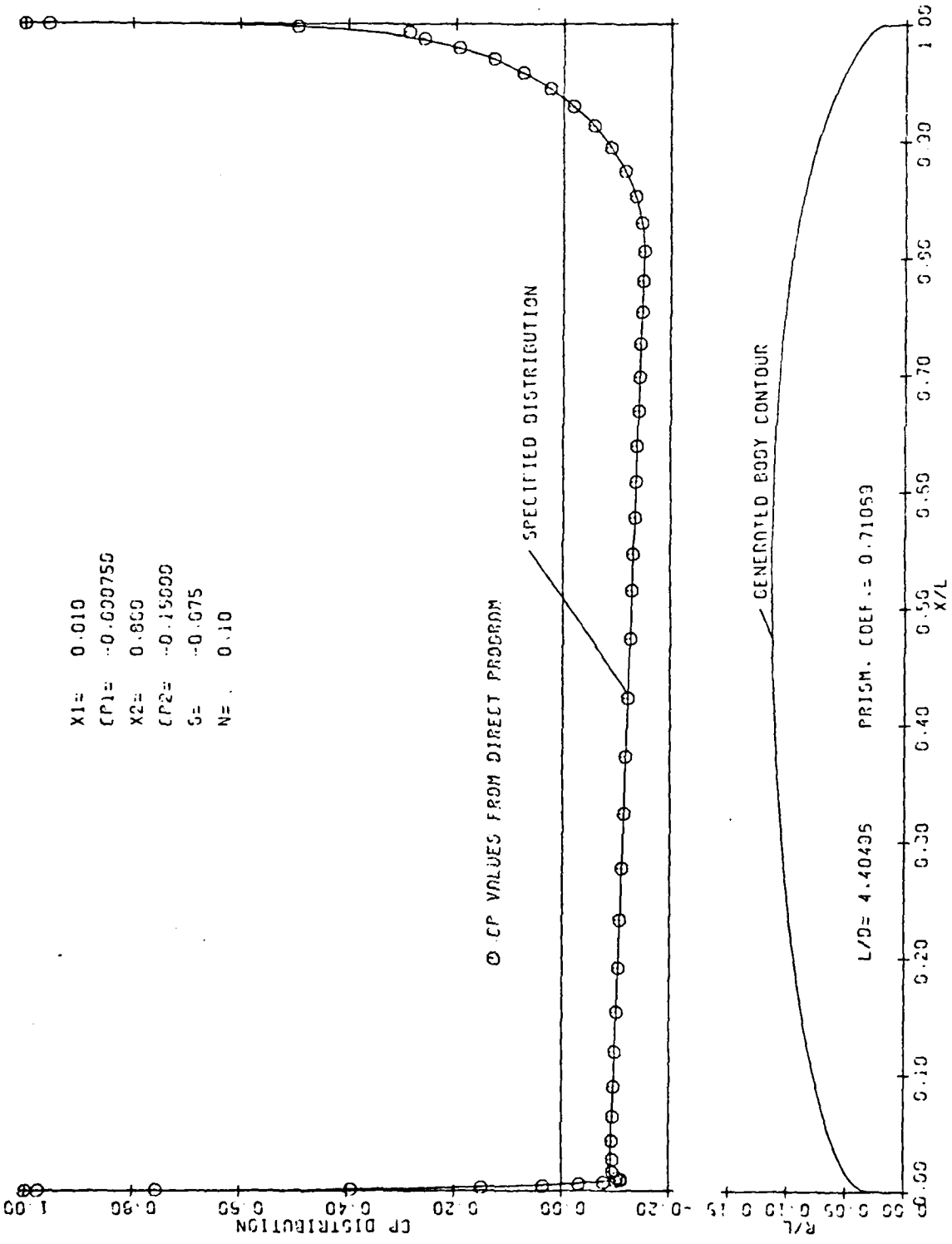


Figure 27. Pressure Distribution and Body Contour, Case No. 17.

# INVERSE BODY CASE 18

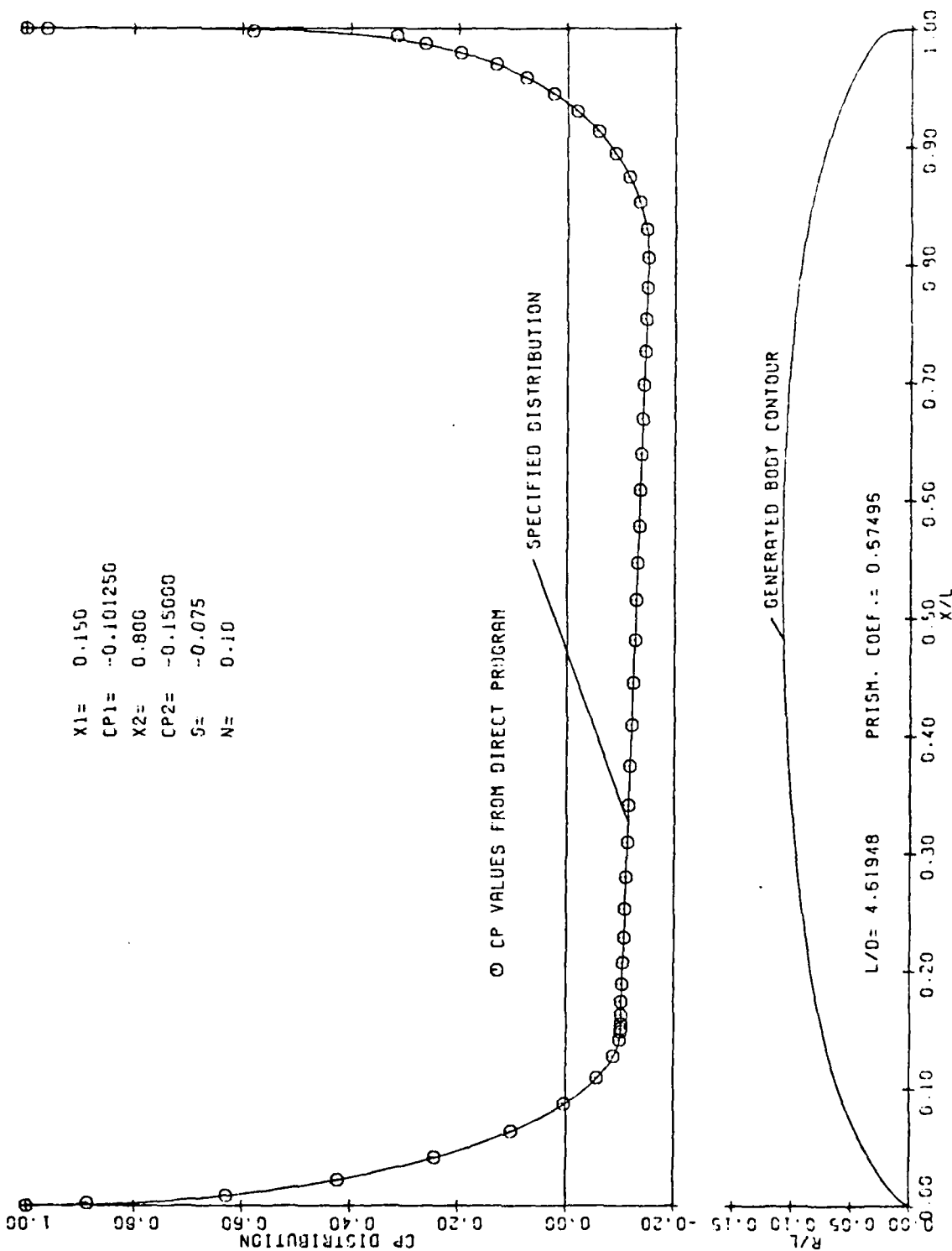


Figure 28. Pressure Distribution and Body Contour, Case No. 18.

# INVERSE BODY CASE 19

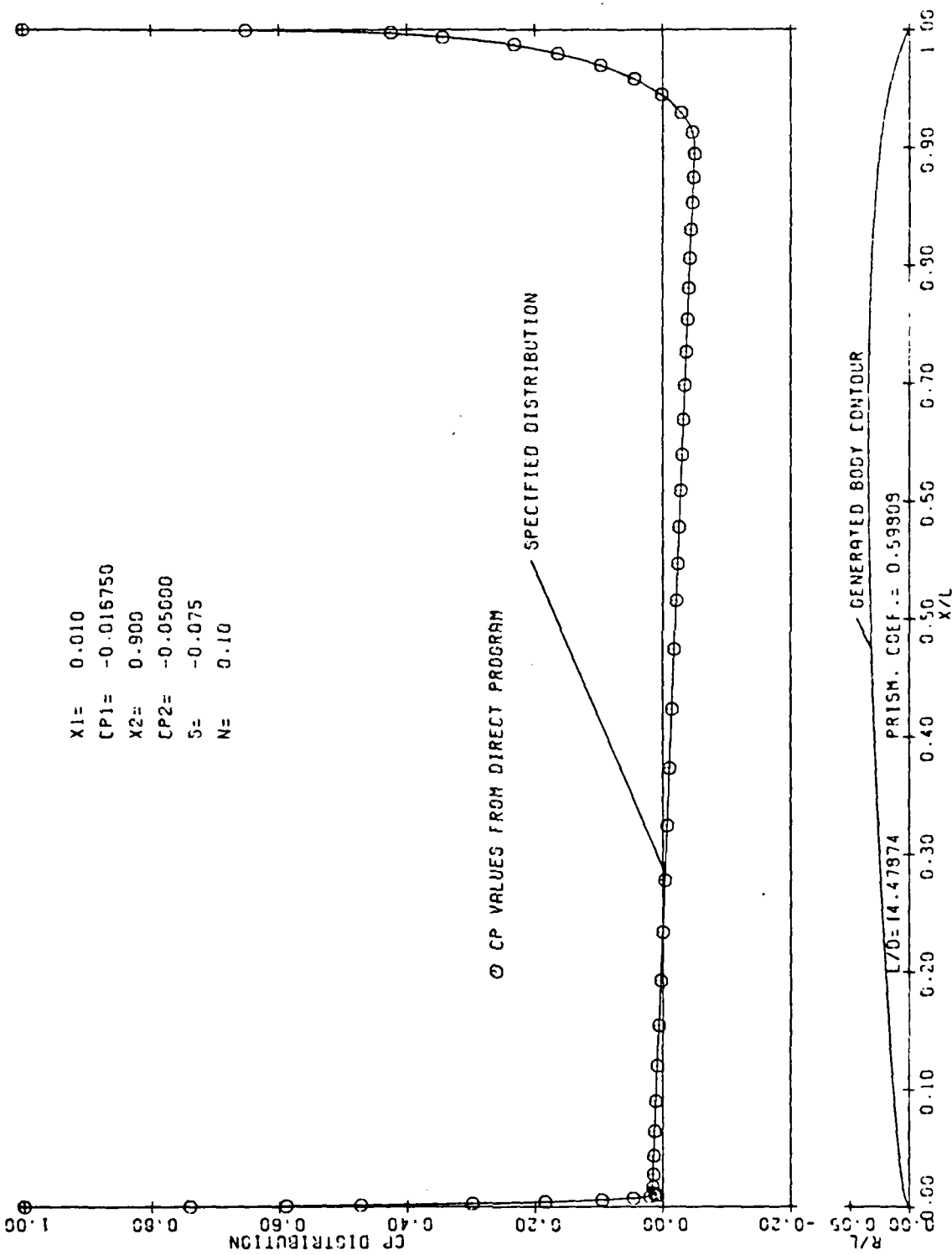


Figure 29. Pressure Distribution and Body Contour, Case No. 19.

# INVERSE BODY CASE 20

X1= 0.010  
CP1= -0.009250  
X2= 0.900  
CP2= -0.07500  
S= -0.075  
N= 0.10

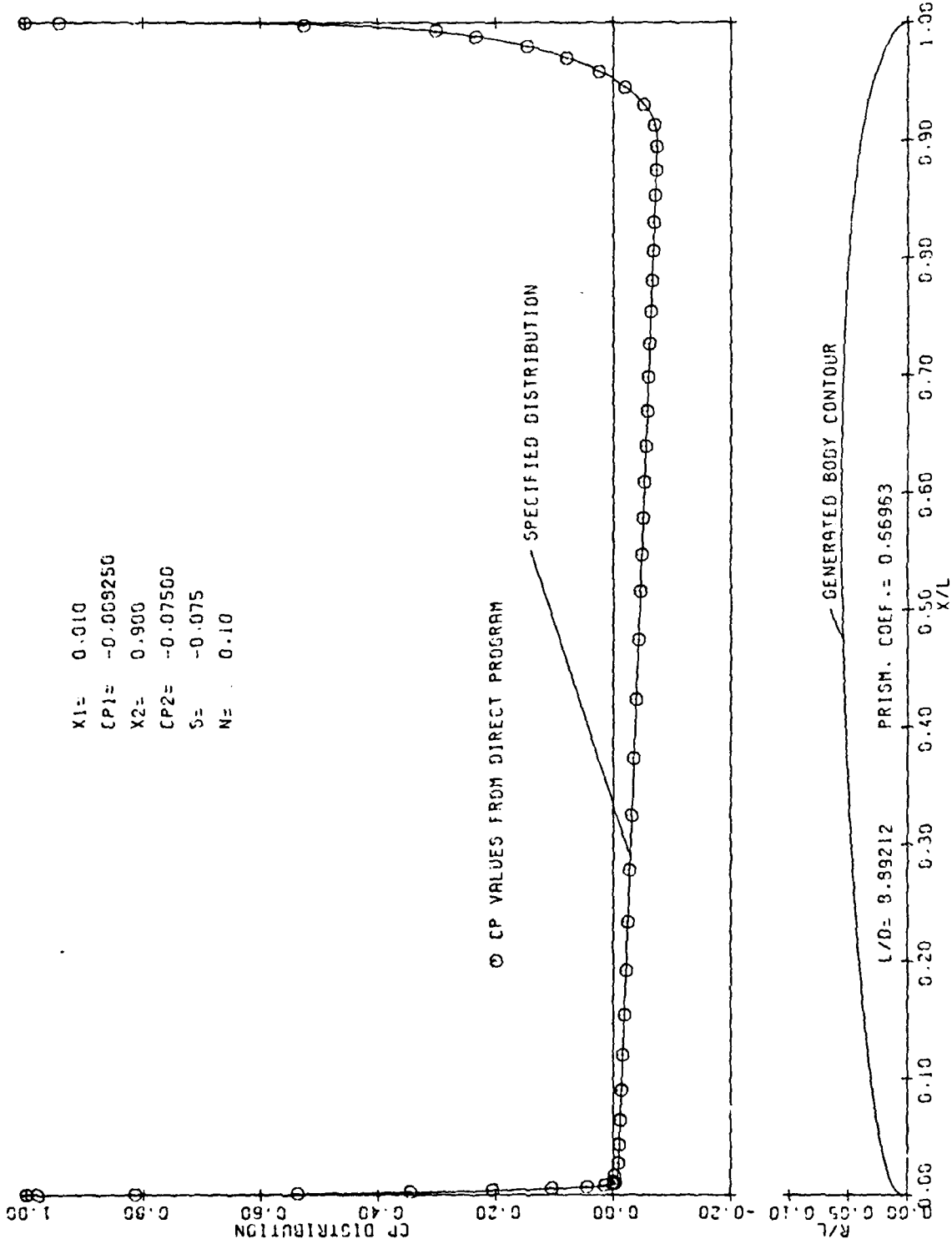


Figure 30. Pressure Distribution and Body Contour, Case No. 20.

# INVERSE BODY CASE 21

X1= 0.040  
CP1= -0.010500  
X2= 0.900  
CP2= -0.07500  
S= -0.075  
N= 0.10

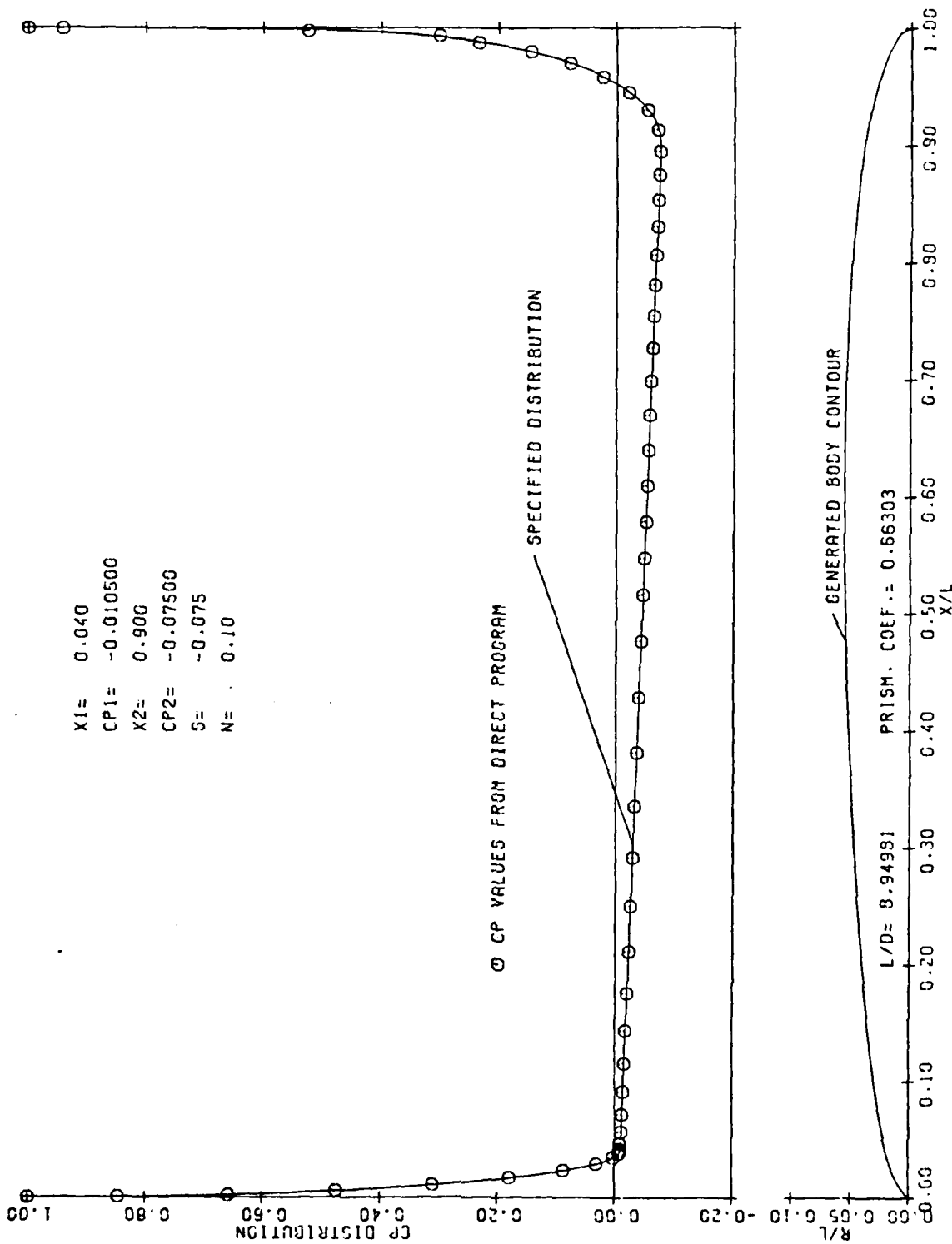


Figure 31. Pressure Distribution and Body Contour, Case No. 21.

# INVERSE BODY CASE 22

X1= 0.010  
CP1= -0.033250  
X2= 0.900  
CP2= -0.10000  
S= -0.075  
N= 0.10

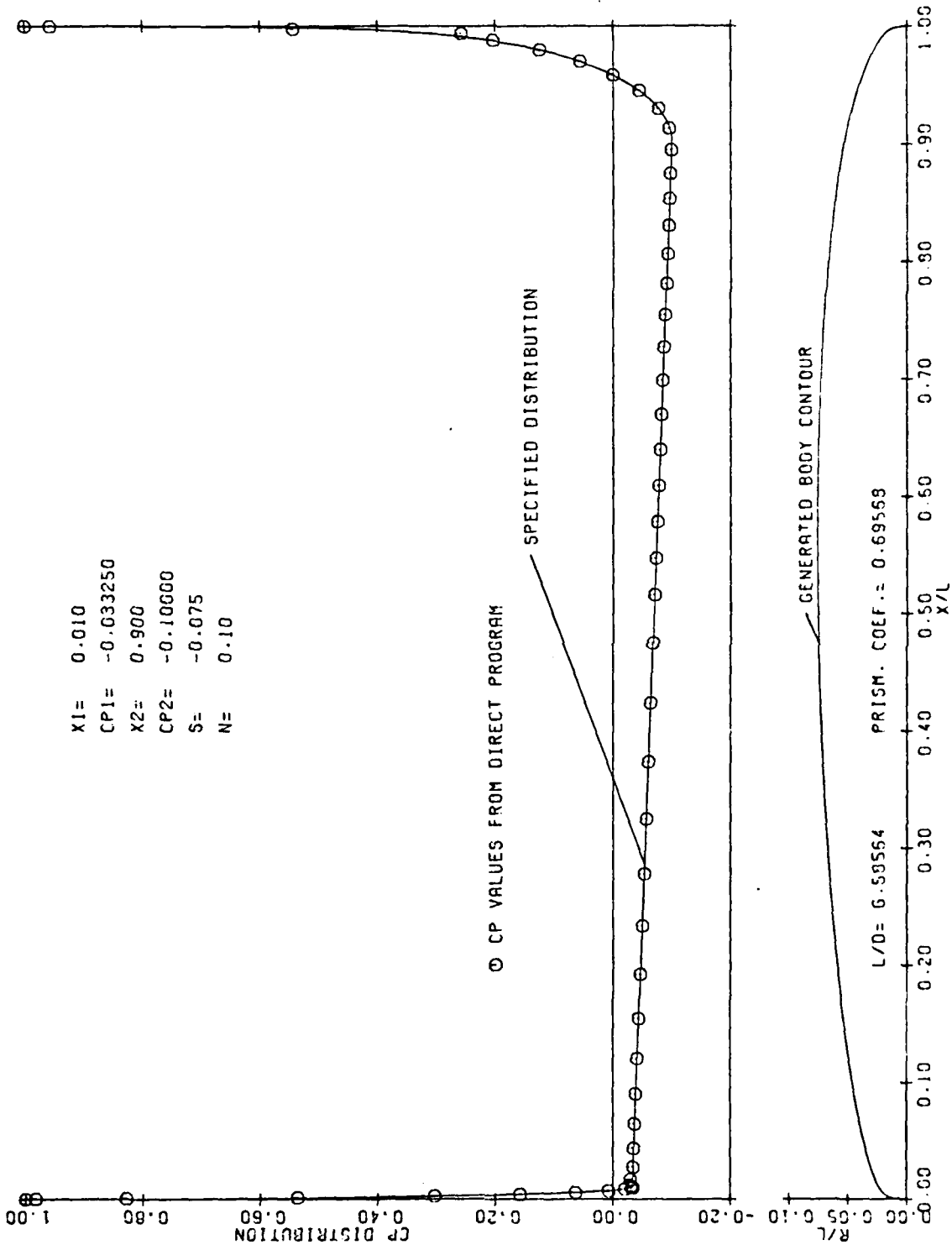


Figure 32. Pressure Distribution and Body Contour, Case No. 22.

# INVERSE BODY CASE 23

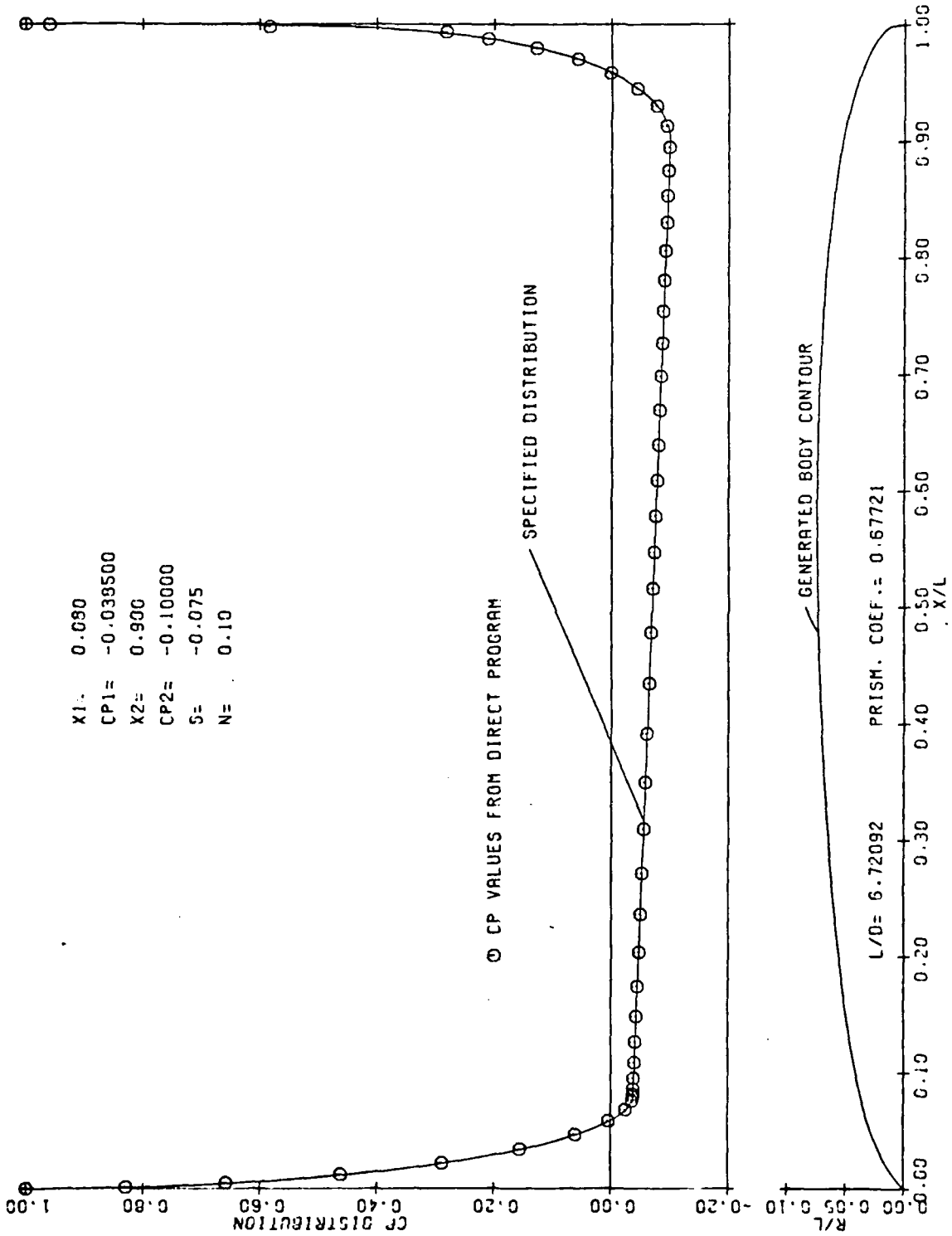


Figure 33. Pressure Distribution and Body Contour, Case No. 23.

# INVERSE BODY CASE 24

X1= 0.010  
 CP1= -0.059250  
 X2= 0.900  
 CP2= -0.12500  
 S= -0.075  
 N= 0.10

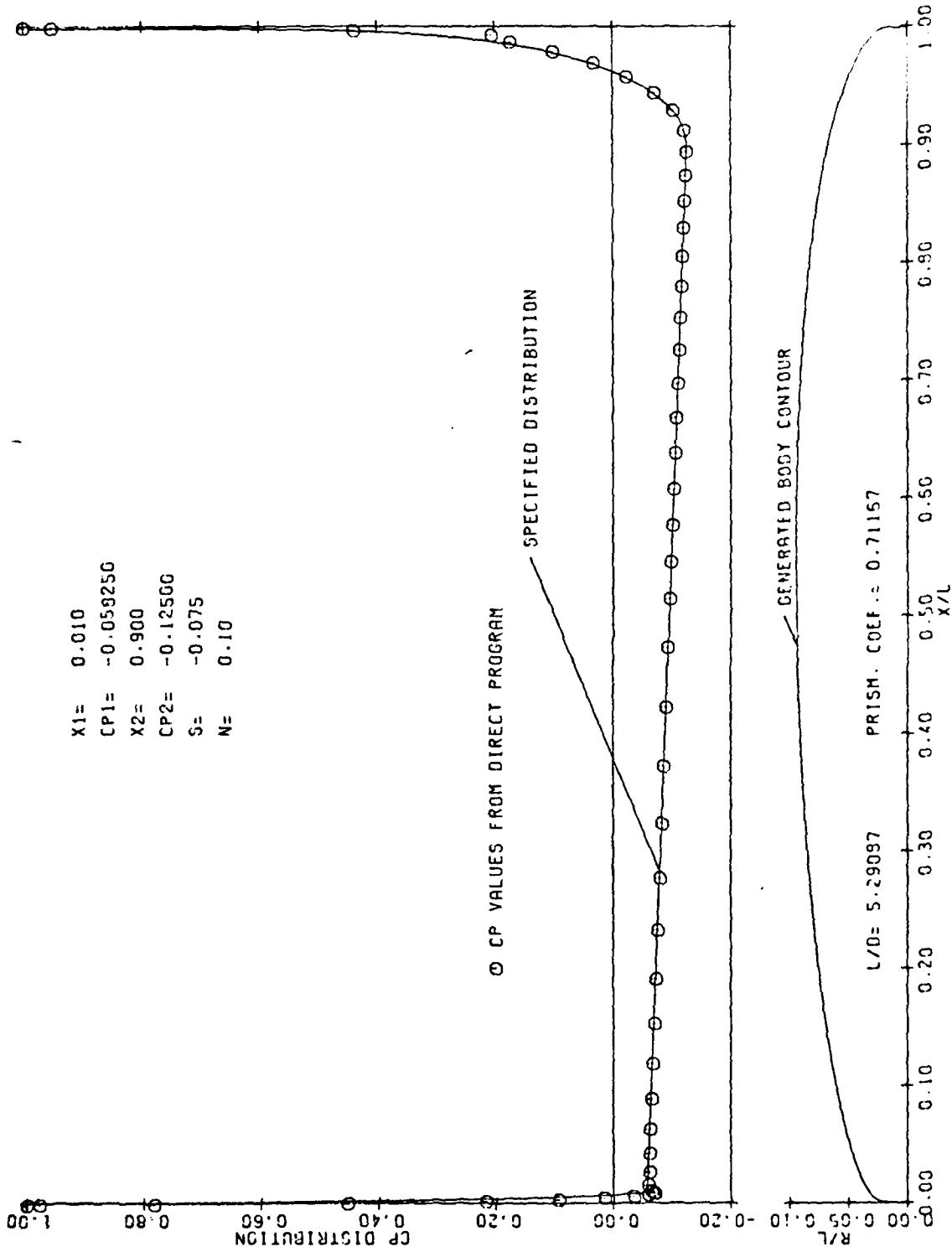


Figure 34. Pressure Distribution and Body Contour, Case No. 24.

# INVERSE BODY CASE 25

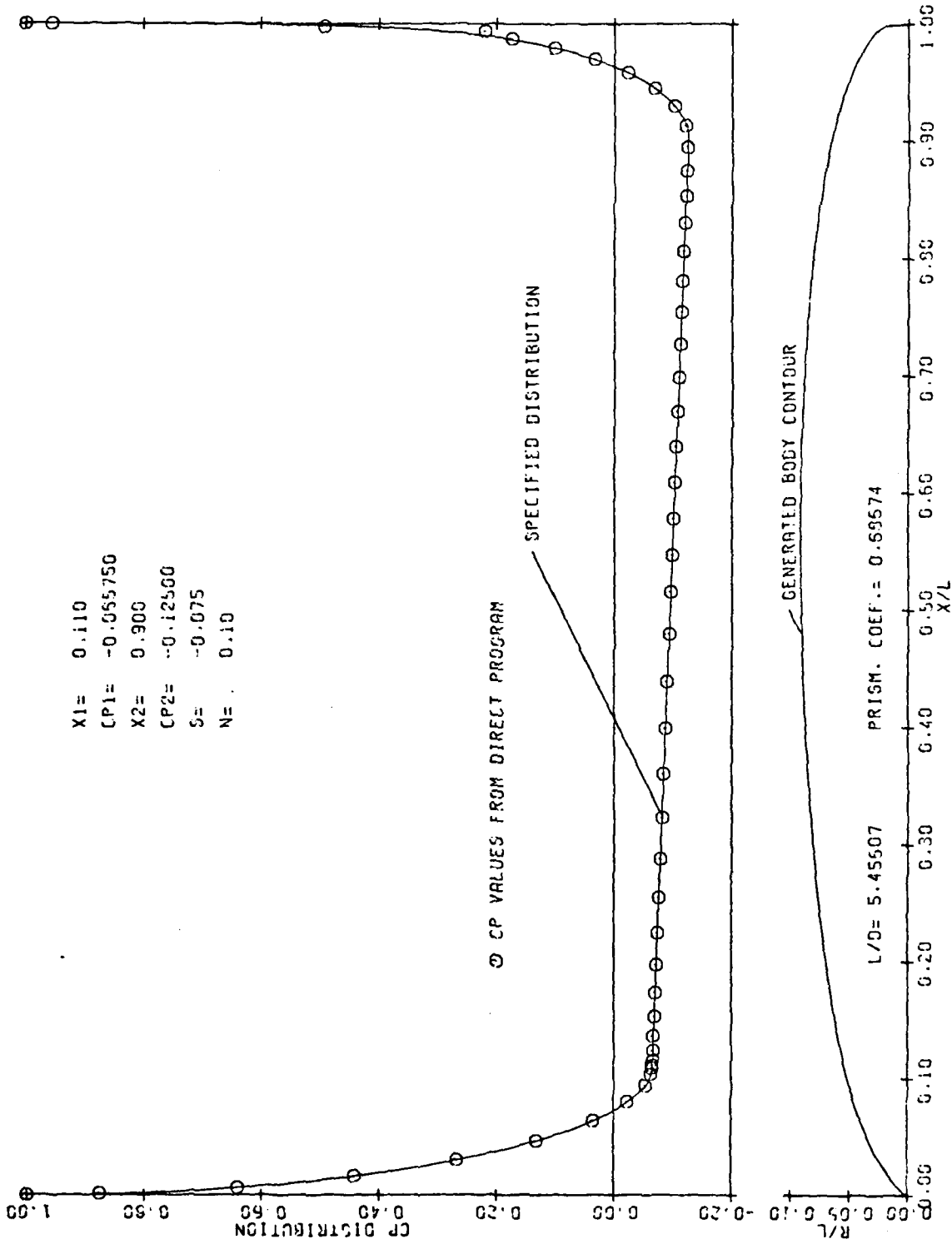


Figure 35. Pressure Distribution and Body Contour, Case No. 25.

# INVERSE BODY CASE 26

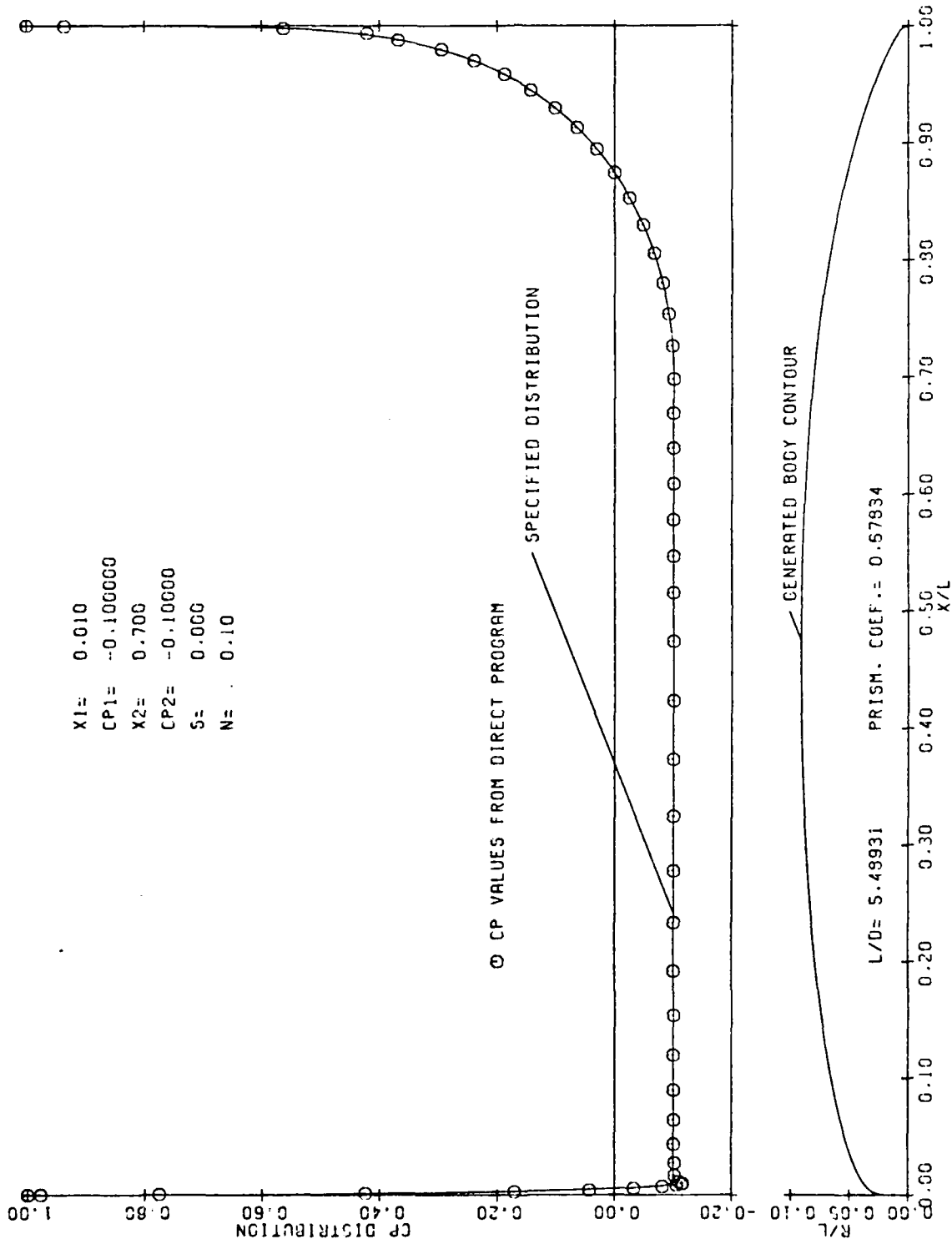


Figure 36. Pressure Distribution and Body Contour, Case No. 26.

# INVERSE BODY CASE 27

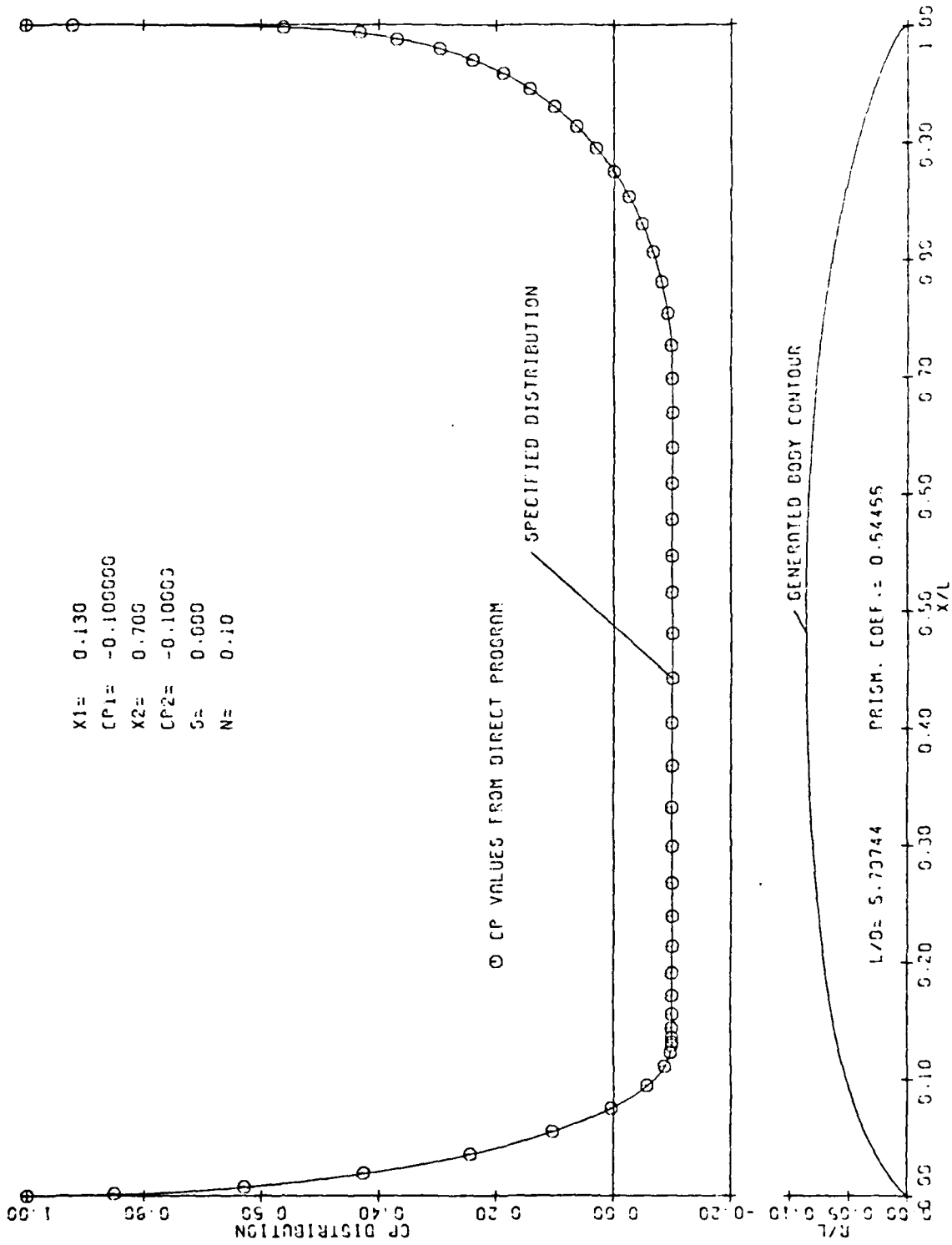


Figure 37. Pressure Distribution and Body Contour, Case No. 27.

# INVERSE BODY CASE 28

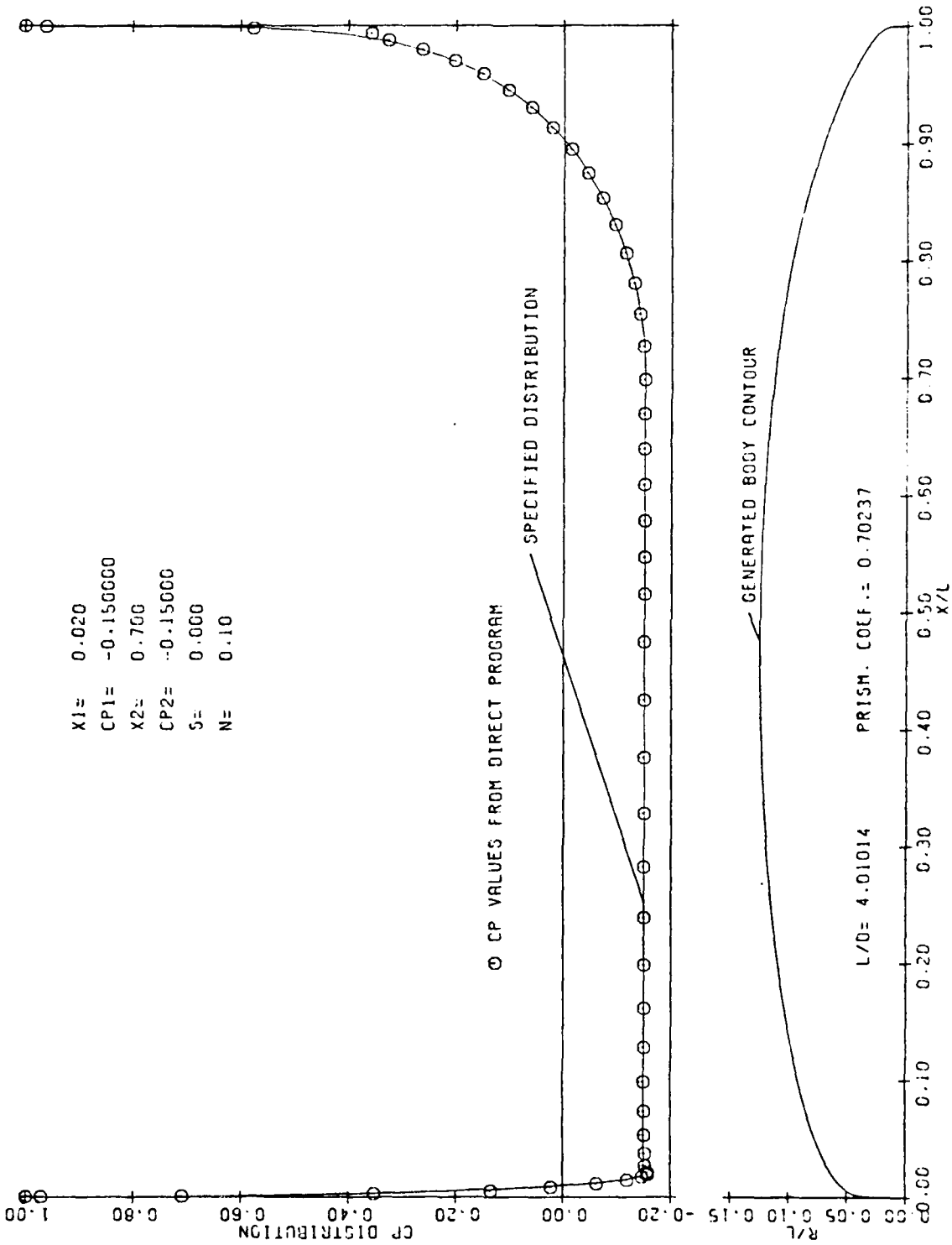


Figure 38. Pressure Distribution and Body Contour, Case No. 28.

# INVERSE BODY CASE 29

X1= 0.190  
CP1= -0.150000  
X2= 0.700  
CP2= -0.150000  
S= 0.000  
N= 0.10

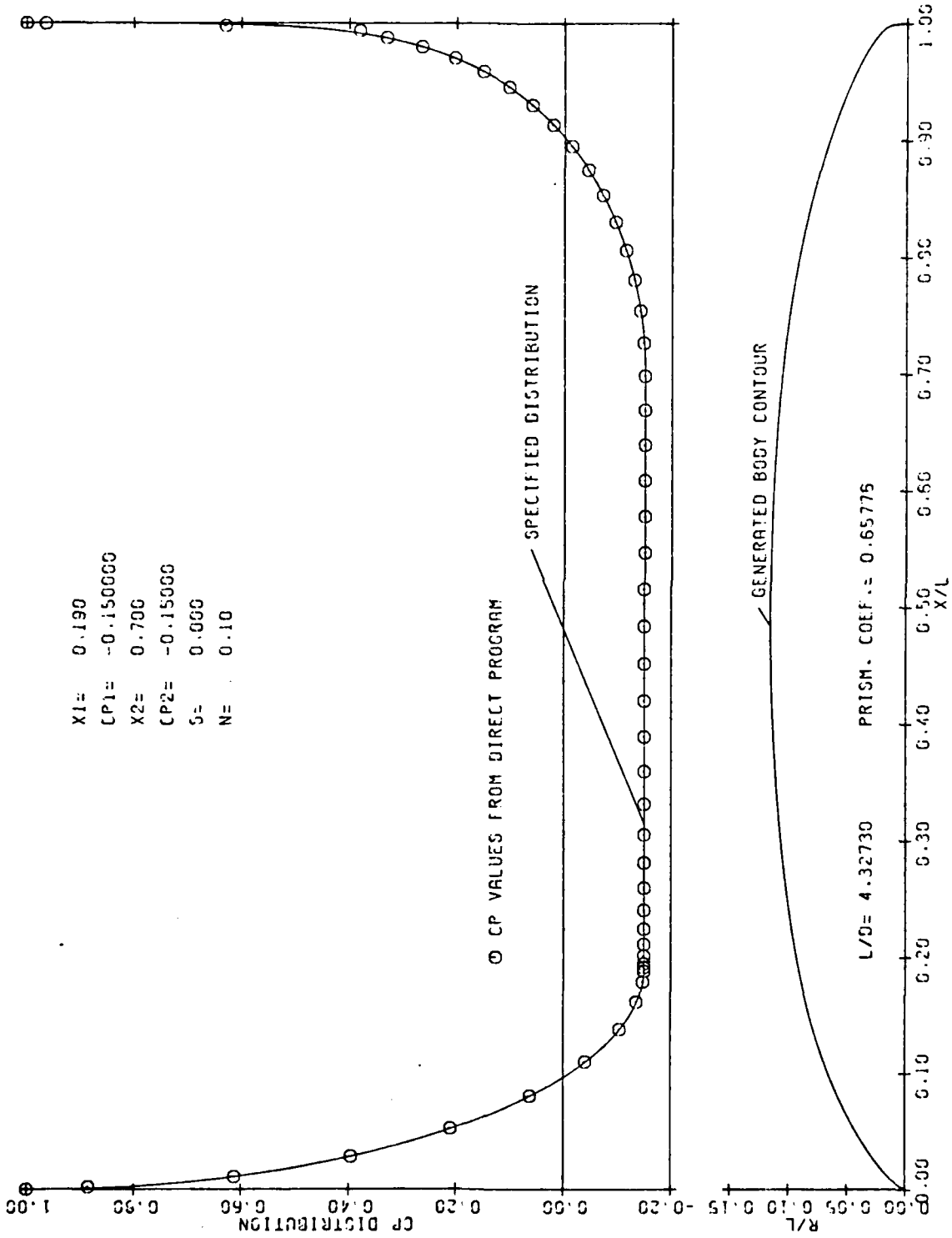


Figure 39. Pressure Distribution and Body Contour, Case No. 29.

# INVERSE BODY CASE 30

X1= 0.090  
CP1= -0.175000  
X2= 0.700  
CP2= -0.175000  
S= 0.000  
N= 0.10

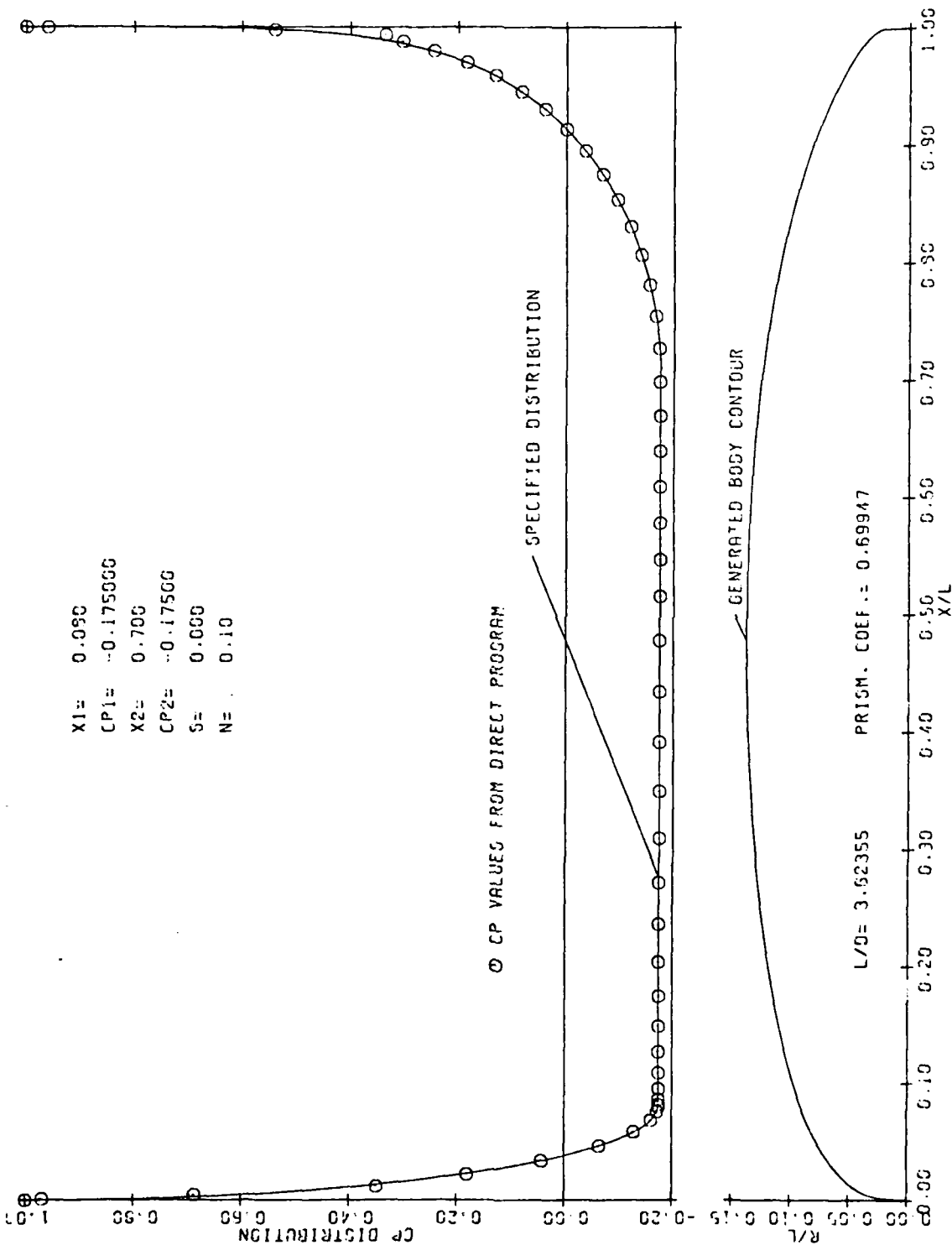


Figure 40. Pressure Distribution and Body Contour, Case No. 30.

# INVERSE BODY CASE 31

X1= 0.230  
 CP1= -0.175000  
 X2= 0.700  
 CP2= -0.17500  
 S= 0.000  
 N= 0.10

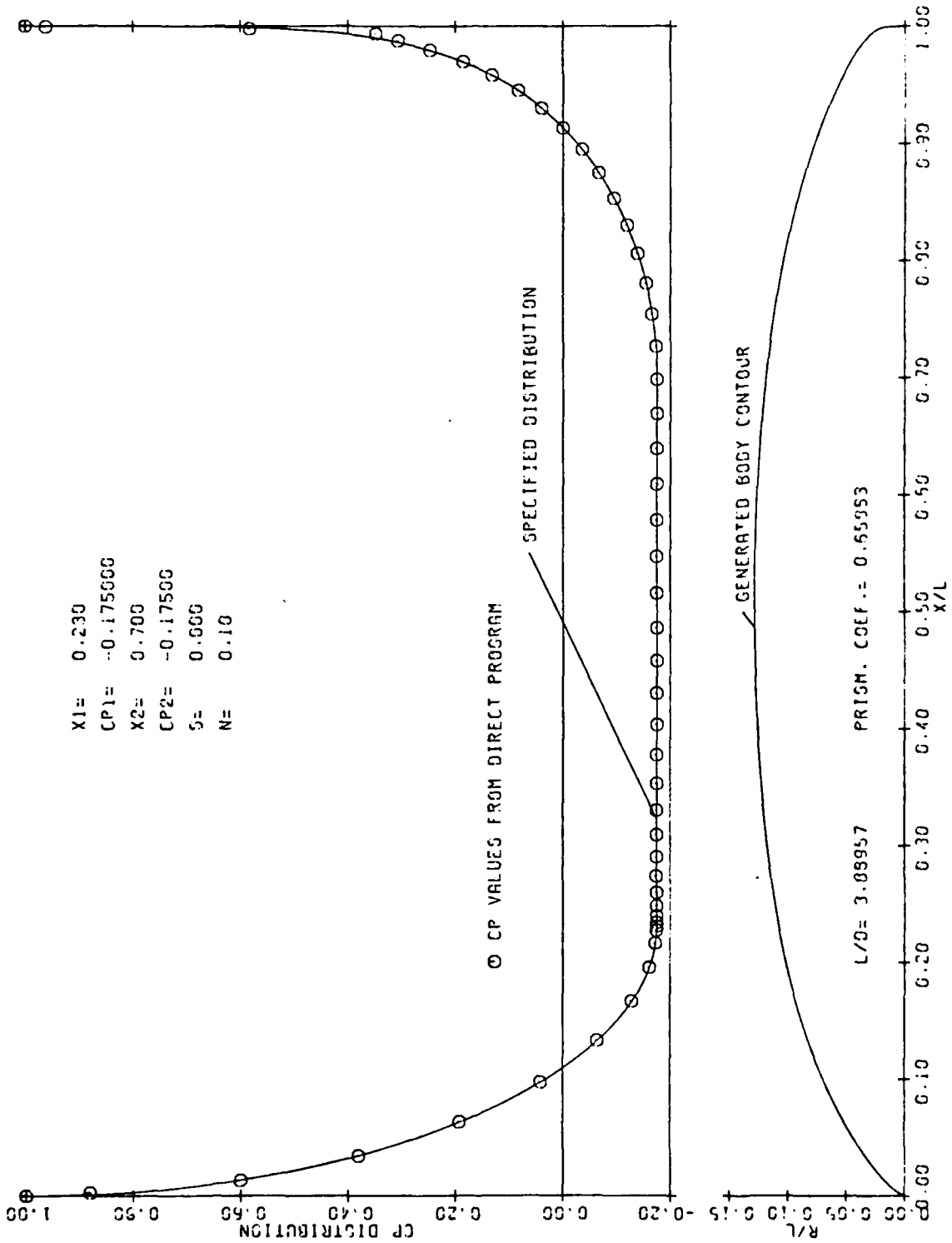


Figure 41. Pressure Distribution and Body Contour, Case No. 31.

# INVERSE BODY CASE 32

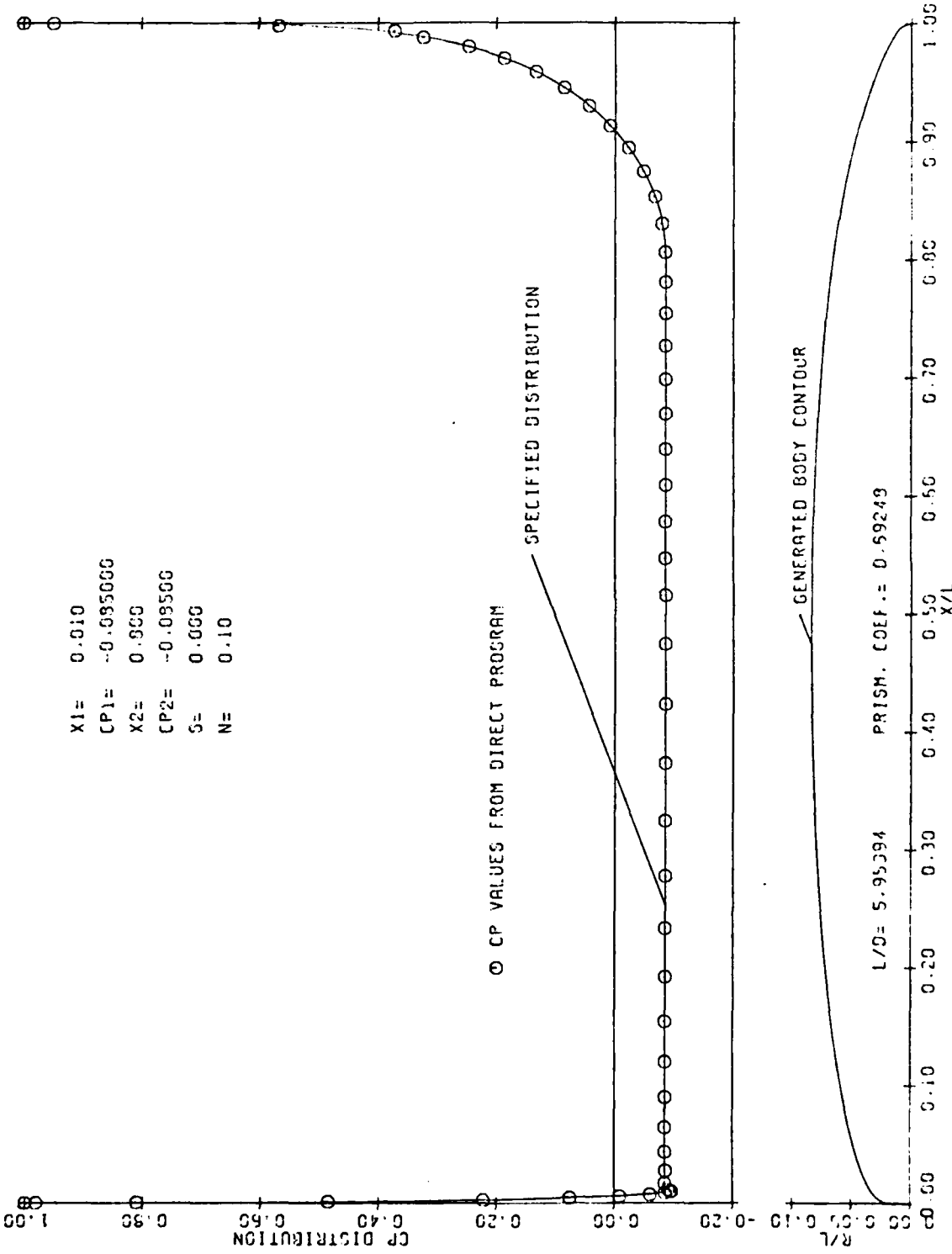


Figure 42. Pressure Distribution and Body Contour, Case No. 32.

# INVERSE BODY CASE 33

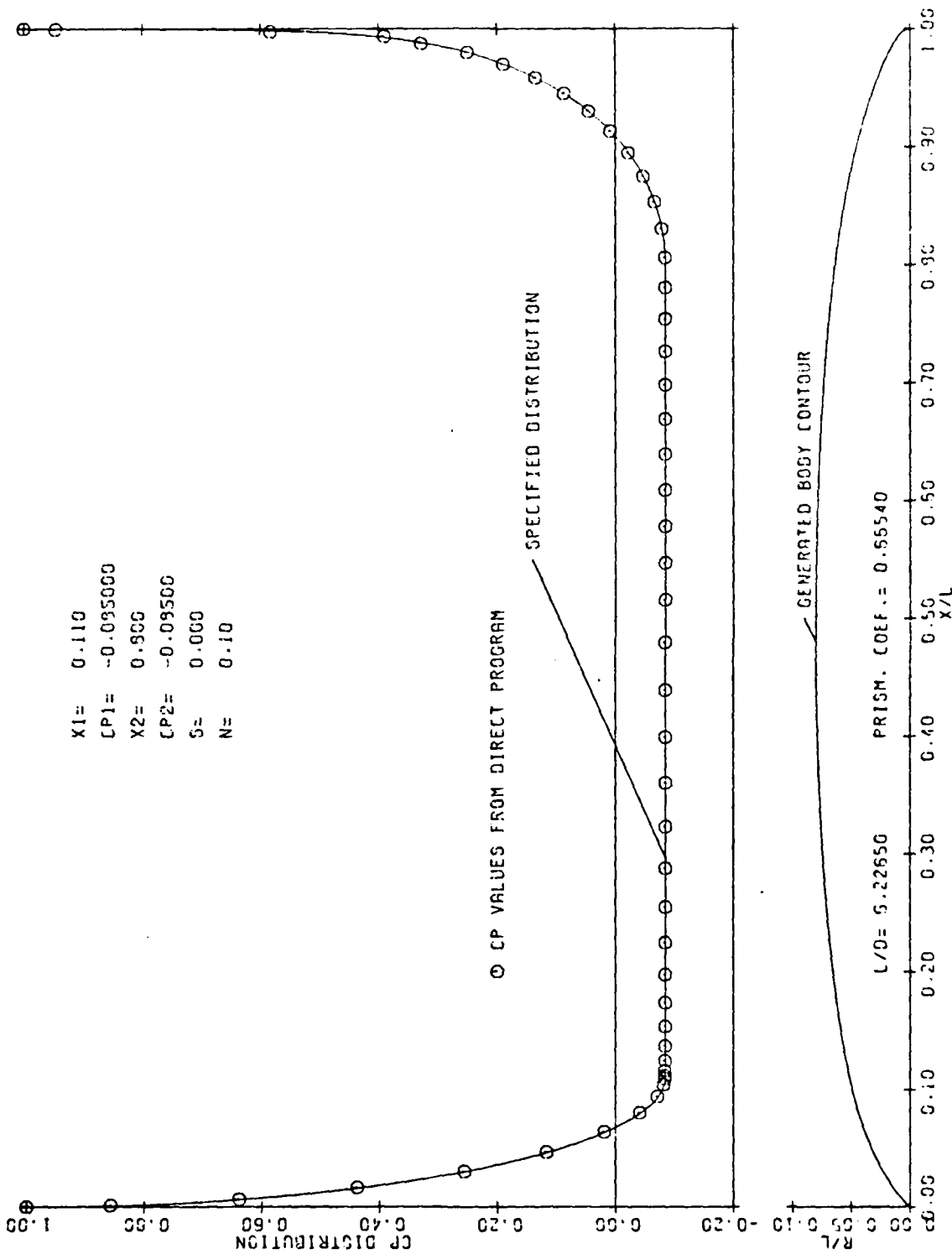


Figure 43. Pressure Distribution and Body Contour, Case No. 33.

# INVERSE BODY CASE 34

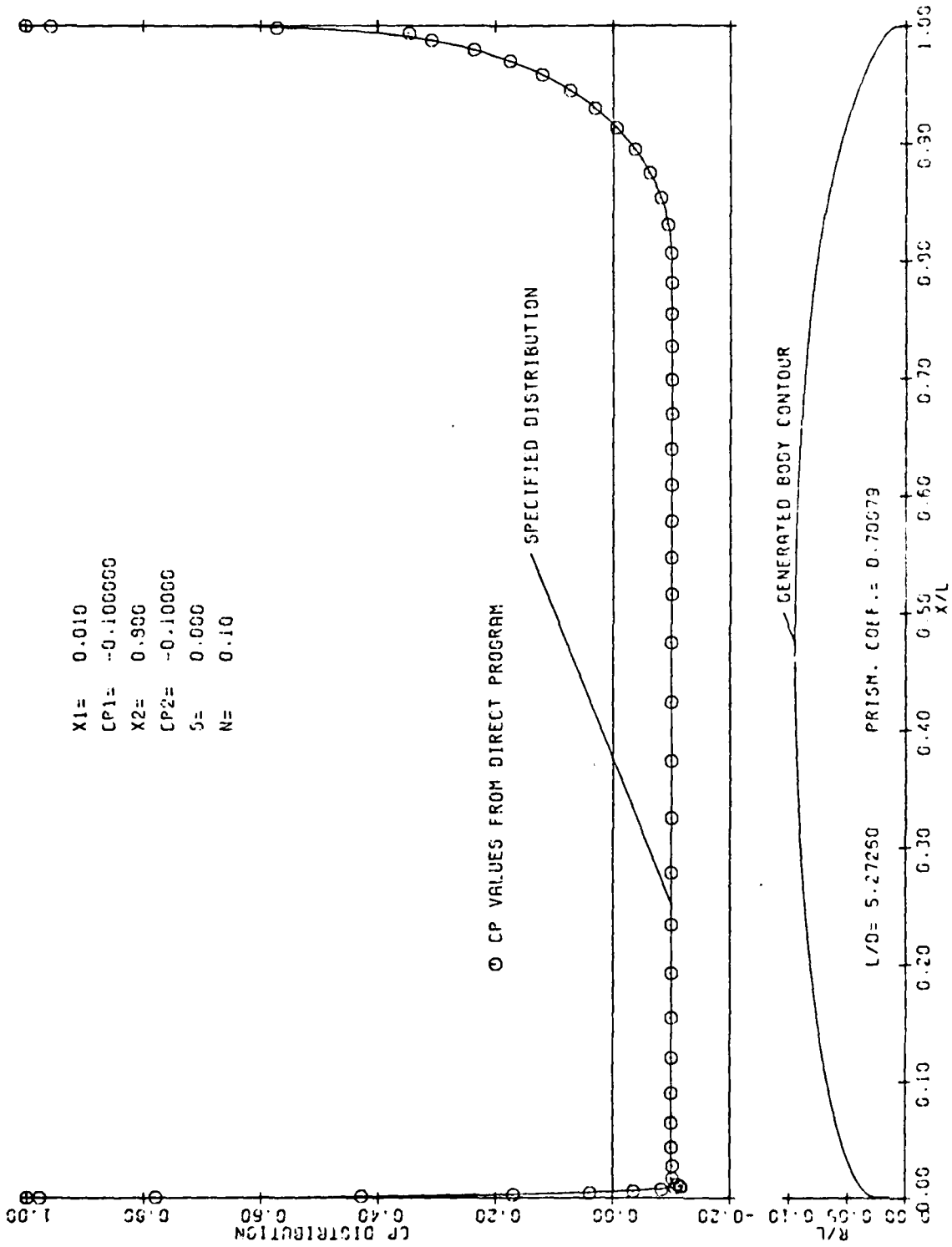


Figure 44. Pressure Distribution and Body Contour, Case No. 34.

# INVERSE BODY CASE 35

X1= 0.130  
CP1= -0.100000  
X2= 0.860  
CP2= -0.100000  
S= 0.000  
N= 0.10

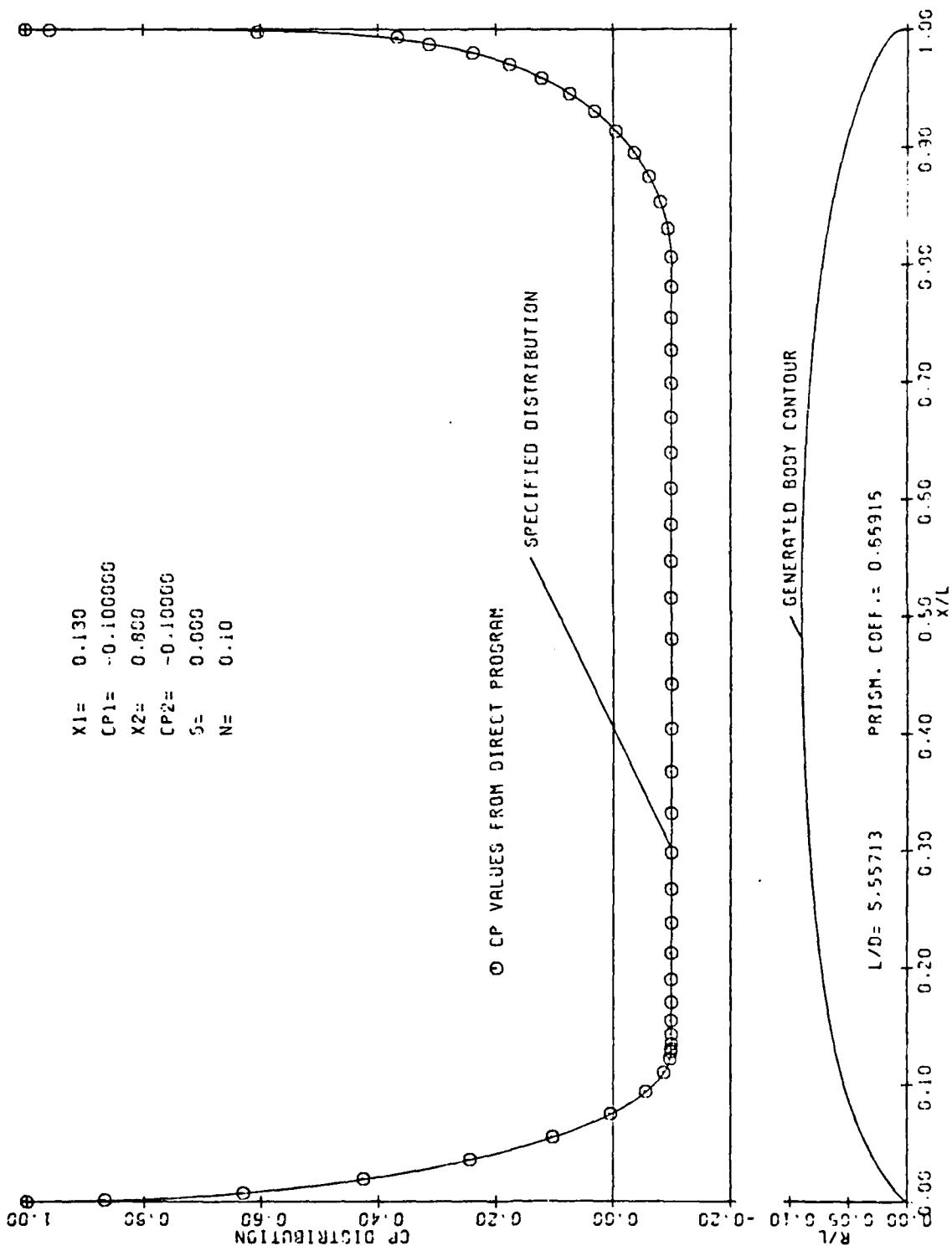


Figure 45. Pressure Distribution and Body Contour, Case No. 35.

# INVERSE BODY CASE 36

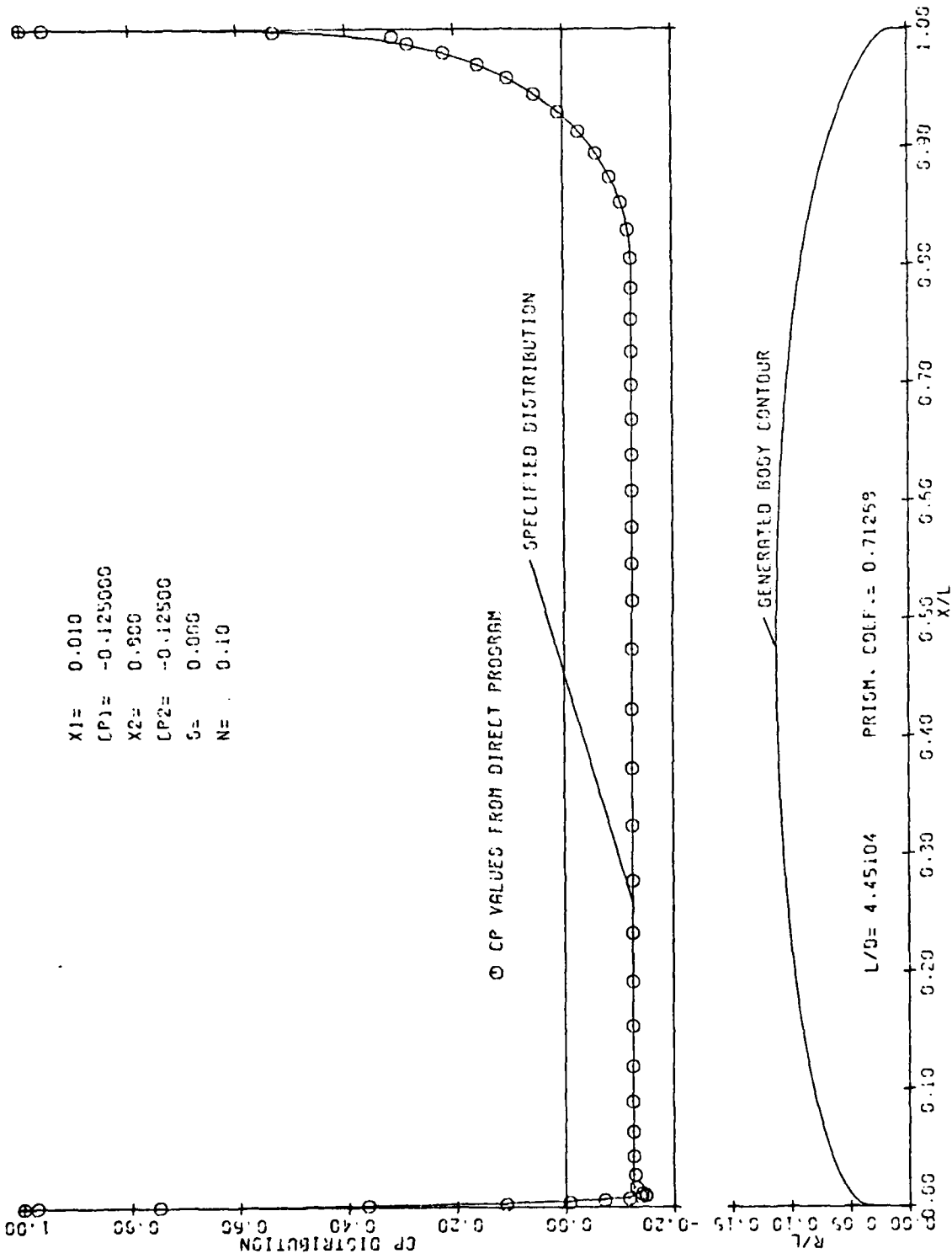


Figure 46. Pressure Distribution and Body Contour, Case No. 36.

# INVERSE BODY CASE 37

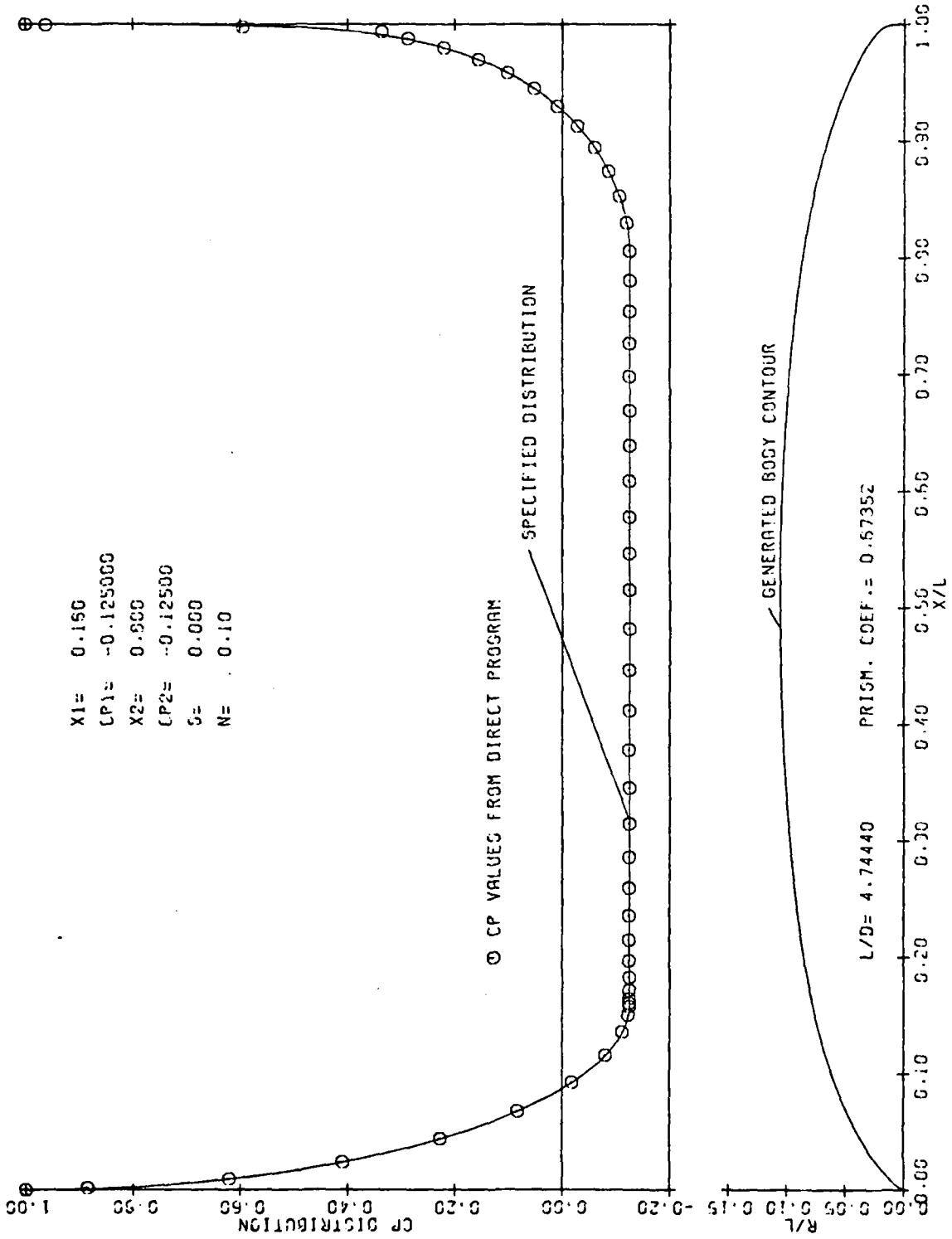


Figure 47. Pressure Distribution and Body Contour, Case No. 37.

# INVERSE BODY CASE 38

X1= 0.020  
 CP1= -0.135000  
 X2= 0.000  
 CP2= -0.13500  
 S= 0.000  
 N= 0.10

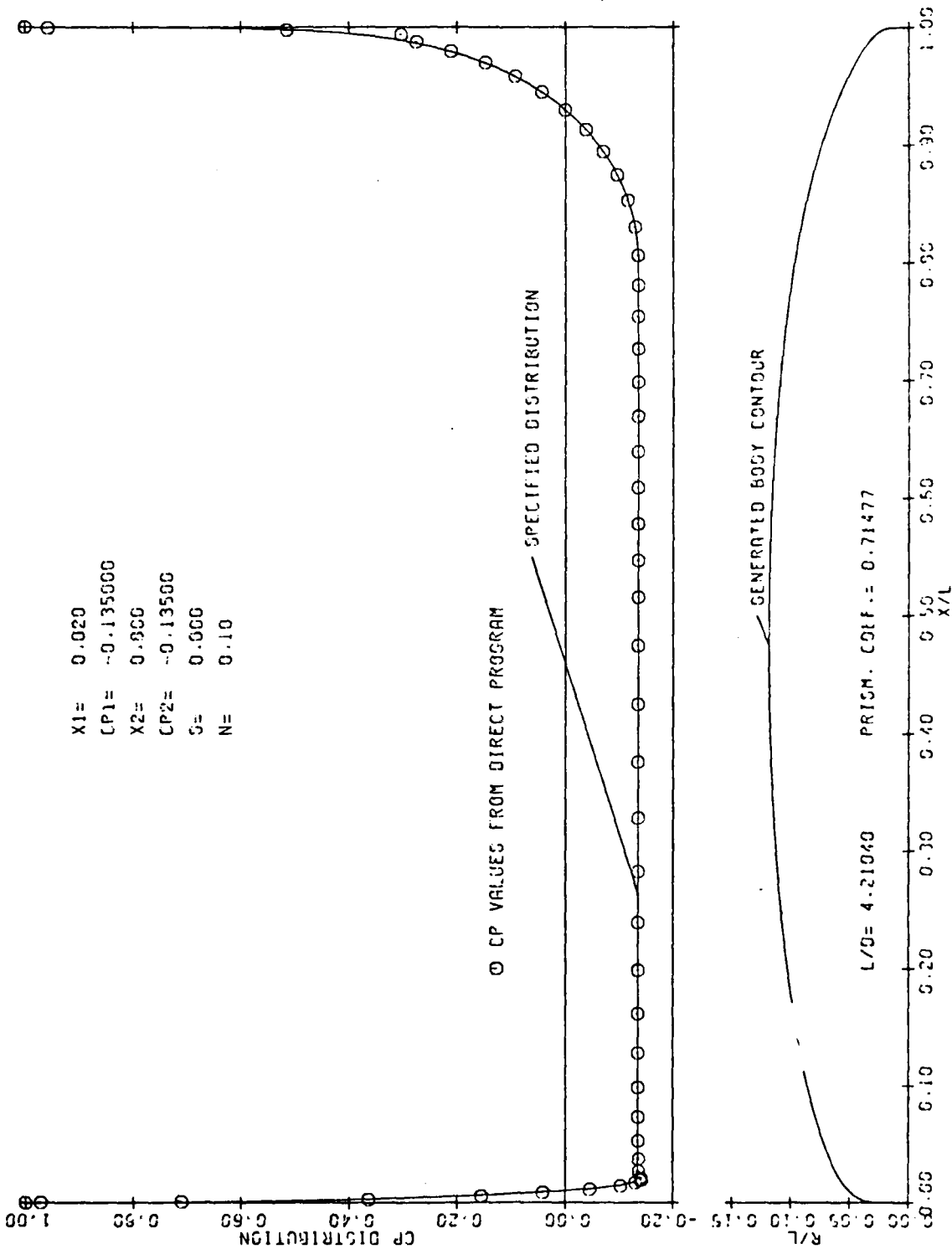


Figure 48. Pressure Distribution and Body Contour, Case No. 38.

# INVERSE BODY CASE 39

X1= 0.190  
CP1= -0.135000  
X2= 0.900  
CP2= -0.135000  
S= 0.000  
N= 0.10

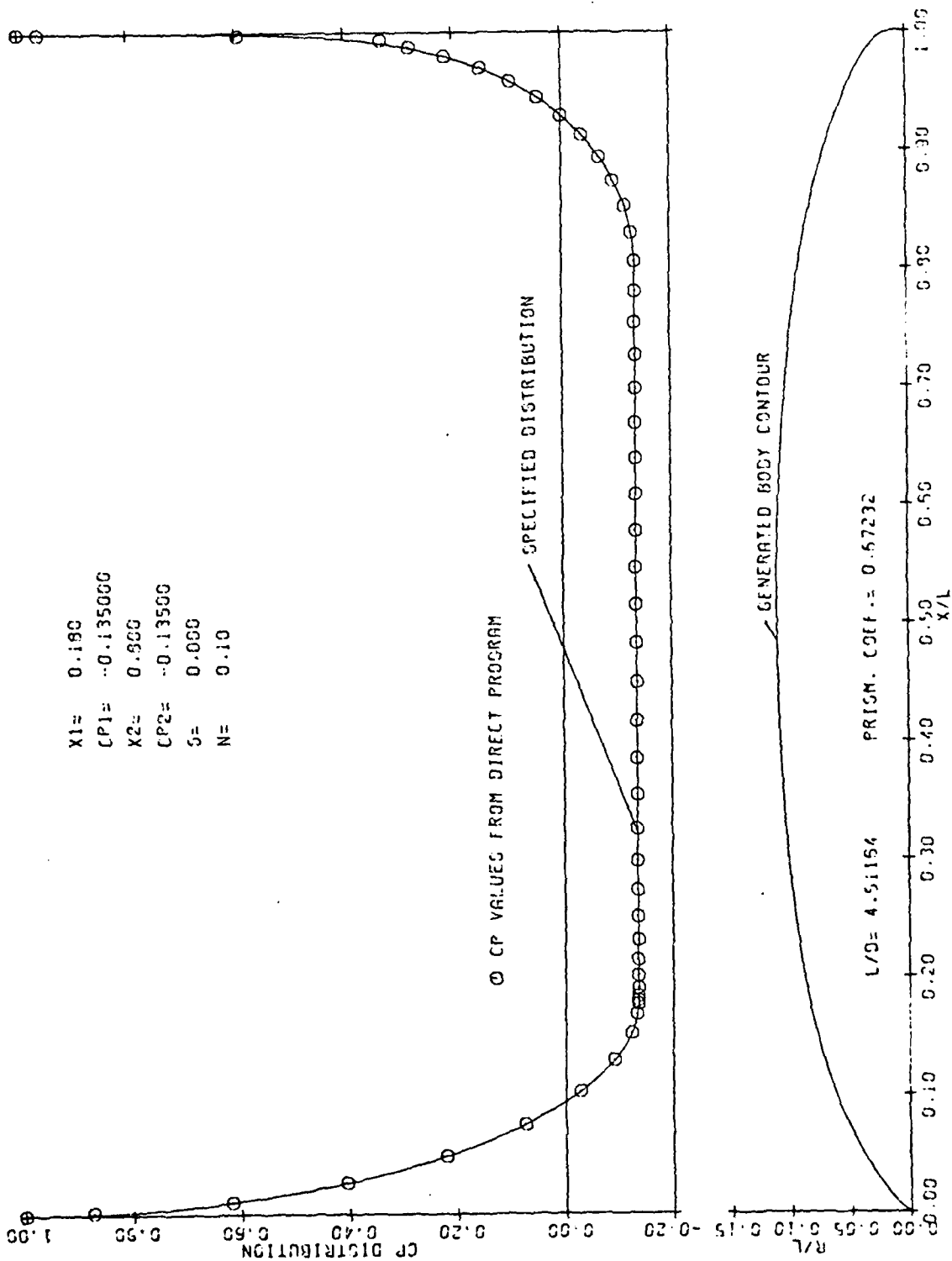


Figure 49. Pressure Distribution and Body Contour, Case No. 39.

# INVERSE BODY CASE 40

X1= 0.010  
CP1= -0.035000  
X2= 0.900  
CP2= -0.035000  
S= 0.000  
N= 0.10

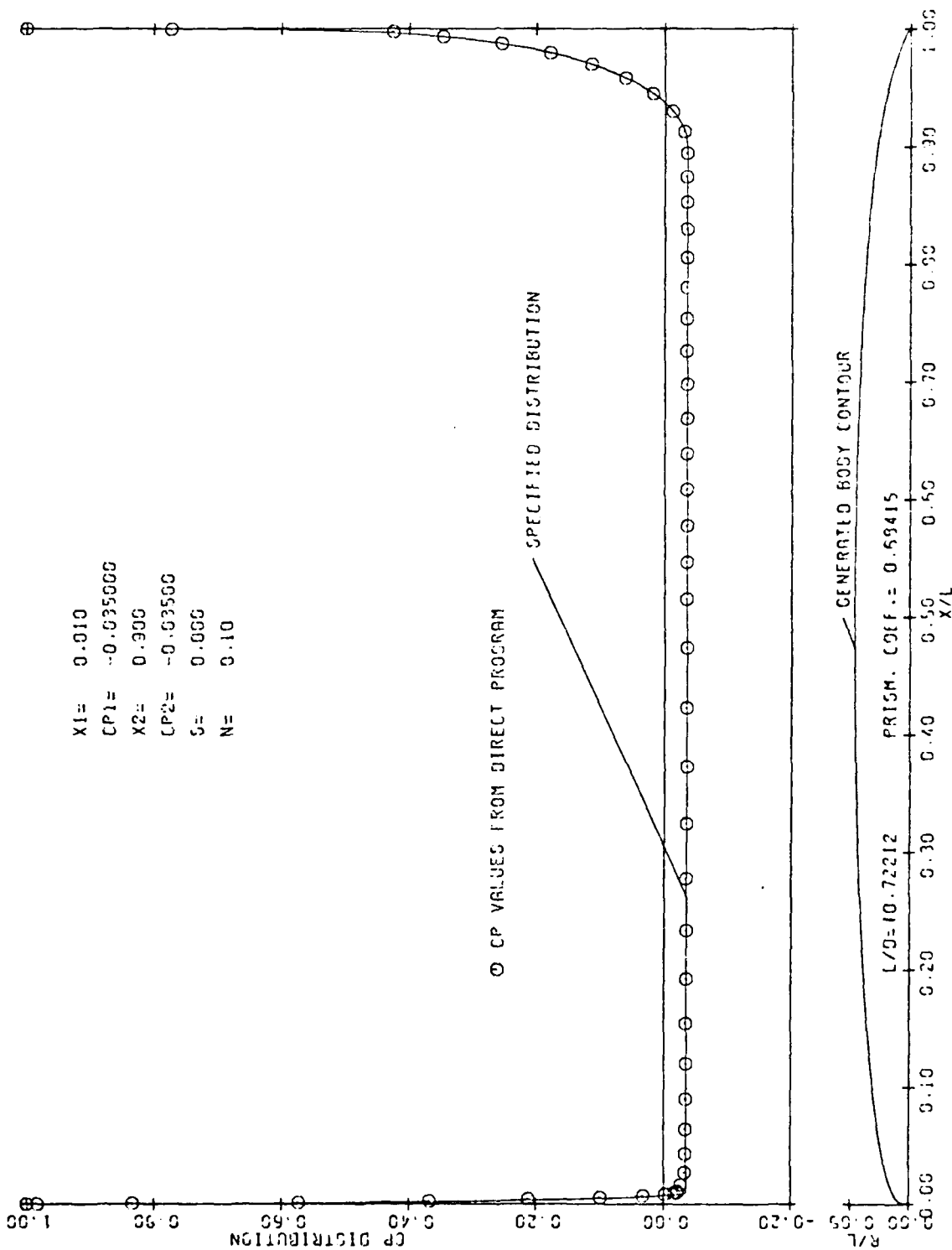


Figure 50. Pressure Distribution and Body Contour, Case No. 40.

# INVERSE BODY CASE 41

X1= 0.040  
CP1= -0.035000  
X2= 0.900  
CP2= -0.035000  
S= 0.000  
N= 0.10

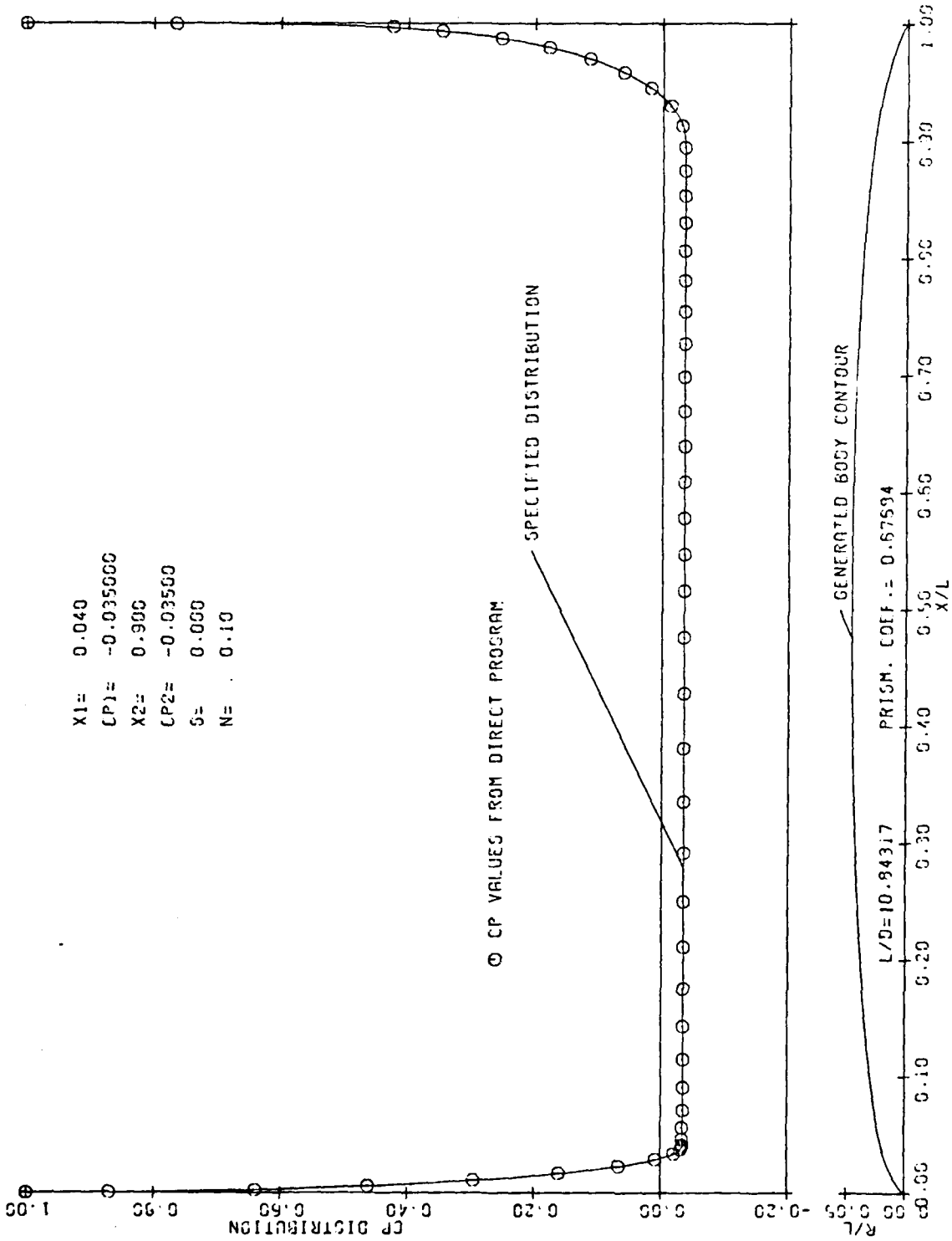


Figure 51. Pressure Distribution and Body Contour, Case No. 41.

# INVERSE BODY CASE 42

X1= 0.010  
CP1= -0.050000  
X2= 0.900  
CP2= -0.050000  
S= 0.000  
N= 0.10

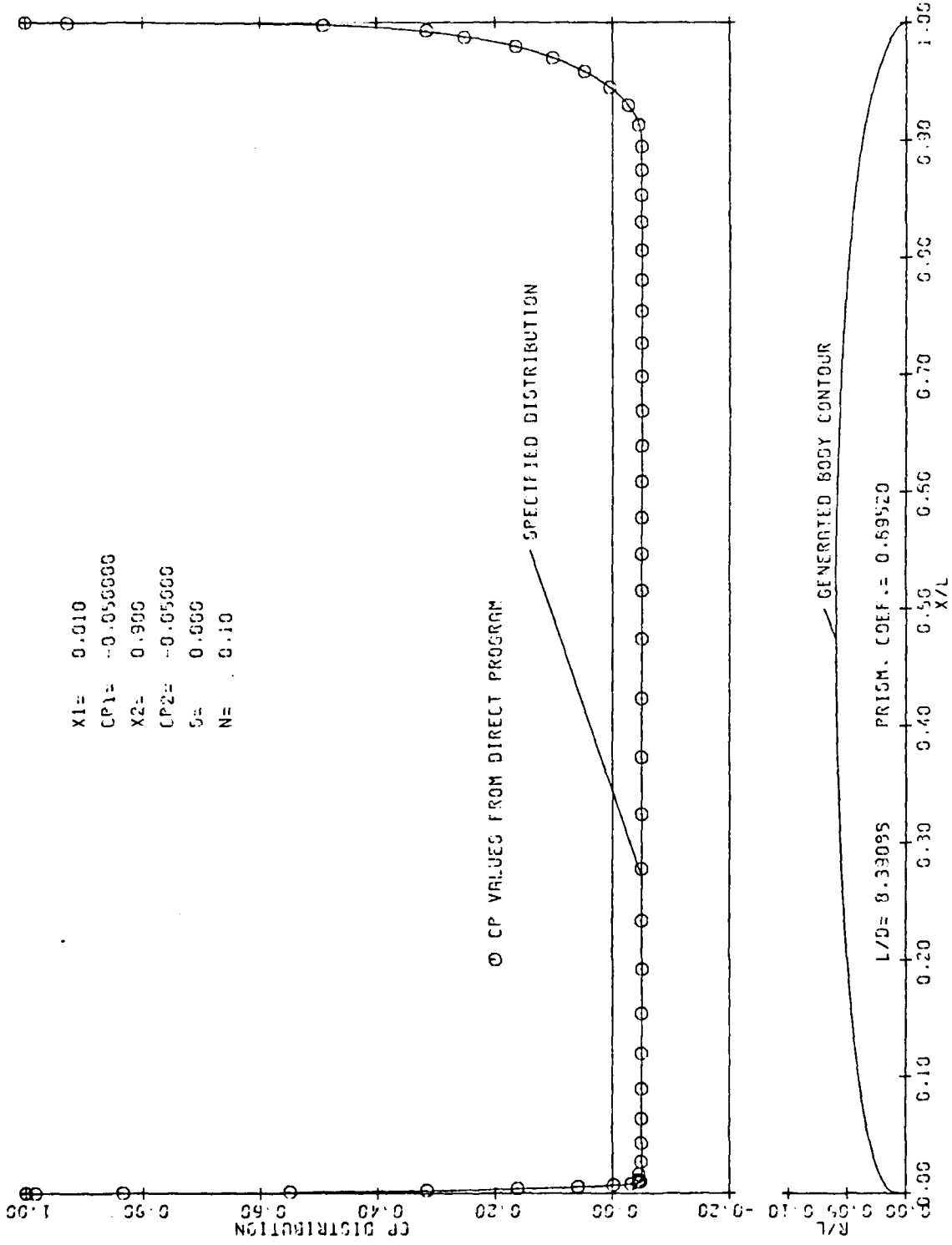


Figure 52. Pressure Distribution and Body Contour, Case No. 42.

# INVERSE BODY CASE 43

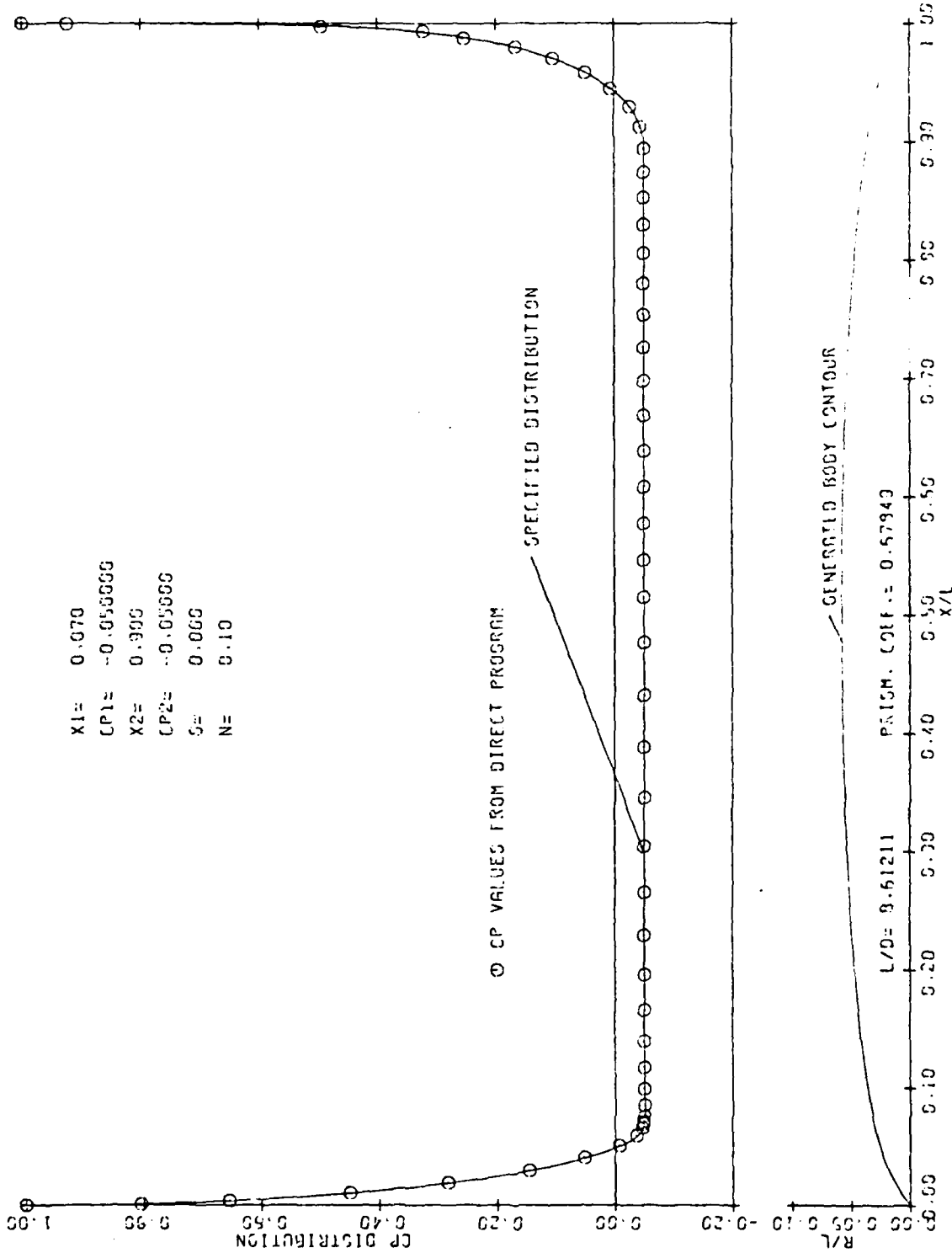


Figure 53. Pressure Distribution and Body Contour, Case No. 43.

# INVERSE BODY CASE 44

X1= 0.010  
CP1= -0.075000  
X2= 0.900  
CP2= -0.07500  
S= 0.000  
N= 0.10

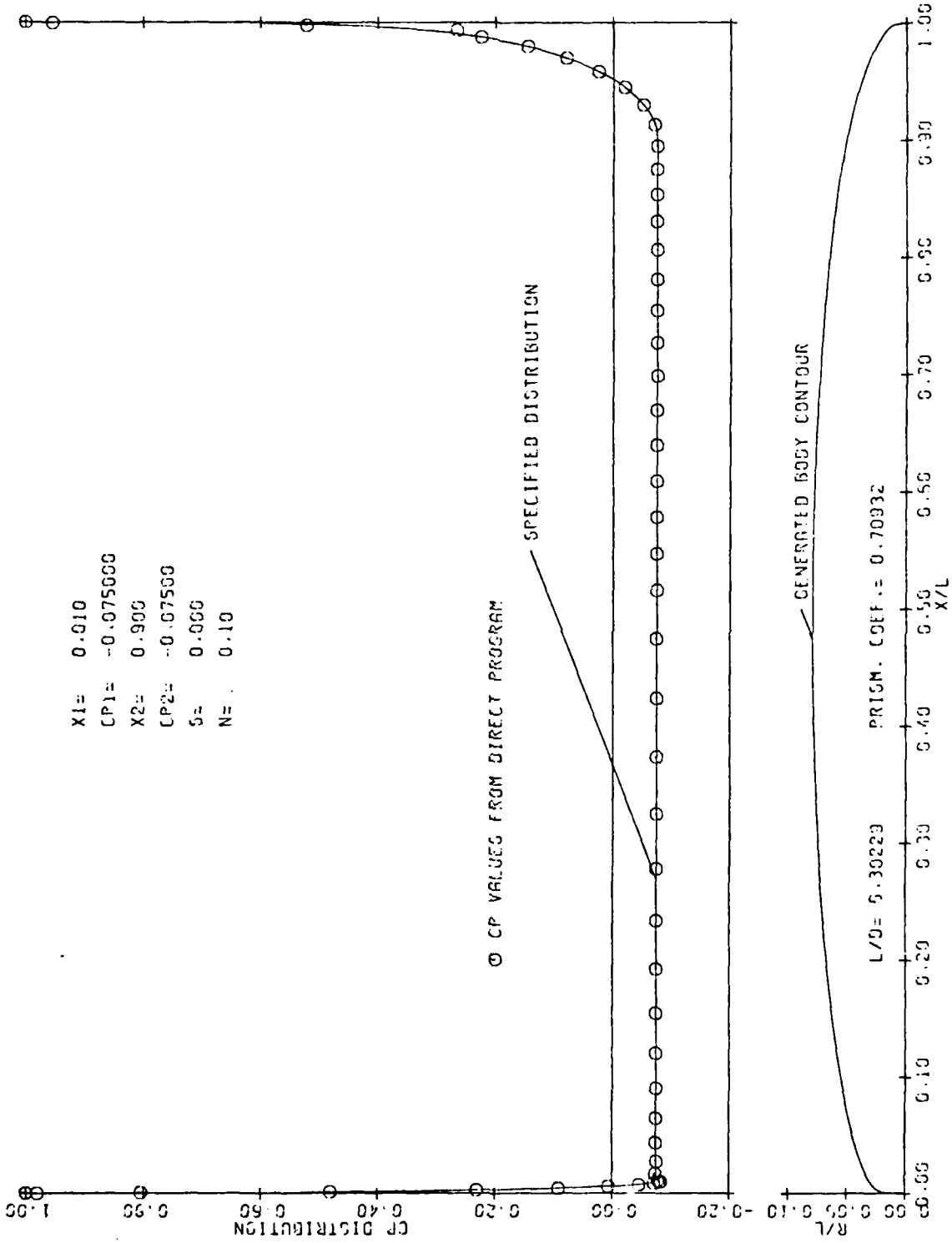


Figure 54. Pressure Distribution and Body Contour, Case No. 44.

# INVERSE BODY CASE 45

X1= 0.100  
CP1= -0.075000  
X2= 0.900  
CP2= -0.075000  
S= 0.000  
N= 0.10

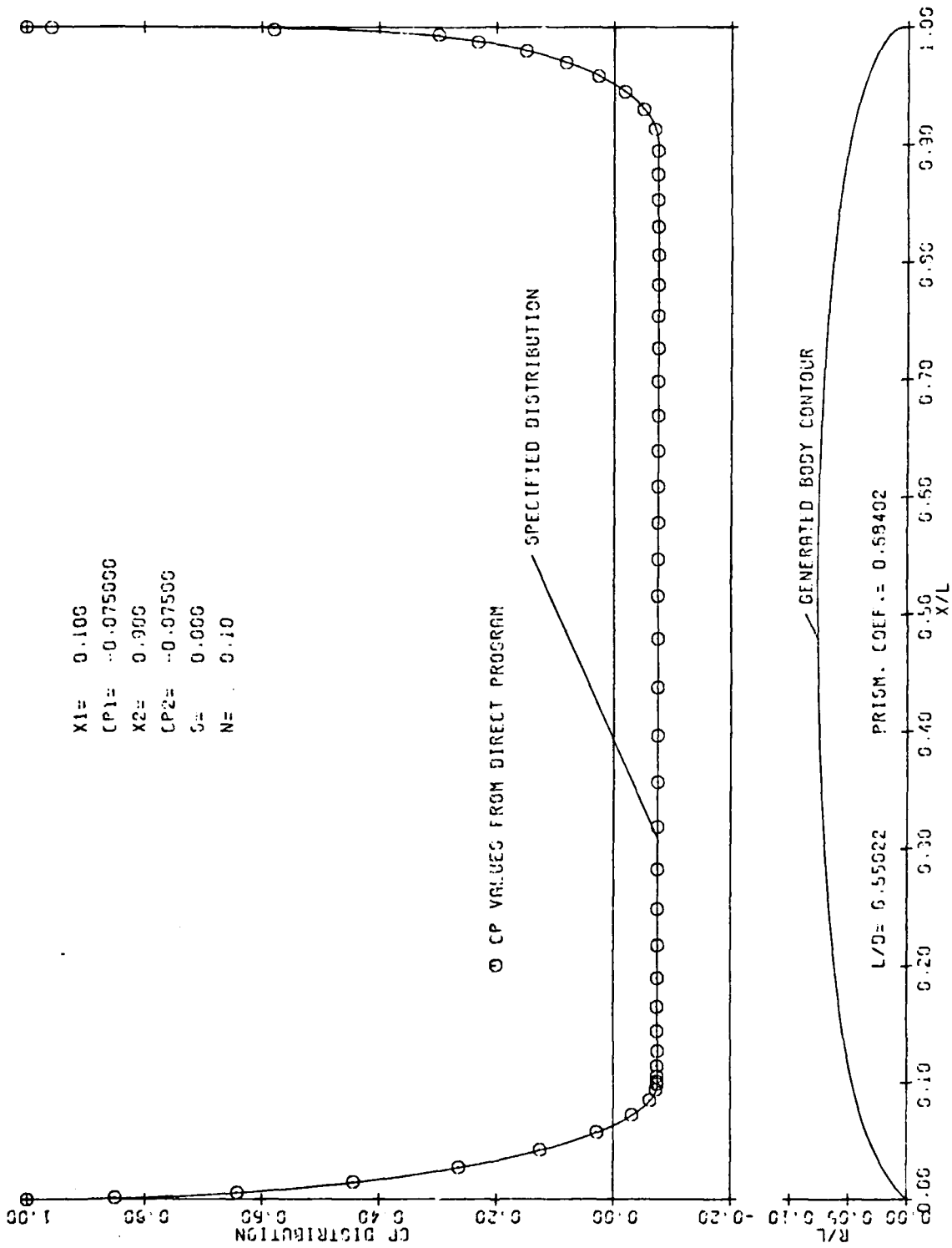


Figure 55. Pressure Distribution and Body Contour, Case No. 45.

# INVERSE BODY CASE 46

X1= 0.010  
CP1= -0.100000  
X2= 0.900  
CP2= -0.100000  
S= 0.000  
N= 0.10

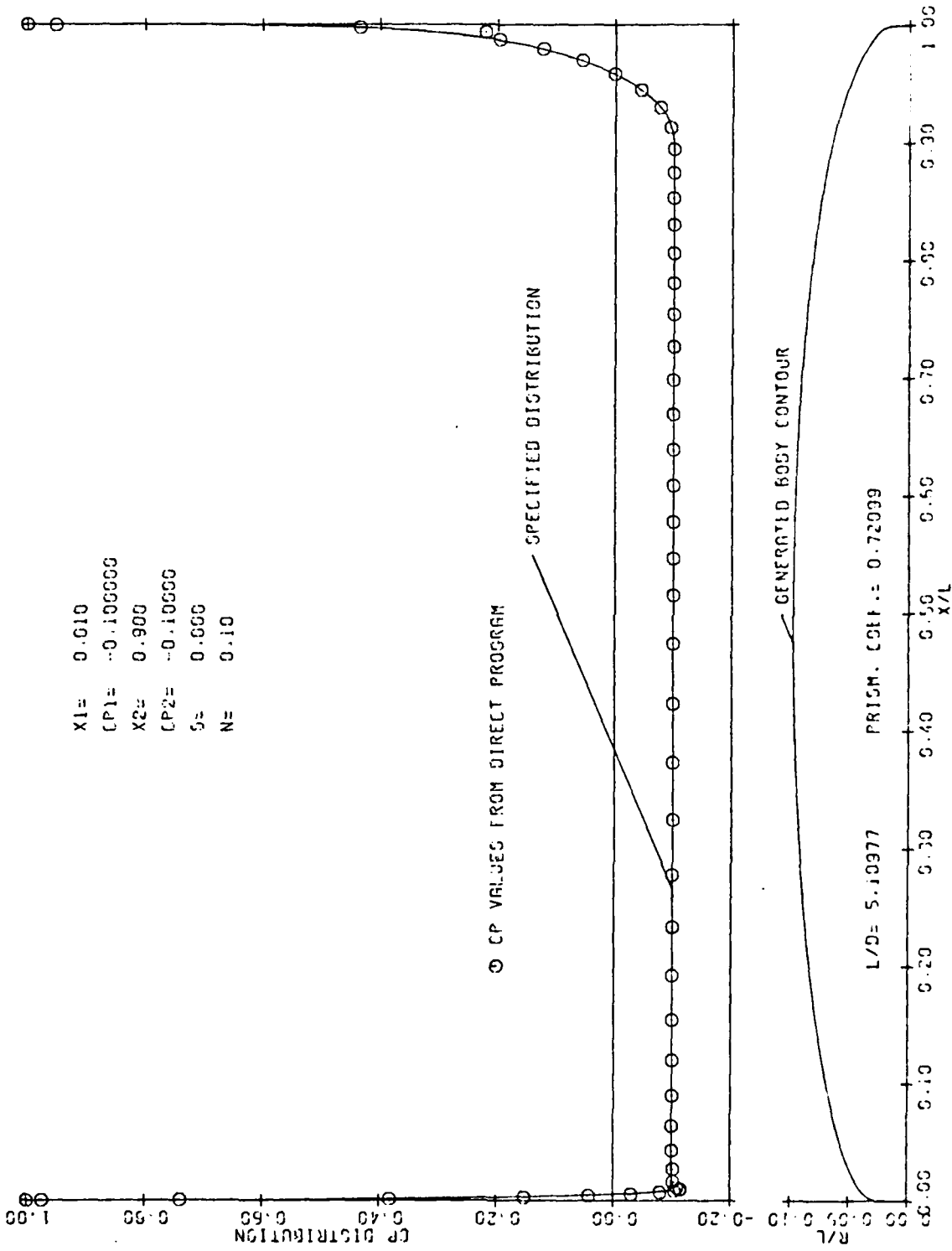


Figure 56. Pressure Distribution and Body Contour, Case No. 46.

INVERSE BODY CASE 47

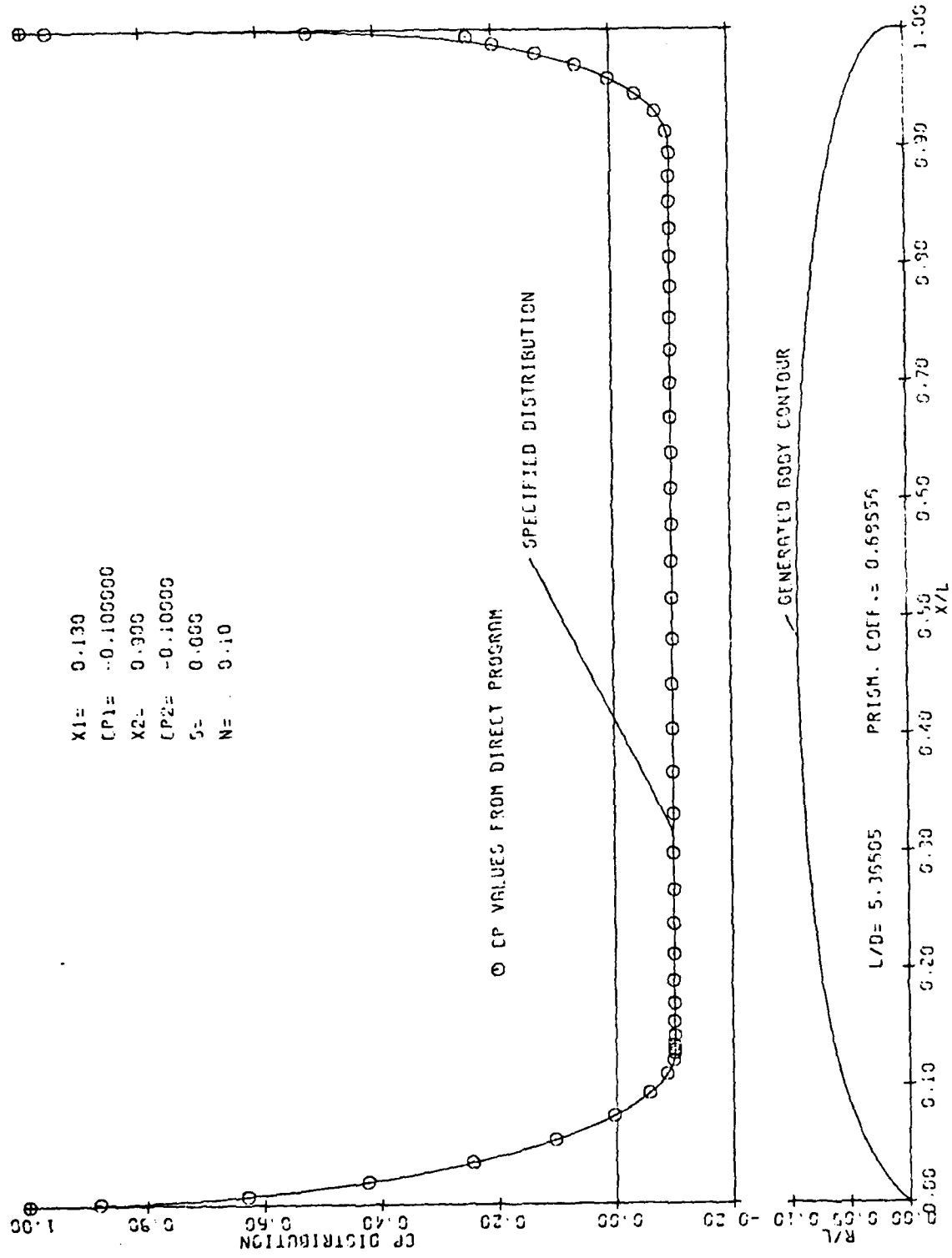


Figure 57. Pressure Distribution and Body Contour, Case No. 47.

# INVERSE BODY CASE 48

X1= 0.050  
CP1= -0.110000  
X2= 0.000  
CP2= -0.110000  
S= 0.000  
N= 0.10

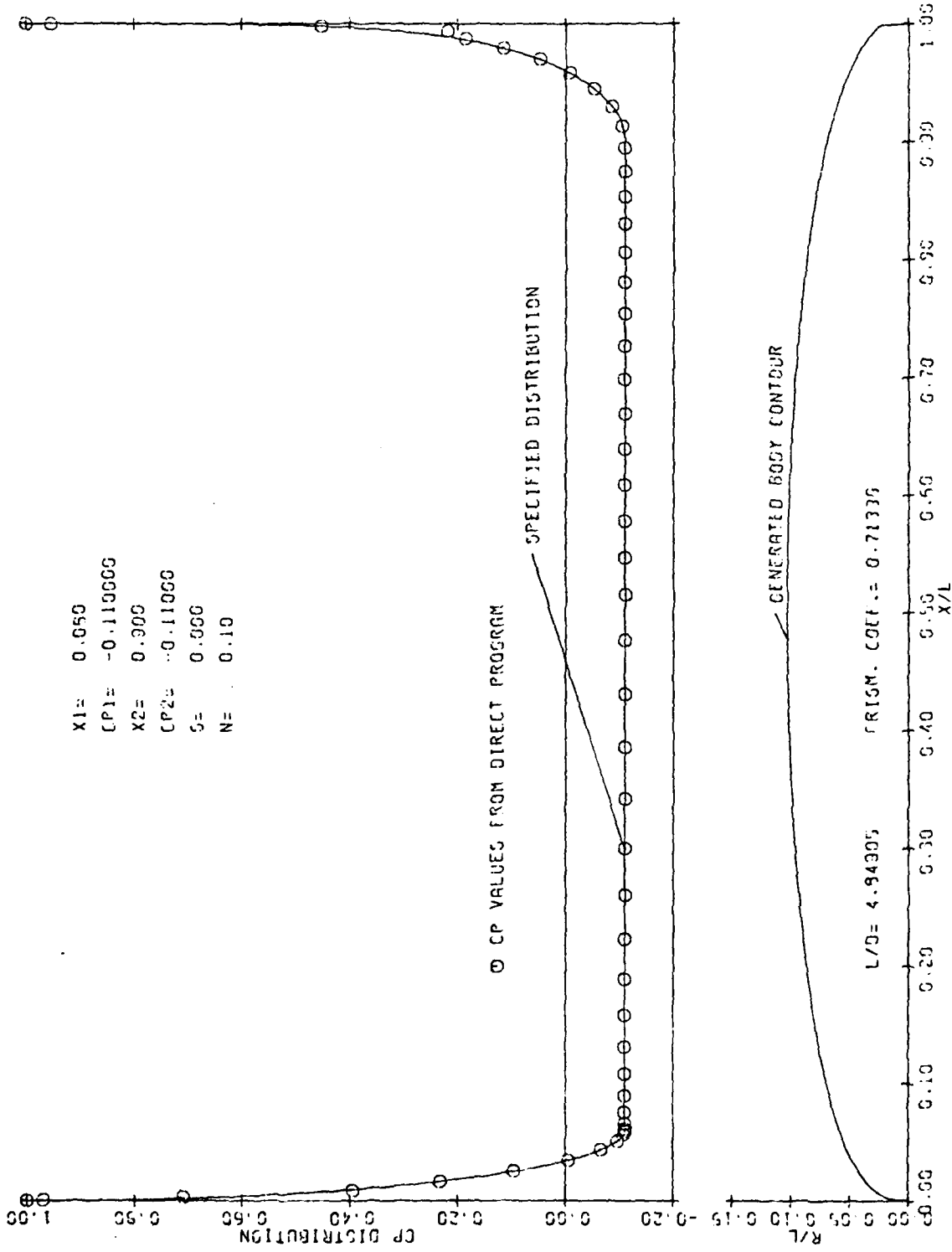


Figure 58. Pressure Distribution and Body Contour, Case No. 48.

# INVERSE BODY CASE 49

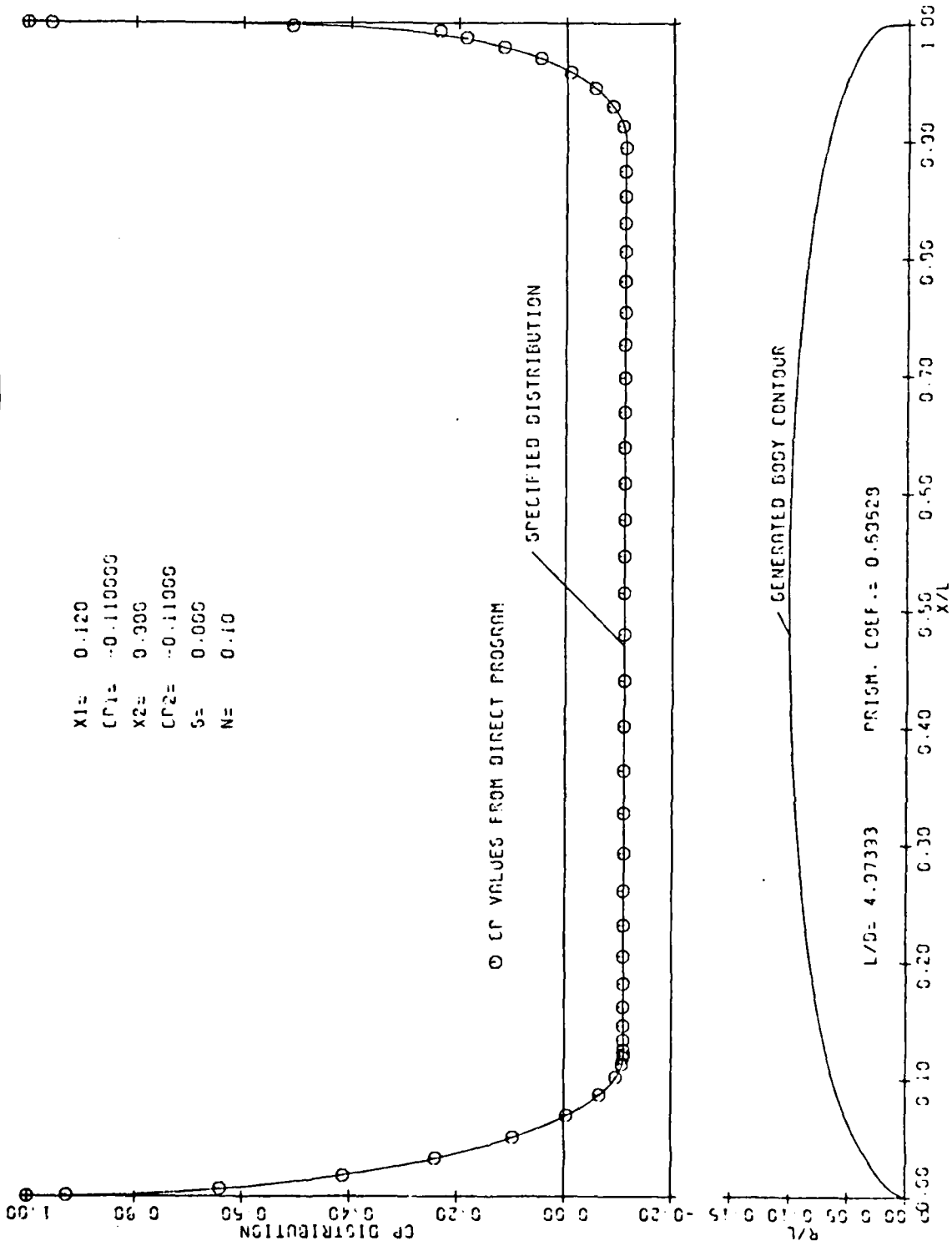


Figure 59. Pressure Distribution and Body Contour, Case No. 49.

# INVERSE BODY CASE 50

XI= 0.010  
CP1= -0.136750  
X2= 0.700  
CP2= -0.09500  
S= 0.075  
N= 0.10

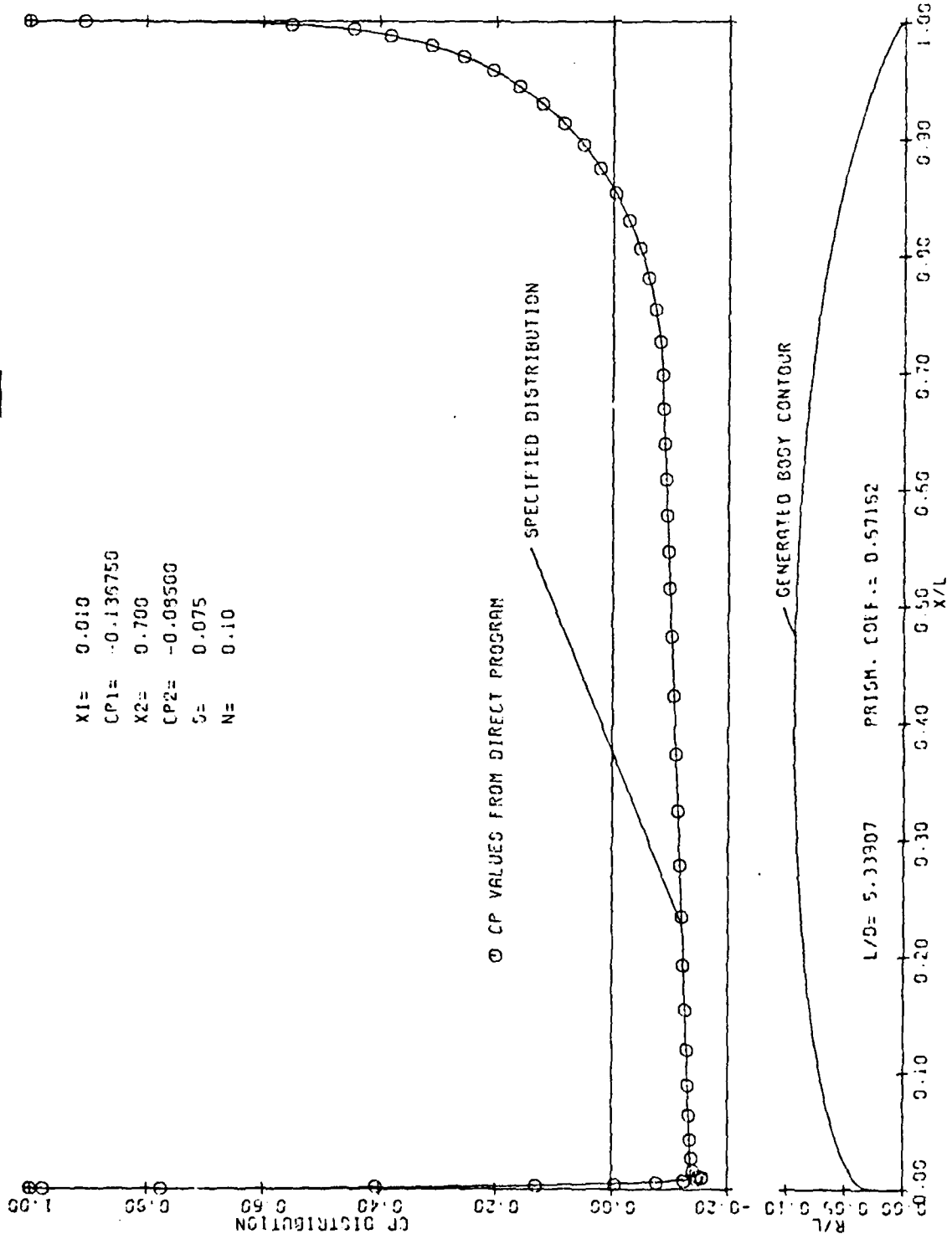
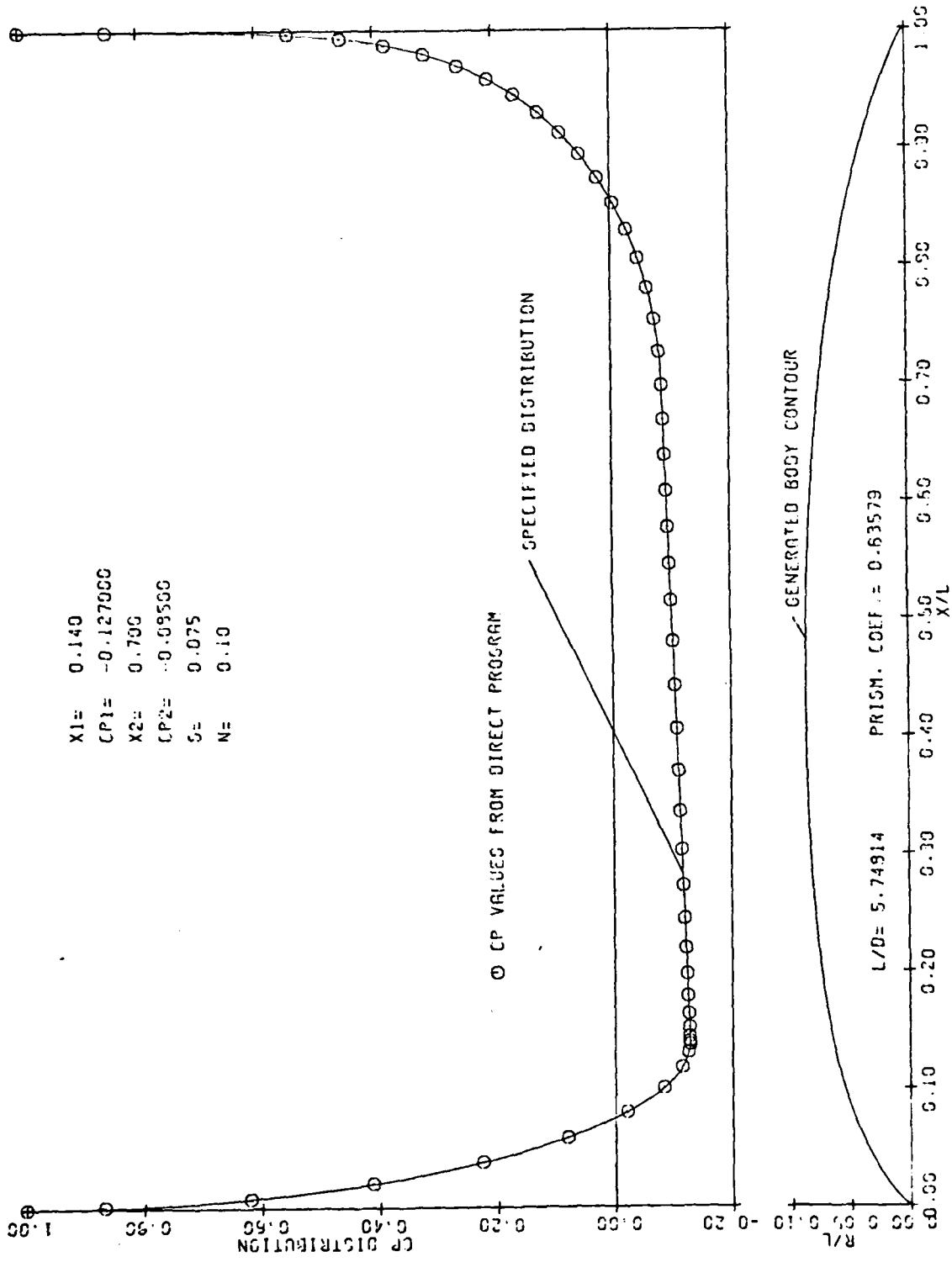


Figure 60. Pressure Distribution and Body Contour, Case No. 50.

# INVERSE BODY CASE 51



X1= 0.140  
CP1= -0.127000  
X2= 0.700  
CP2= -0.09500  
S= 0.075  
N= 0.10

Figure 61. Pressure Distribution and Body Contour, Case No. 51.

# INVERSE BODY CASE 52

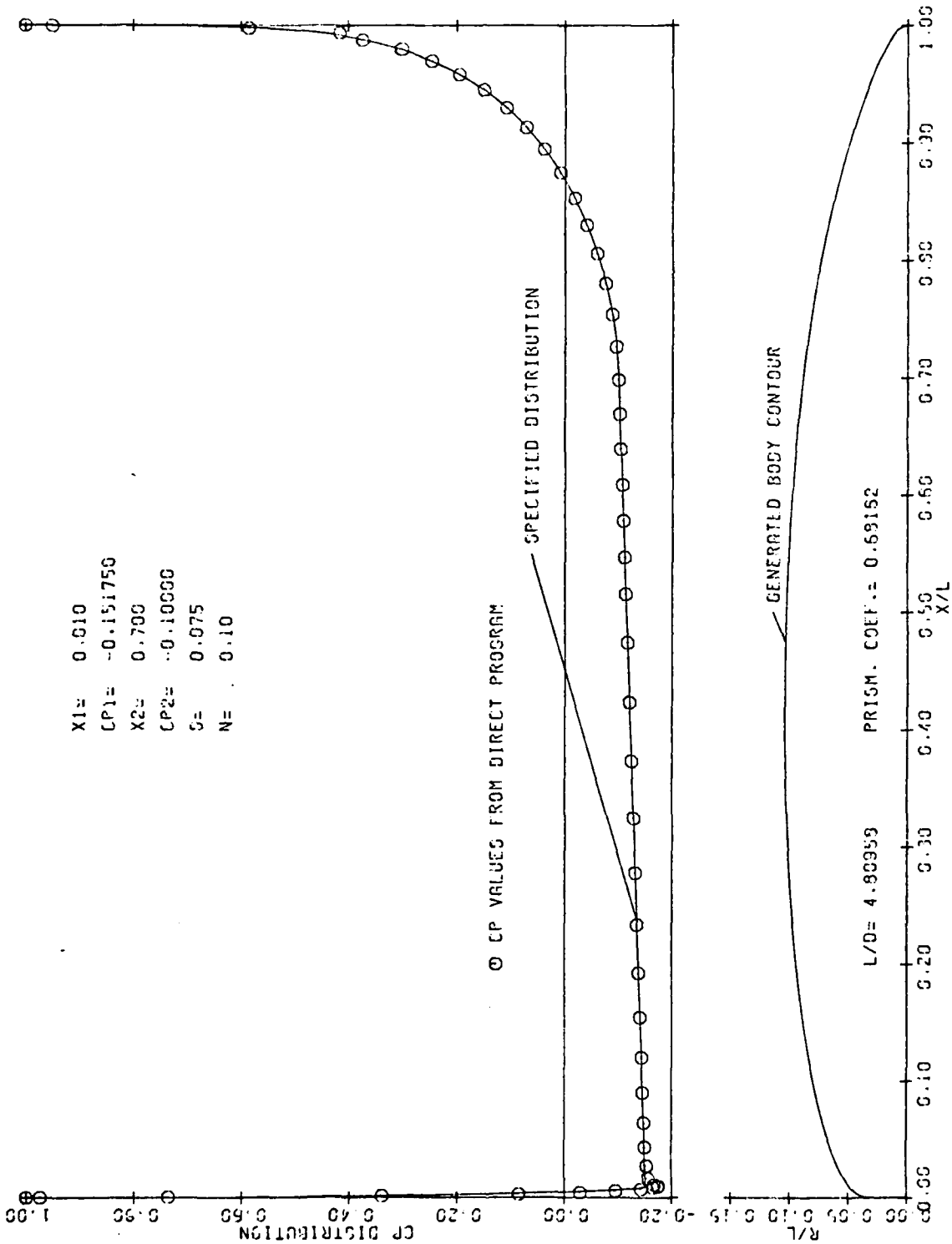


Figure 62. Pressure Distribution and Body Contour, Case No. 52.

# INVERSE BODY CASE 53

X1= 0.150  
 CP1= -0.140500  
 X2= 0.700  
 CP2= -0.100000  
 S= 0.075  
 N= 0.10

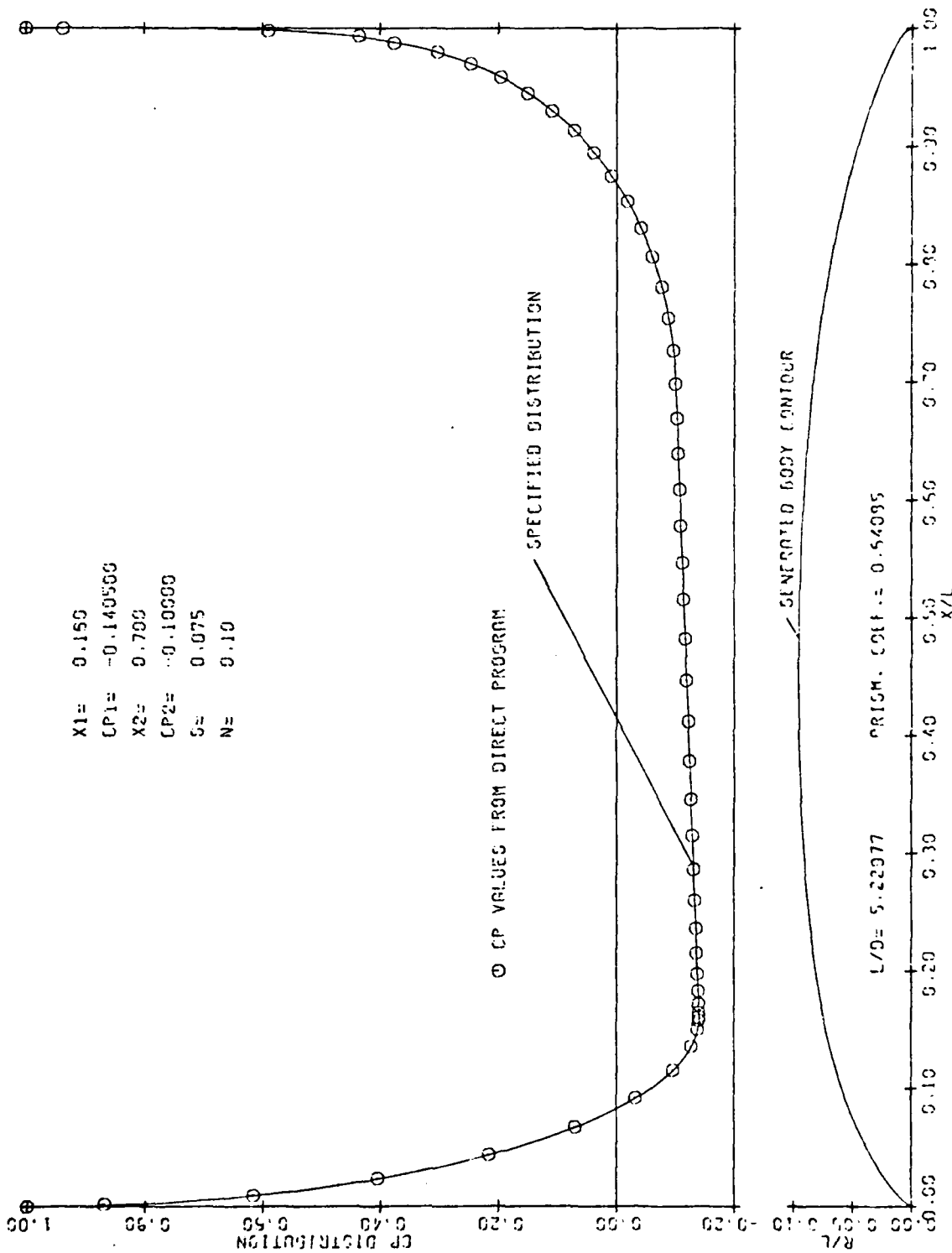


Figure 63. Pressure Distribution and Body Contour, Case No. 53.

# INVERSE BODY CASE 54

X1= 0.020  
 CP1= -0.175000  
 X2= 0.700  
 CP2= -0.12500  
 S= 0.075  
 N= 0.10

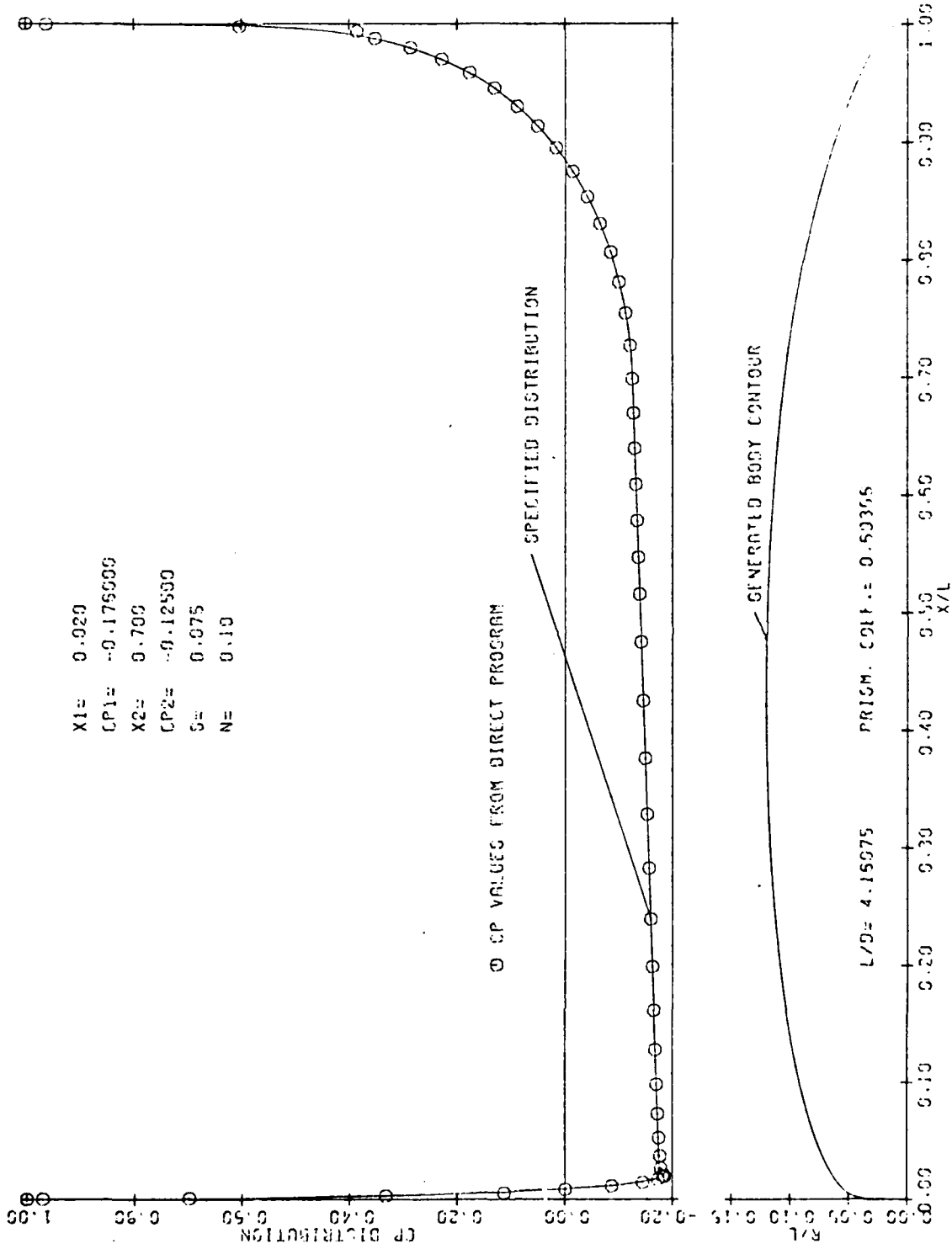


Figure 64. Pressure Distribution and Body Contour, Case No. 54.

# INVERSE BODY CASE 55

X1= 0.199  
CP1= -0.153250  
X2= 0.700  
CP2= -0.12500  
S= 0.075  
N= 0.10

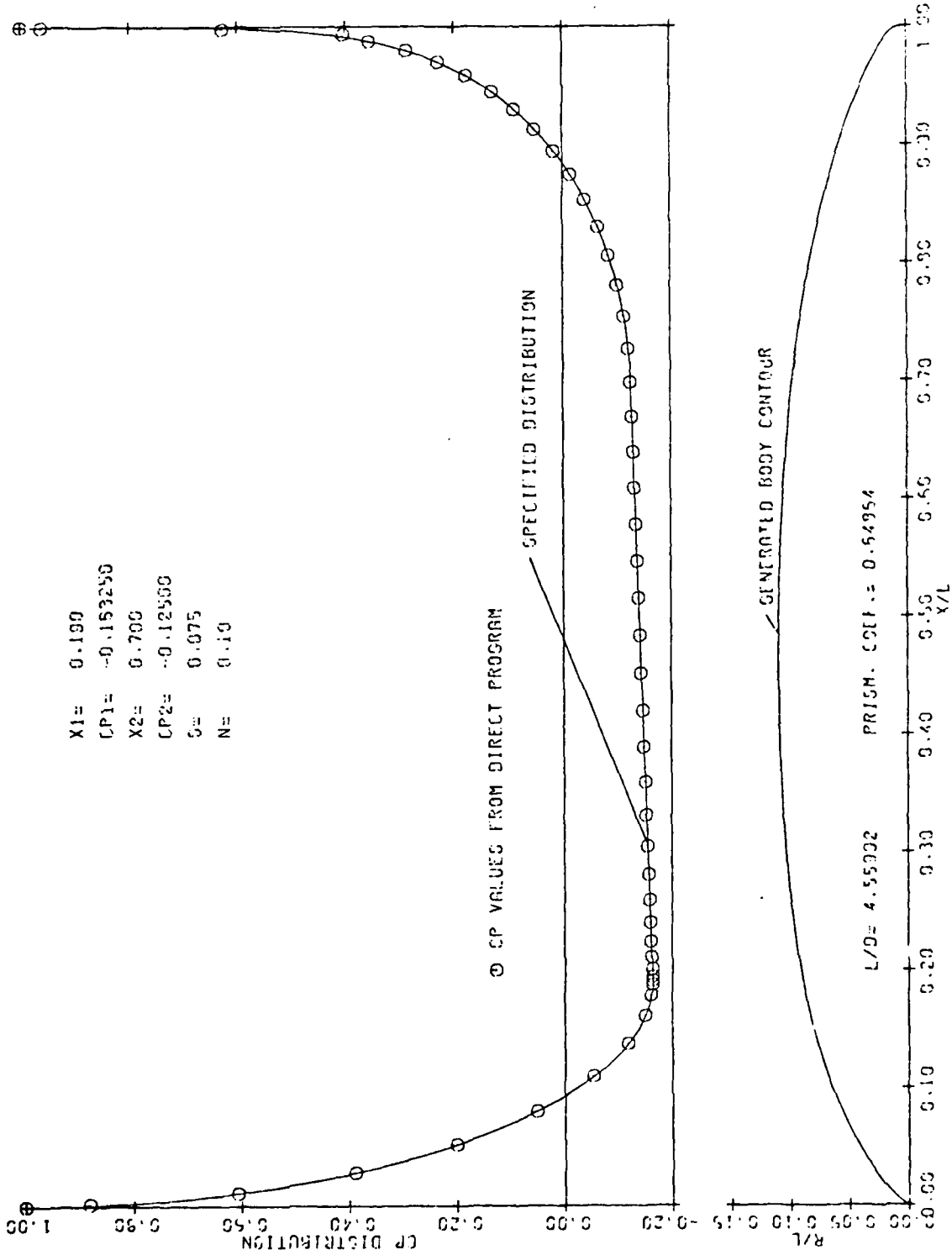


Figure 65. Pressure Distribution and Body Contour, Case No. 55.

# INVERSE BODY CASE 56

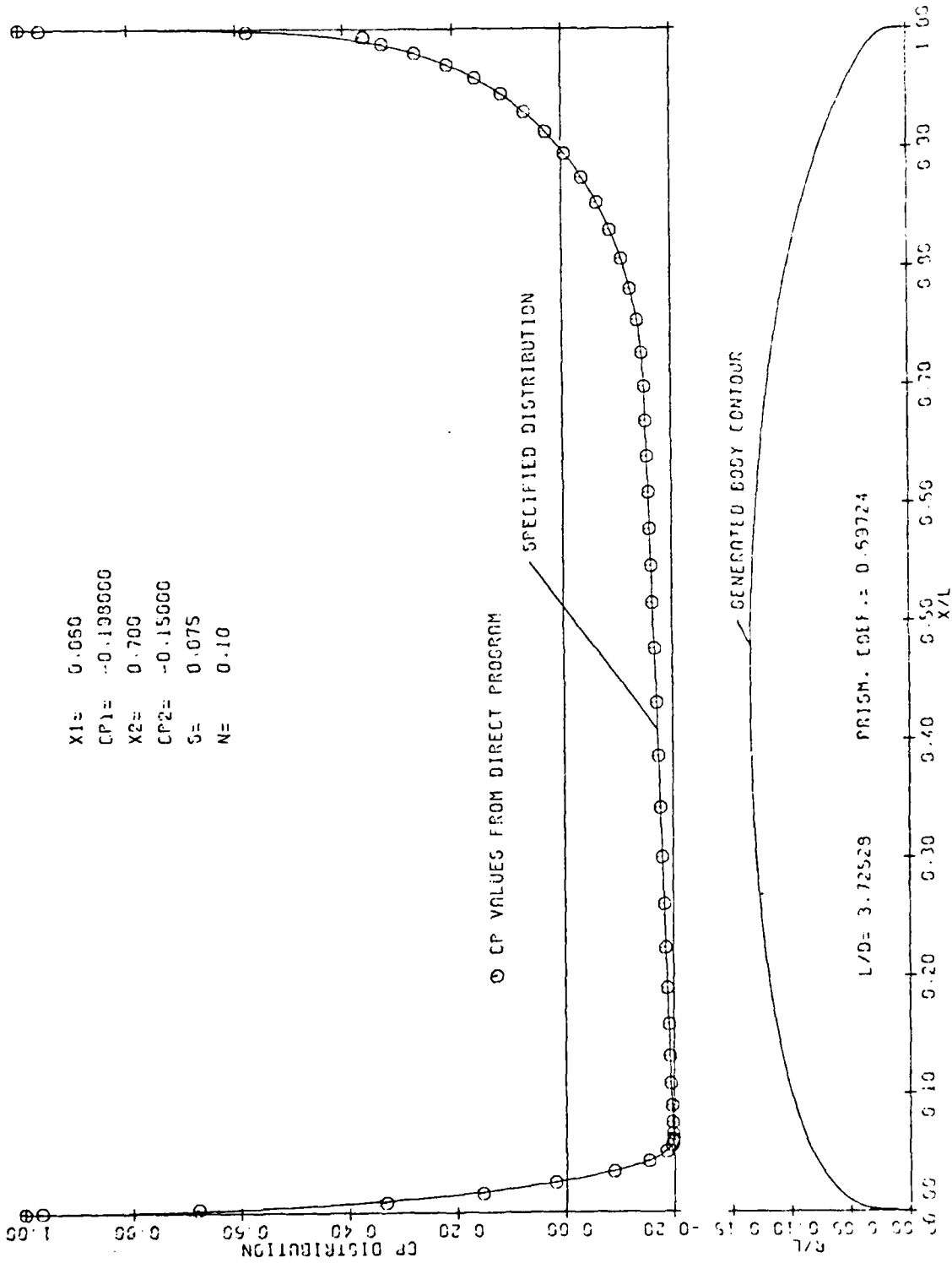


Figure 66. Pressure Distribution and Body Contour, Case No. 56.

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INVERSE AXISYMMETRIC BODY STUDY. (U)

AUG 81 J J EISENHUTH, G H HOFFMAN

N00024-79-C-6043

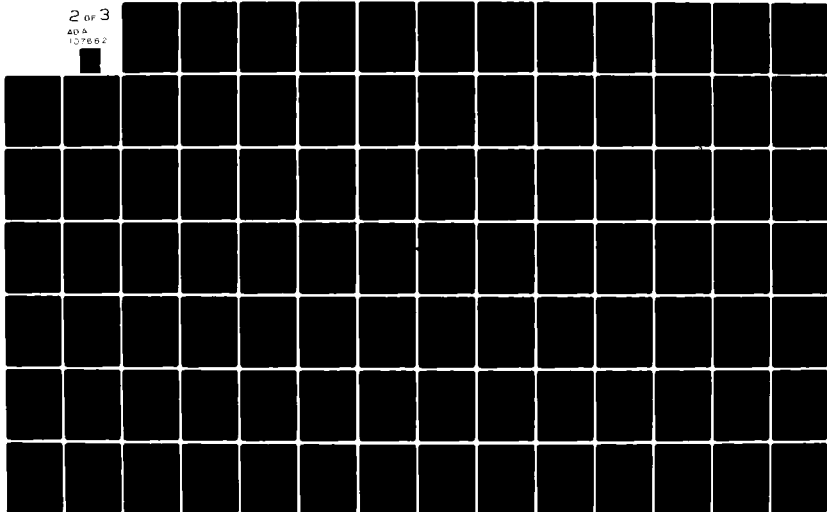
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# INVERSE BODY CASE 57

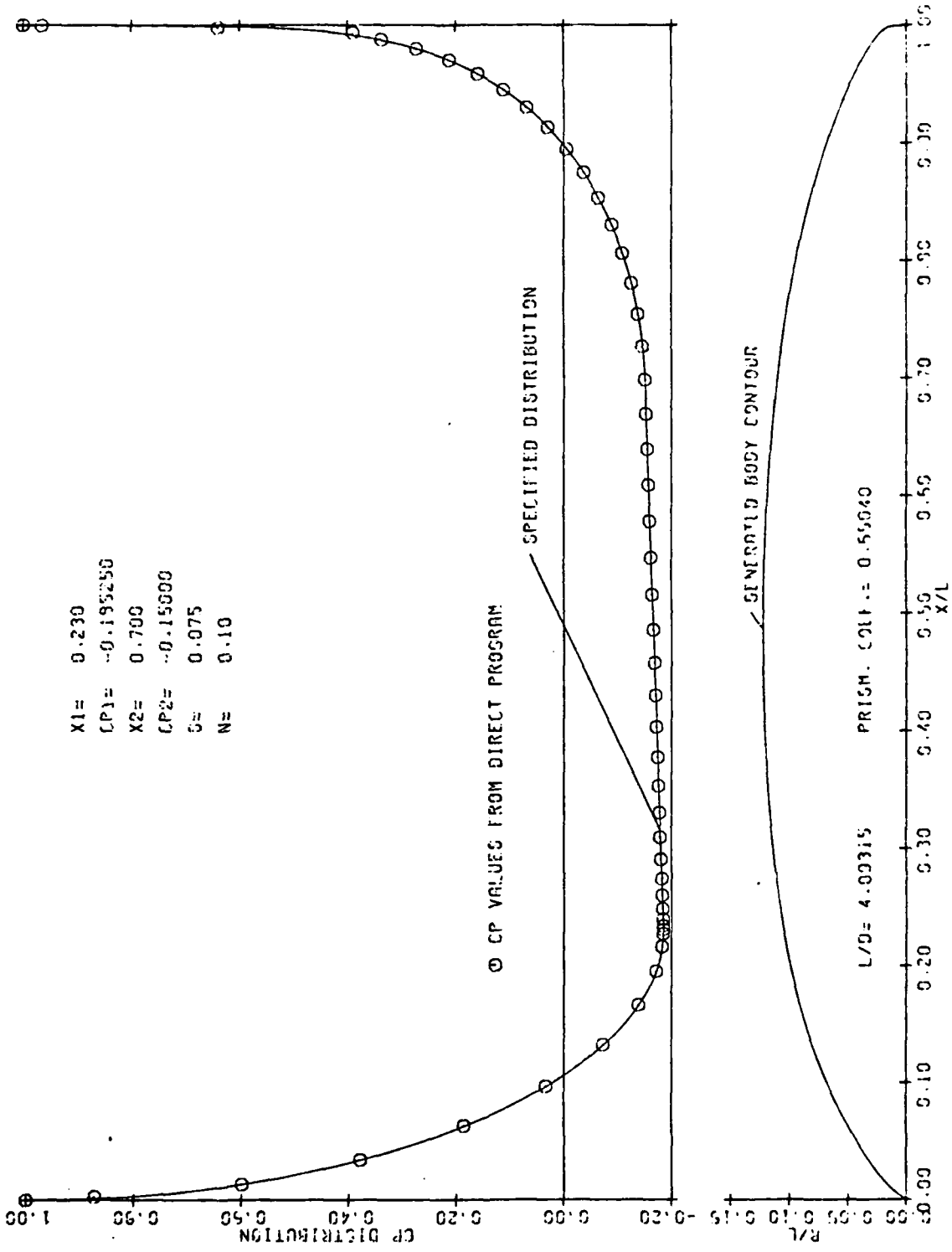


Figure 67. Pressure Distribution and Body Contour, Case No. 57.

# INVERSE BODY CASE 58

X1= 0.140  
CP1= -0.217000  
X2= 0.700  
CP2= -0.17500  
S= 0.075  
N= 0.10

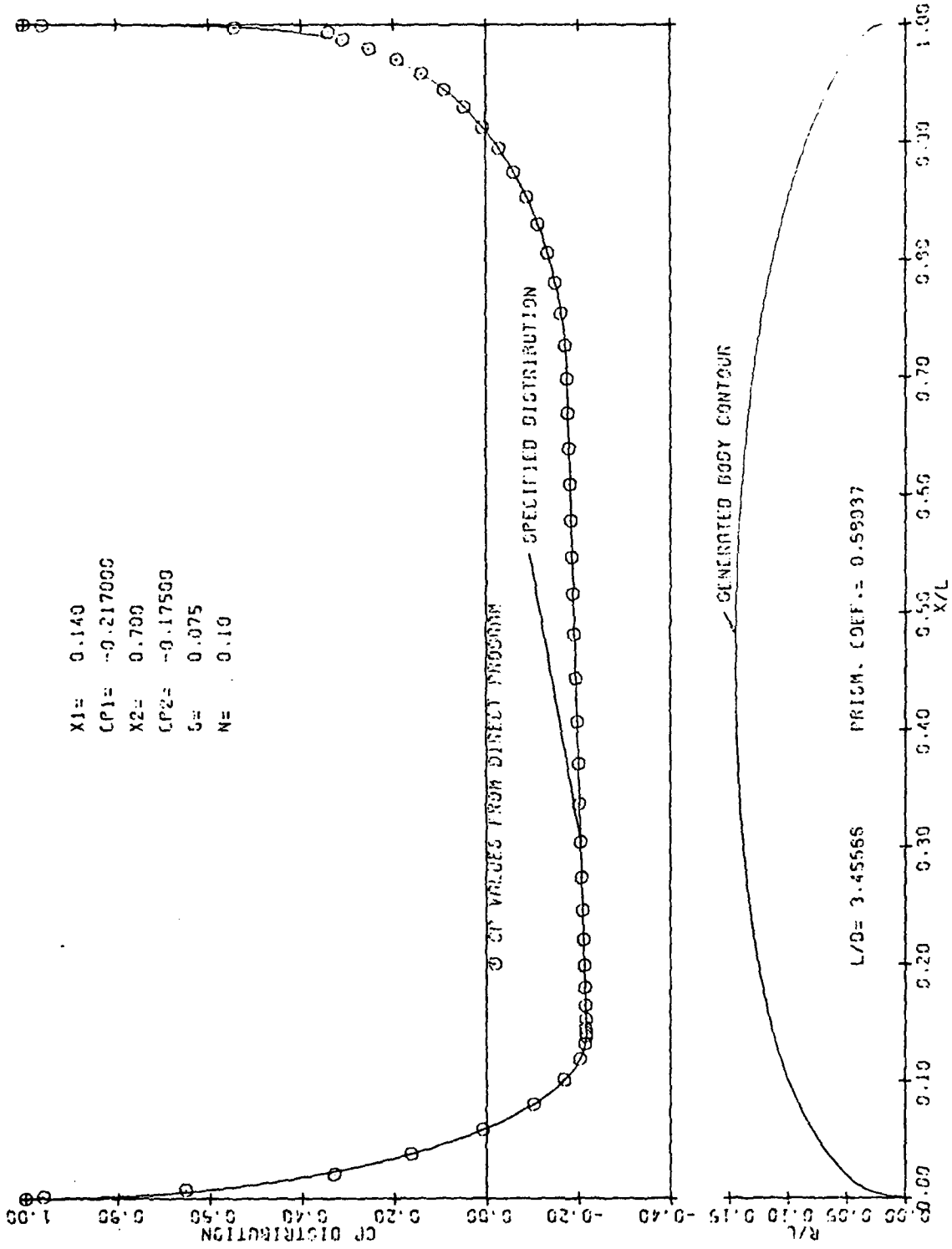


Figure 68. Pressure Distribution and Body Contour, Case No. 58.

# INVERSE BODY CASE 59

X1= 0.250  
CP1= -0.209000  
X2= 0.700  
CP2= -0.17500  
S= 0.075  
N= 0.10

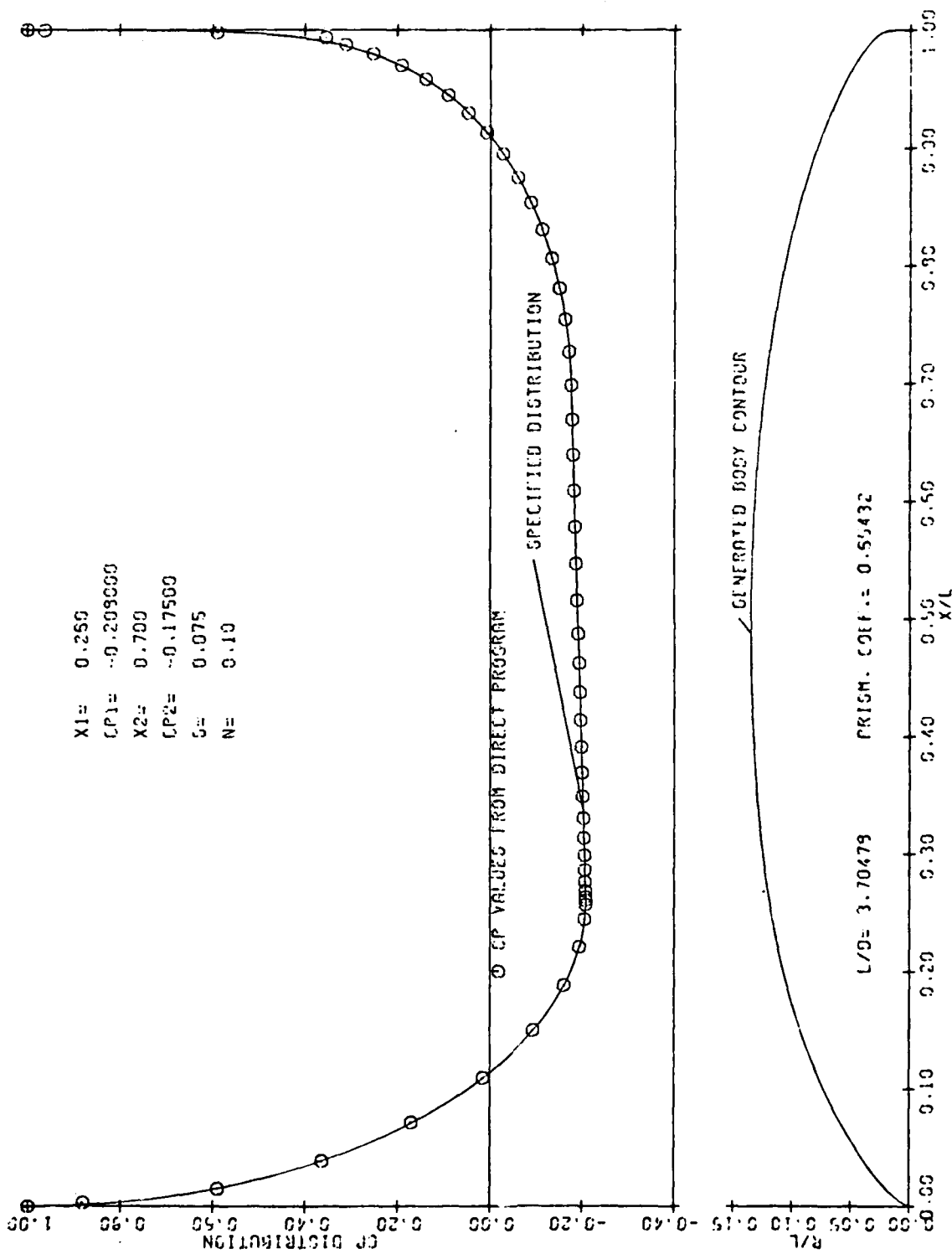


Figure 69. Pressure Distribution and Body Contour, Case No. 59.

# INVERSE BODY CASE 60

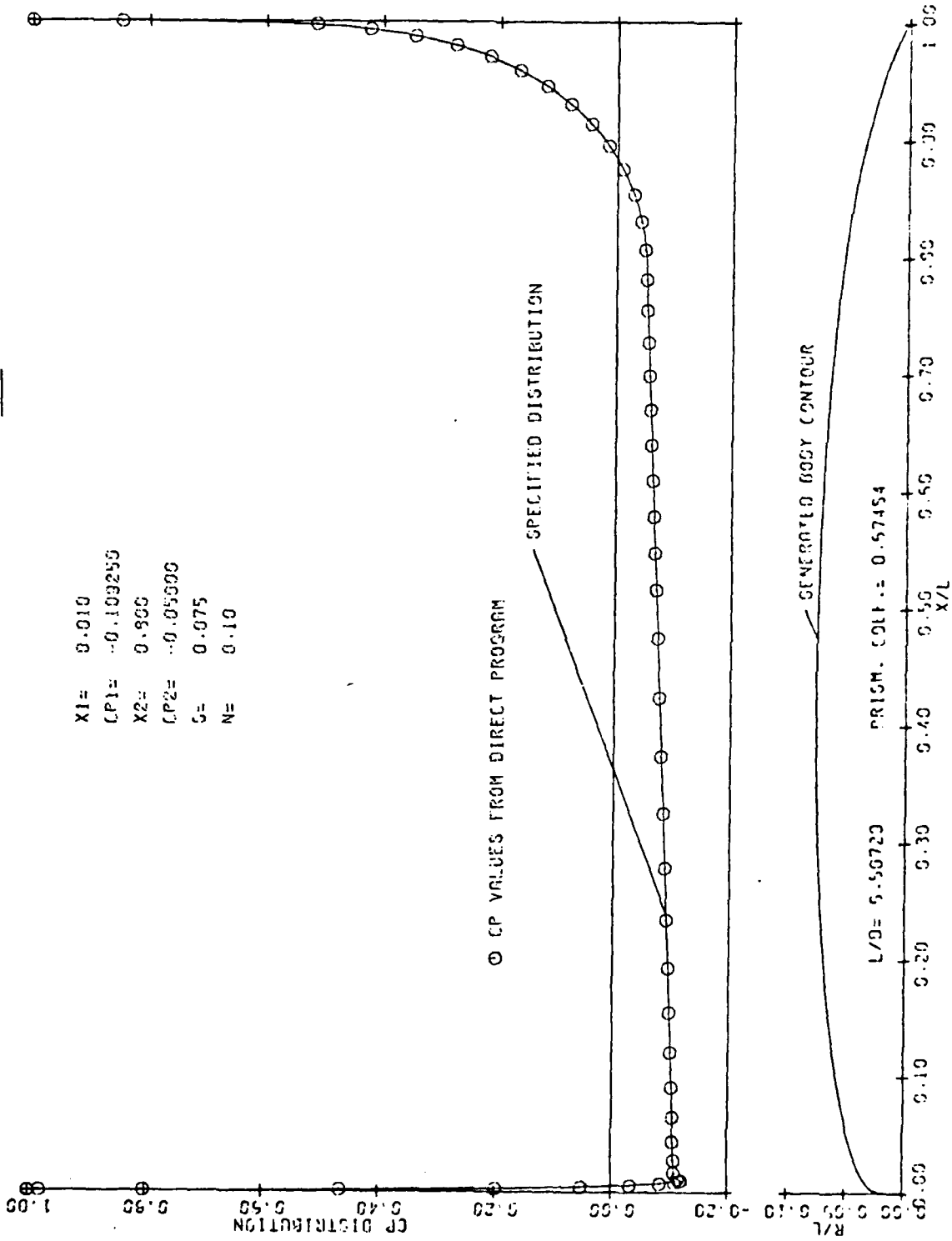


Figure 70. Pressure Distribution and Body Contour, Case No. 60.

# INVERSE BODY CASE 61

X1= 0.110  
CP1= -0.101750  
X2= 0.800  
CP2= -0.050000  
S= 0.075  
N= 0.10

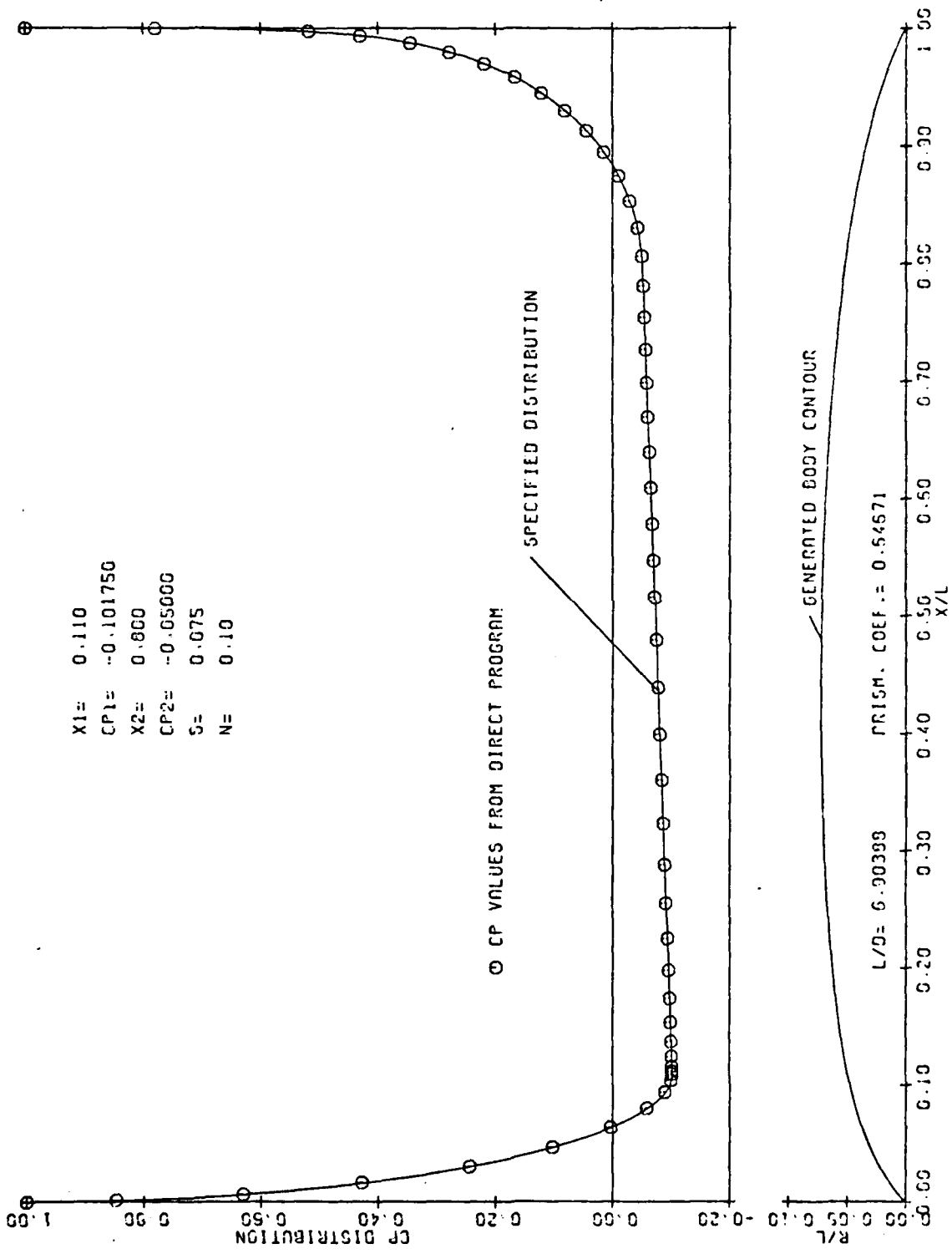


Figure 71. Pressure Distribution and Body Contour, Case No. 61.

# INVERSE BODY CASE 62

X1= 0.010  
 CP1= -0.134250  
 X2= 0.900  
 CP2= -0.07500  
 Q= 0.075  
 NE 0.10

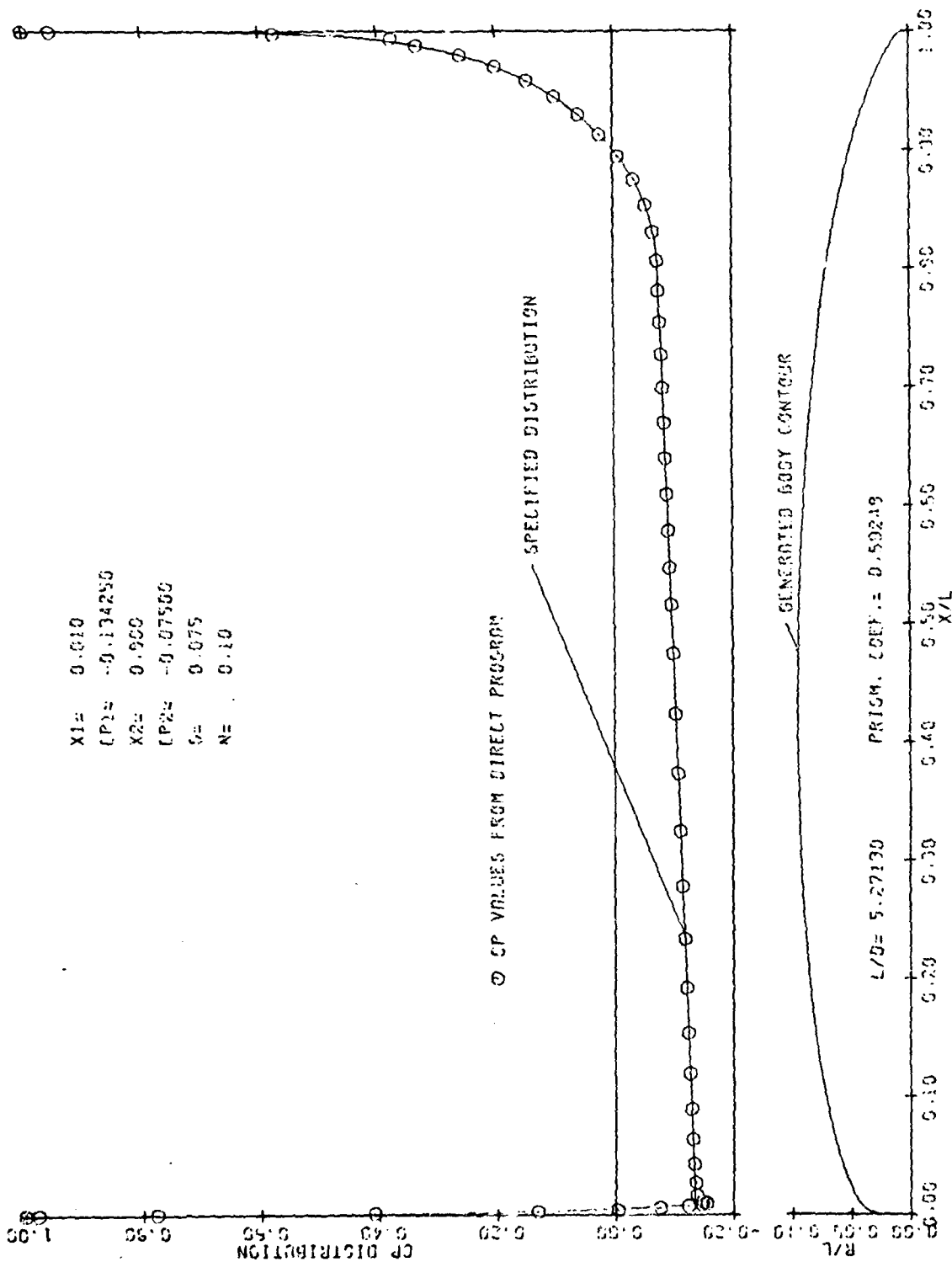


Figure 72. Pressure Distribution and Body Contour, Case No. 62.

# INVERSE BODY CASE 63

X1= 0.140  
CP1= -0.124500  
X2= 0.900  
CP2= -0.07500  
S= 0.075  
N= 0.10

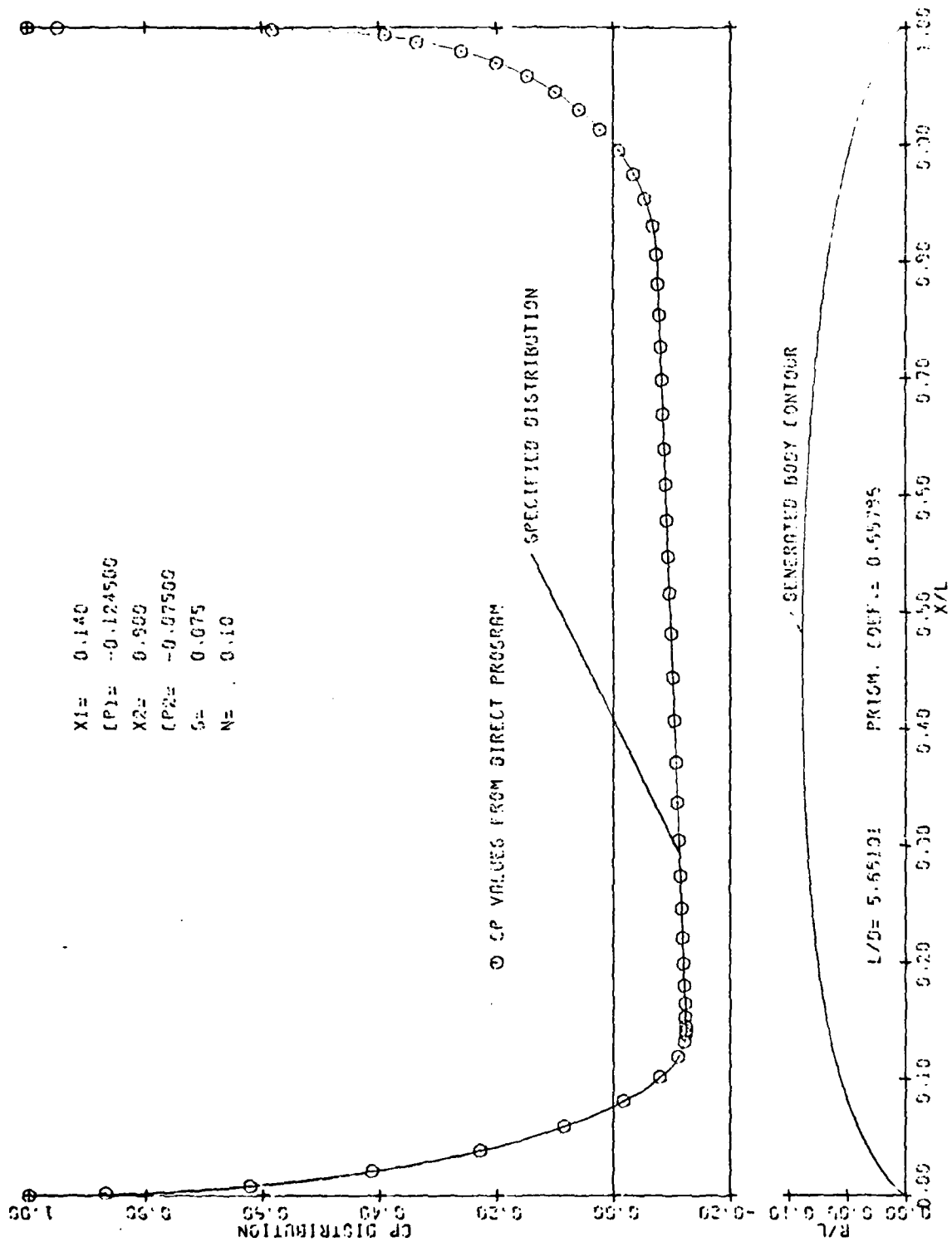


Figure 73. Pressure Distribution and Body Contour, Case No. 63.

# INVERSE BODY CASE 64

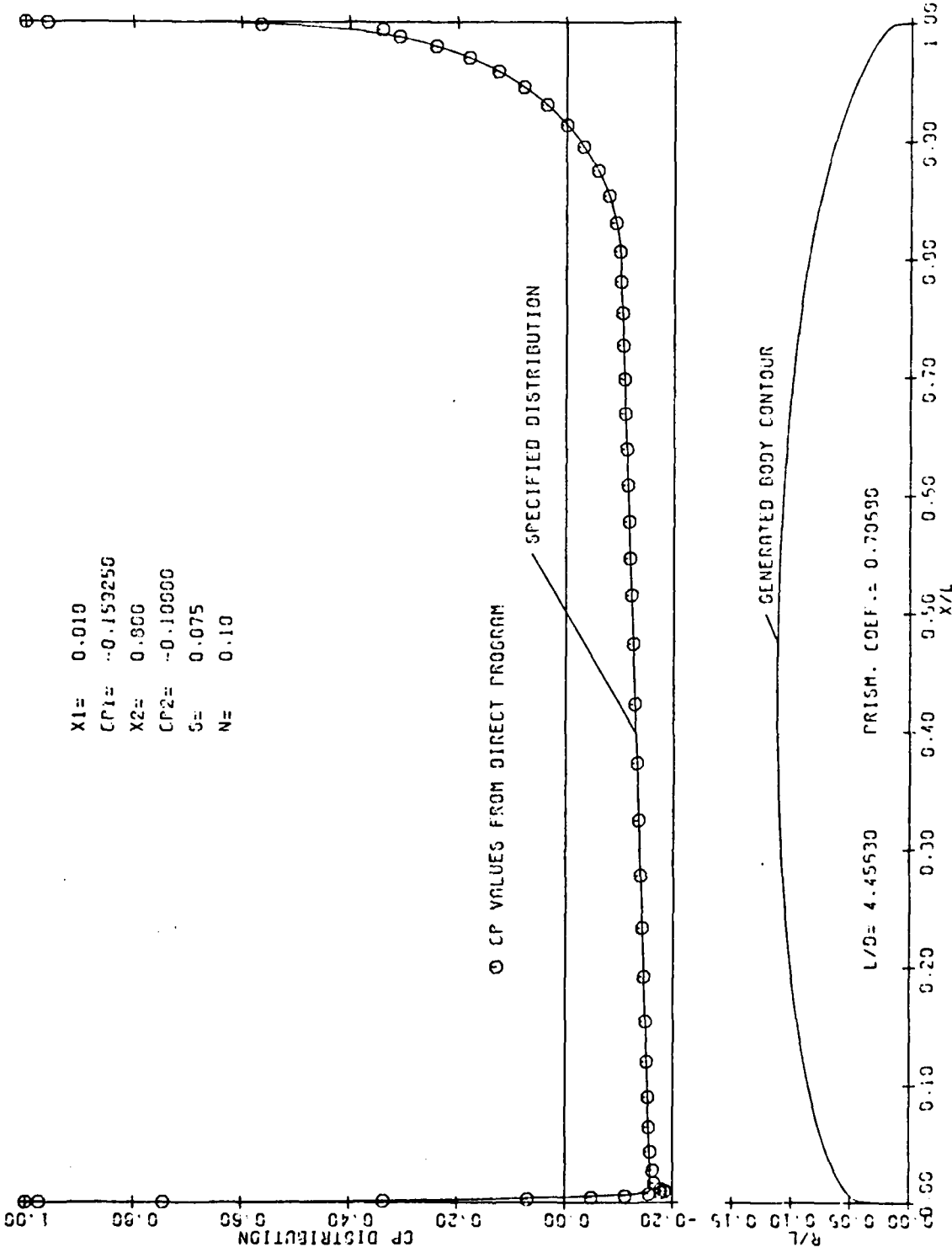


Figure 74. Pressure Distribution and Body Contour, Case No. 64.

# INVERSE BODY CASE 65

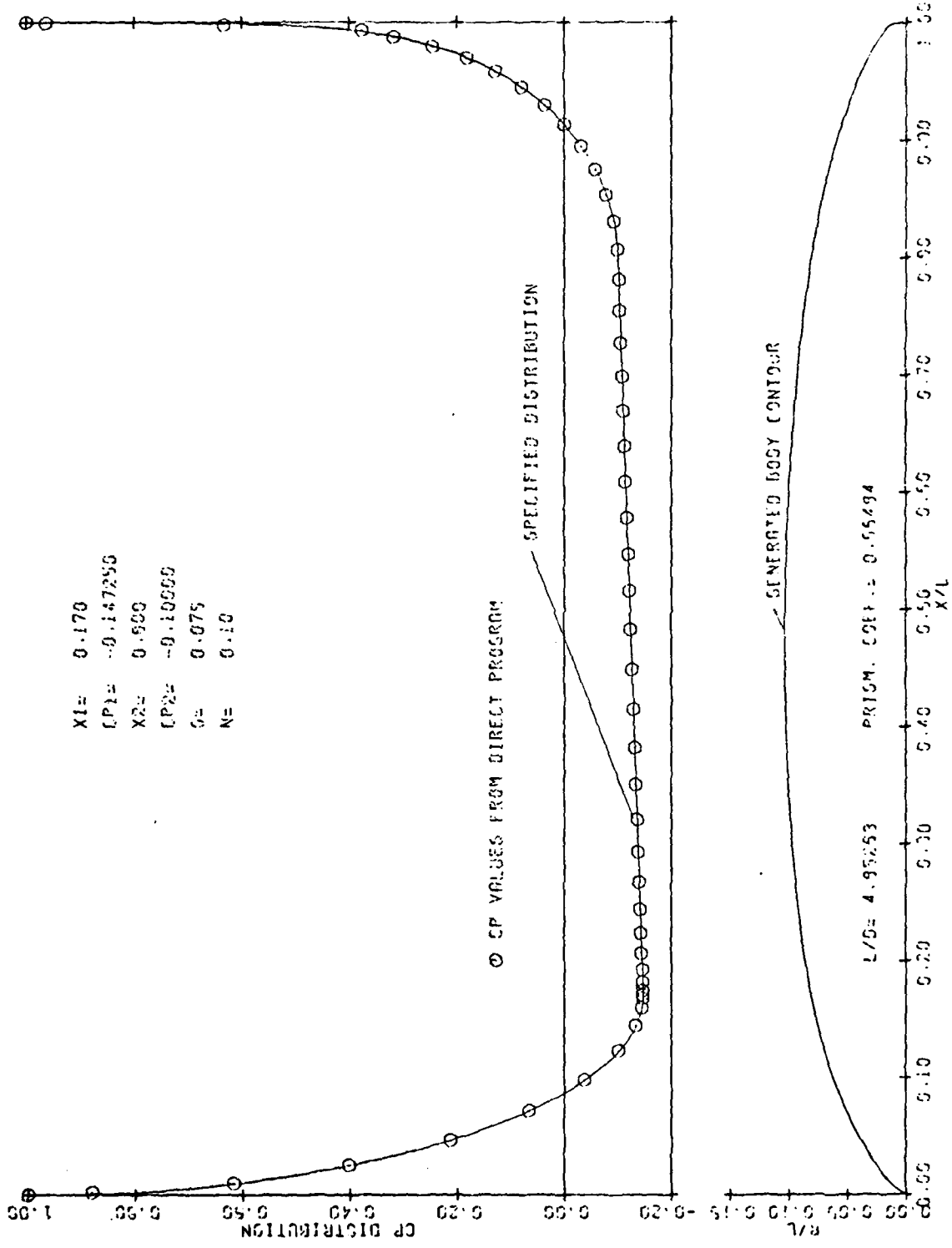


Figure 75. Pressure Distribution and Body Contour, Case No. 65.

# INVERSE BODY CASE 66

X1= 0.020  
 CP1= -0.159500  
 X2= 0.500  
 CP2= -0.11000  
 S= 0.075  
 N= 0.10

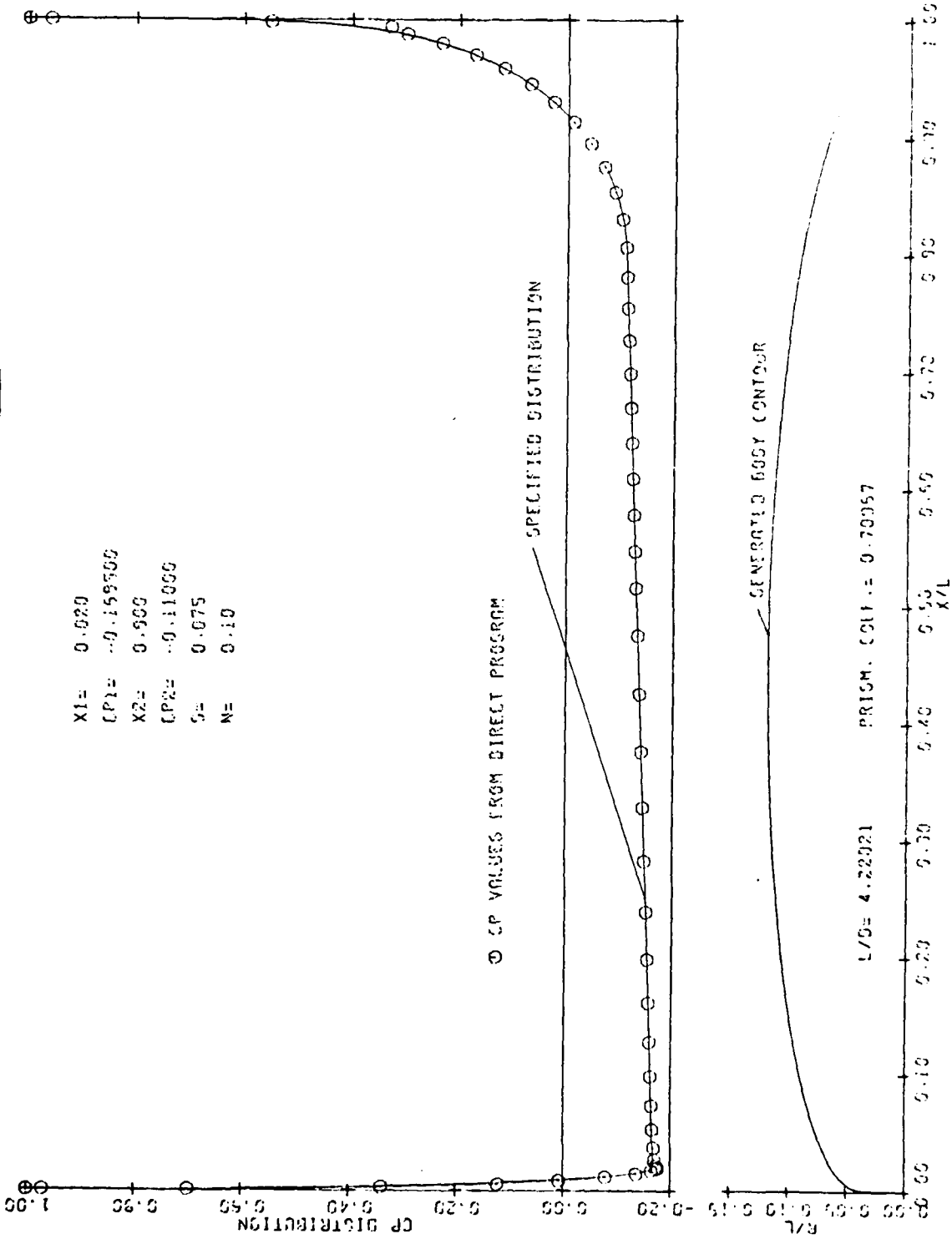


Figure 76. Pressure Distribution and Body Contour, Case No. 66.

# INVERSE BODY CASE 67

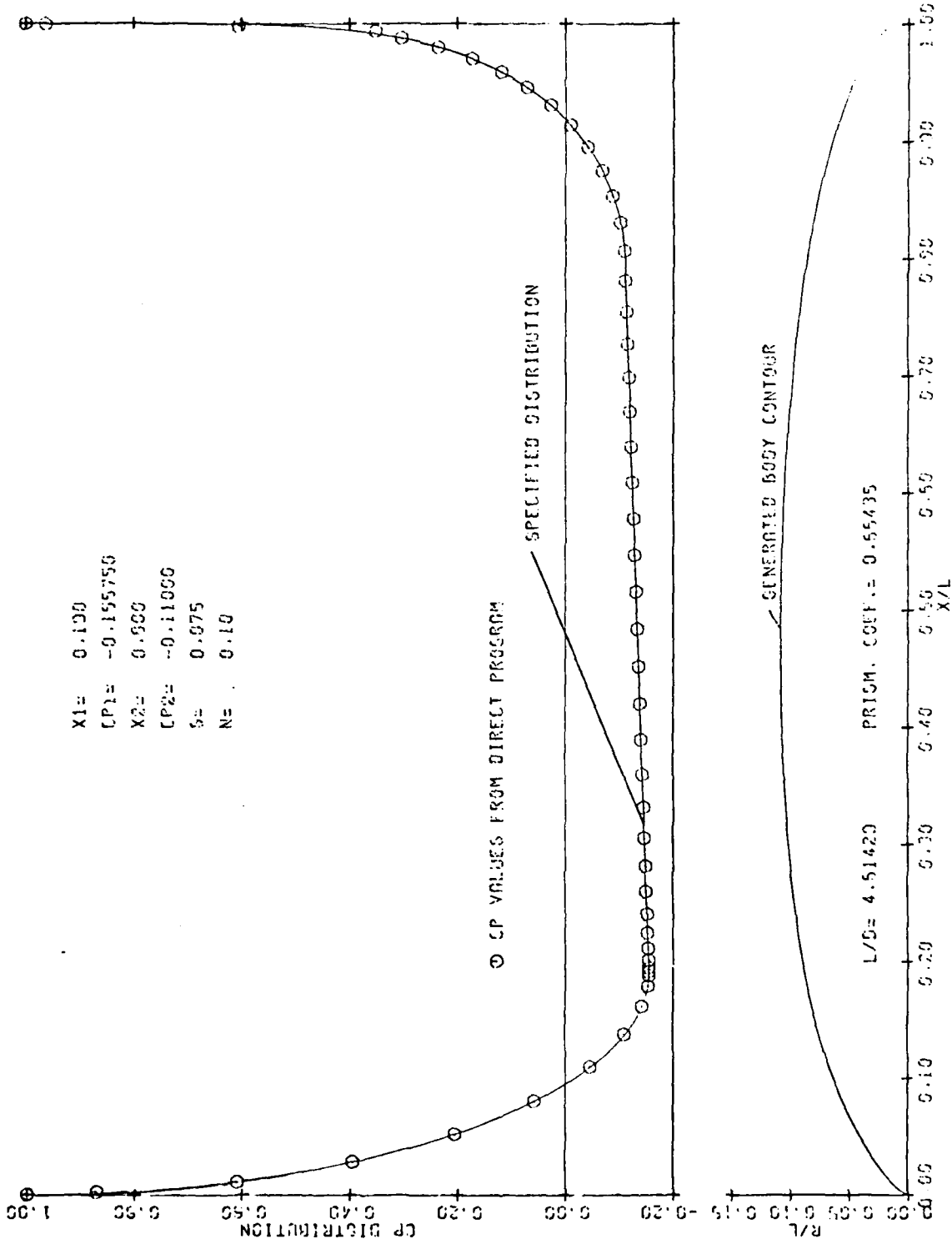


Figure 77. Pressure Distribution and Body Contour, Case No. 67.

# INVERSE BODY CASE 68

X1= 0.050  
 CP1= -0.191250  
 X2= 0.900  
 CP2= -0.12500  
 S= 0.075  
 NE 0.10

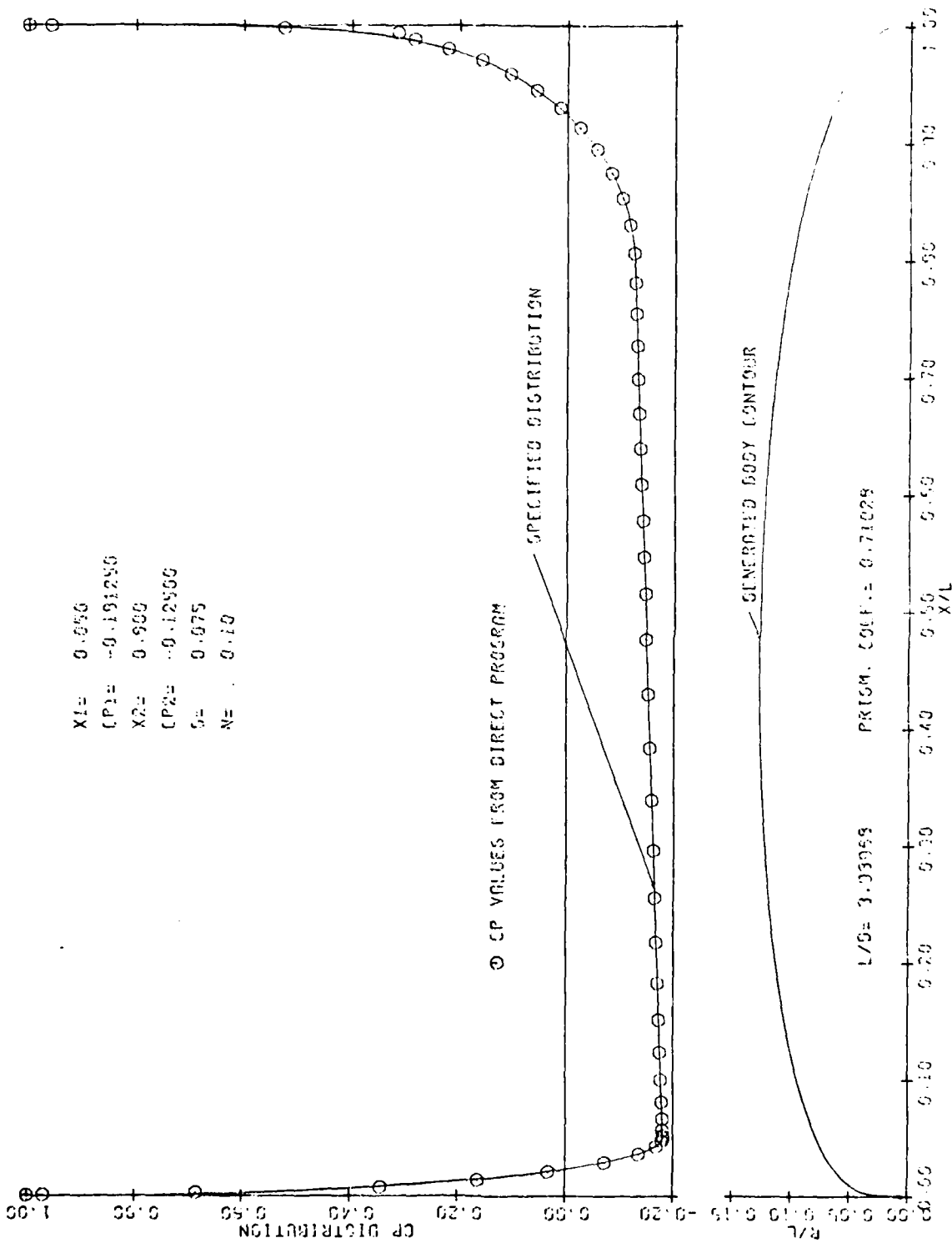


Figure 78. Pressure Distribution and Body Contour, Case No. 13.

# INVERSE BODY CASE 69

X1= 0.130  
CP1= -0.175250  
X2= 0.860  
CP2= -0.125600  
S= 0.075  
N= 0.10

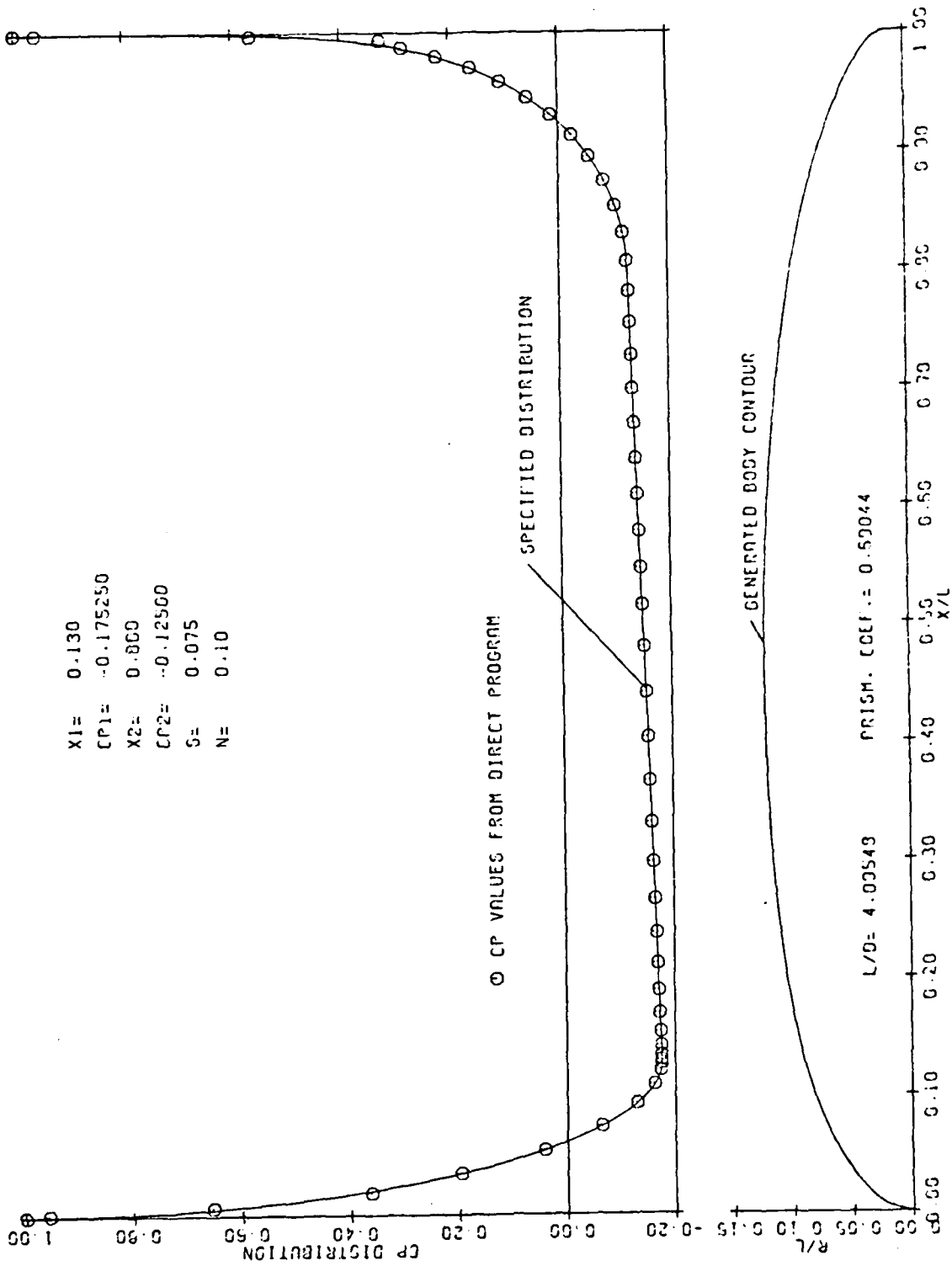


Figure 79. Pressure Distribution and Body Contour, Case No. 69.

# INVERSE BODY CASE 70

X1= 0.010  
CP1= -0.001750  
X2= 0.000  
CP2= -0.02500  
S= 0.075  
N= 0.10

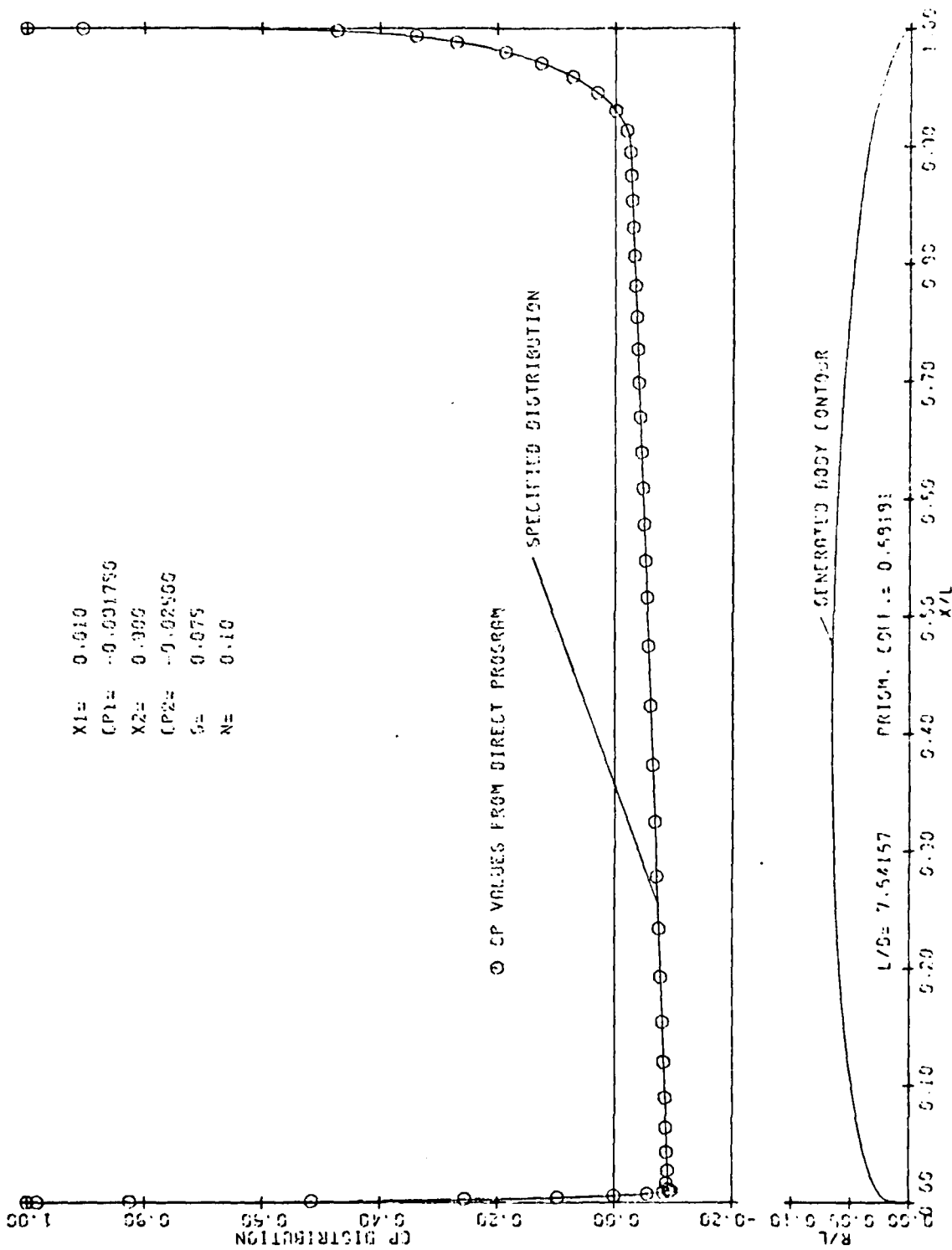


Figure 80. Pressure Distribution and Body Contour, Case No. 70.

# INVERSE BODY CASE 71

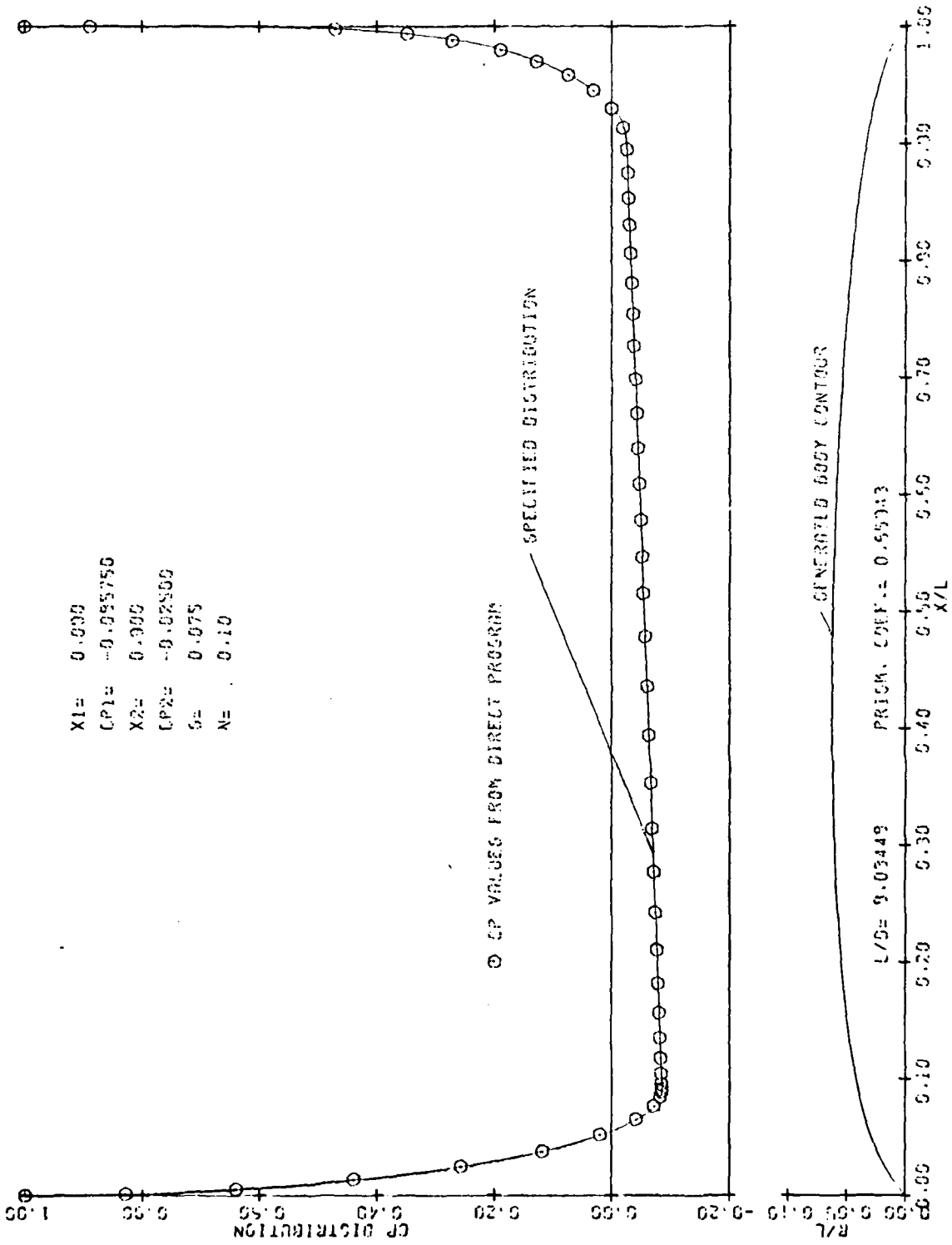


Figure 81. Pressure Distribution and Body Contour, Case No. 71.

# INVERSE BODY CASE 72

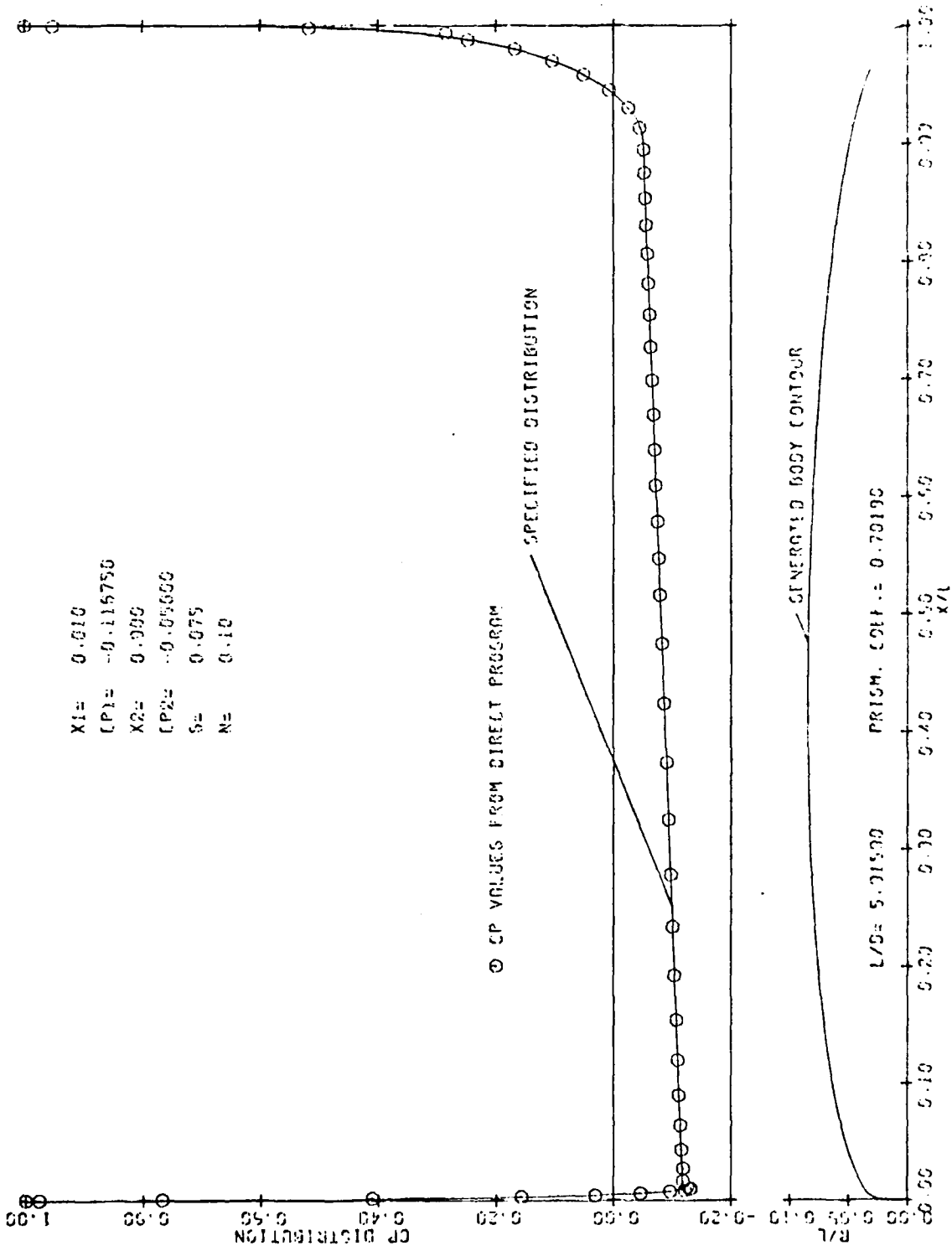


Figure 82. Pressure Distribution and Body Contour, Case No. 72.

# INVERSE BODY CASE 73

X1= 0.120  
CP1= -0.109500  
X2= 0.900  
CP2= -0.050000  
S= 0.075  
N= 0.10

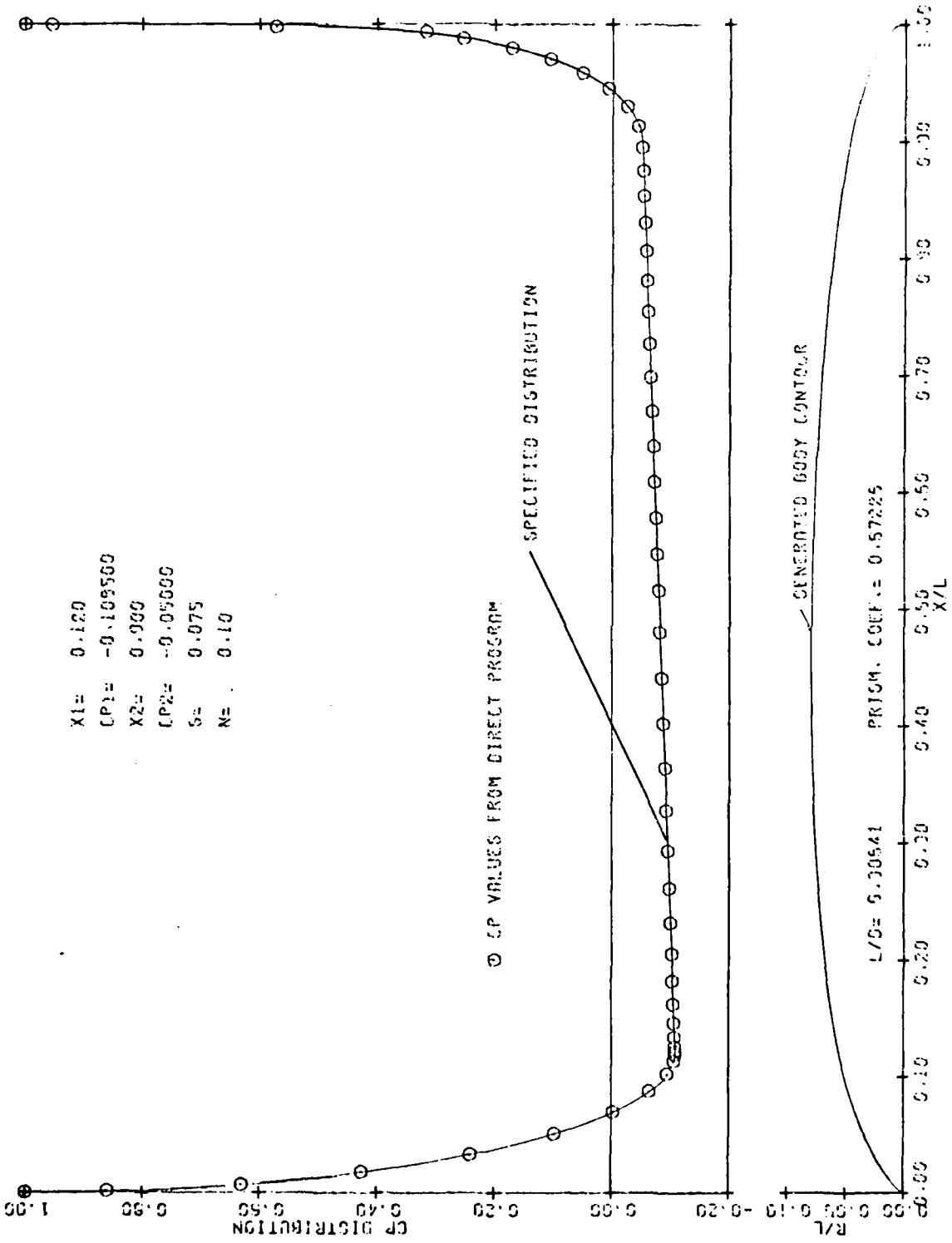


Figure 83. Pressure Distribution and Body Contour, Case No. 73.

# INVERSE BODY CASE 74

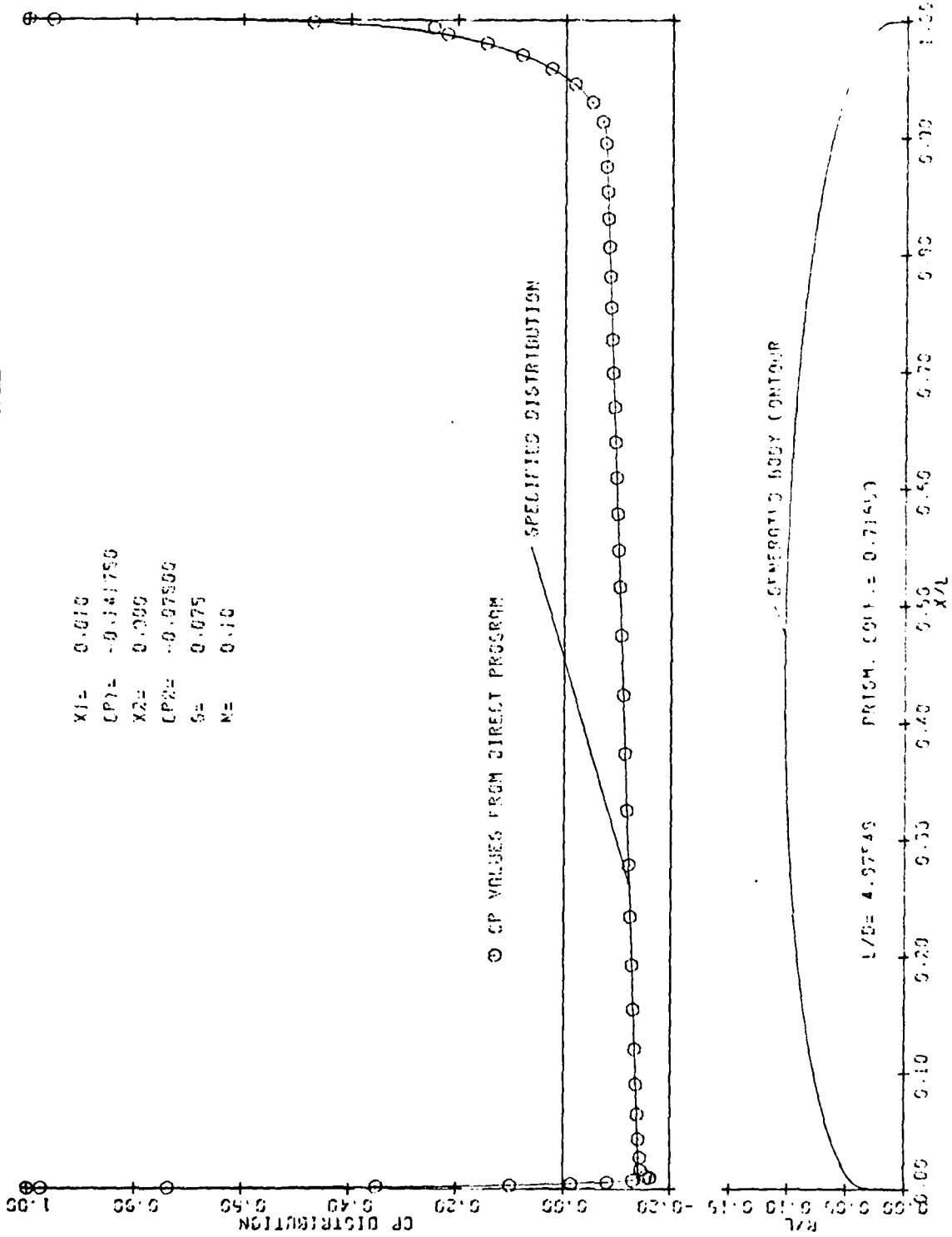


Figure 84. Pressure Distribution and Body Contour, Case No. 74.

# INVERSE BODY CASE 75

X1= 0.150  
CP1= -0.131250  
X2= 0.900  
CP2= -0.07500  
S= 0.075  
N= 0.10

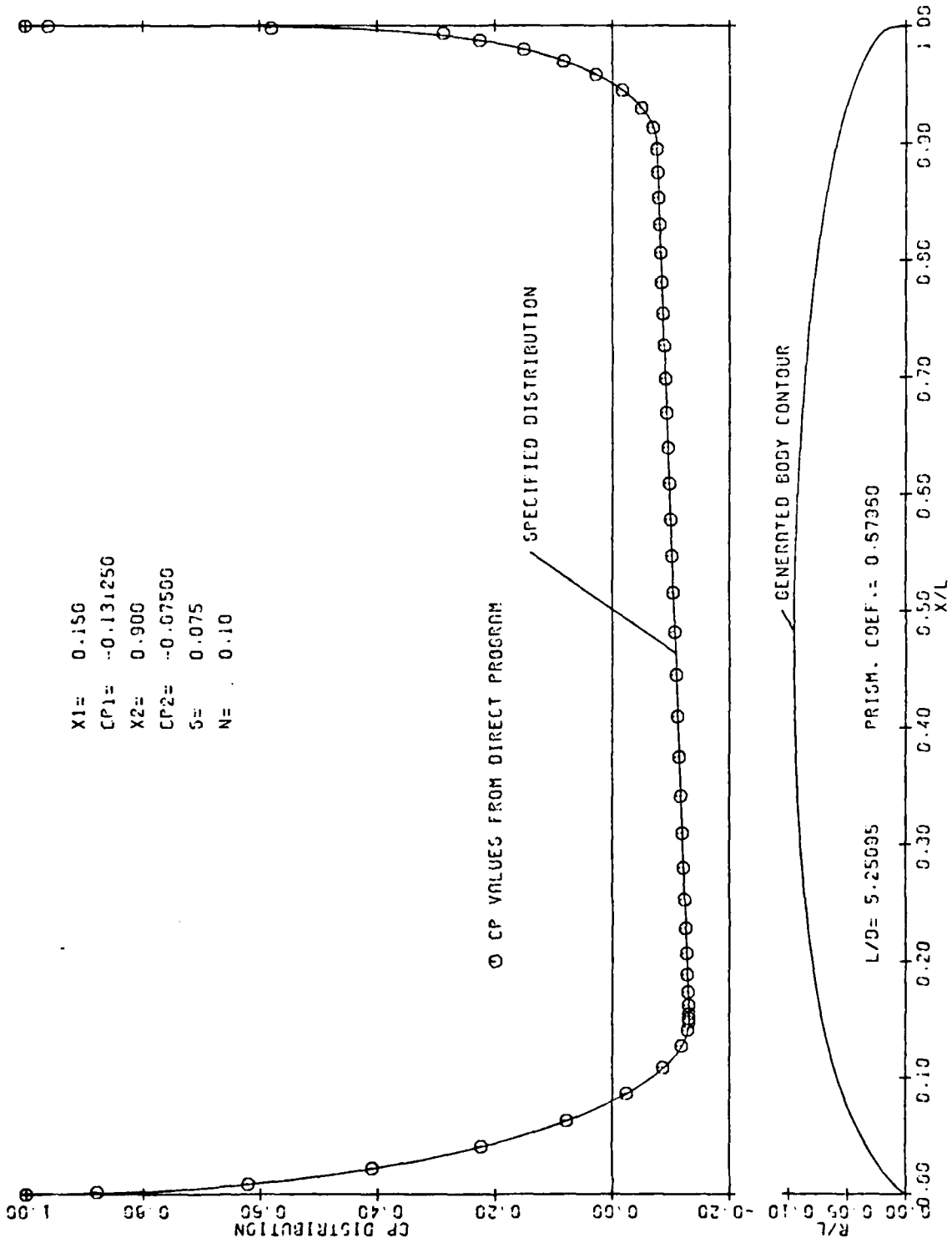


Figure 85. Pressure Distribution and Body Contour, Case No. 75.

# INVERSE BODY CASE 76

X1= 0.100  
CF1= -0.150000  
X2= 0.900  
CF2= -0.100000  
S= 0.075  
N= 0.10

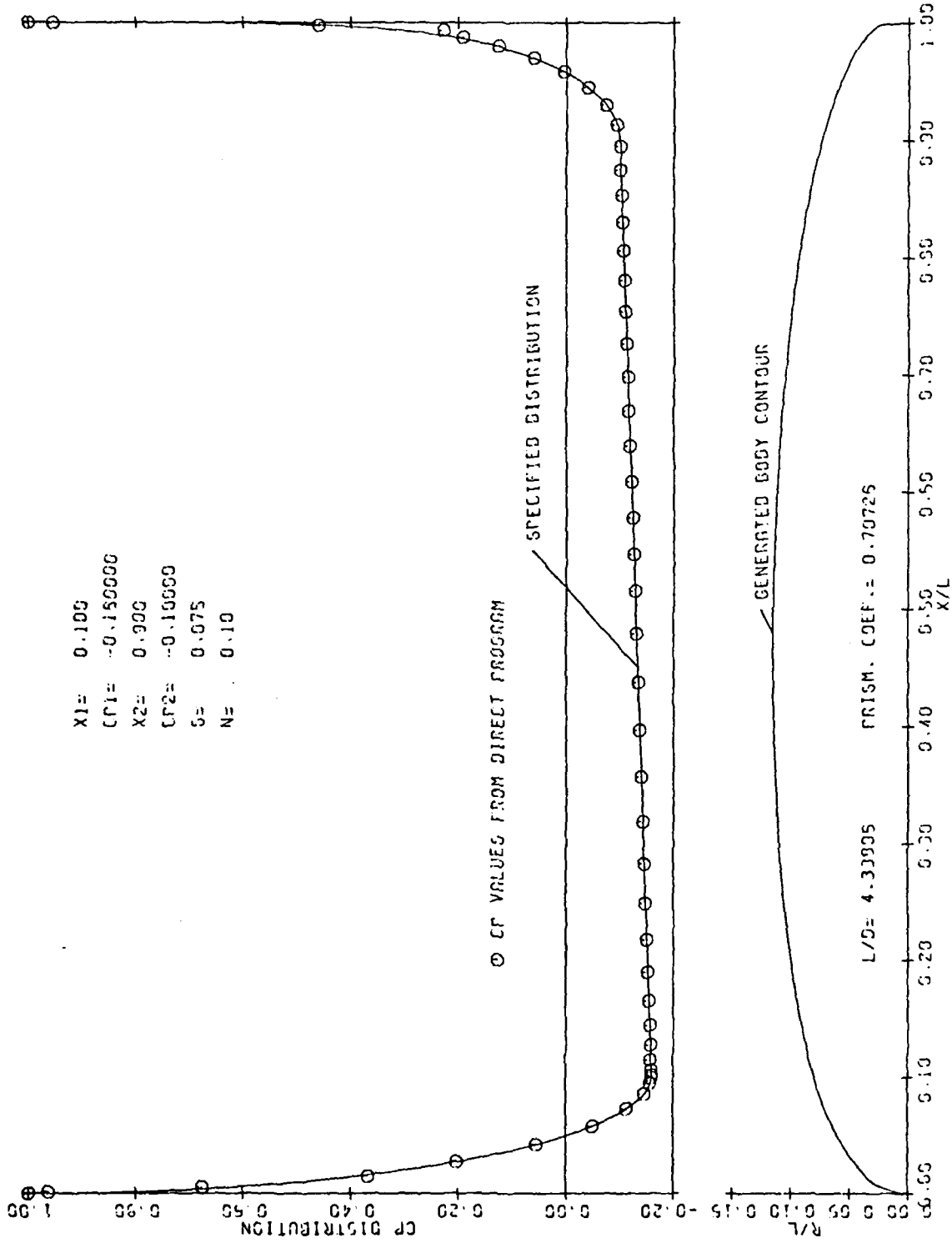


Figure 86. Pressure Distribution and Body Contour, Case No. 76.

# INVERSE BODY CASE 77

X1= 0.100  
 CP1= -0.153250  
 X2= 0.900  
 CP2= -0.100000  
 S= 0.075  
 N= 0.10

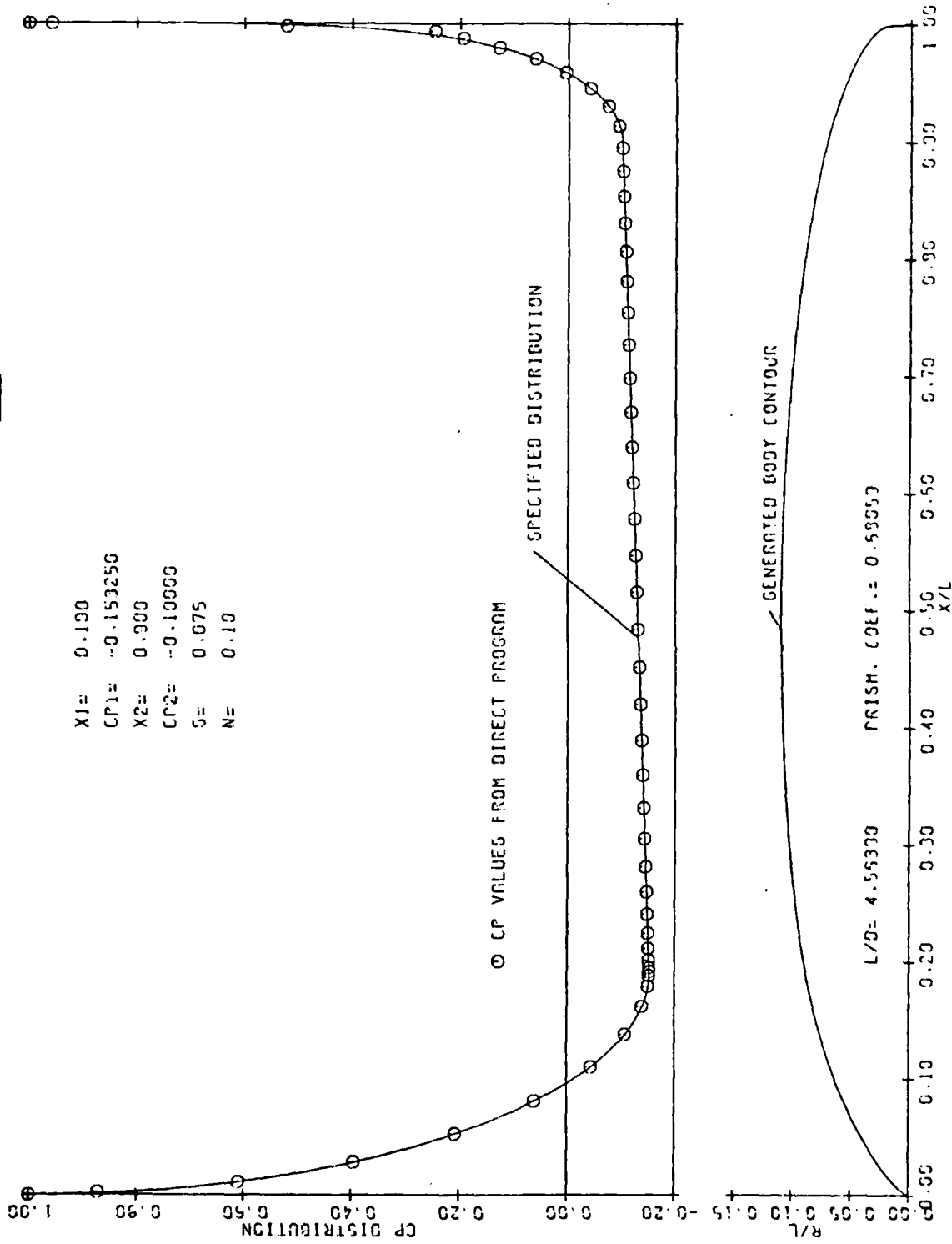


Figure 87. Pressure Distribution and Body Contour, Case No. 77.

INVERSE BODY CASE 1

$T_w = 50.00$   
 $V_w = 50.00$

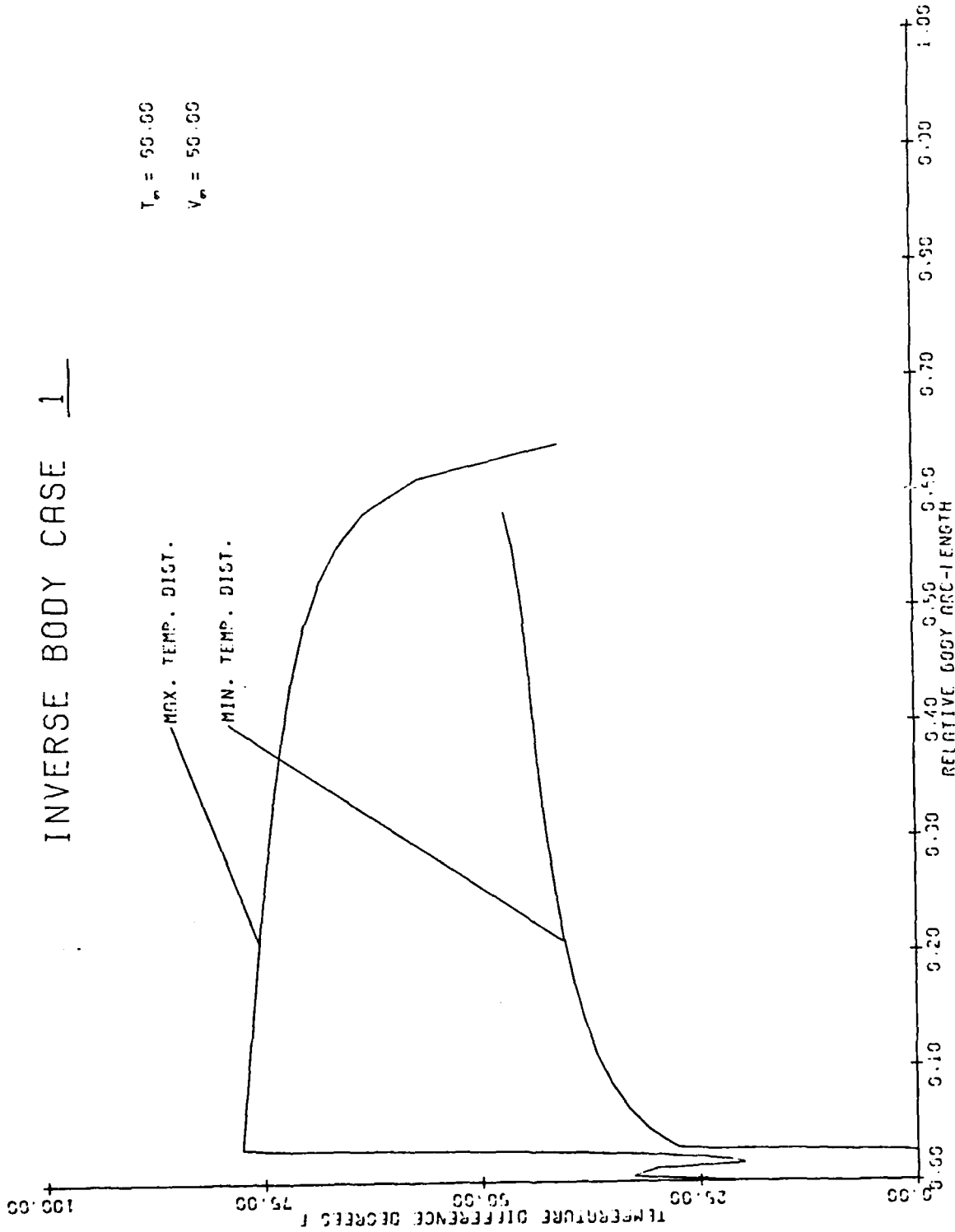


Figure 88. Temperature Distributions, Case No. 1.

INVERSE BODY CASE 1

$T_w = 50.00$   
 $V_w = 50.00$

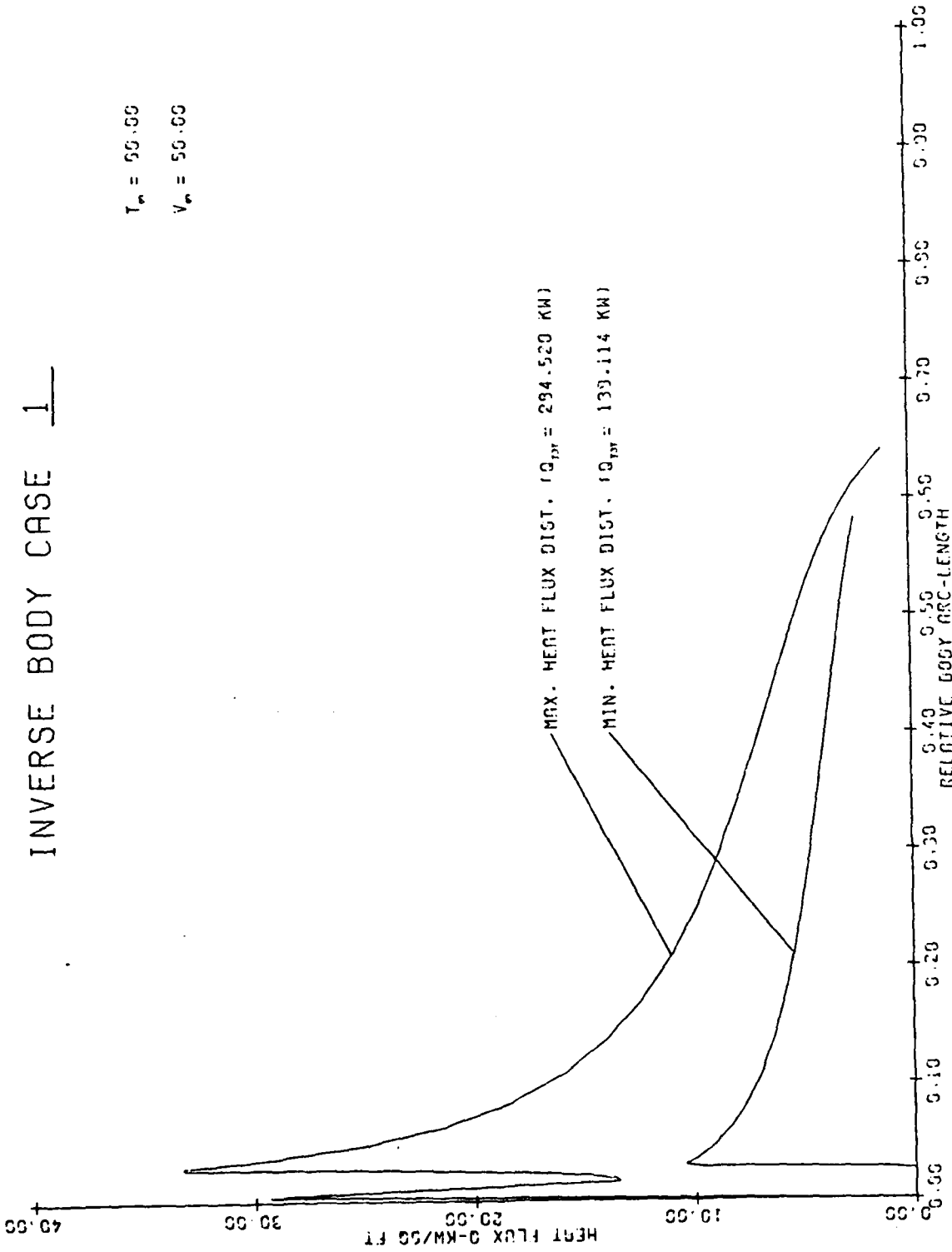


Figure 89. Heat Flux Distributions, Case No. 1.

# INVERSE BODY CASE 2

$T_m = 50.00$   
 $V_m = 50.00$

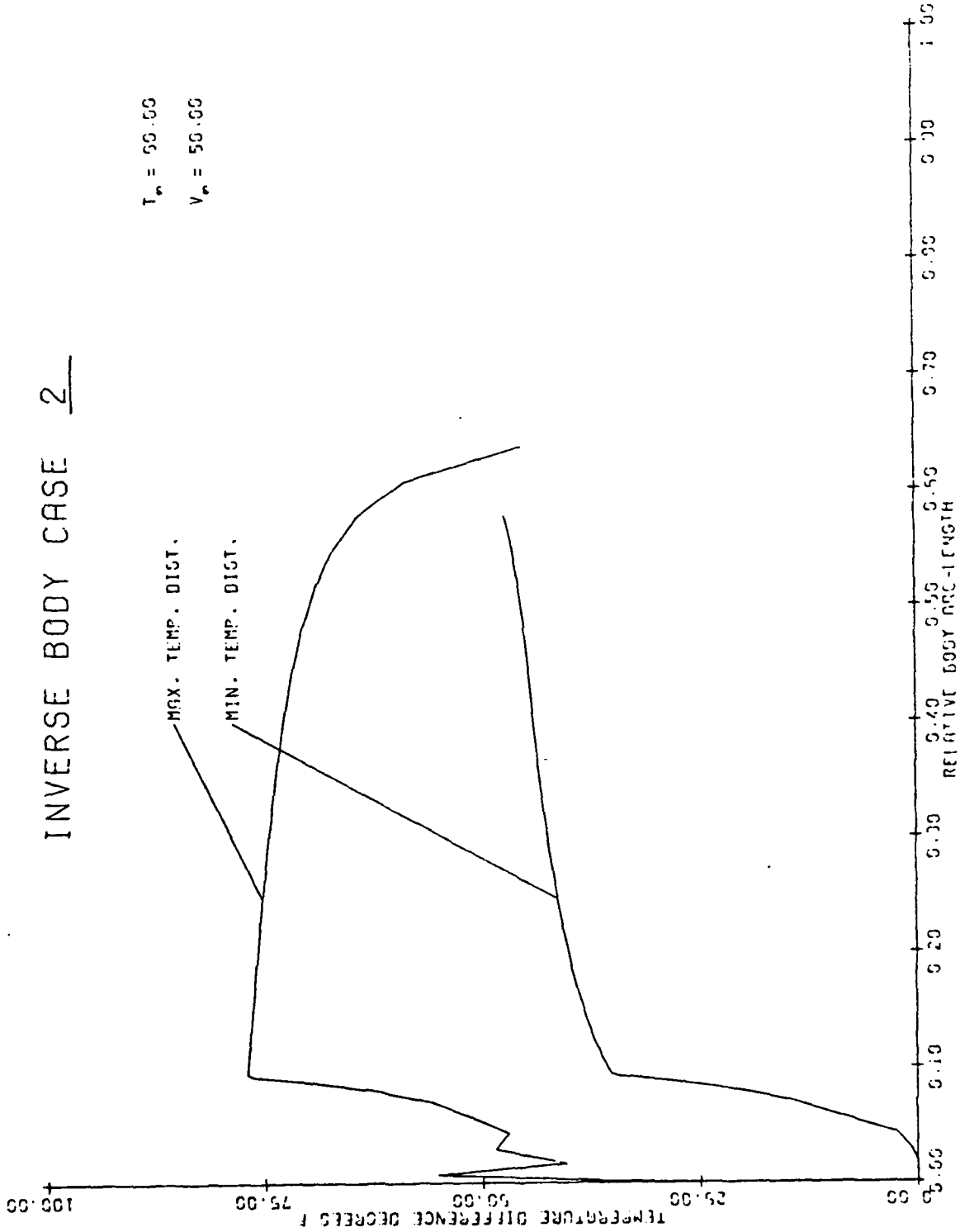


Figure 90. Temperature Distributions, Case No. 2.

INVERSE BODY CASE 2

$T_w = 50.00$   
 $V_w = 50.00$

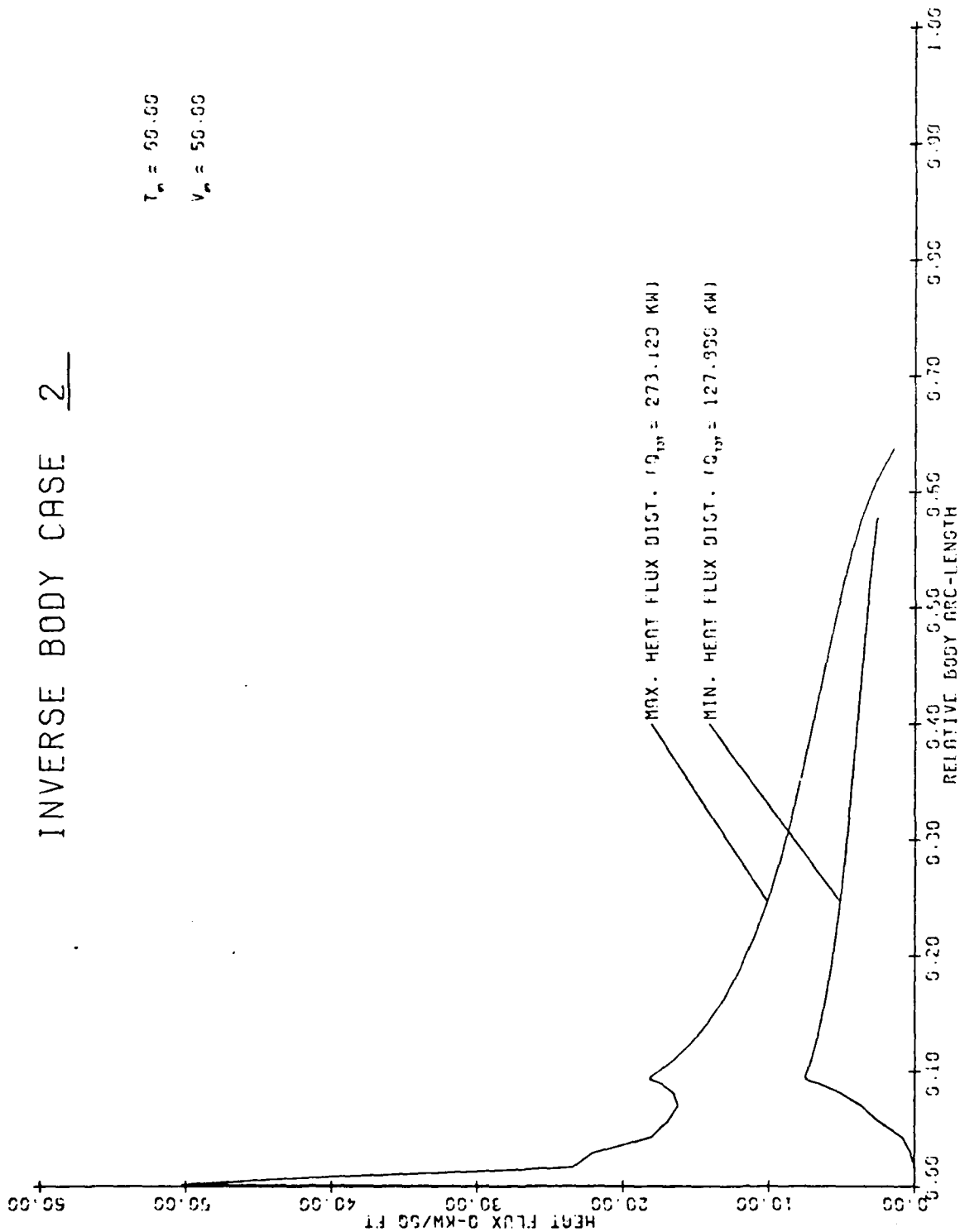


Figure 91. Heat Flux Distributions, Case No. 2.

INVERSE BODY CASE 3

$T_w = 50.00$   
 $V_w = 50.00$

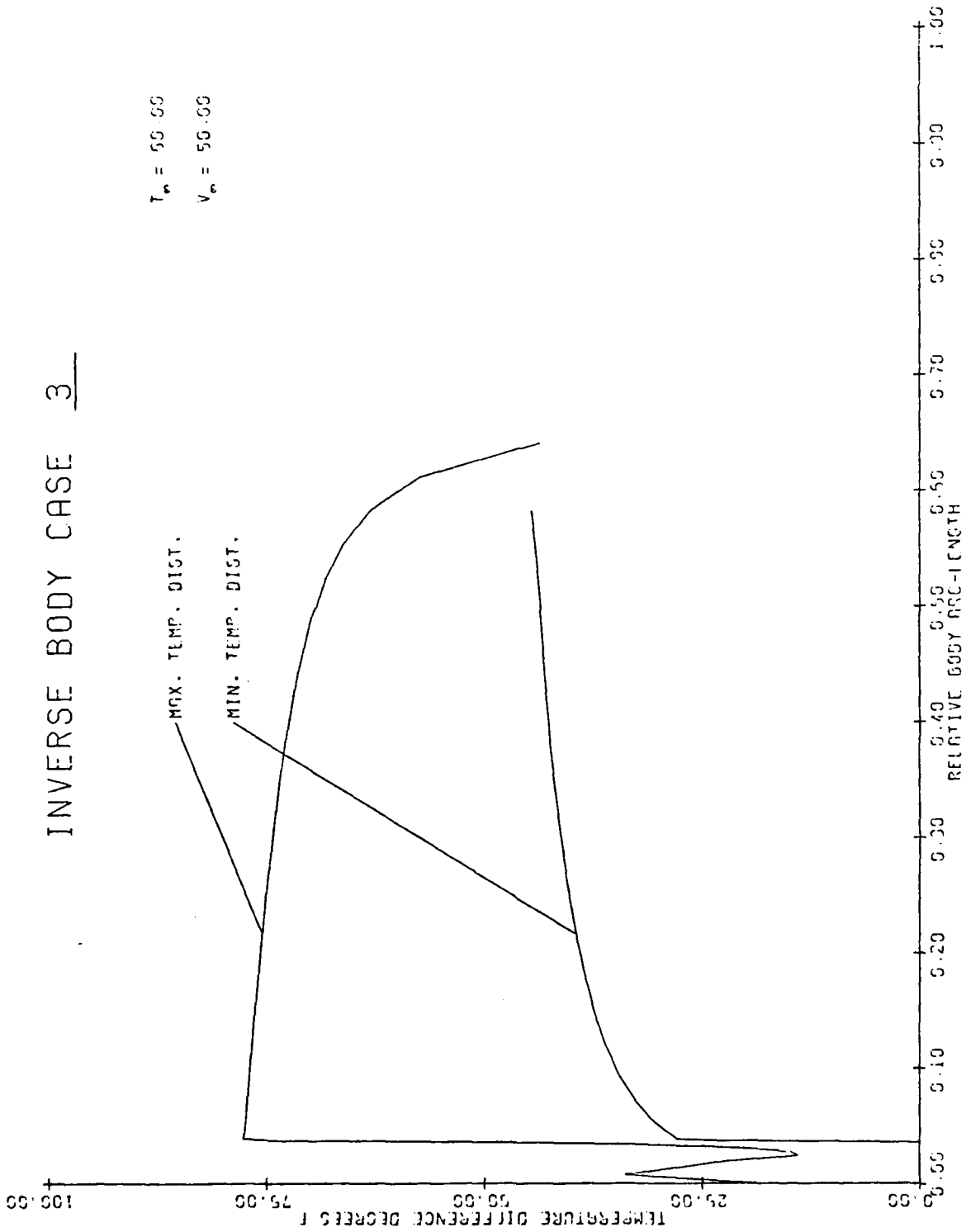


Figure 92. Temperature Distributions, Case No. 3.

INVERSE BODY CASE 3

$T_w = 55.00$   
 $V_w = 50.00$

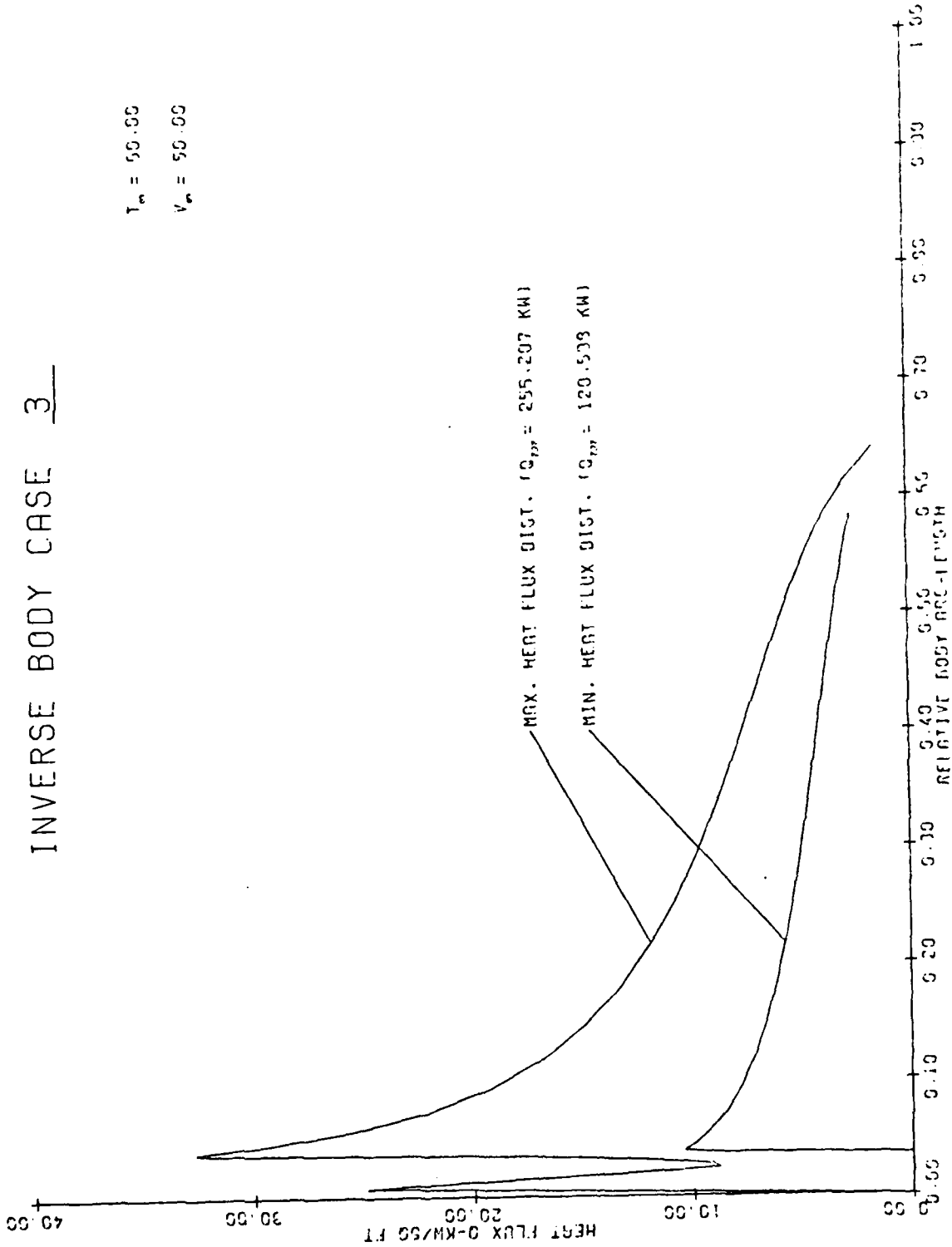


Figure 93. Heat Flux Distributions, Case No. 3.

INVERSE BODY CASE 4

$T_m = 50.00$   
 $V_m = 50.00$

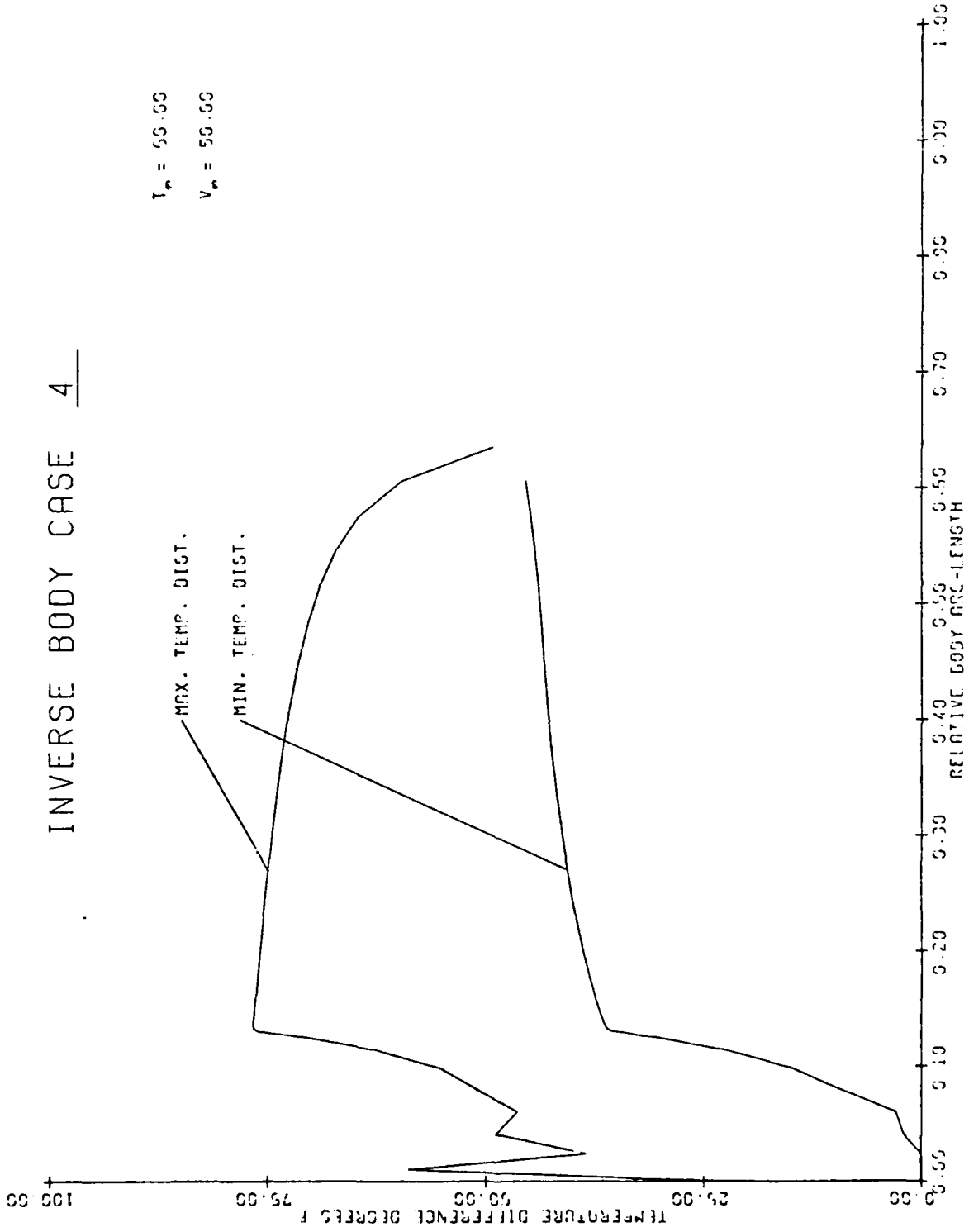


Figure 94. Temperature Distributions, Case No. 4.

INVERSE BODY CASE 4

$T_w = 50.00$

$V_w = 50.00$

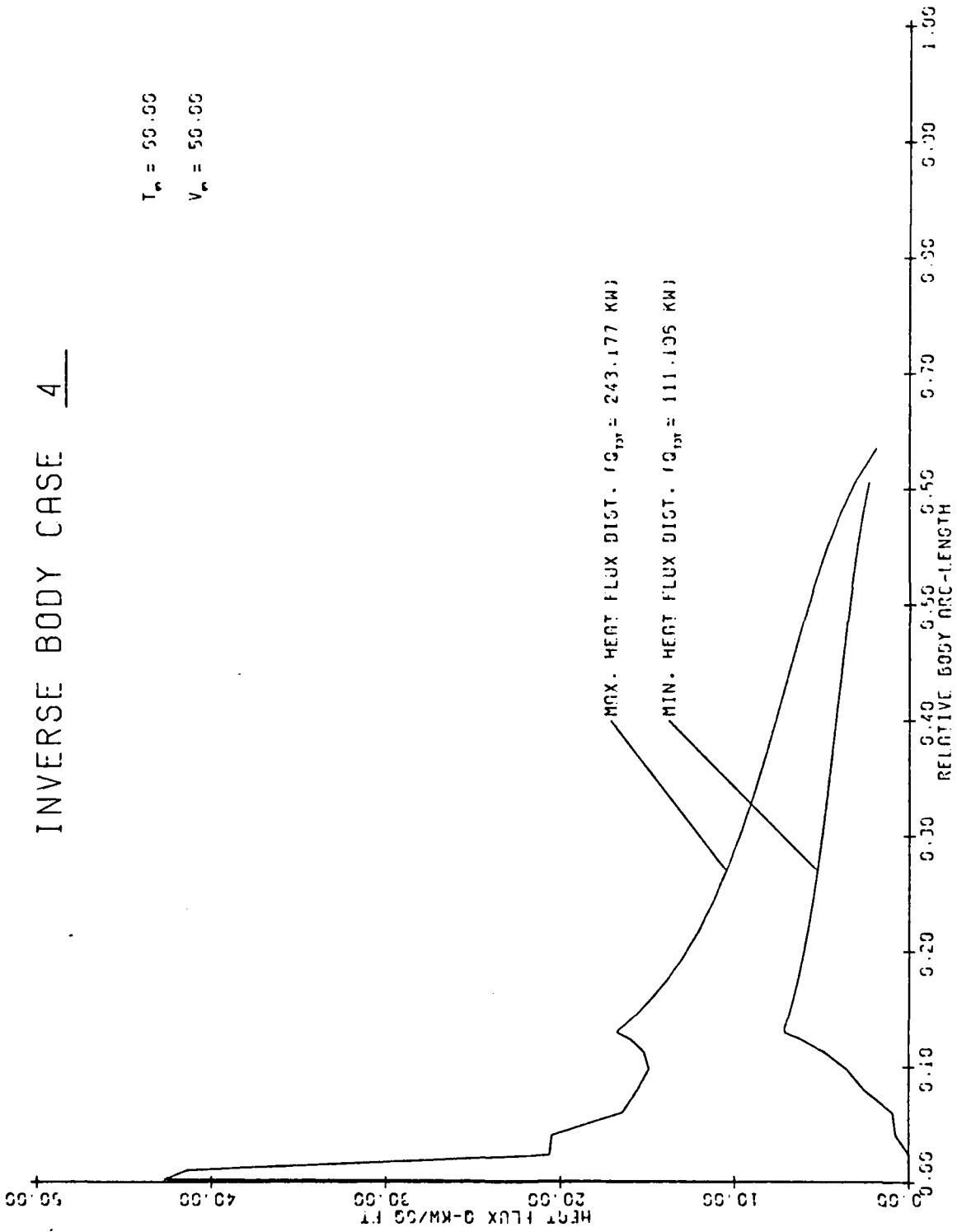


Figure 95. Heat Flux Distributions, Case No. 4.

INVERSE BODY CASE 5

$T_m = 50.00$   
 $V_m = 50.00$

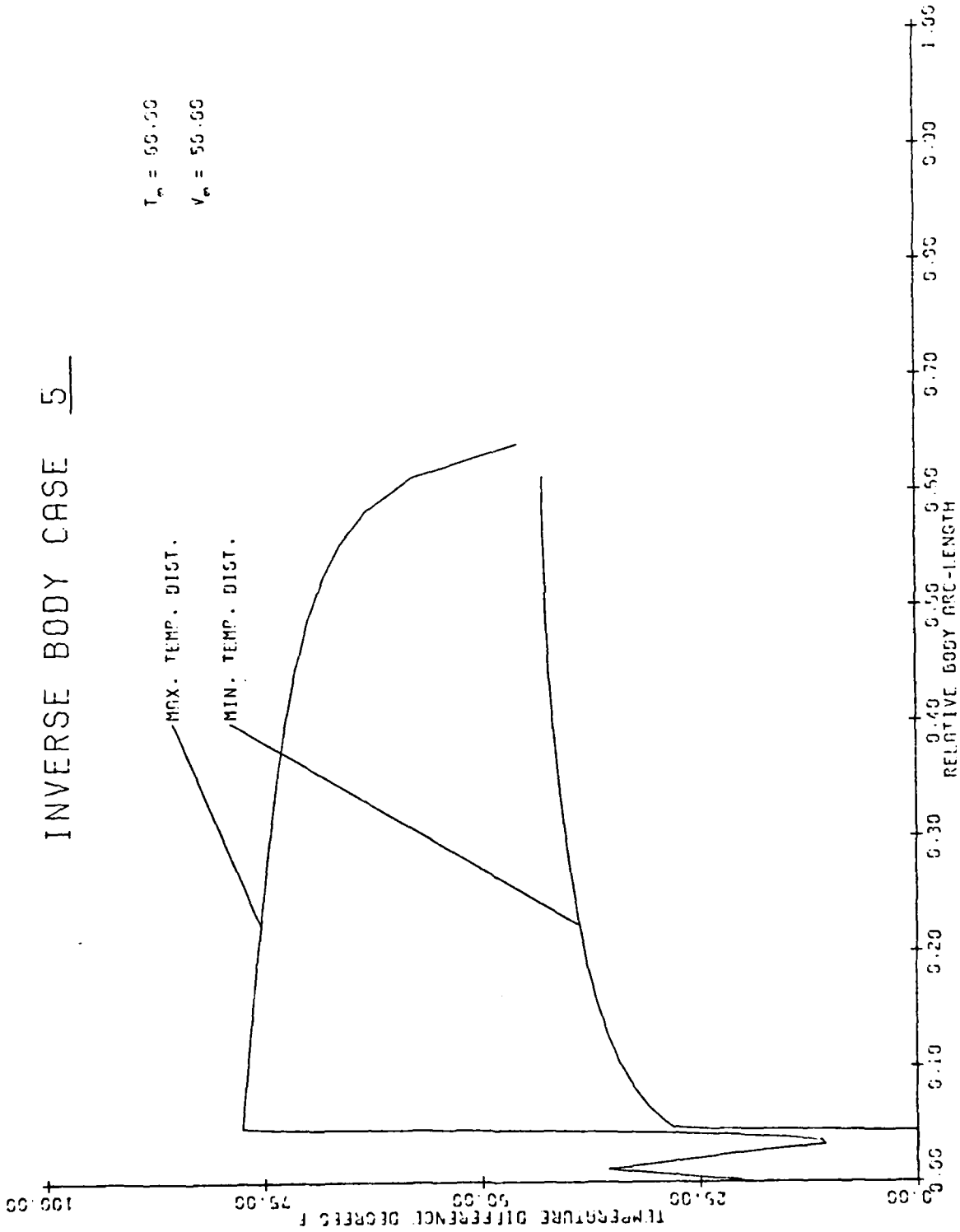


Figure 96. Temperature Distributions, Case No. 5.

INVERSE BODY CASE 5

$T_w = 50.00$

$V_w = 50.00$

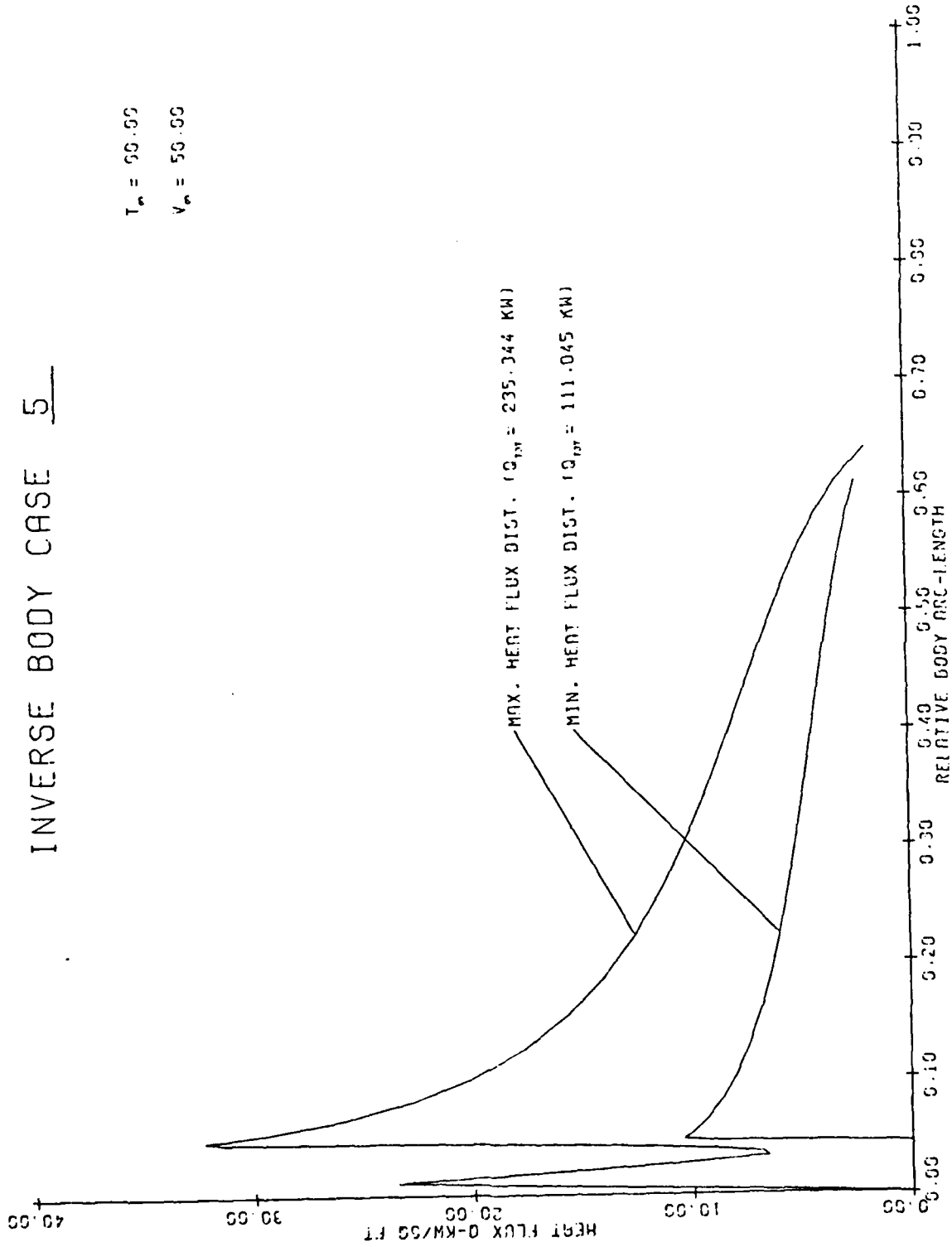


Figure 97. Heat Flux Distributions, Case No. 5.

INVERSE BODY CASE 6

$T_m = 50.00$

$V_m = 50.00$

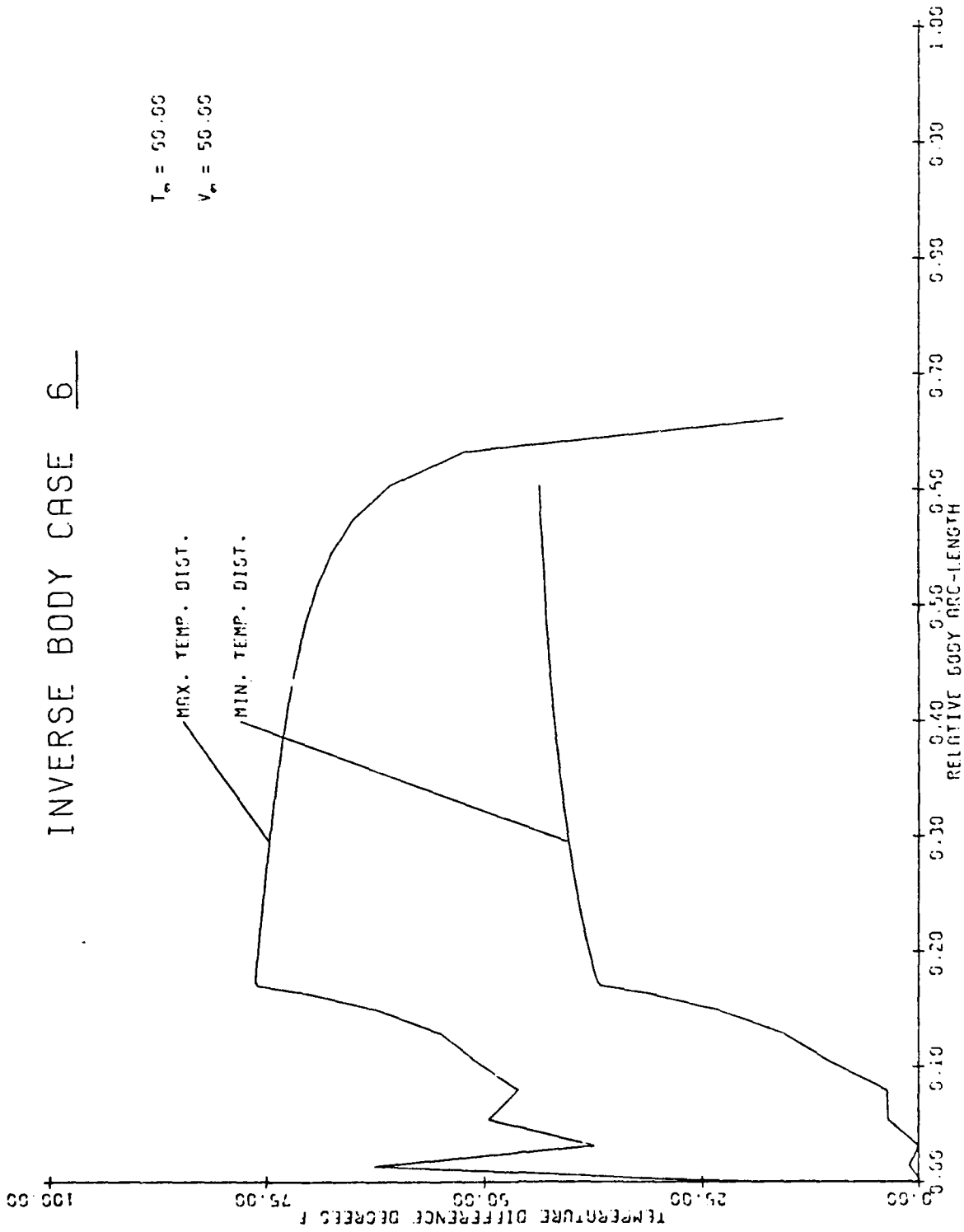


Figure 98. Temperature Distributions, Case No. 6.

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# INVERSE BODY CASE 6

$T_w = 50.00$   
 $V_w = 50.00$

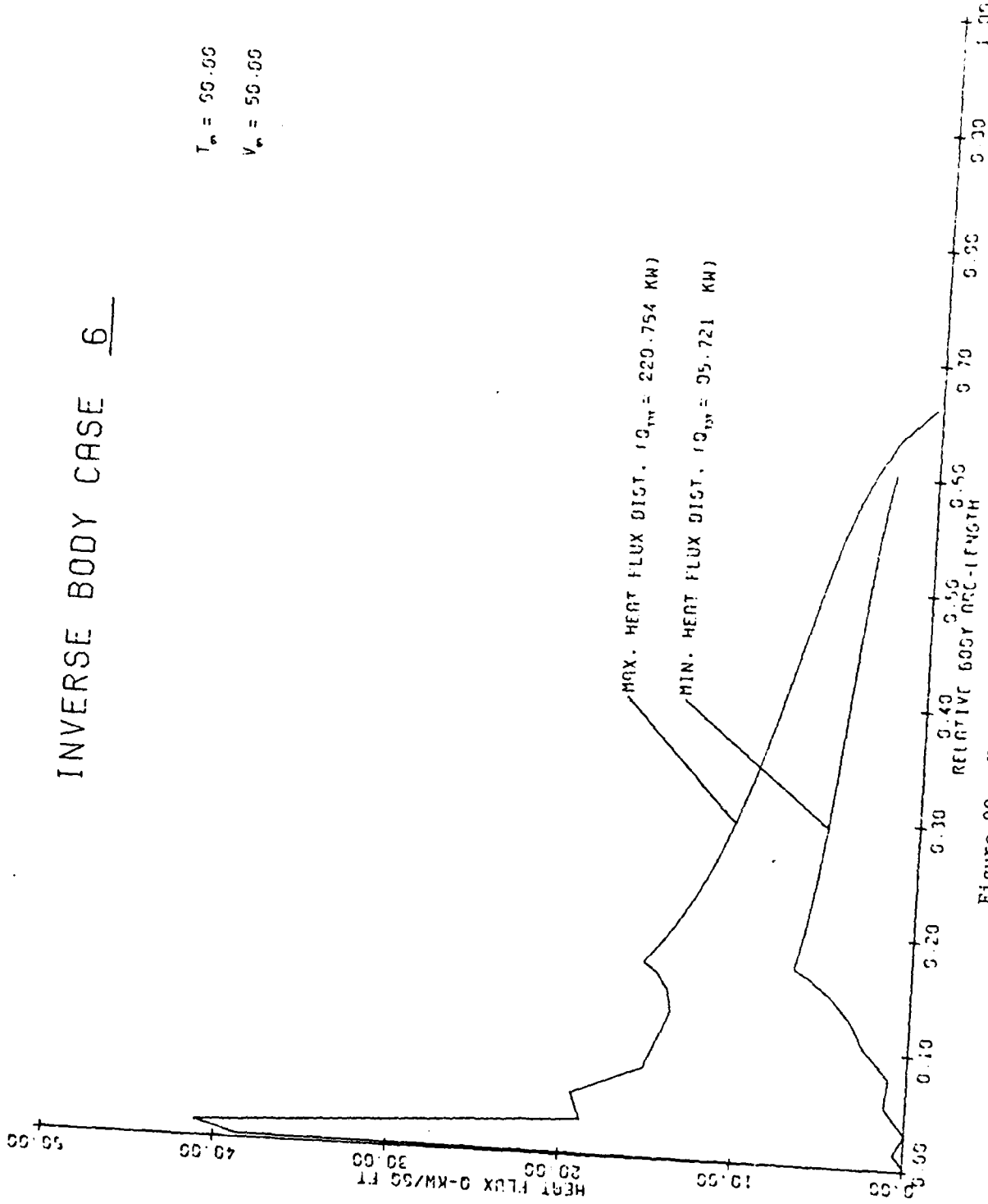


Figure 99. Heat Flux Distributions, Case No. 6.

# INVERSE BODY CASE 7

$T_m = 50.00$   
 $V_m = 50.00$

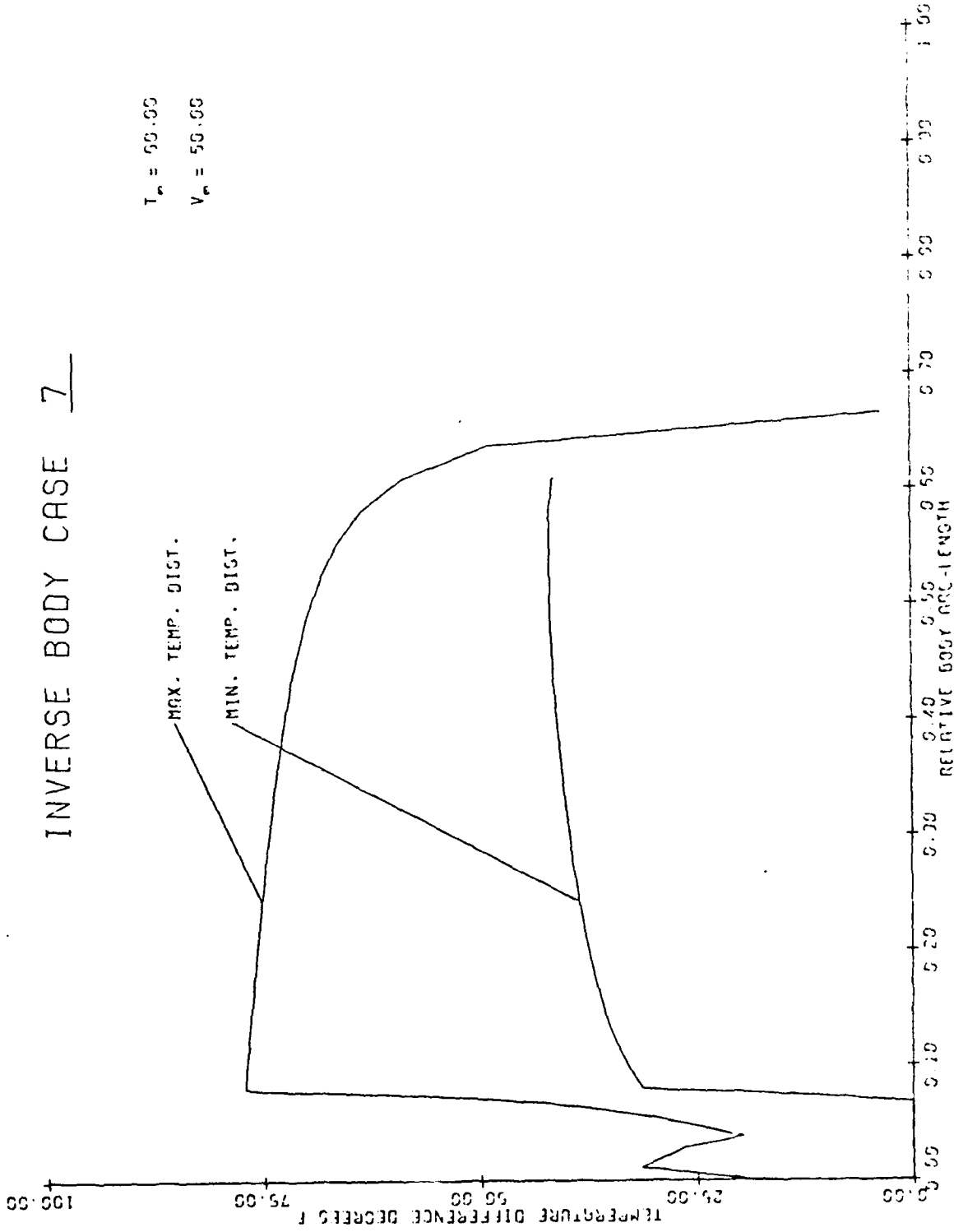


Figure 100. Temperature Distributions, Case No. 7.

# INVERSE BODY CASE 7

$T_w = 50.00$

$V_w = 50.00$

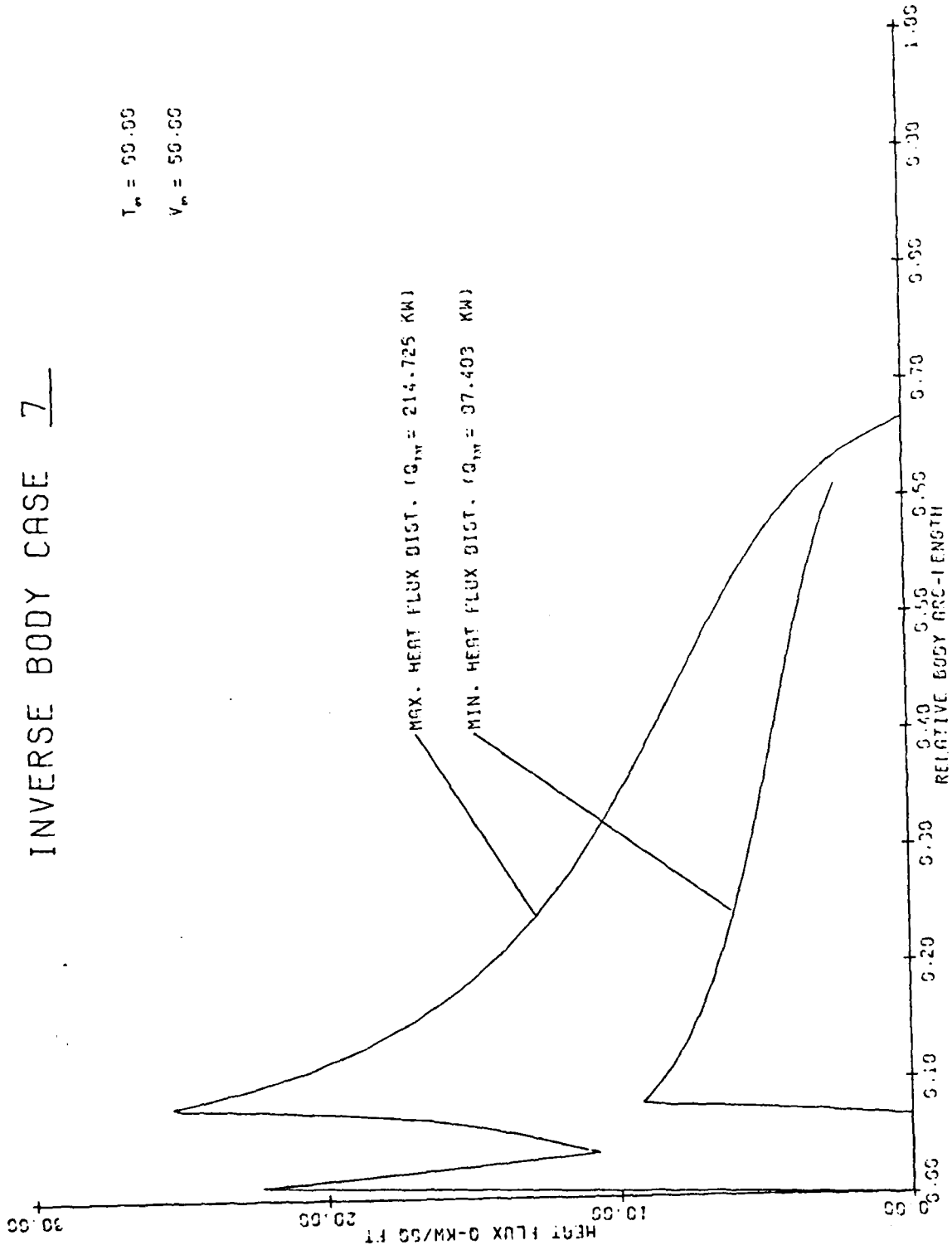


Figure 101. Heat Flux Distributions, Case No. 7.

INVERSE BODY CASE 8

$T_p = 50.00$   
 $V_p = 50.00$

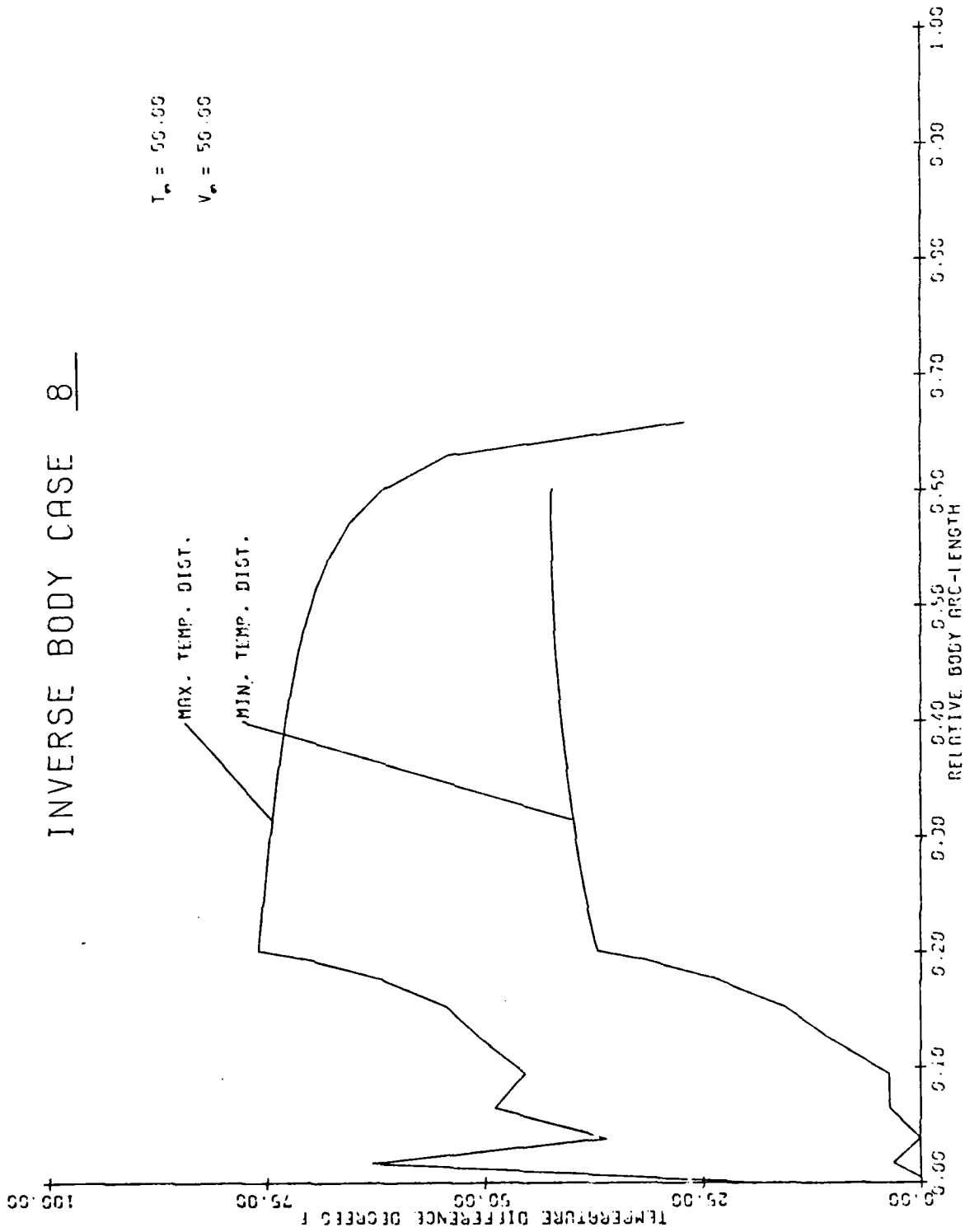


Figure 102. Temperature Distributions, Case No. 8.

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# INVERSE BODY CASE 8

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

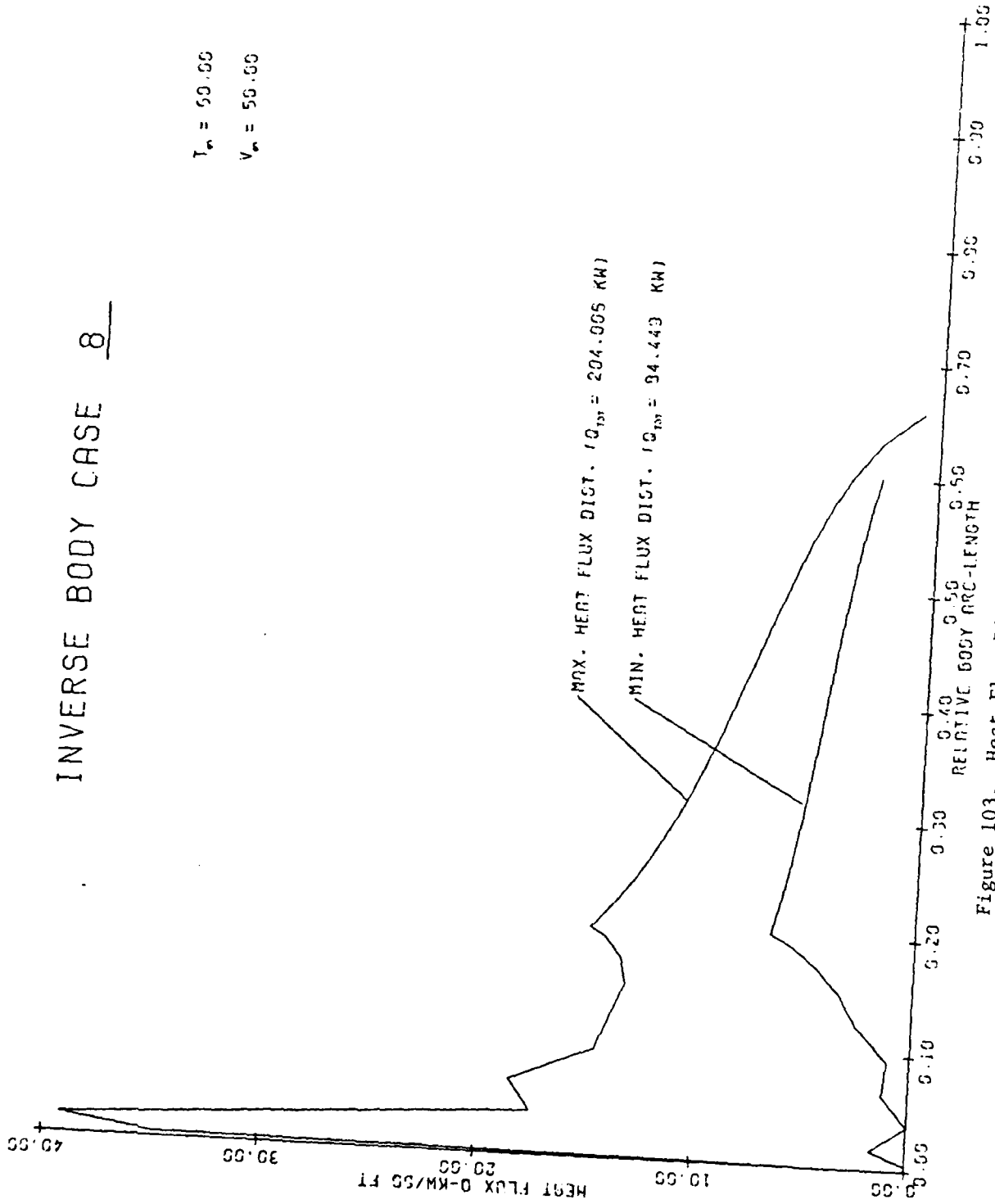


Figure 103. Heat Flux Distributions, Case No. 8.

INVERSE BODY CASE 9

$T_m = 50.00$   
 $V_m = 50.00$

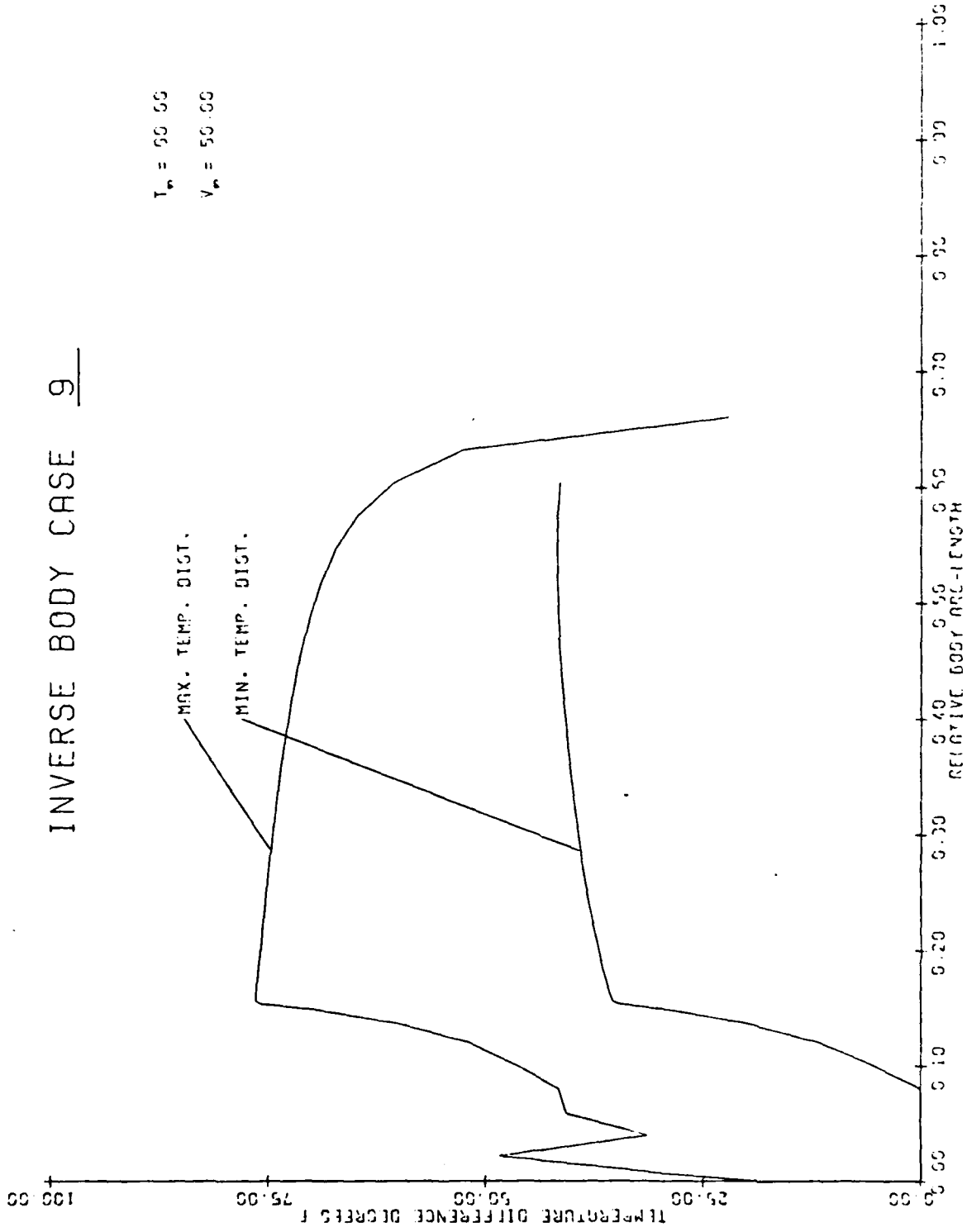


Figure 104. Temperature Distributions, Case No. 9.

# INVERSE BODY CASE 9

$T_w = 50.00$

$V_w = 50.00$

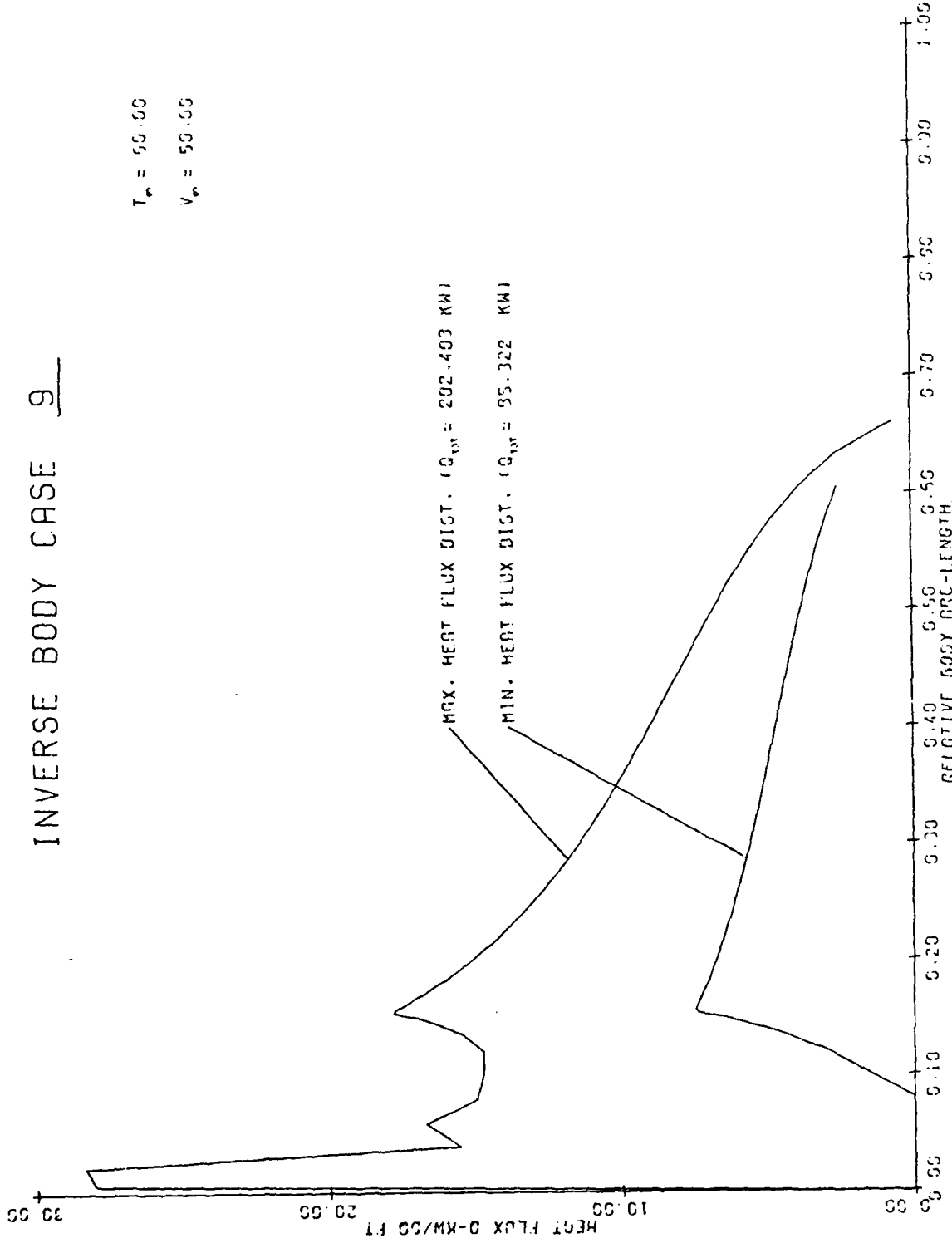


Figure 105. Heat Flux Distributions, Case No. 9.

# INVERSE BODY CASE 10

$T_a = 50.00$   
 $V_a = 50.00$

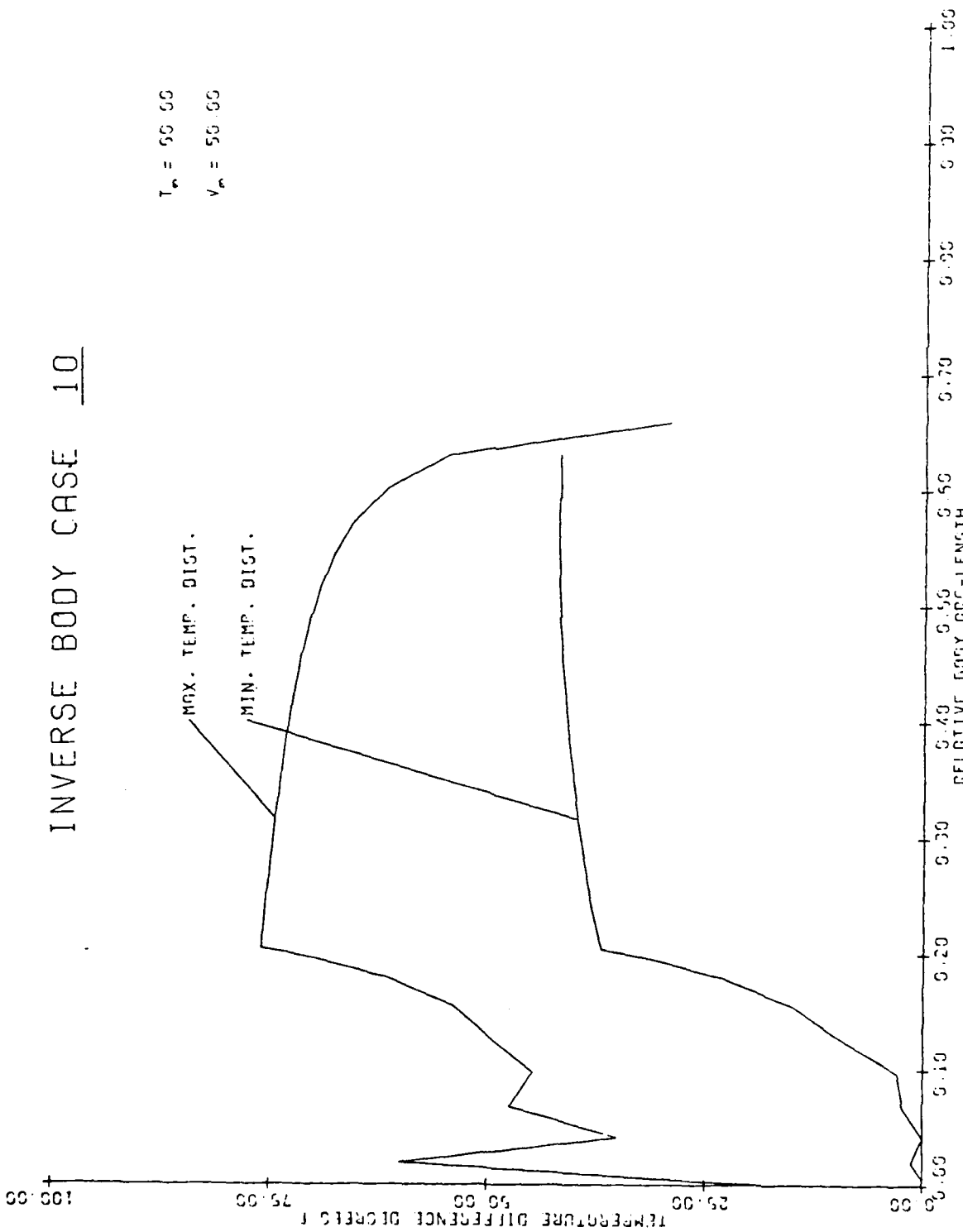


Figure 106. Temperature Distributions, Case No. 10.

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# INVERSE BODY CASE 10

$T_w = 50.00$   
 $V_w = 50.00$

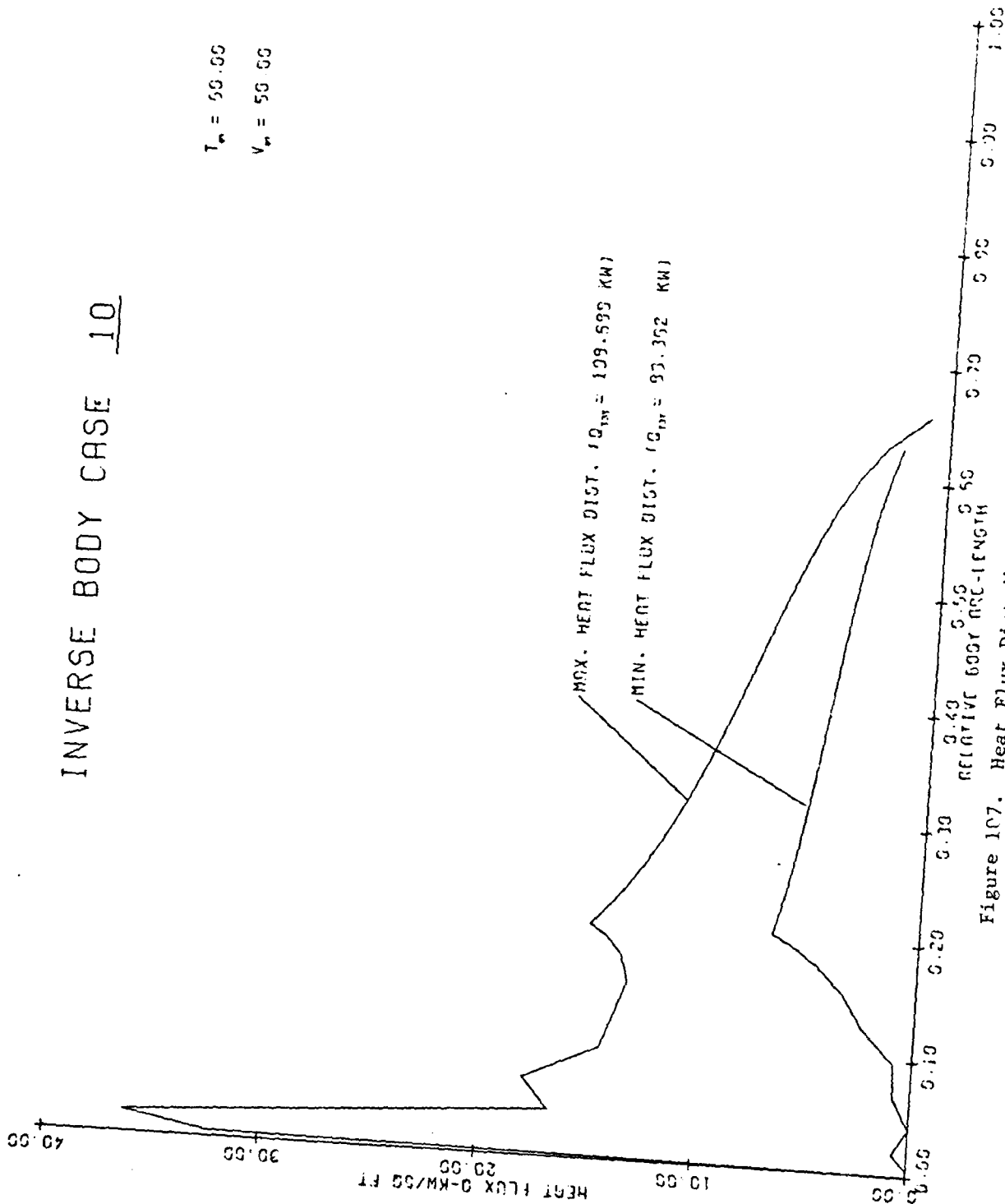


Figure 107. Heat Flux Distributions, Case No. 10.

INVERSE BODY CASE 11

$T_m = 50.00$

$V_m = 50.00$

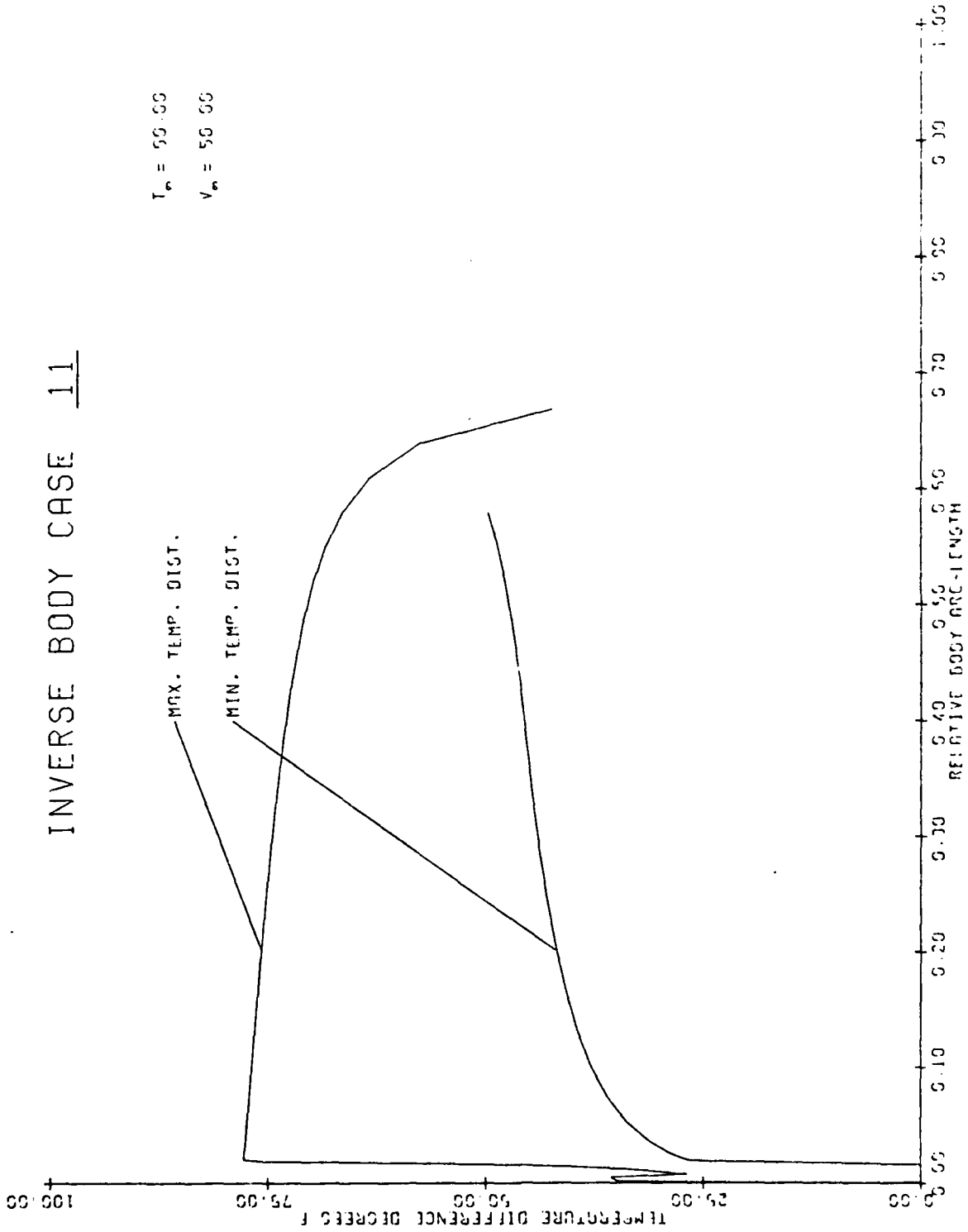


Figure 108. Temperature Distributions, Case No. 11.

INVERSE BODY CASE 11

$T_w = 50.00$

$V_w = 50.00$

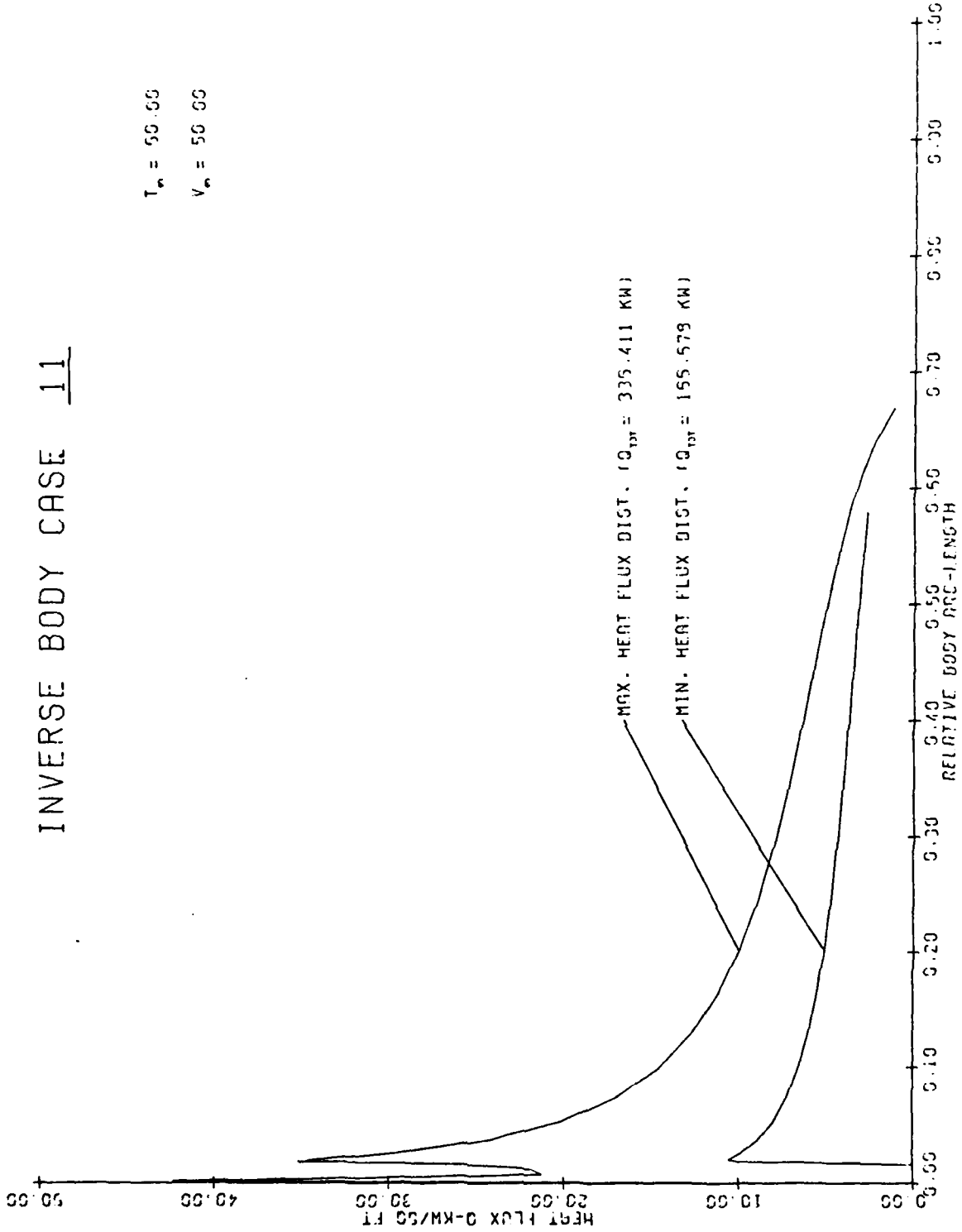


Figure 109. Heat Flux Distributions, Case No. 11.

INVERSE BODY CASE 12

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

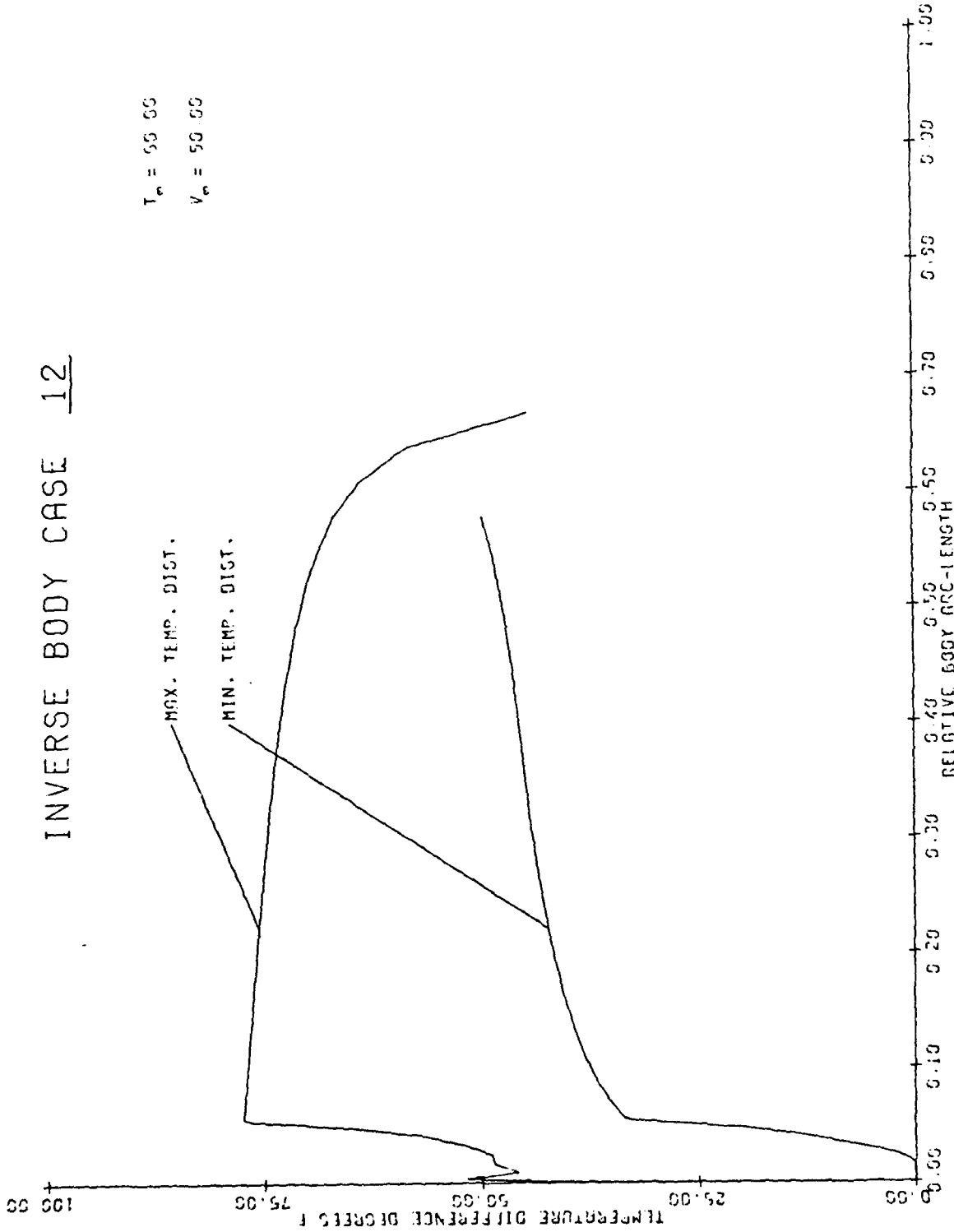


Figure 110. Temperature Distributions, Case No. 12.

INVERSE BODY CASE 12

$T_m = 50.00$   
 $V_m = 50.00$

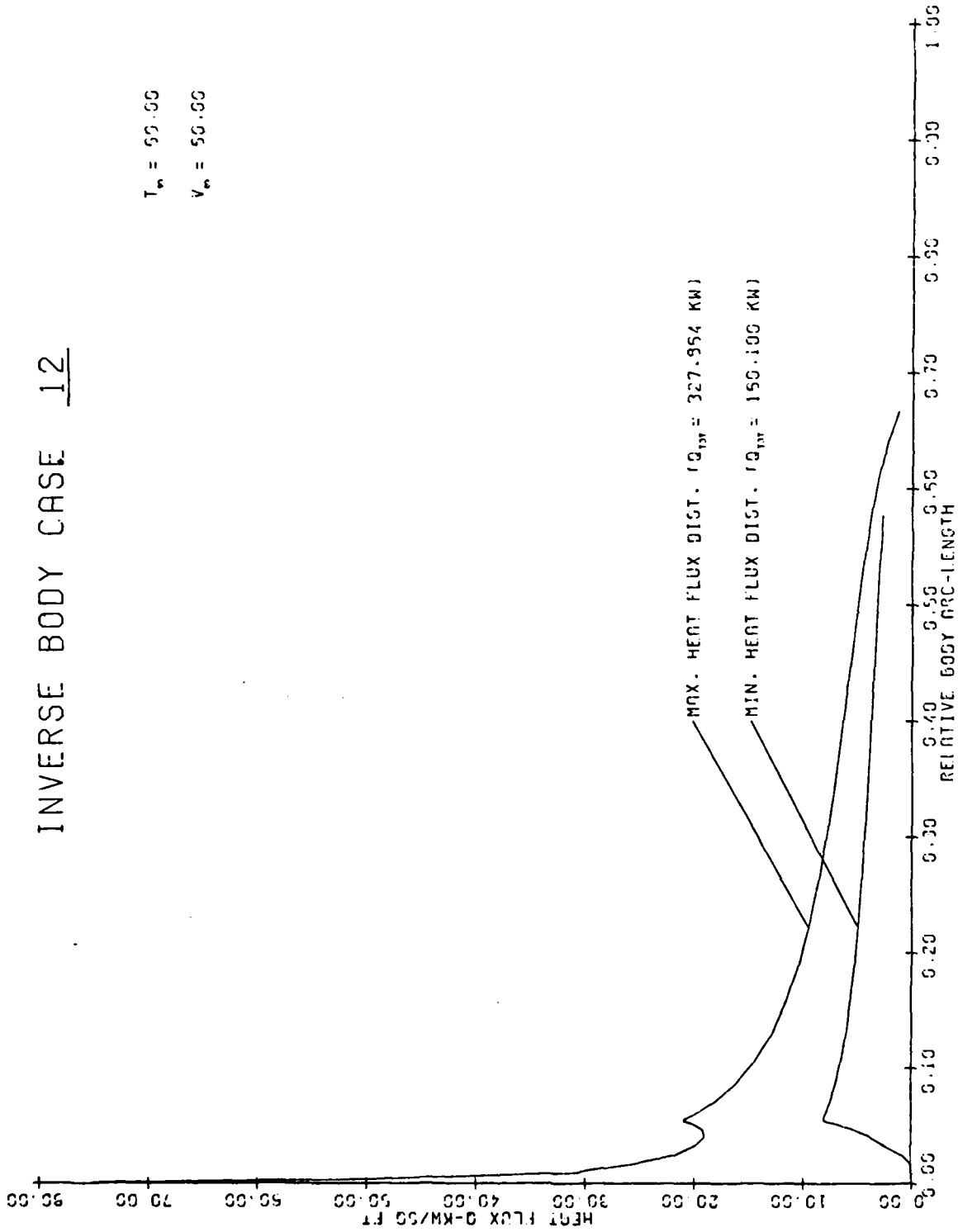


Figure III. Heat Flux Distributions, Case No. 12.

INVERSE BODY CASE 13

$T_m = 50.00$   
 $V_m = 50.00$

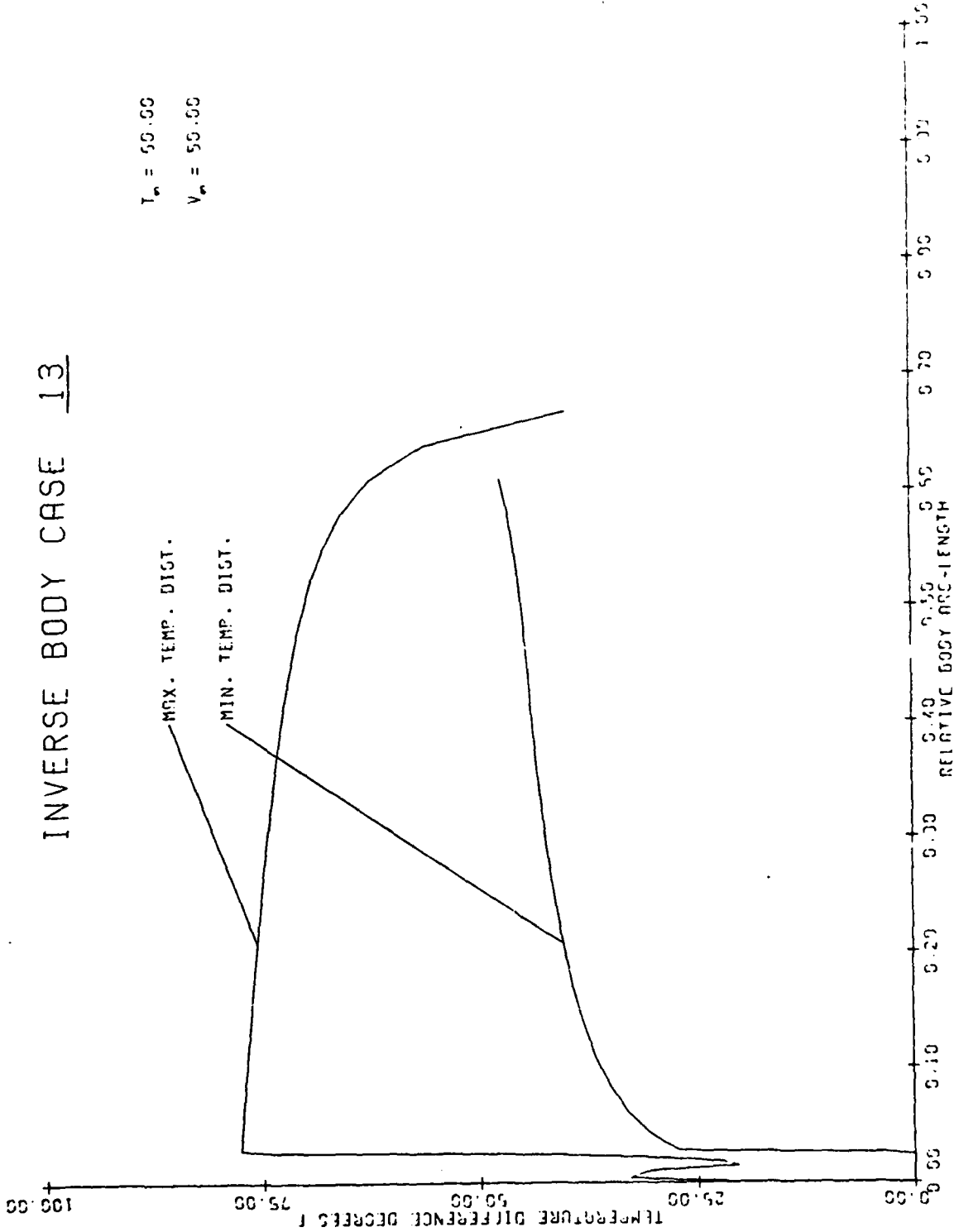


Figure 112. Temperature Distributions, Case No. 13.

# INVERSE BODY CASE 13

$T_w = 50.00$   
 $V_w = 50.00$

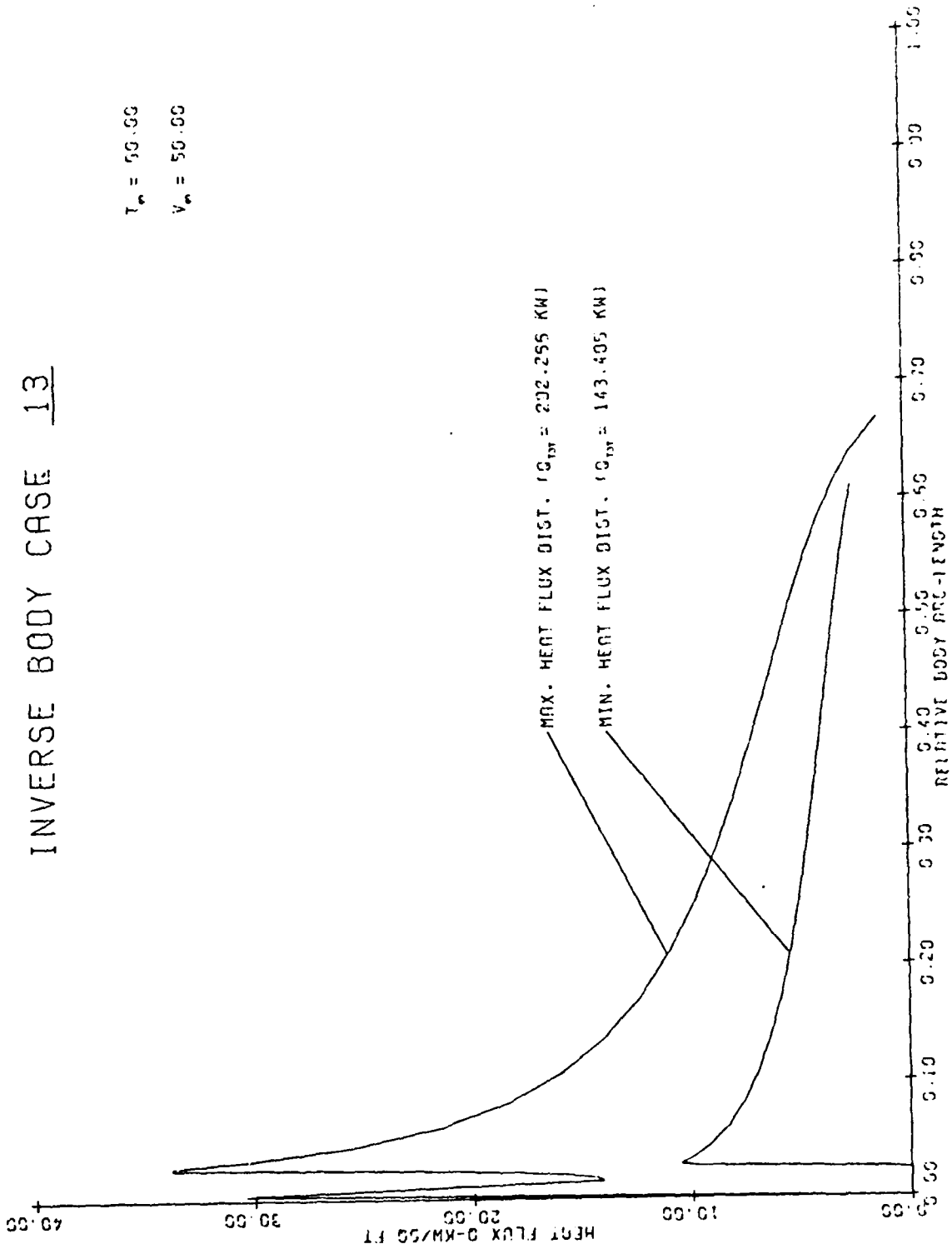


Figure 113. Heat Flux Distributions, Case No. 13.

INVERSE BODY CASE 14

$T_m = 50.00$   
 $V_m = 50.00$

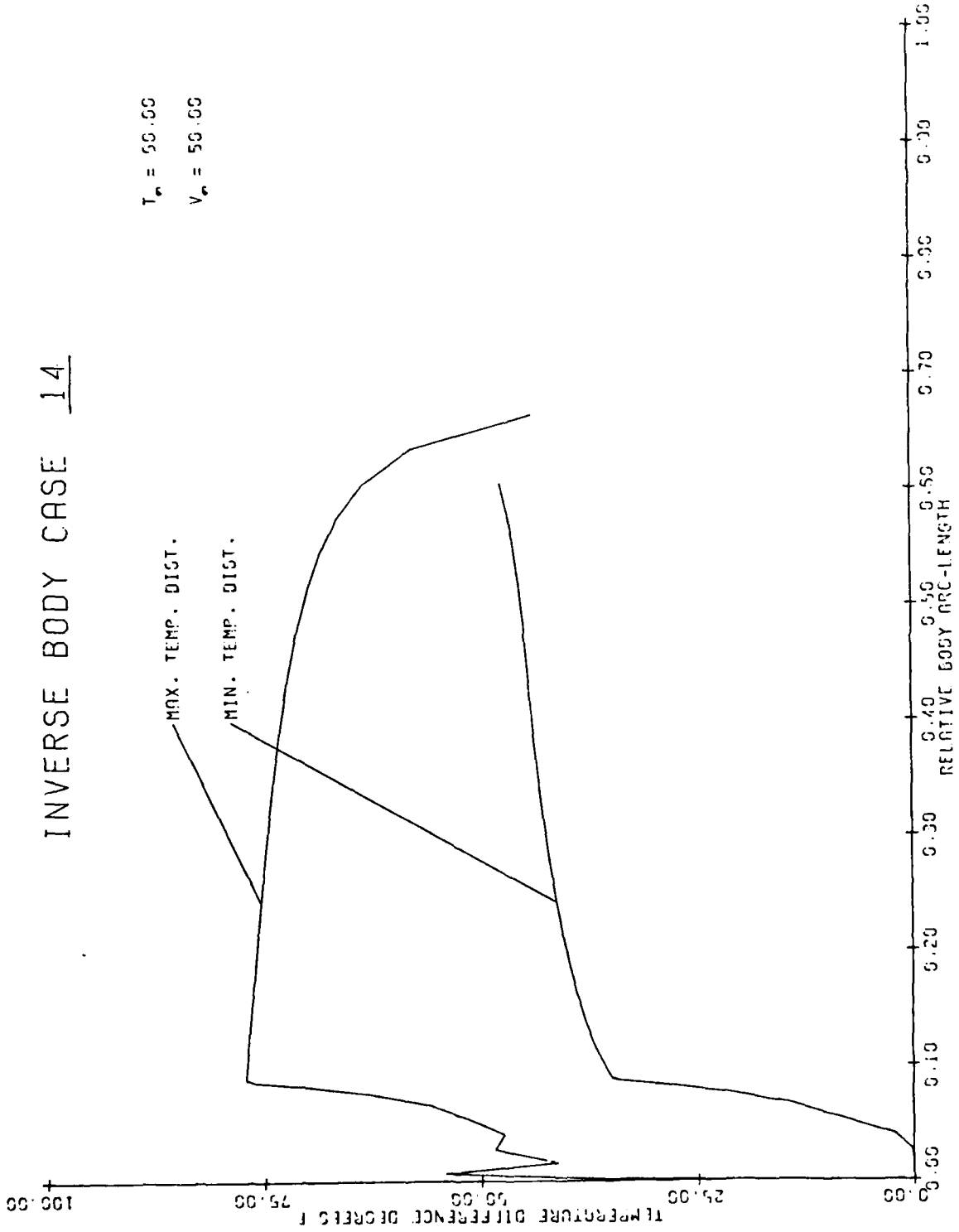


Figure 114. Temperature Distributions, Case No. 14.

INVERSE BODY CASE 14

$T_m = 50.00$   
 $V_m = 50.00$

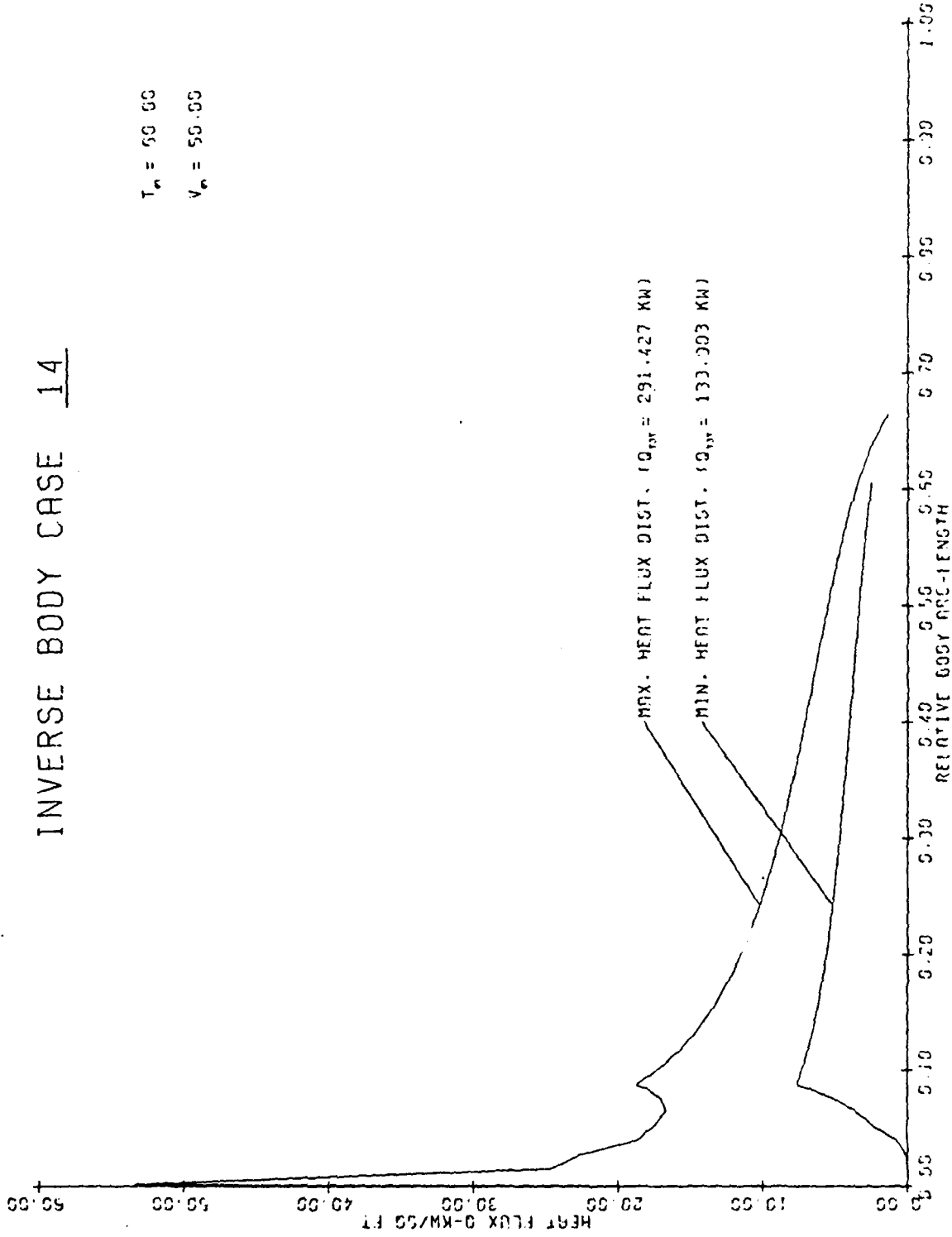


Figure 115. Heat Flux Distributions, Case No. 14.

INVERSE BODY CASE 15

$T_p = 50.00$   
 $V_p = 50.00$

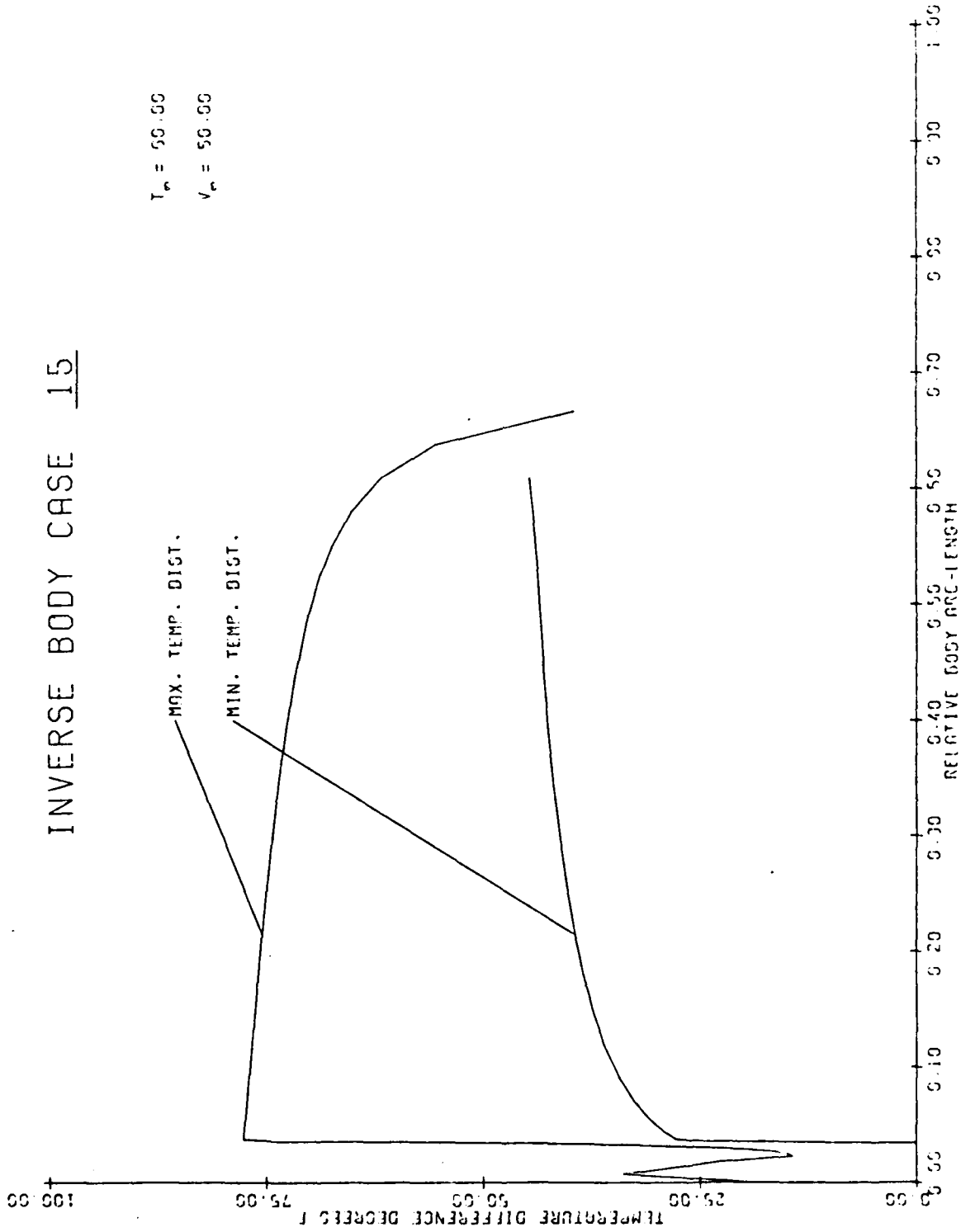


Figure 116. Temperature Distributions, Case No. 15.

INVERSE BODY CASE 15

$T_w = 50.00$

$V_w = 50.00$

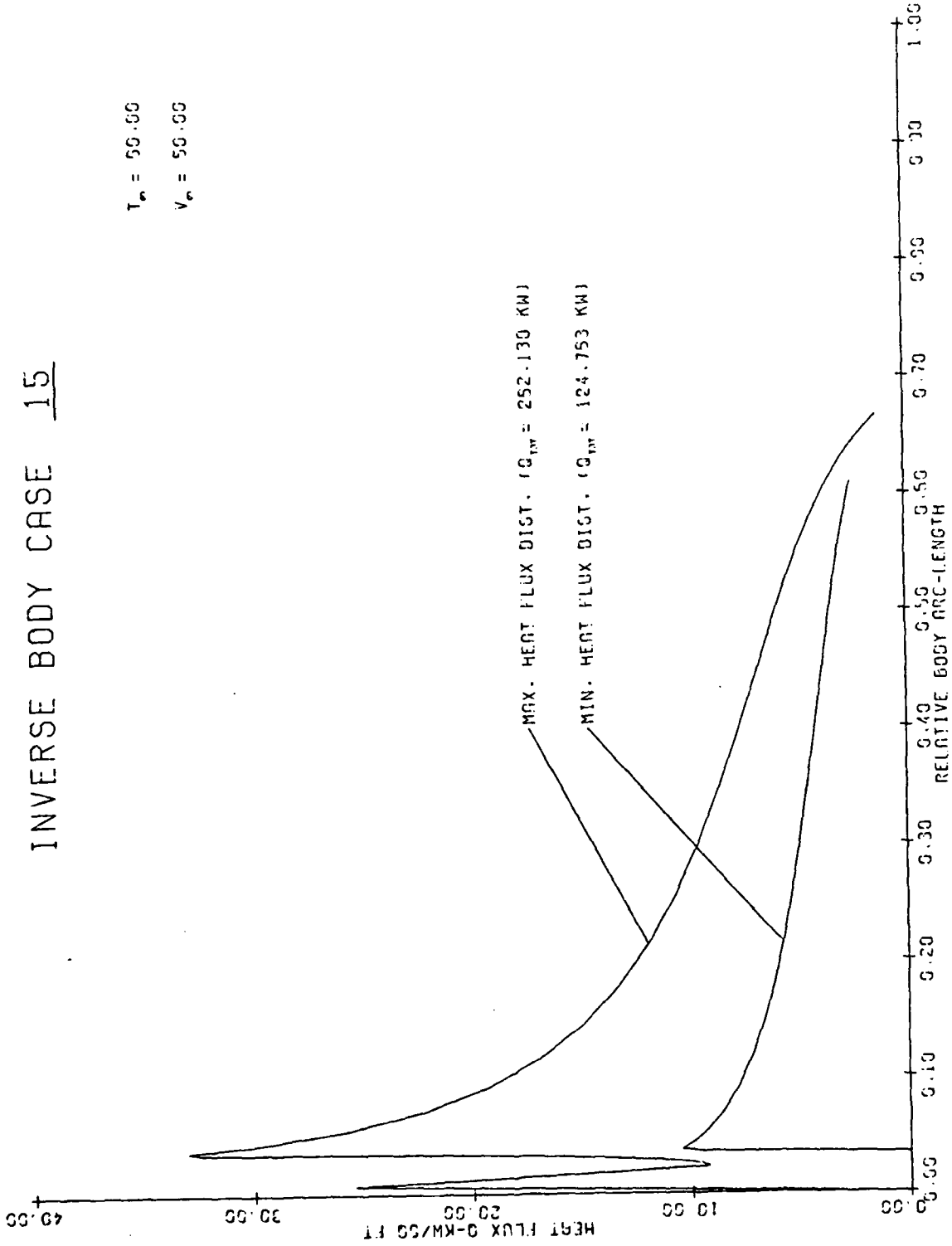


Figure 117. Heat Flux Distributions, Case No. 15.

INVERSE BODY CASE 16

$T_m = 50.00$   
 $V_m = 50.00$

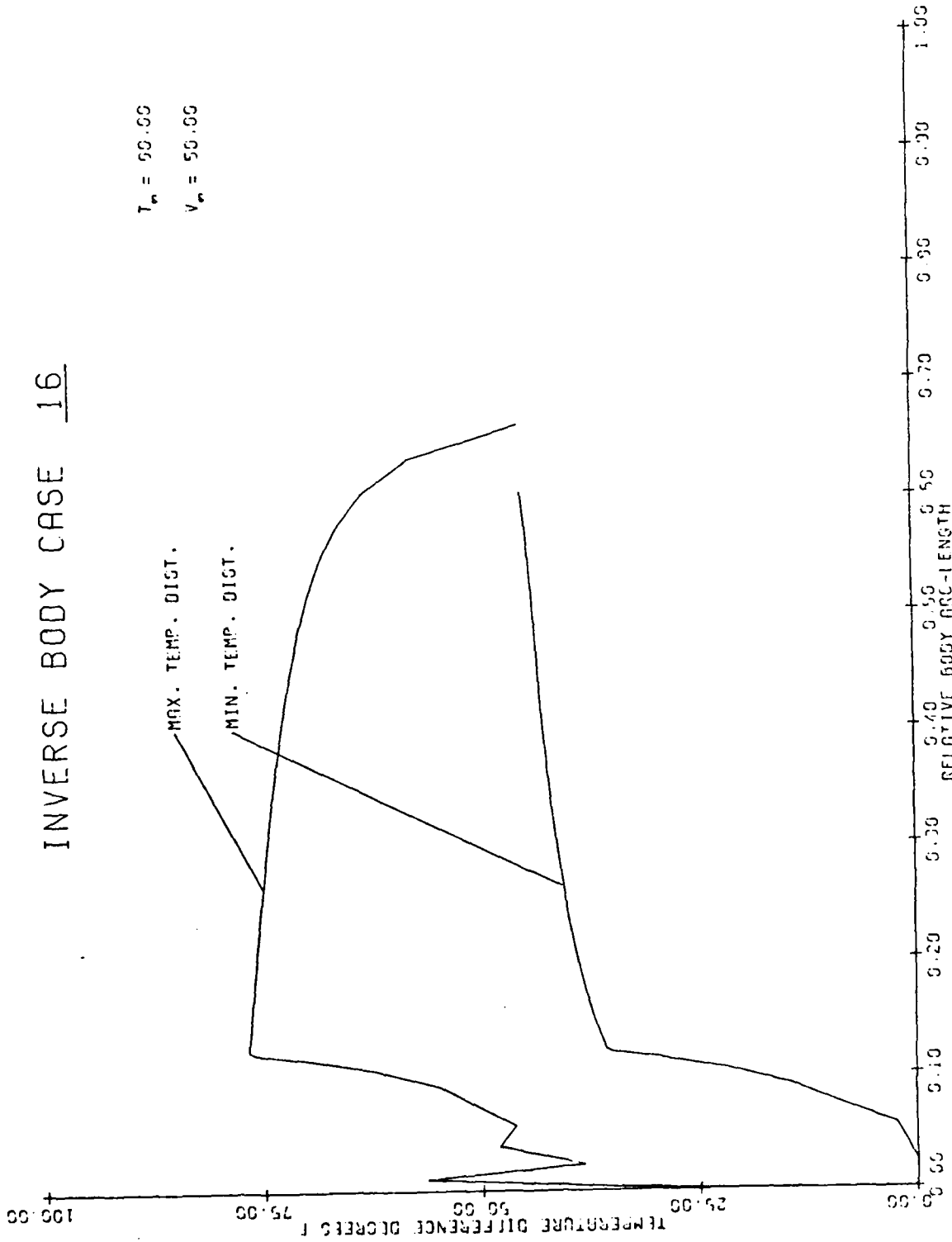


Figure 118, Temperature Distributions, Case No. 16.

INVERSE BODY CASE 16

$T_m = 50.00$

$V_m = 50.00$

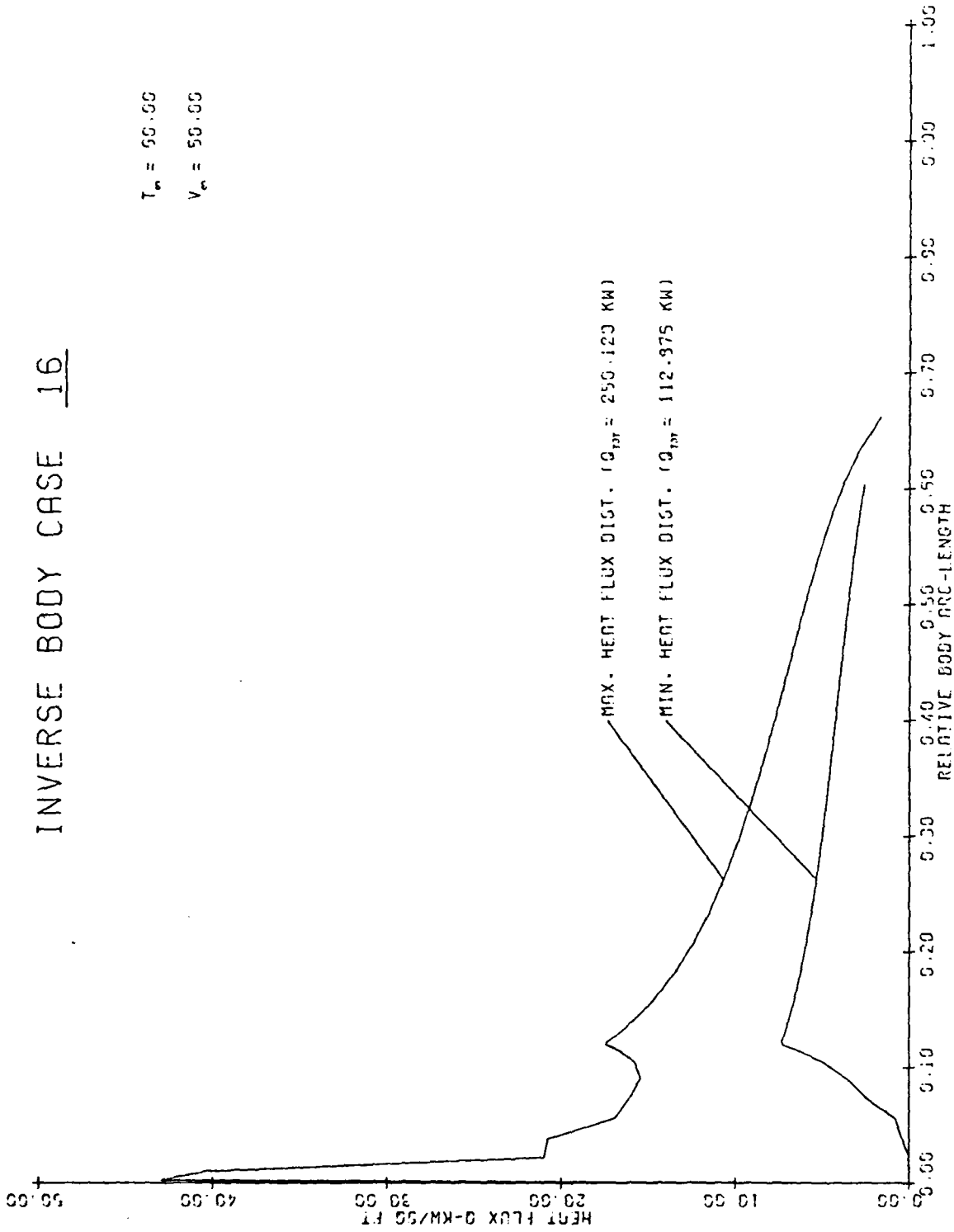


Figure 119. Heat Flux Distributions, Case No. 16.

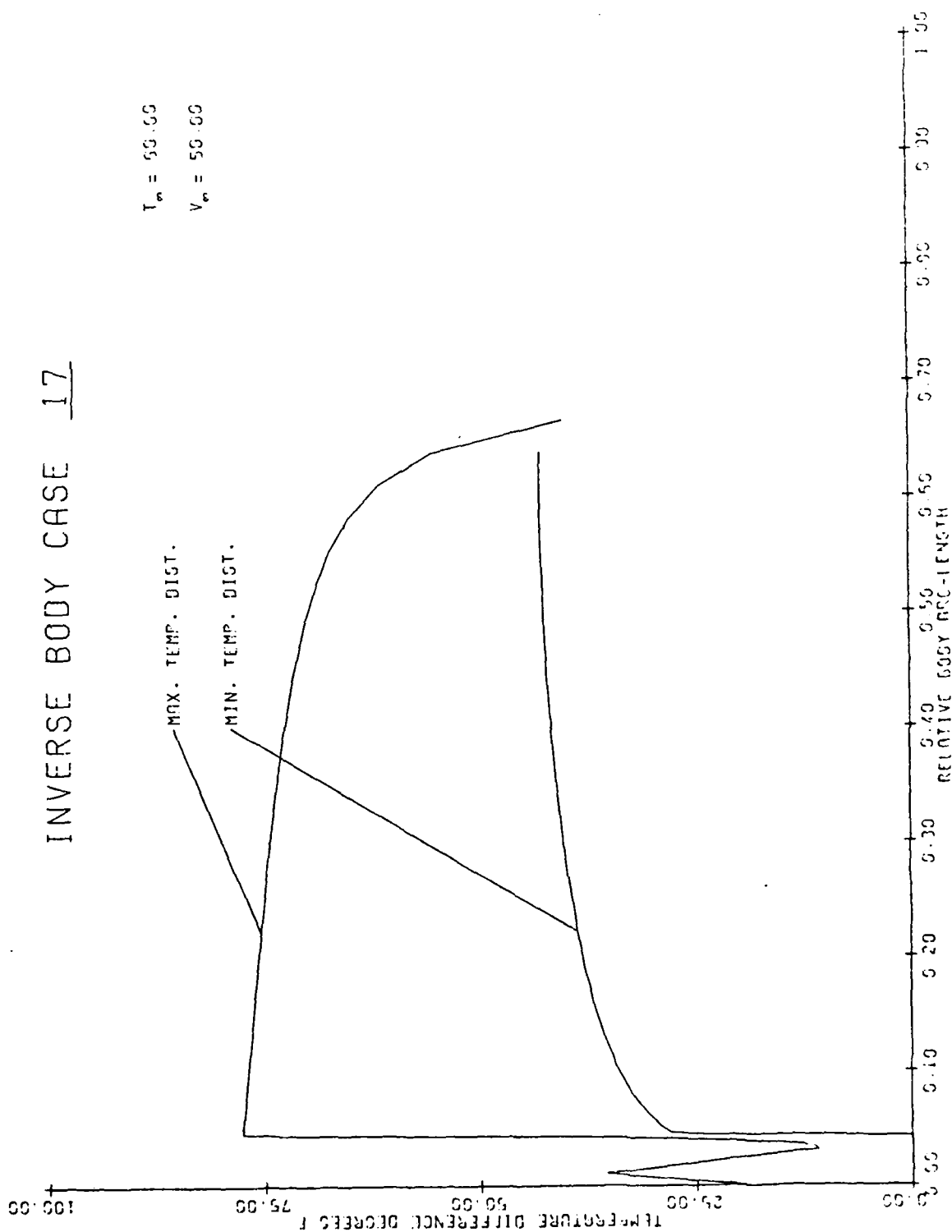


Figure 120. Temperature Distributions, Case No. 17.

# INVERSE BODY CASE 17

$T_w = 50.00$

$V_w = 50.00$

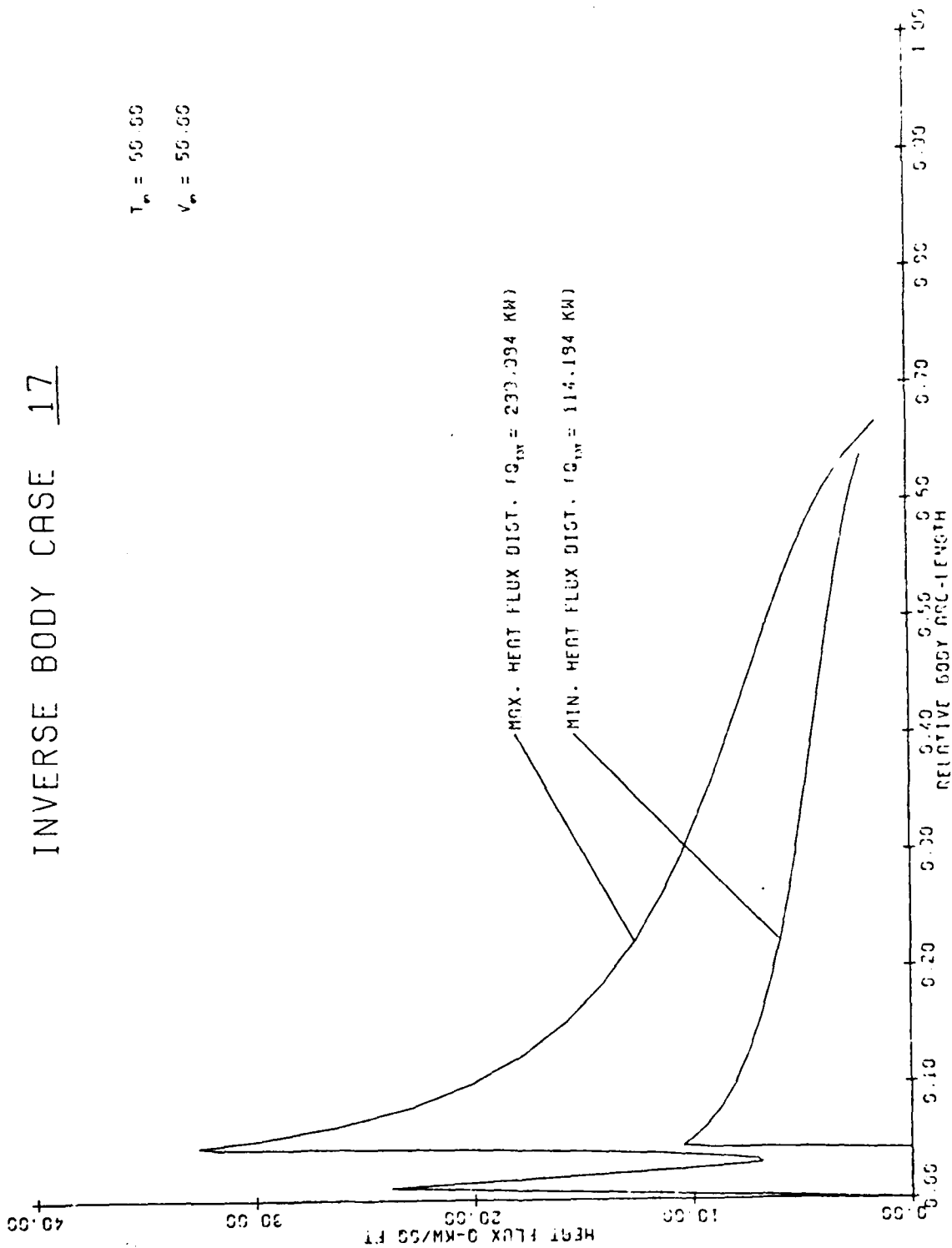


Figure 121. Heat Flux Distributions, Case No. 17

INVERSE BODY CASE 18

$T_m = 50.00$   
 $V_m = 50.00$

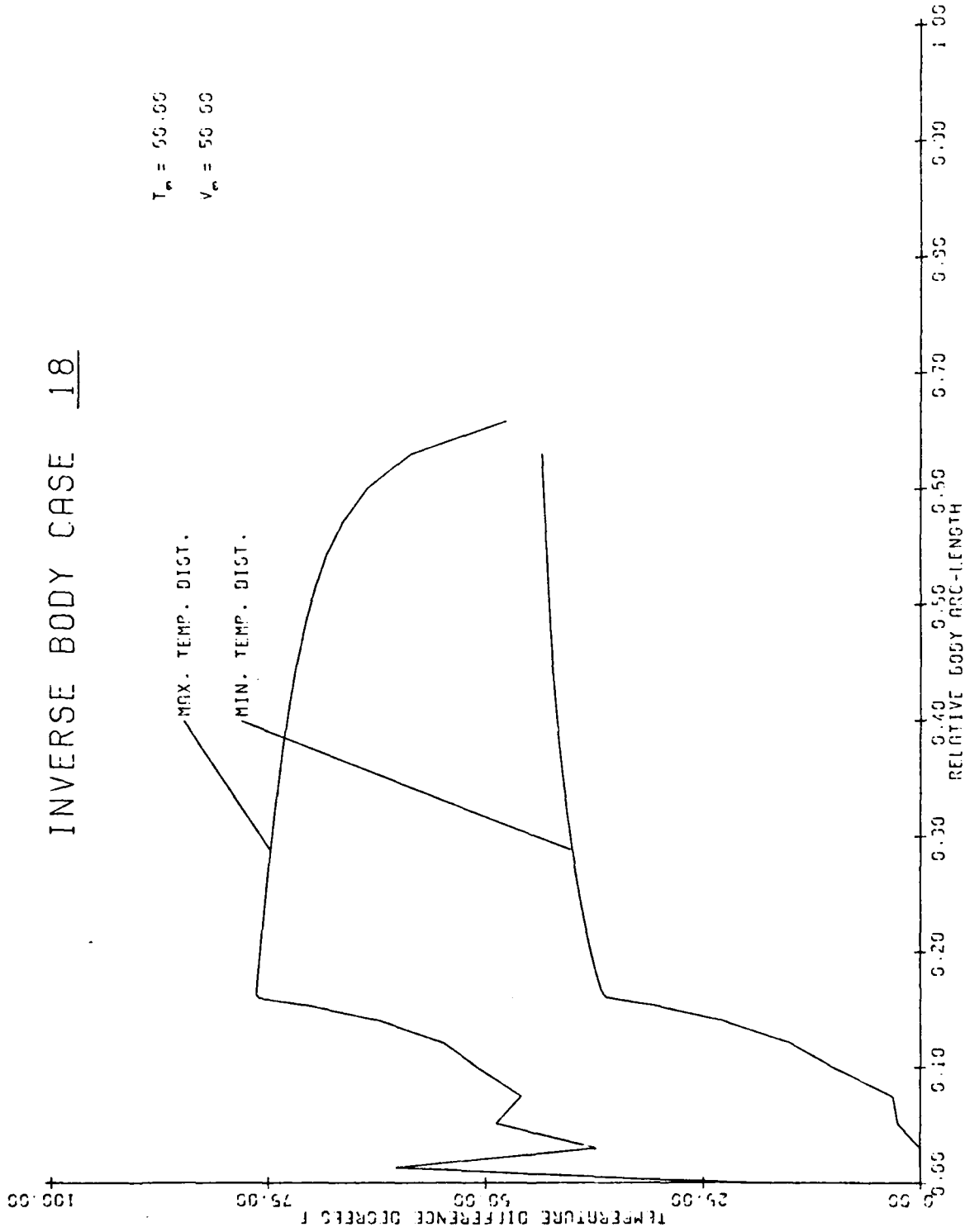


Figure 122. Temperature Distributions, Case No. 18.

INVERSE BODY CASE 18

$T_w = 50.00$   
 $V_w = 50.00$

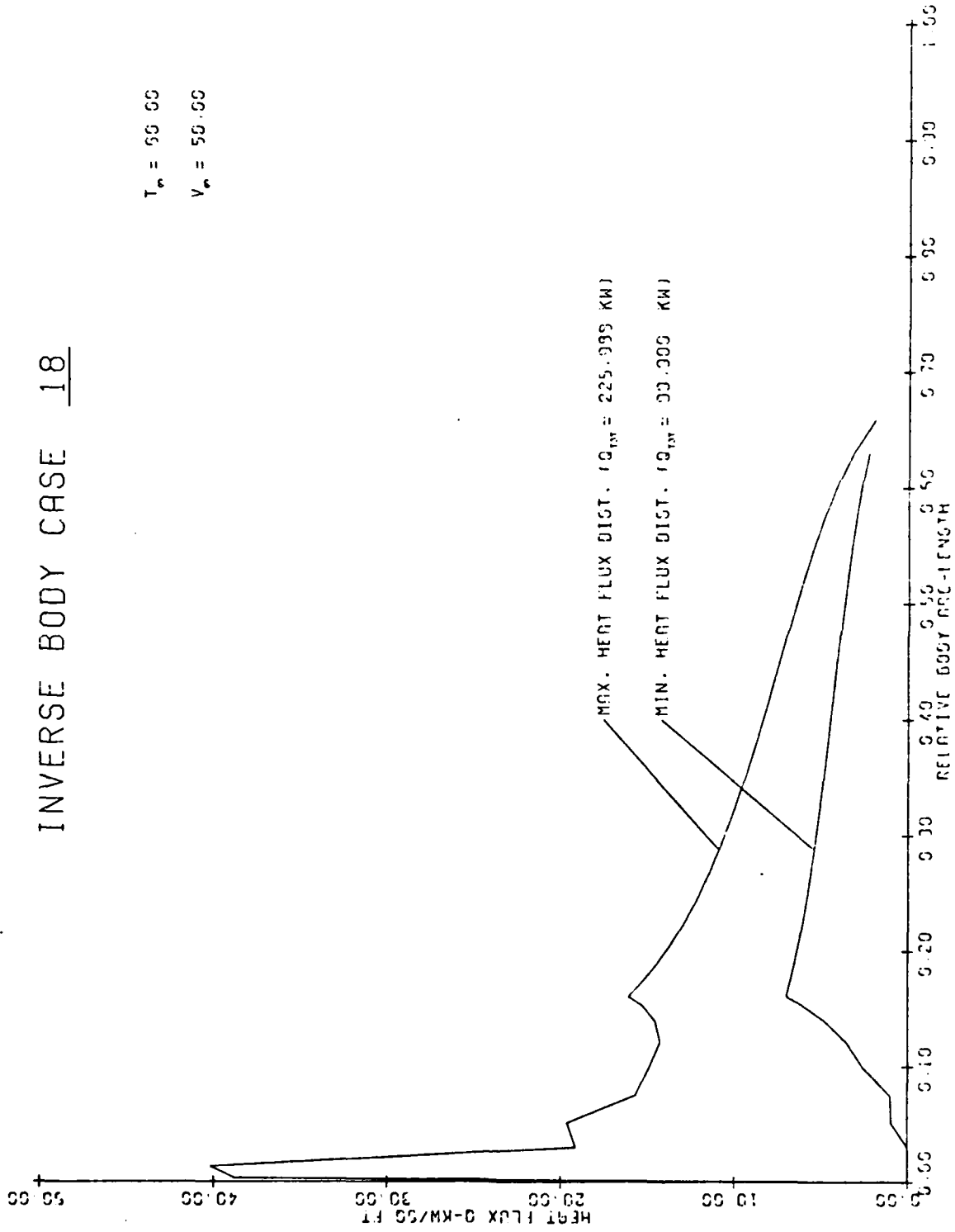


Figure 123. Heat Flux Distributions, Case No. 18.

# INVERSE BODY CASE 19

$T_{\infty} = 55.00$   
 $V_{\infty} = 55.00$

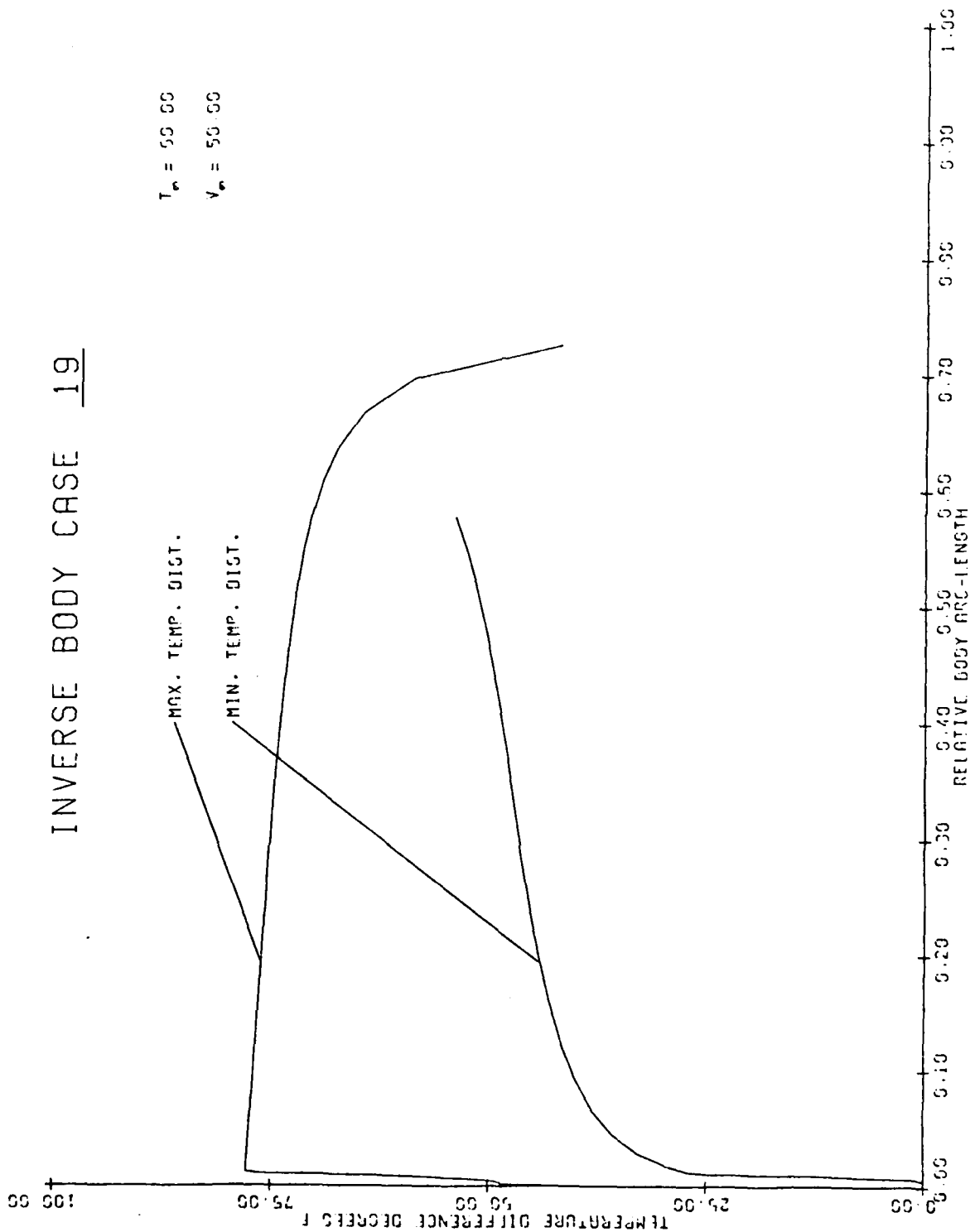


Figure 124. Temperature Distributions, Case No. 19.

INVERSE BODY CASE 19

$T_m = 50.00$

$V_m = 50.00$

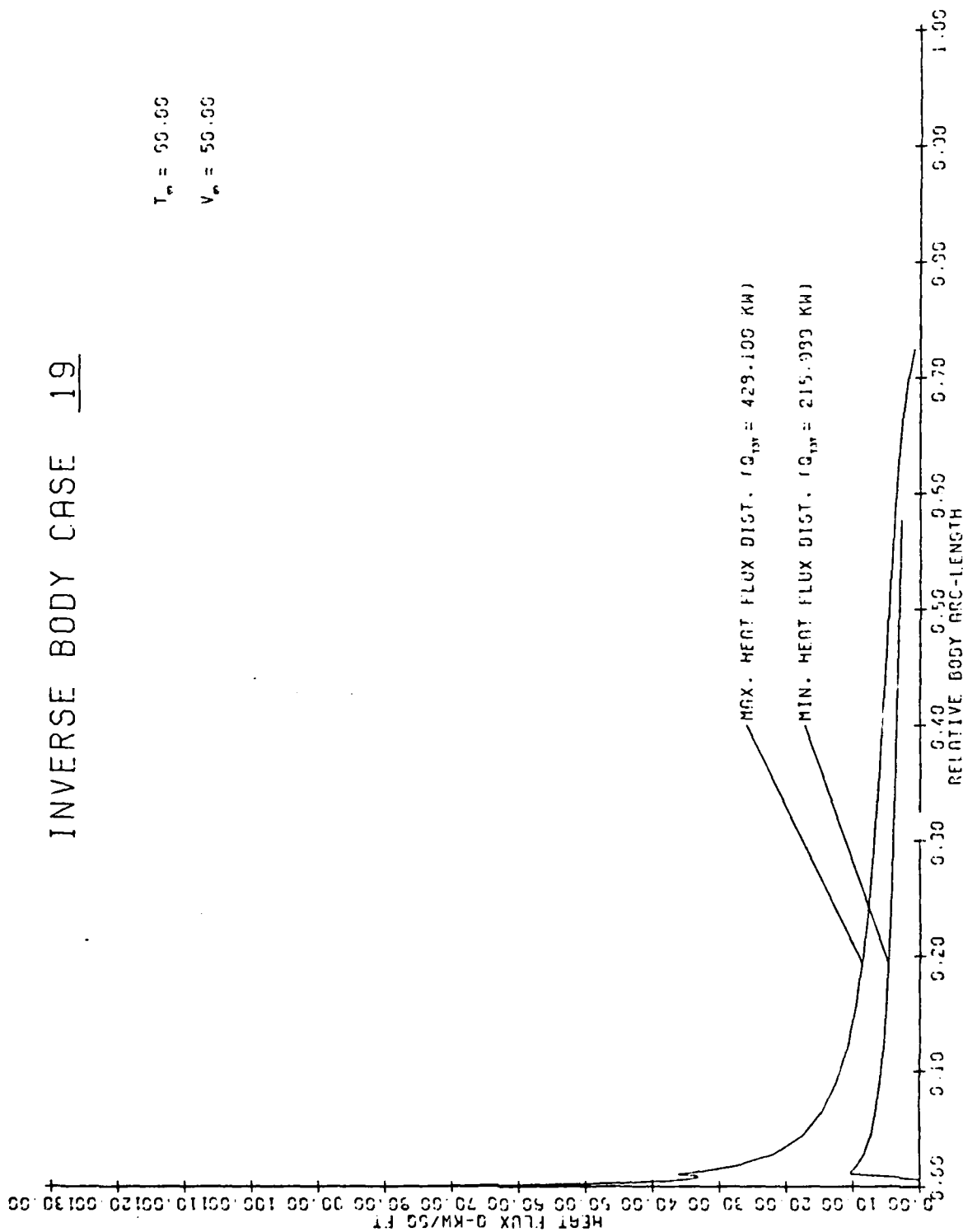


Figure 125. Heat Flux Distributions, Case No. 19.

INVERSE BODY CASE 20

$T_w = 50.00$   
 $V_w = 50.00$

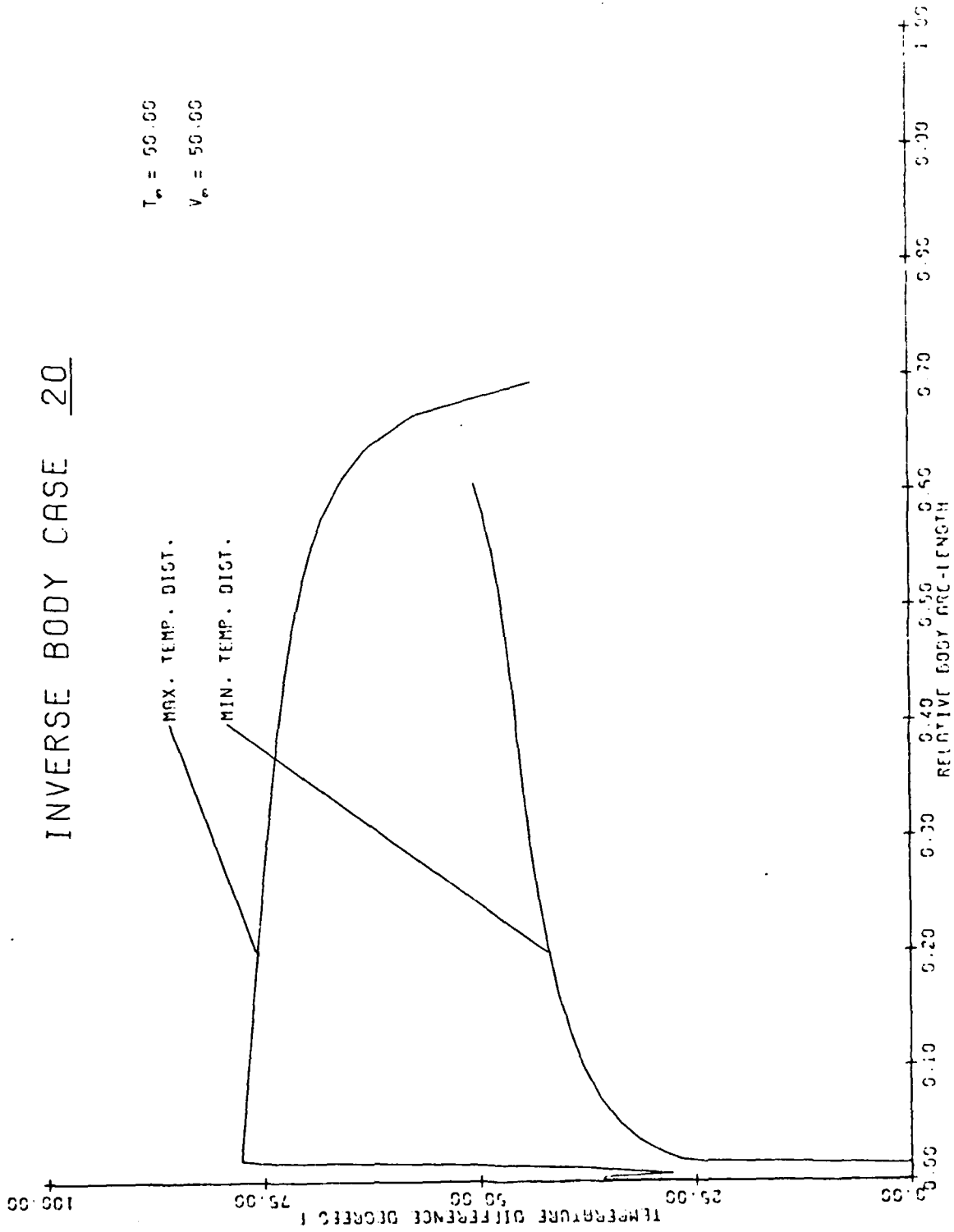


Figure 126. Temperature Distributions, Case No. 20.

INVERSE BODY CASE 20

$r_w = 50.00$

$y_w = 50.00$

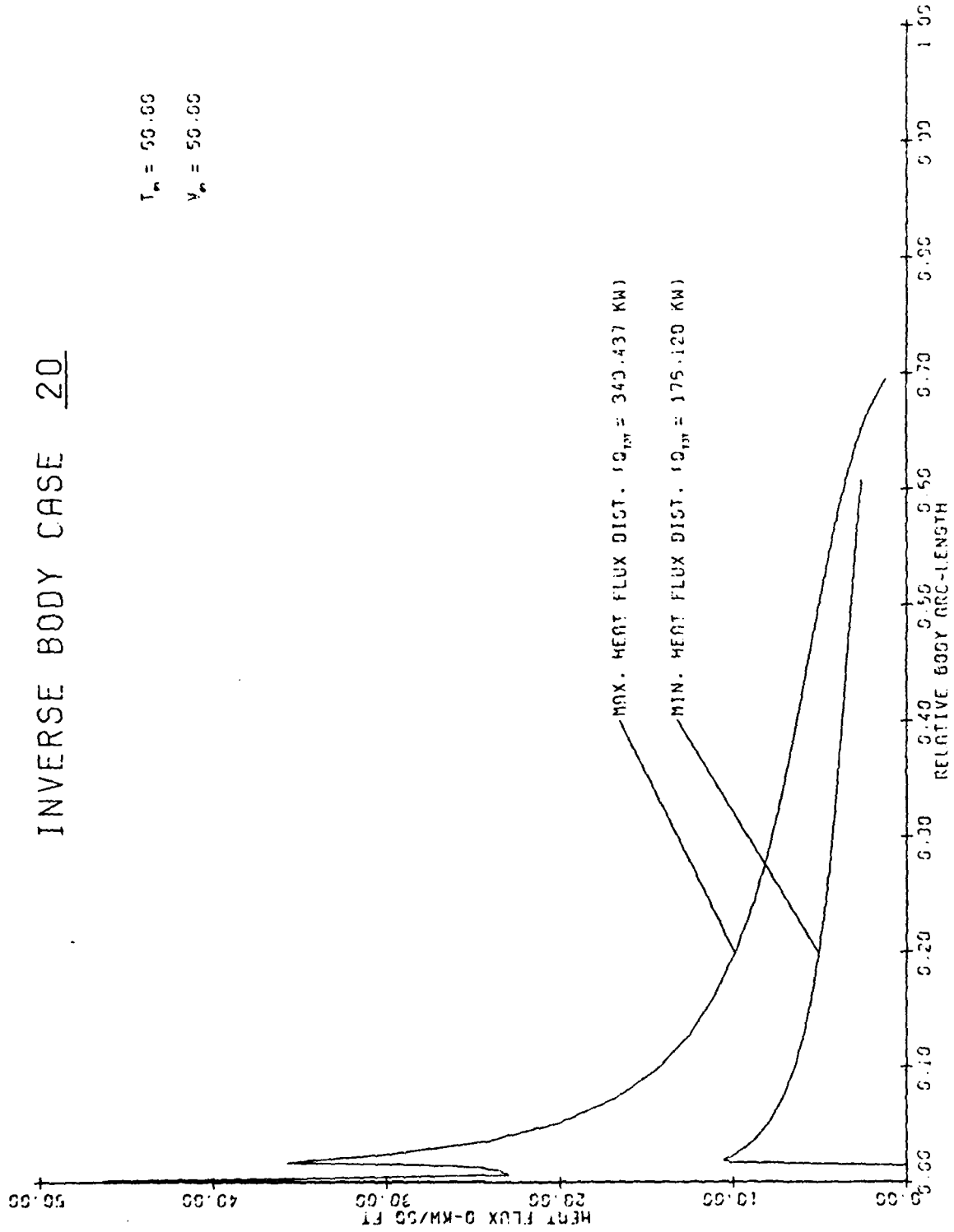


Figure 127. Heat Flux Distributions, Case No. 20.

INVERSE BODY CASE 21

$T_m = 50.00$   
 $V_m = 50.00$

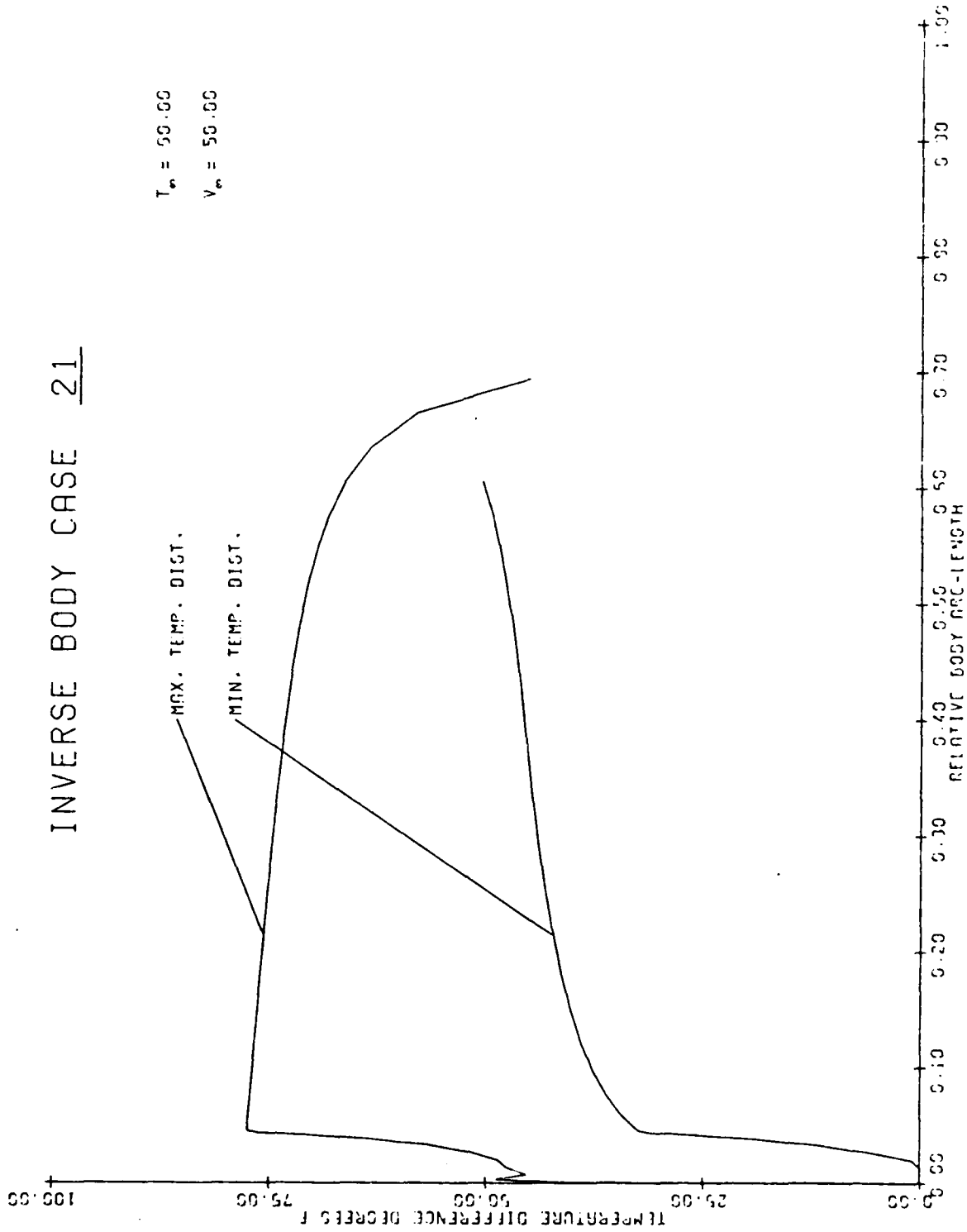


Figure 128. Temperature Distributions, Case No. 21.

INVERSE BODY CASE 21

$T_w = 50.00$   
 $V_w = 50.00$

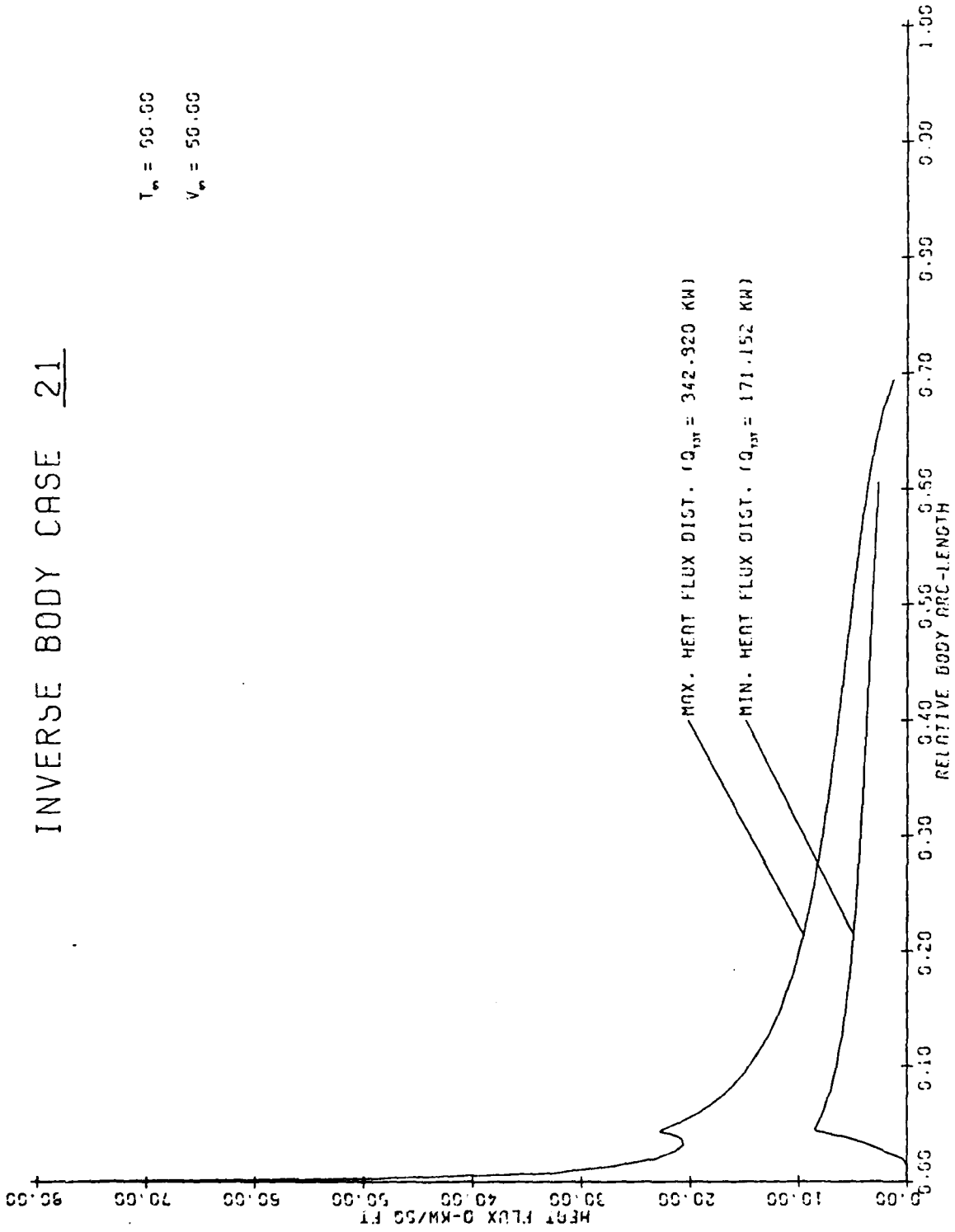


Figure 129. Heat Flux Distributions, Case No. 21.

INVERSE BODY CASE 22

$T_r = 50.00$

$V_r = 50.00$

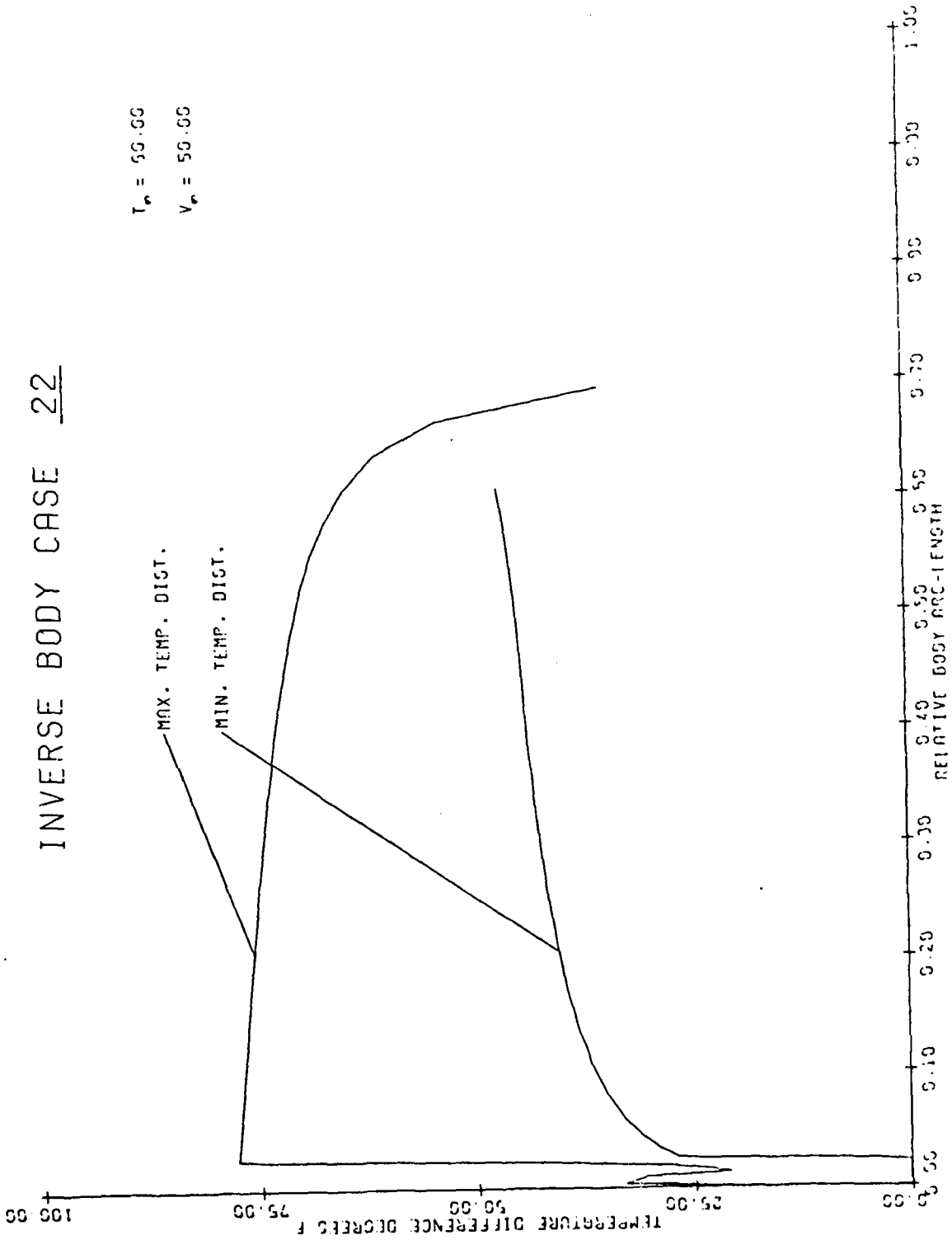


Figure 130. Temperature Distributions, Case No. 22.

INVERSE BODY CASE 22

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

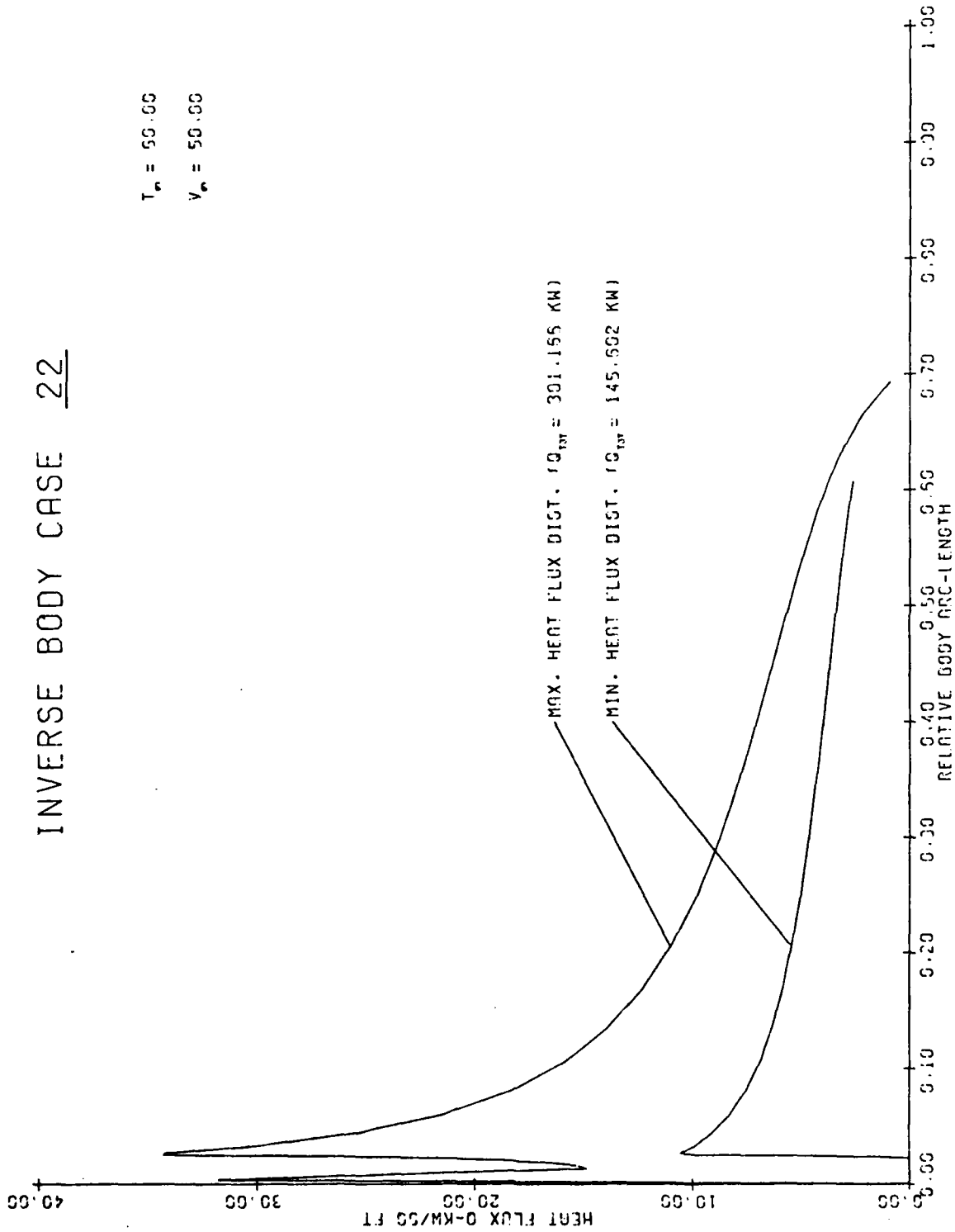


Figure 131. Heat Flux Distributions, Case No. 22.

INVERSE BODY CASE 23

$T_m = 50.00$

$V_m = 50.00$

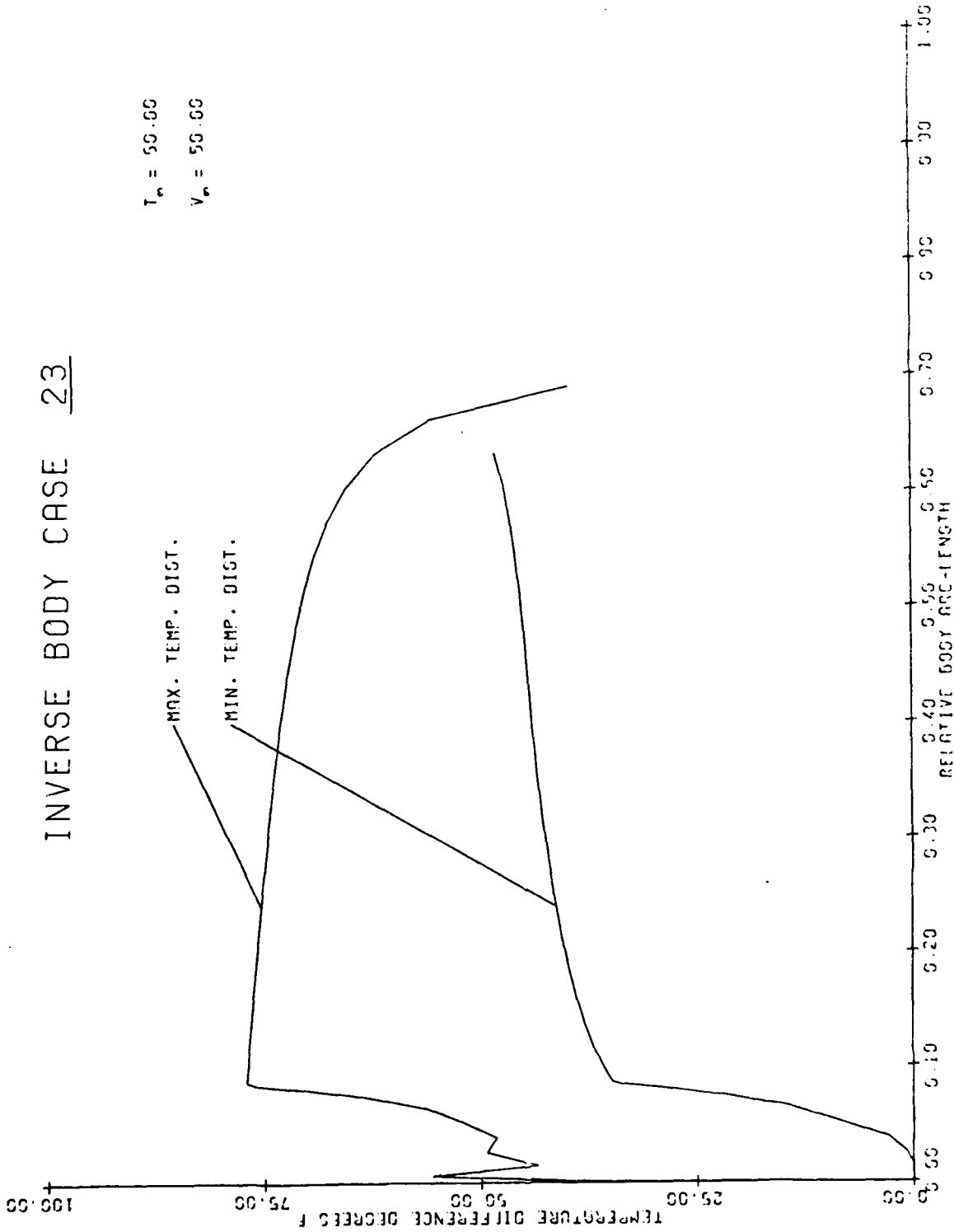


Figure 132. Temperature Distributions, Case No. 23.

INVERSE BODY CASE 23

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

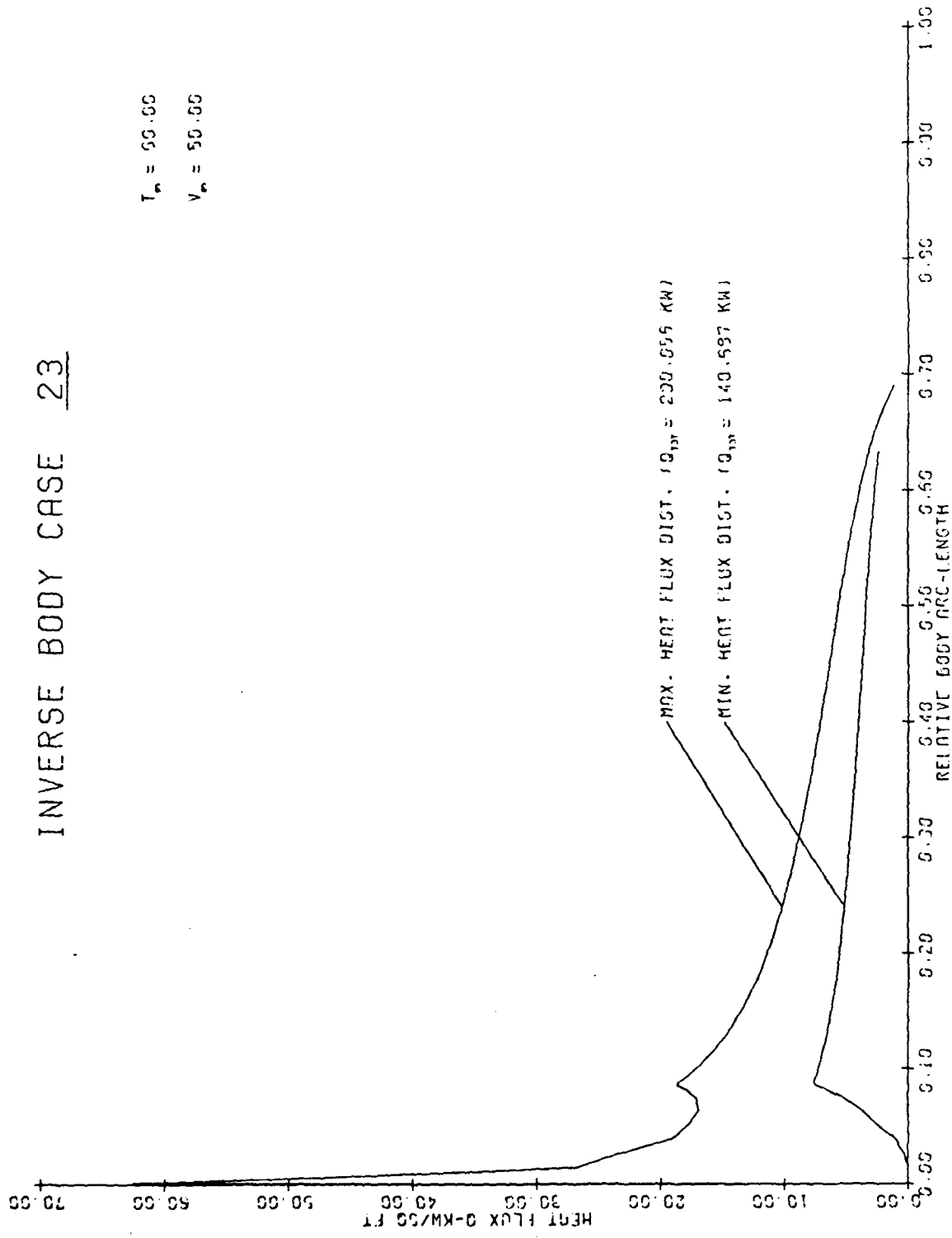


Figure 133. Heat Flux Distributions, Case No. 23.

INVERSE BODY CASE 24

$T_w = 50.00$   
 $V_w = 50.00$

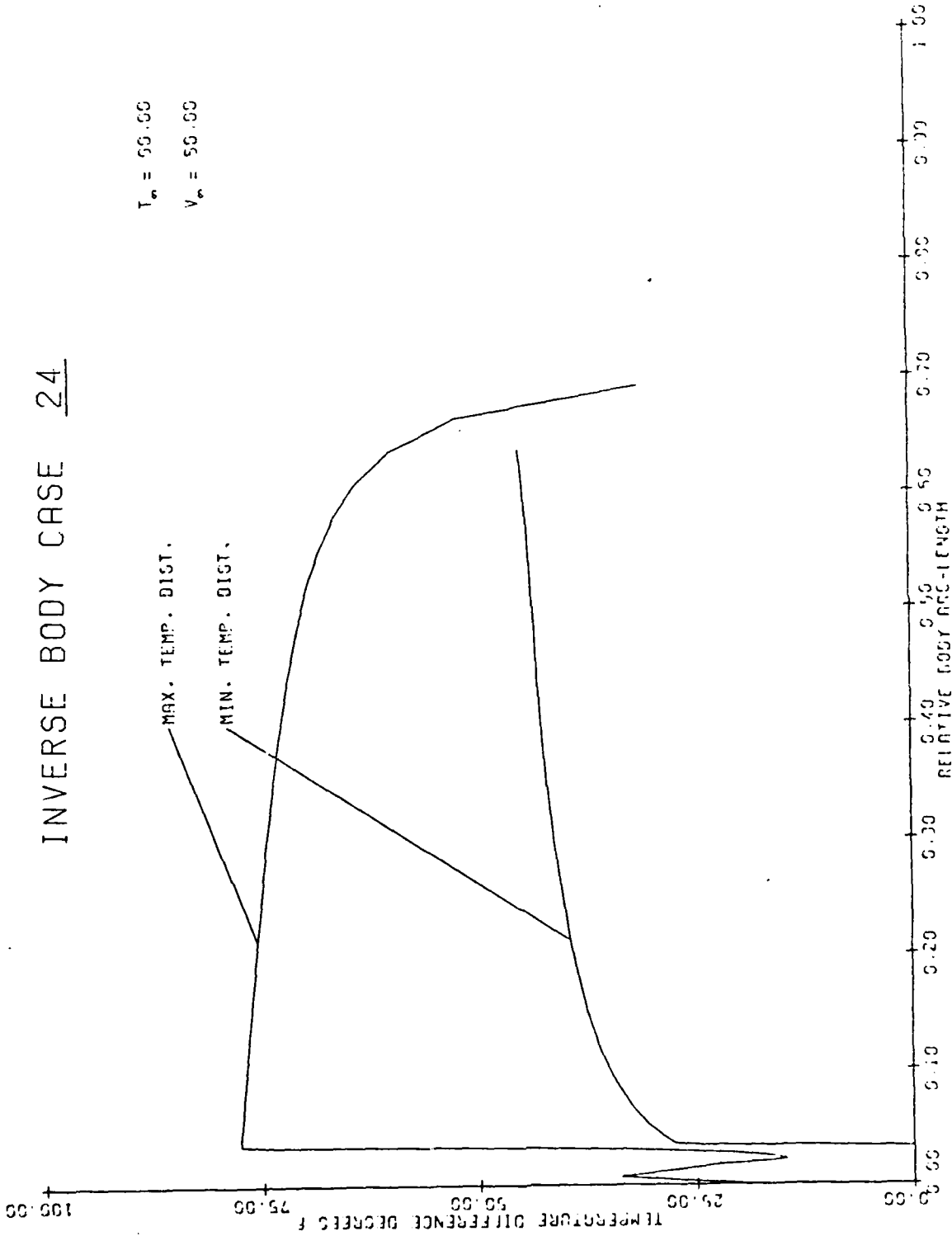


Figure 134. Temperature Distributions, Case No. 24.

INVERSE BODY CASE 24

$T_m = 50.00$

$V_m = 50.00$

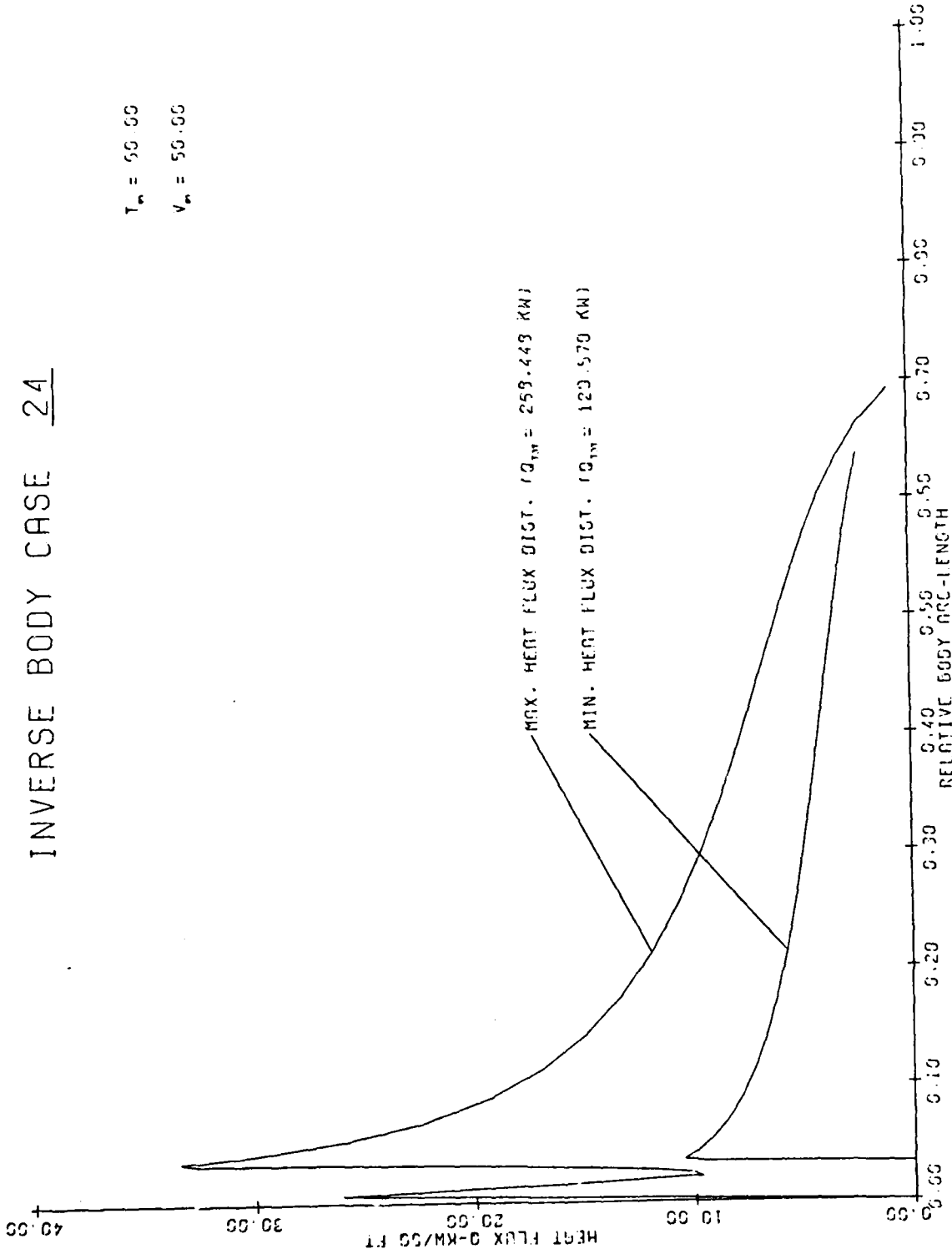


Figure 135. Heat Flux Distributions, Case No. 24.

INVERSE BODY CASE 25

$T_m = 50.00$   
 $V_m = 50.00$

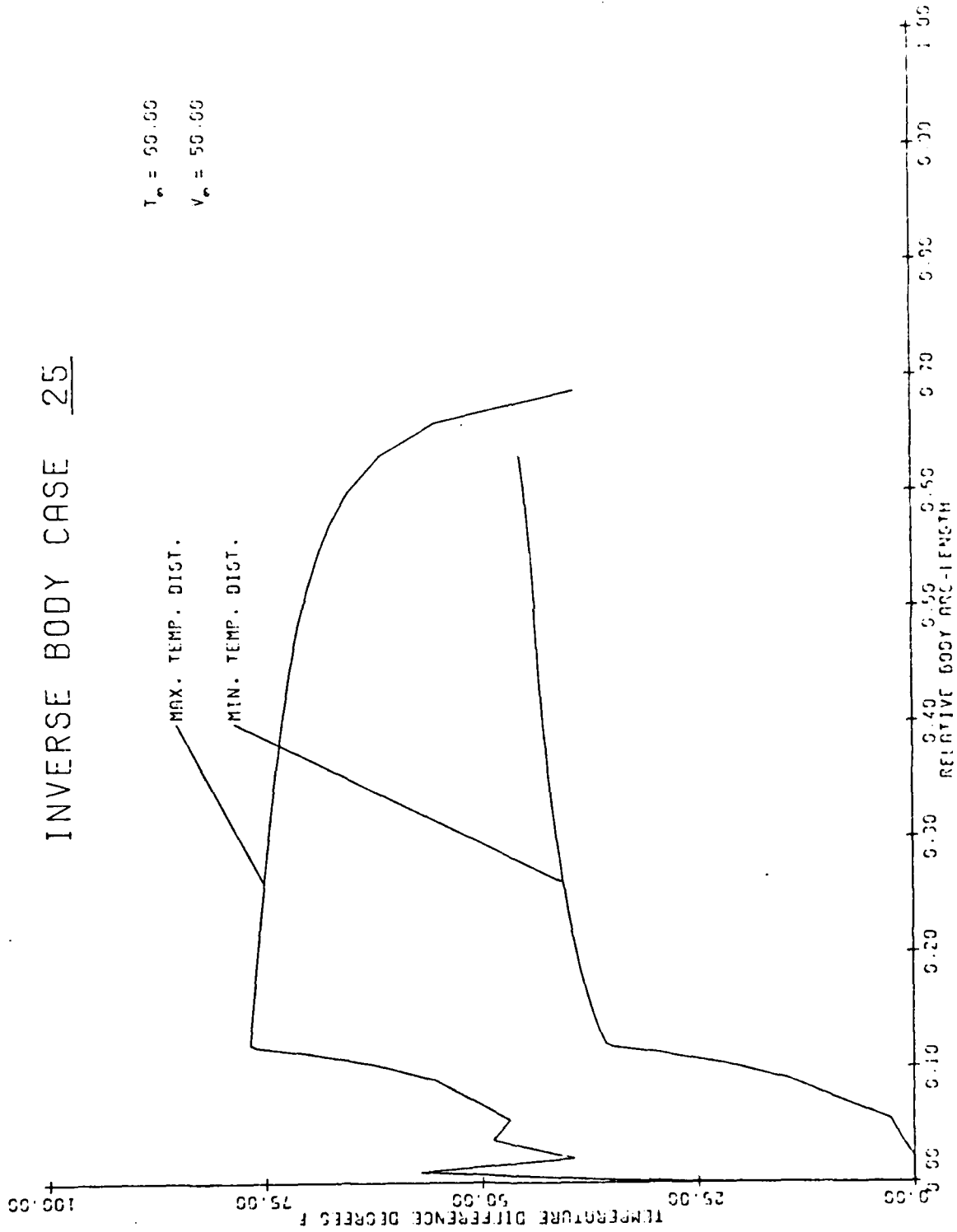


Figure 136. Temperature Distributions, Case No. 25.

INVERSE BODY CASE 25

$T_a = 50.00$   
 $V_a = 50.00$

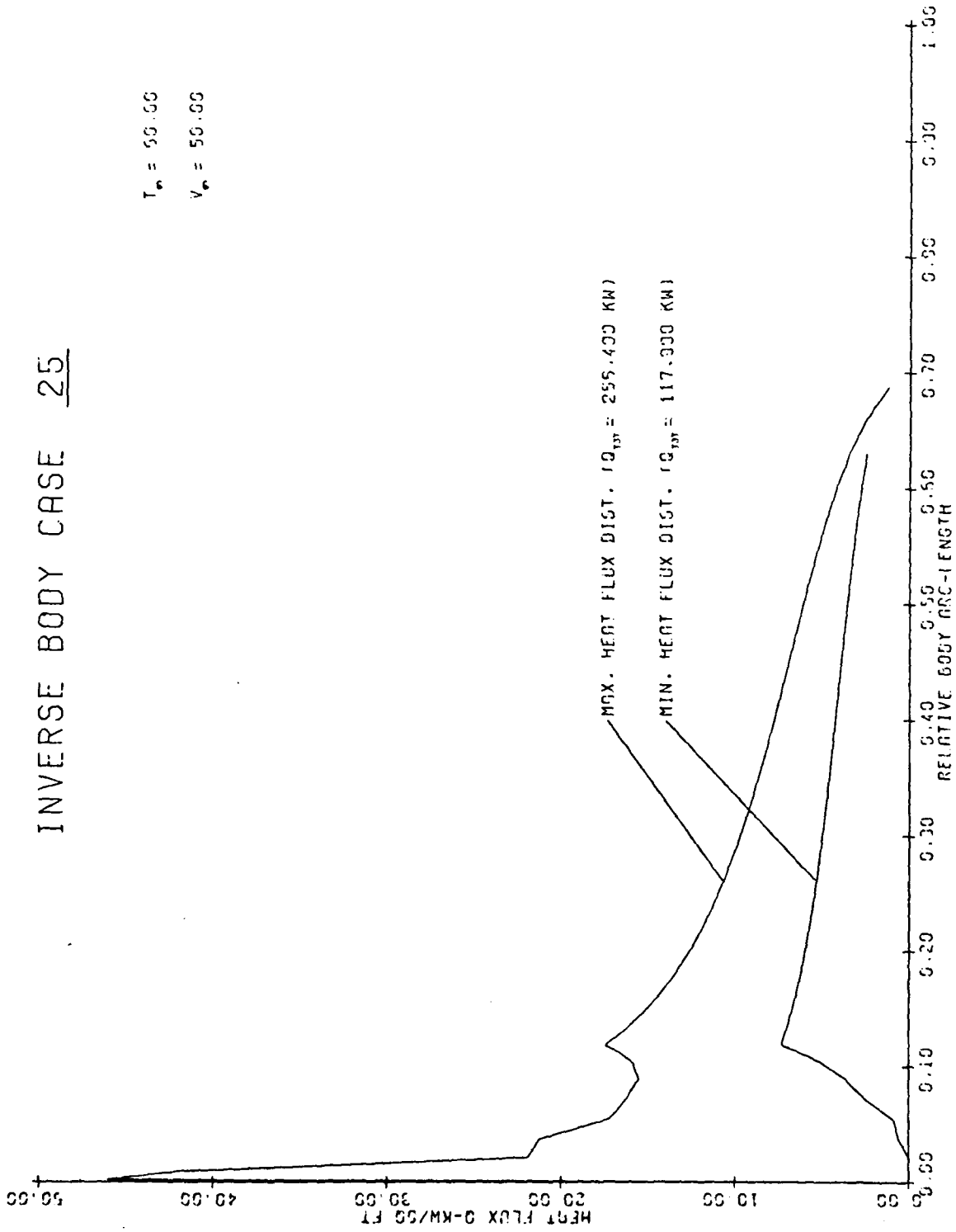


Figure 137. Heat Flux Distributions, Case No. 25.

INVERSE BODY CASE 26

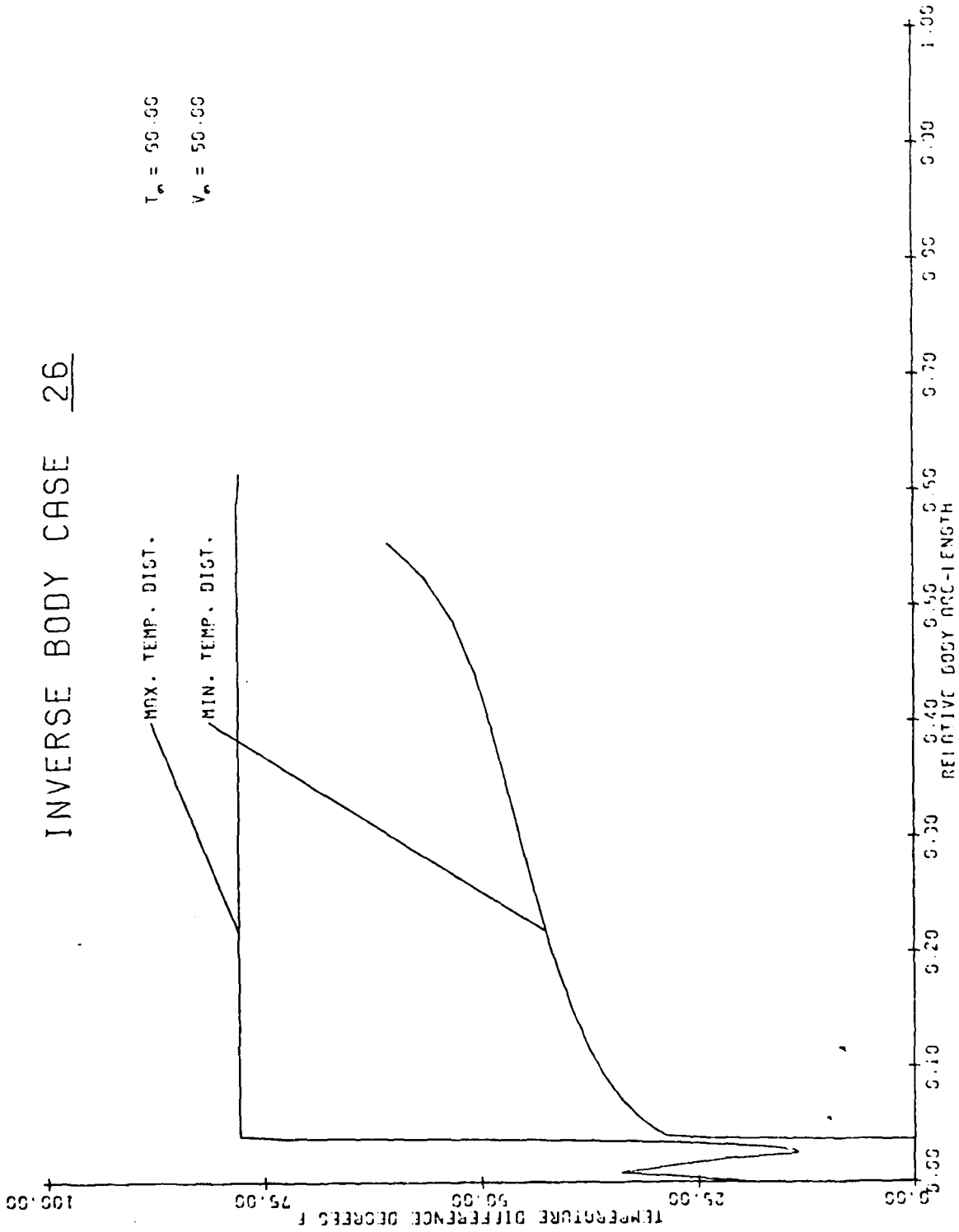


Figure 138. Temperature Distributions, Case No. 26.

INVERSE BODY CASE 26

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

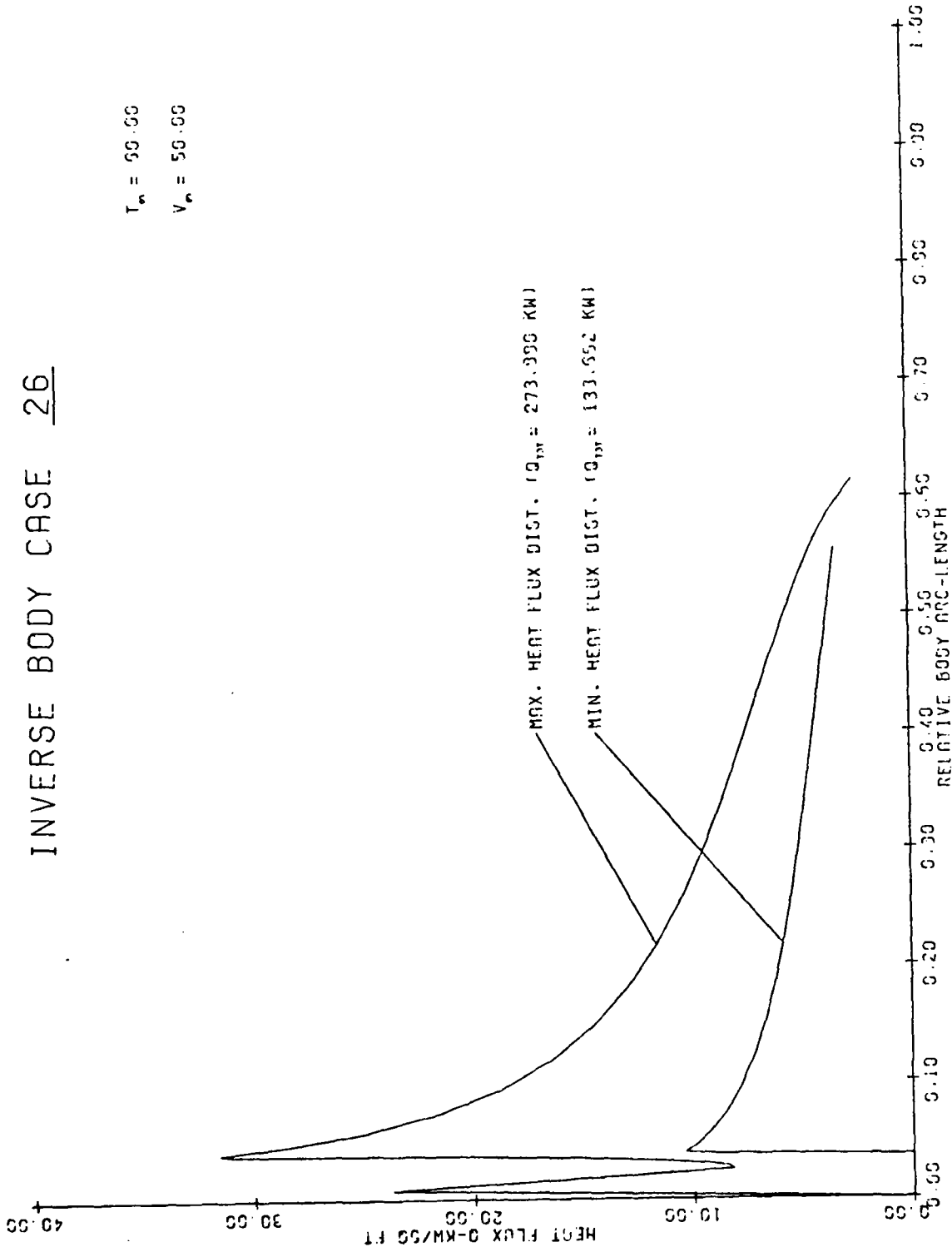


Figure 139. Heat Flux Distributions, Case No. 26.

# INVERSE BODY CASE 27

$T_w = 50.00$

$V_w = 50.00$

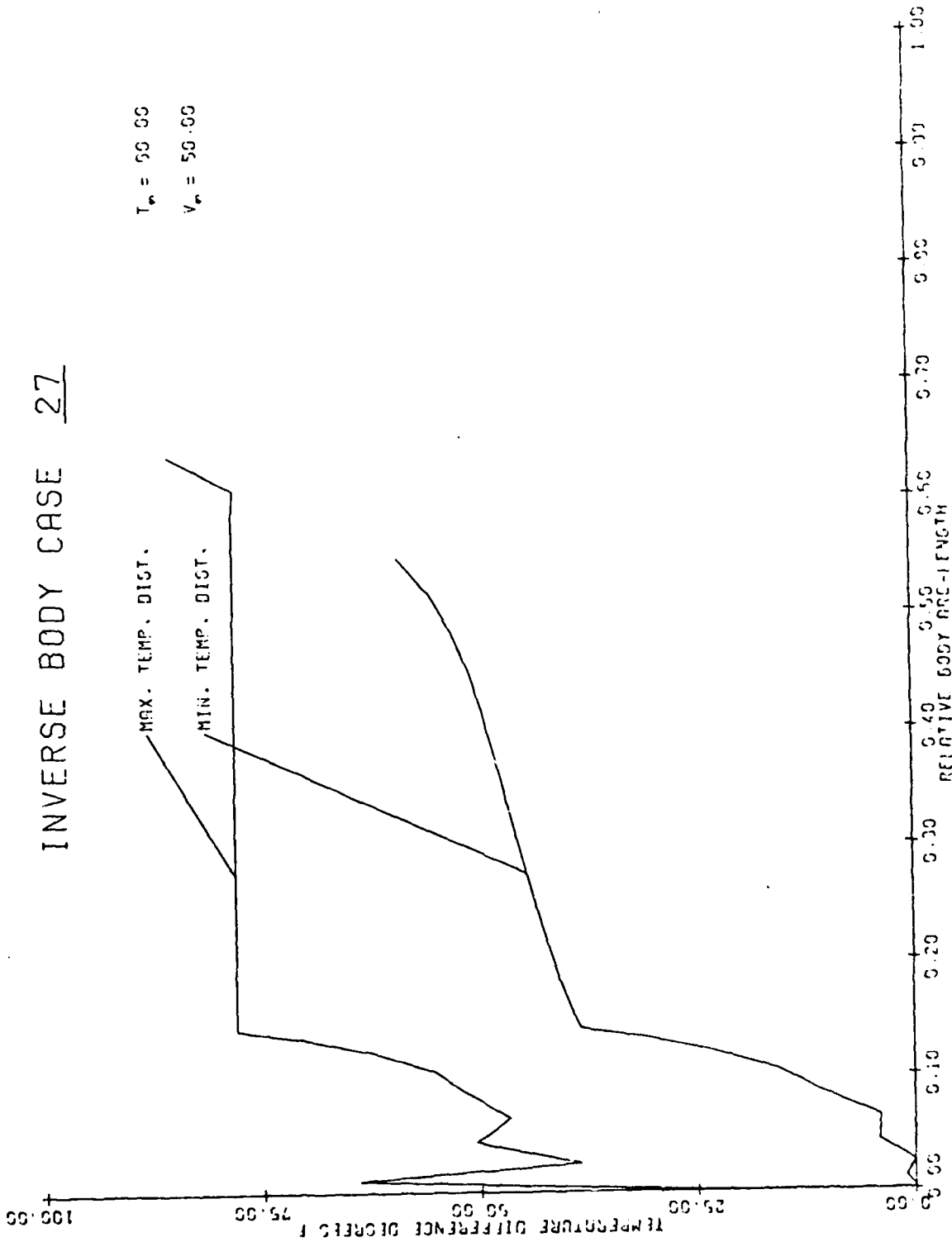


Figure 140. Temperature Distributions, Case No. 27.

INVERSE BODY CASE 27

$T_m = 50.00$

$V_m = 50.00$

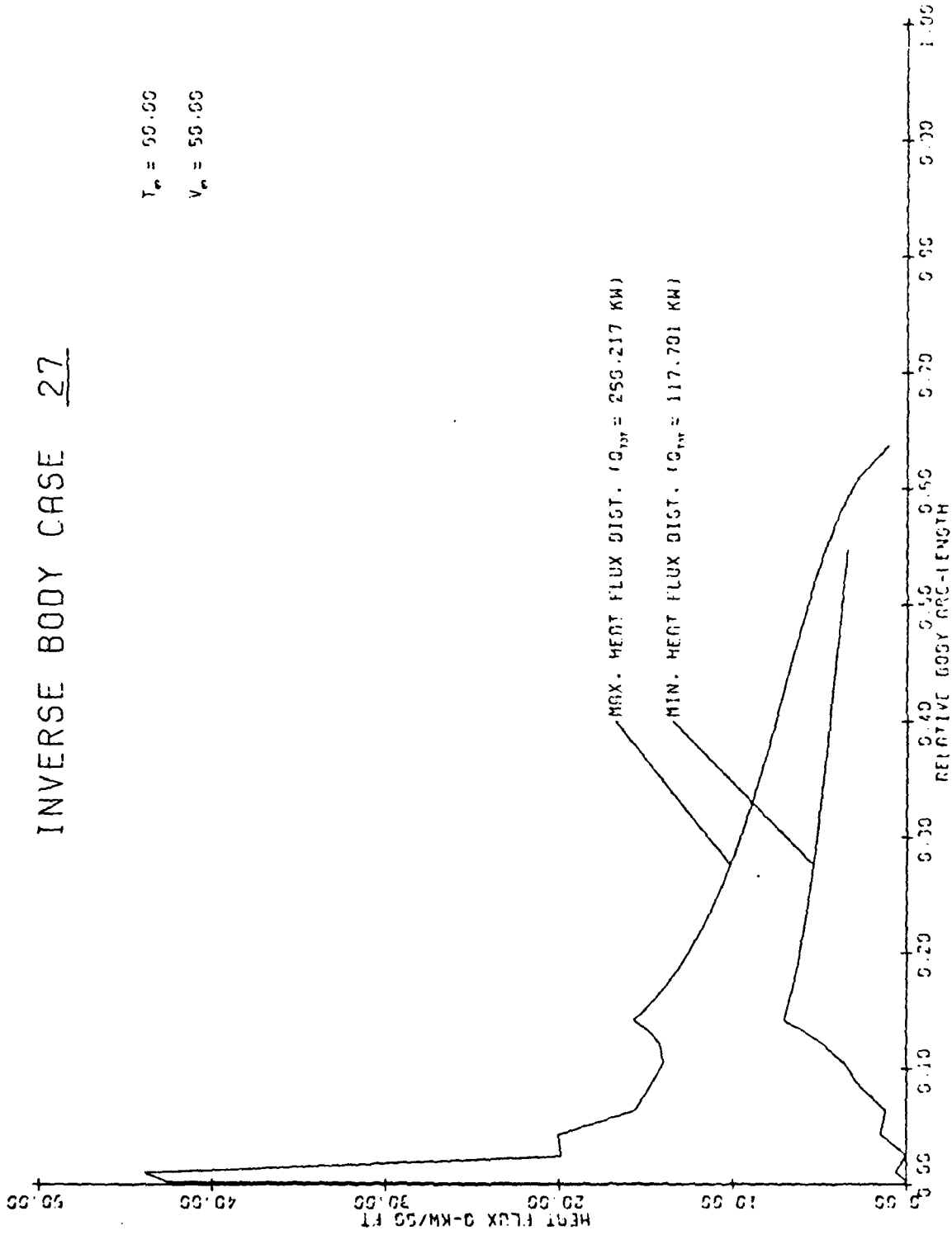


Figure 141. Heat Flux Distributions, Case No. 27.

# INVERSE BODY CASE 28

$T_m = 50.00$   
 $V_m = 50.00$

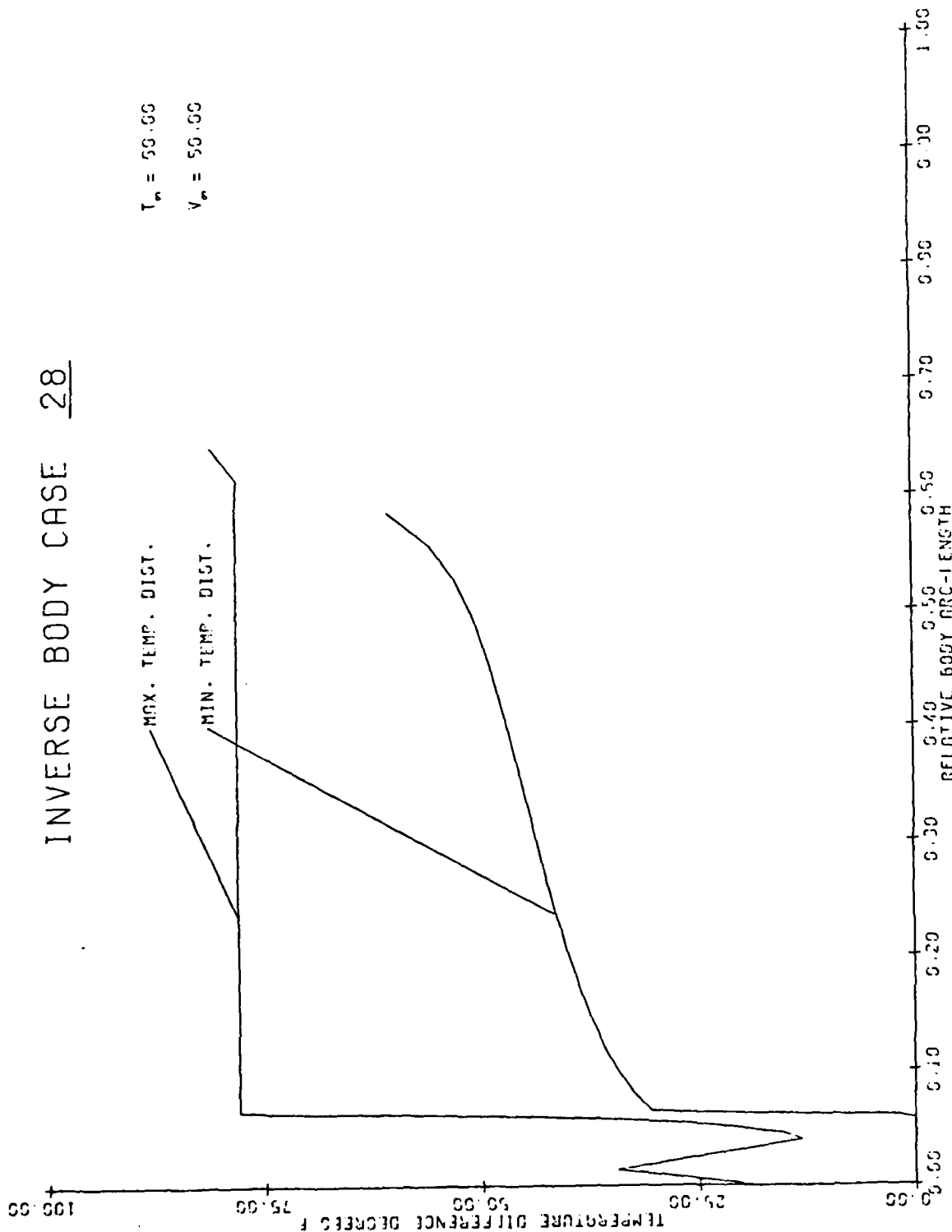


Figure 142. Temperature Distributions, Case No. 28.

# INVERSE BODY CASE 28

$T_m = 50.00$   
 $V_m = 50.00$

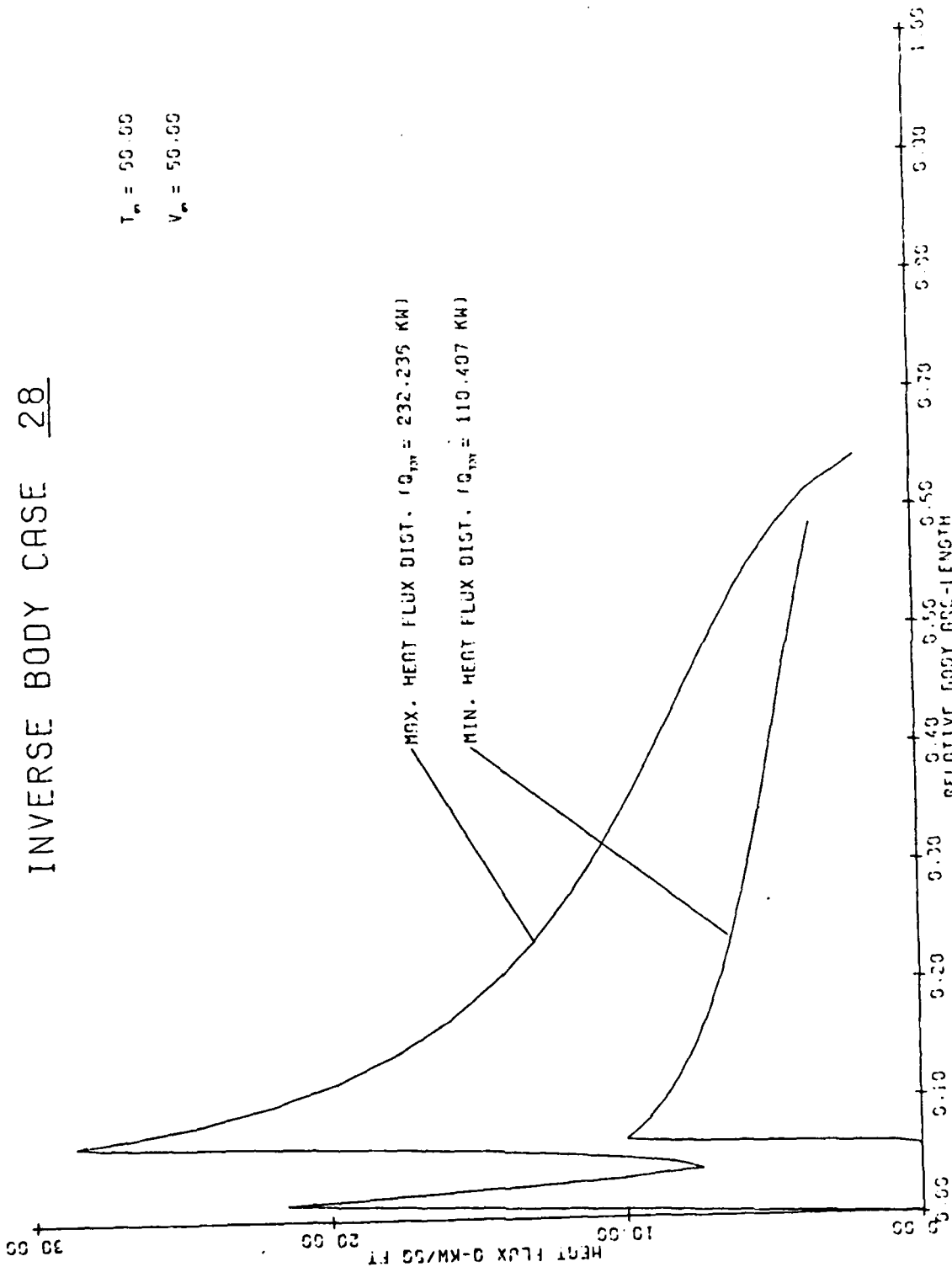


Figure 143. Heat Flux Distributions, Case No. 28.

# INVERSE BODY CASE 29

$T_m = 50.00$

$V_m = 50.00$

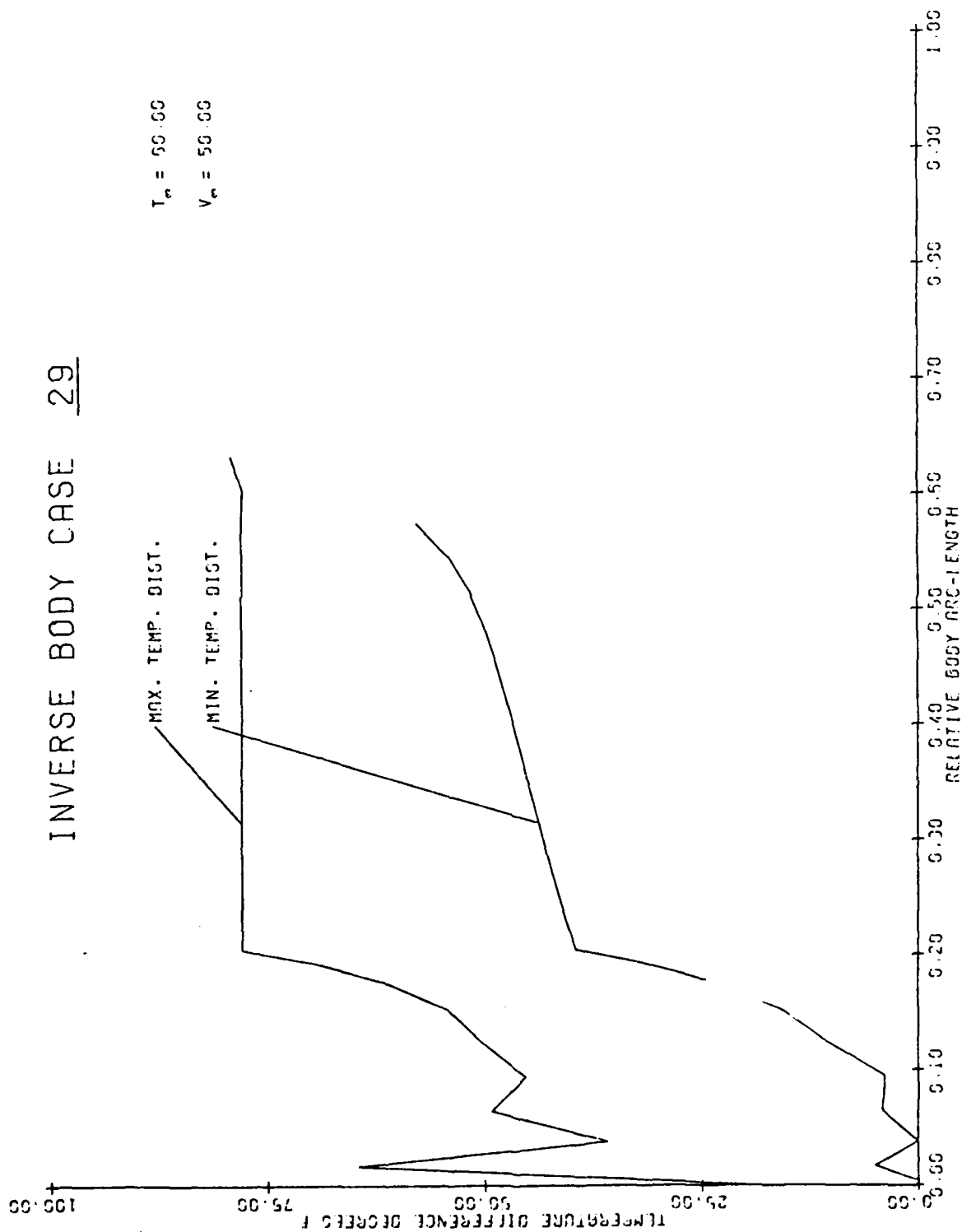


Figure 144. Temperature Distributions, Case No. 29.

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# INVERSE BODY CASE 29

$T_w = 50.00$   
 $V_w = 50.00$

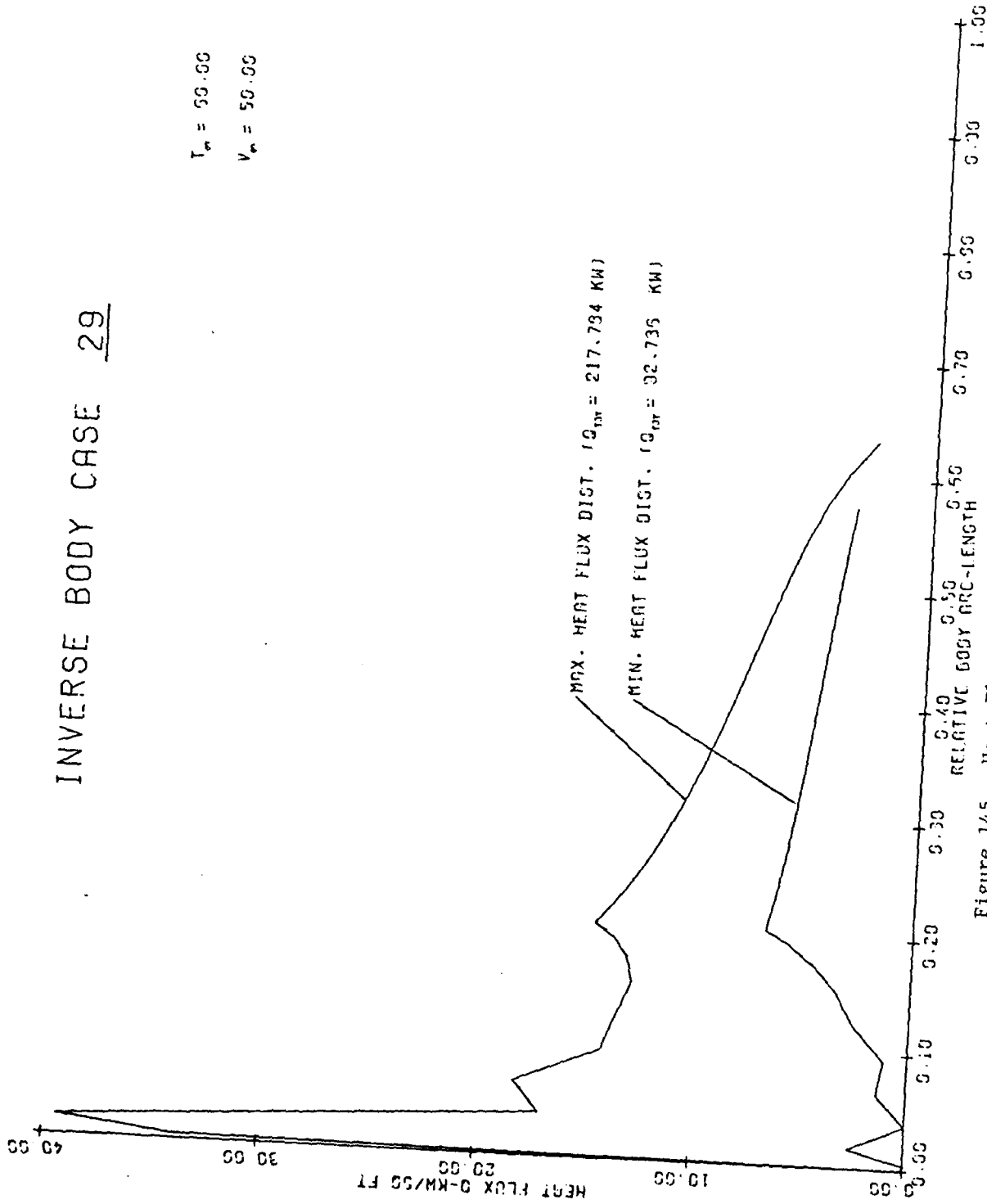


Figure 145. Heat Flux Distributions, Case No. 29.

INVERSE BODY CASE 30

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

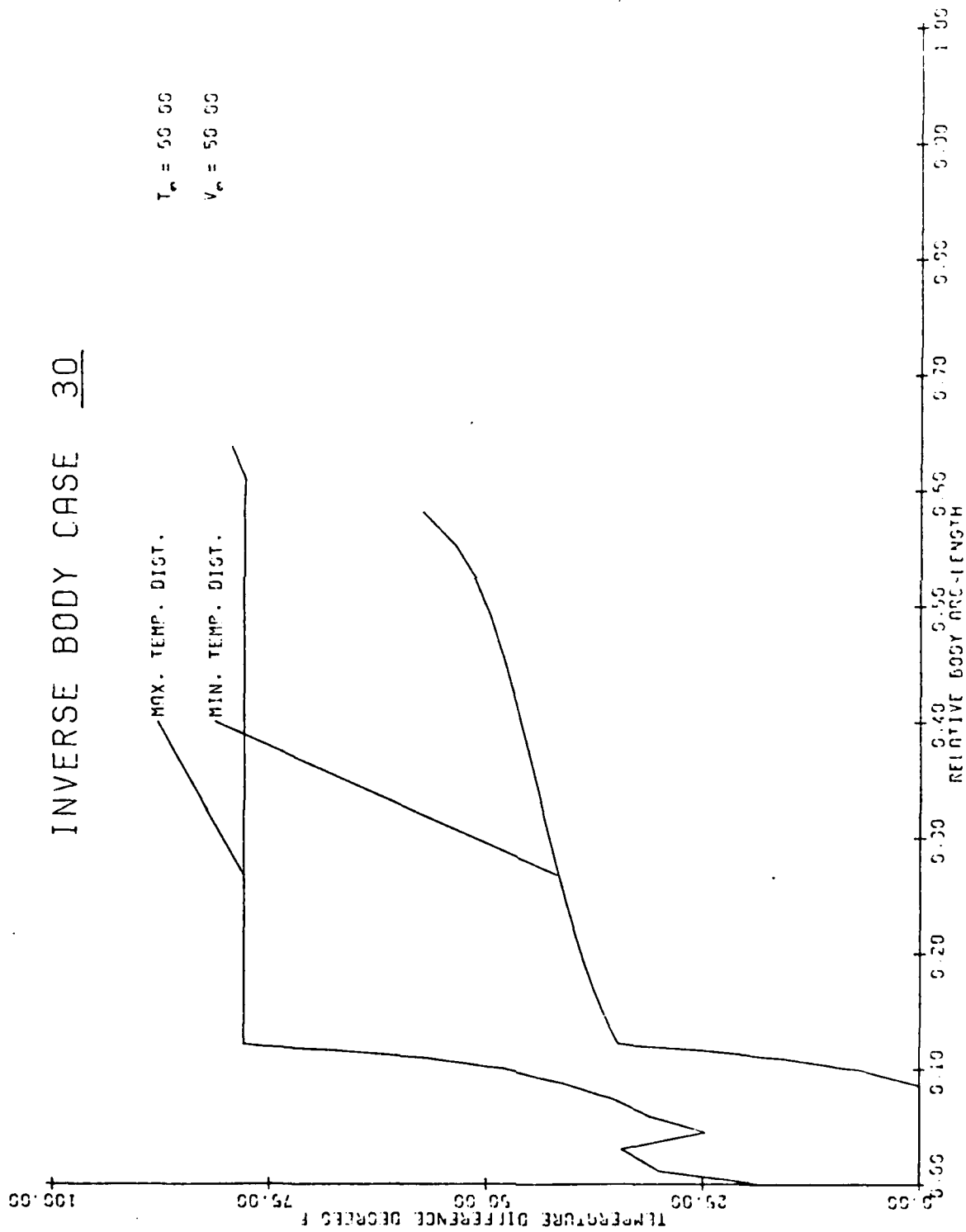


Figure 146. Temperature Distributions, Case No. 30.

INVERSE BODY CASE 30

$T_w = 50.00$

$V_w = 50.00$

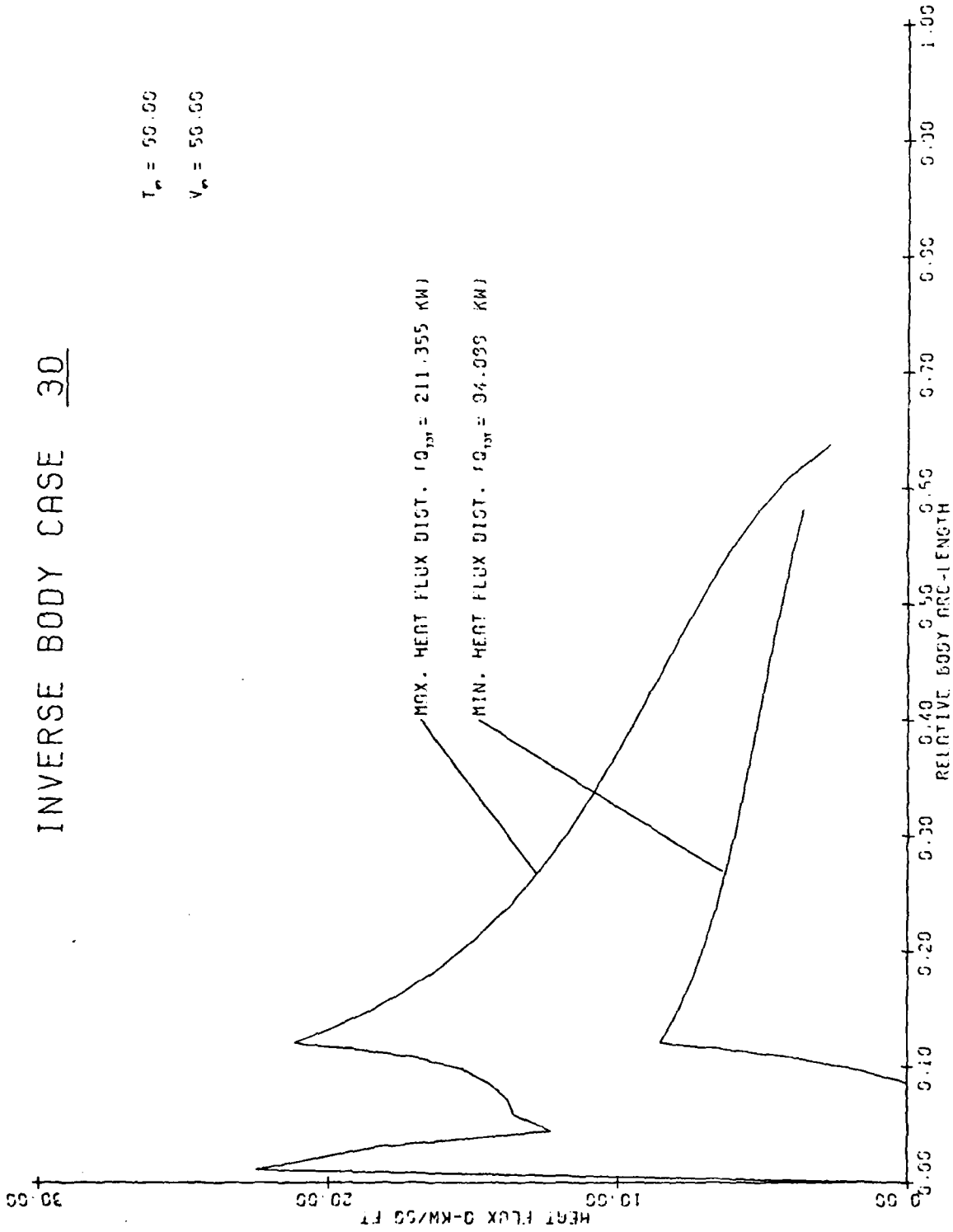


Figure 147. Heat Flux Distributions, Case No. 30.

# INVERSE BODY CASE 31

$T_m = 50.00$   
 $V_m = 50.00$

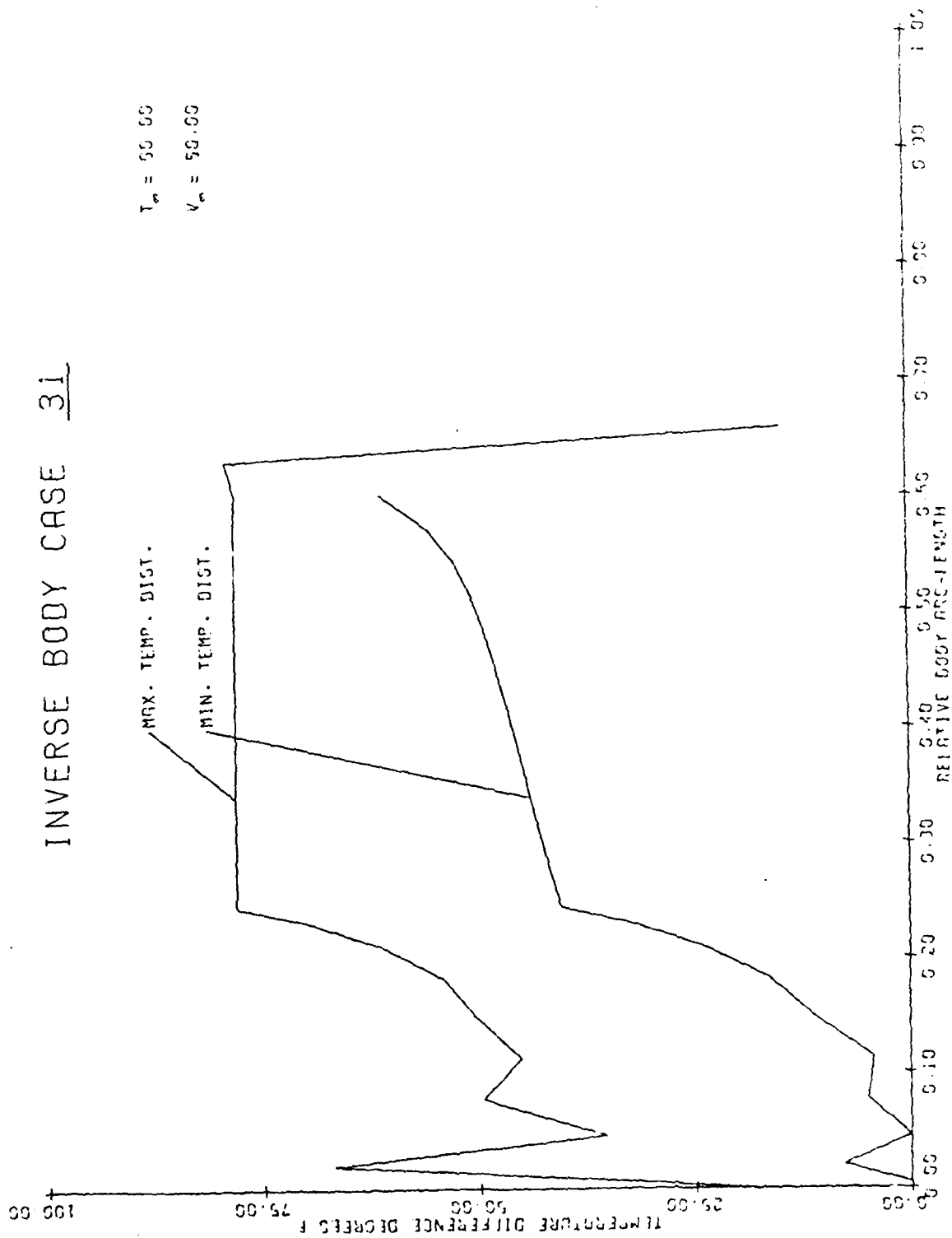


Figure 148. Temperature Distributions, Case No. 31.

INVERSE BODY CASE 31

$T_w = 50.00$

$V_w = 50.00$

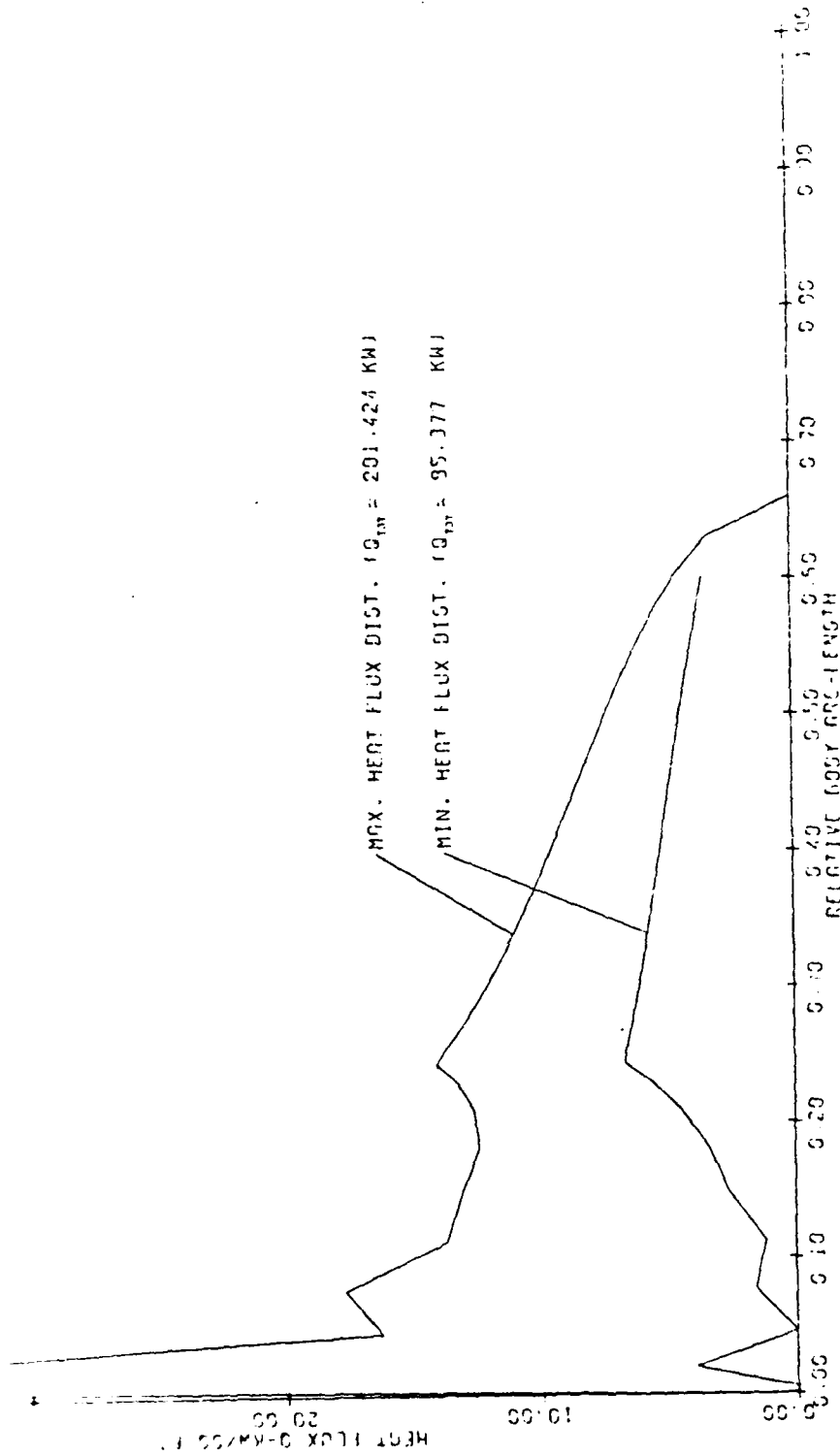


Figure 149. Heat Flux Distributions, Case No. 31.

INVERSE BODY CASE 32

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

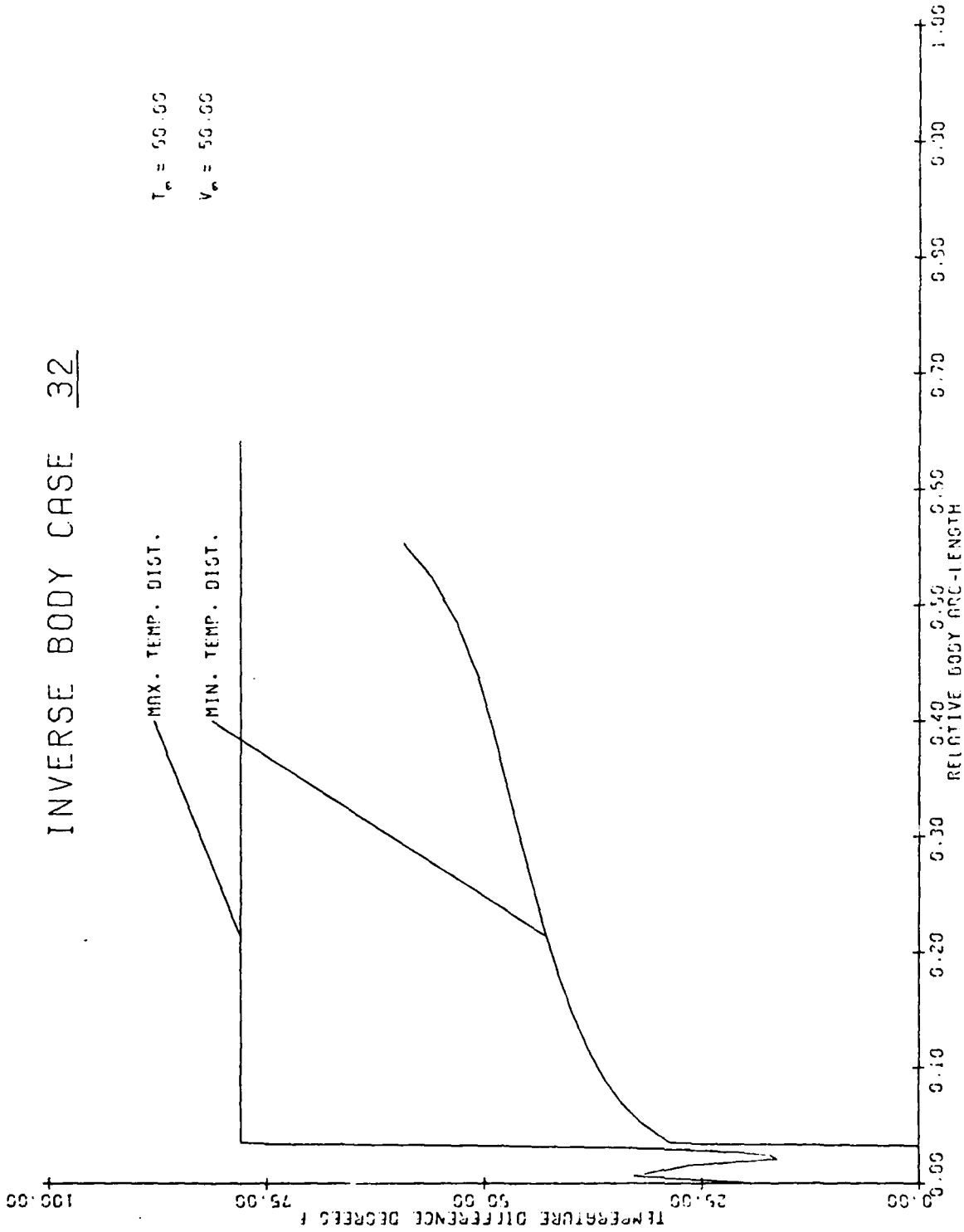


Figure 150. Temperature Distributions, Case No. 32.

INVERSE BODY CASE 32

$T_w = 50.00$

$V_w = 50.00$

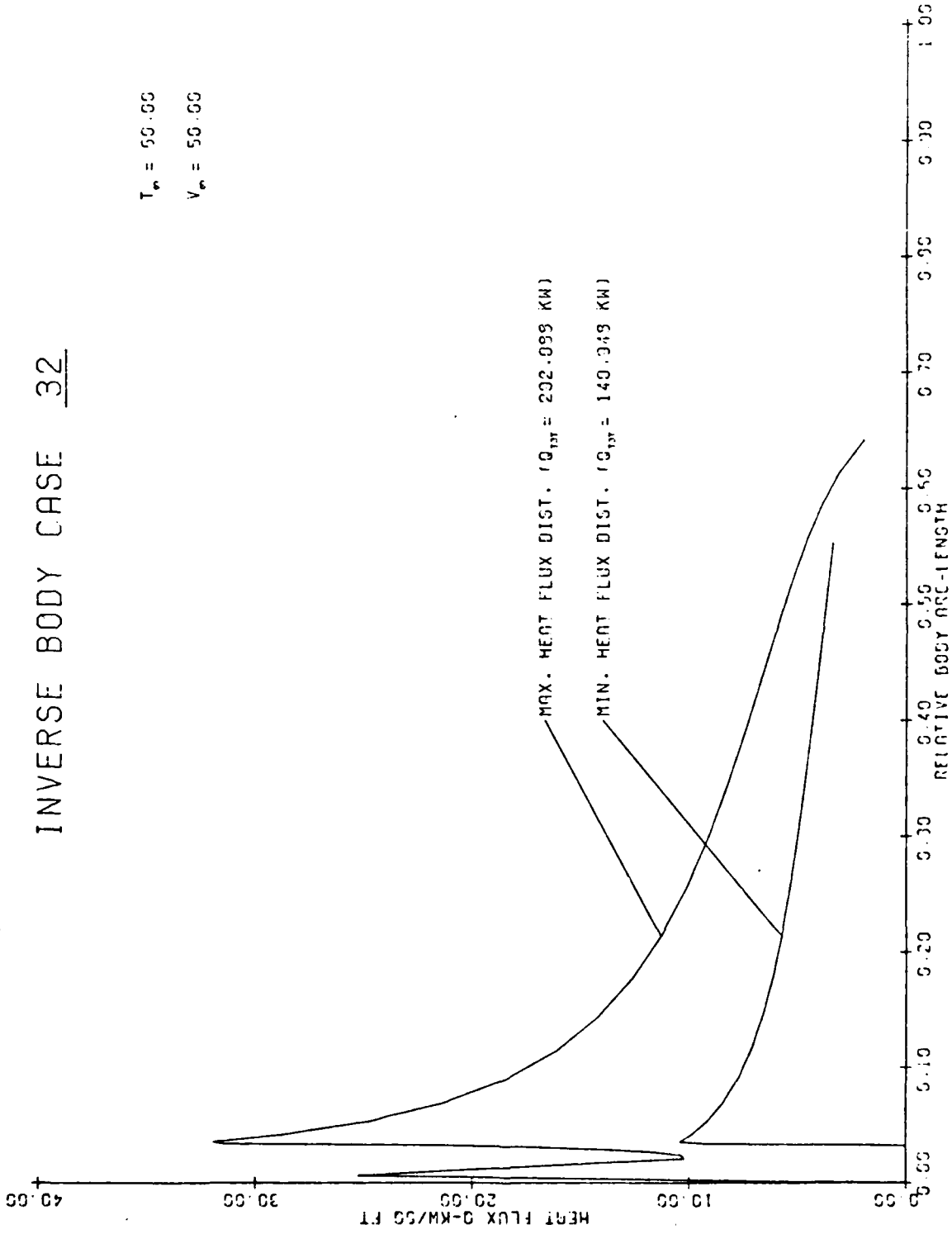


Figure 151. Heat Flux Distributions, Case No. 32.

INVERSE BODY CASE 33

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

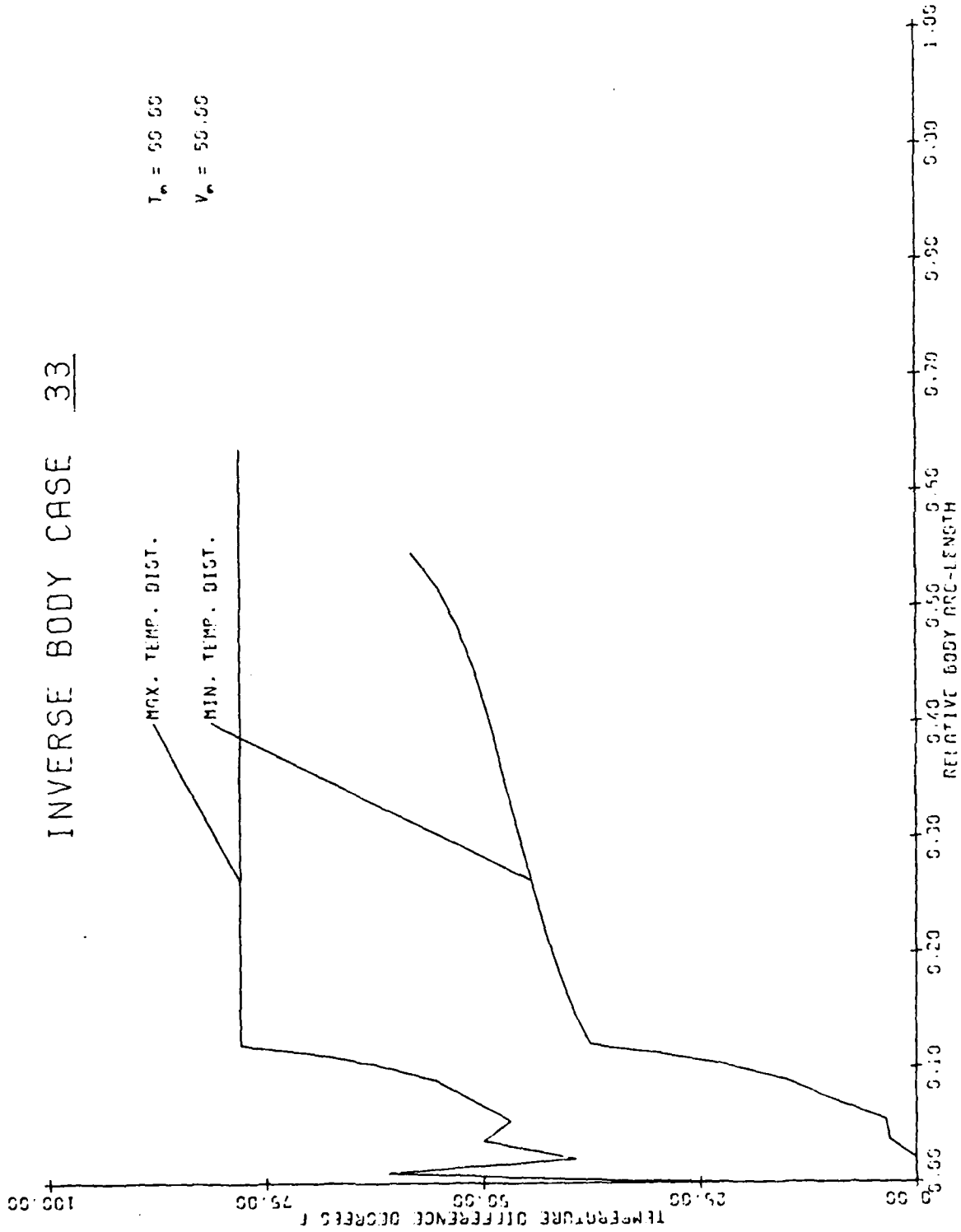


Figure 152. Temperature Distributions, Case No. 33.

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INVERSE BODY CASE 33

$T_w = 50.00$   
 $V_w = 50.00$

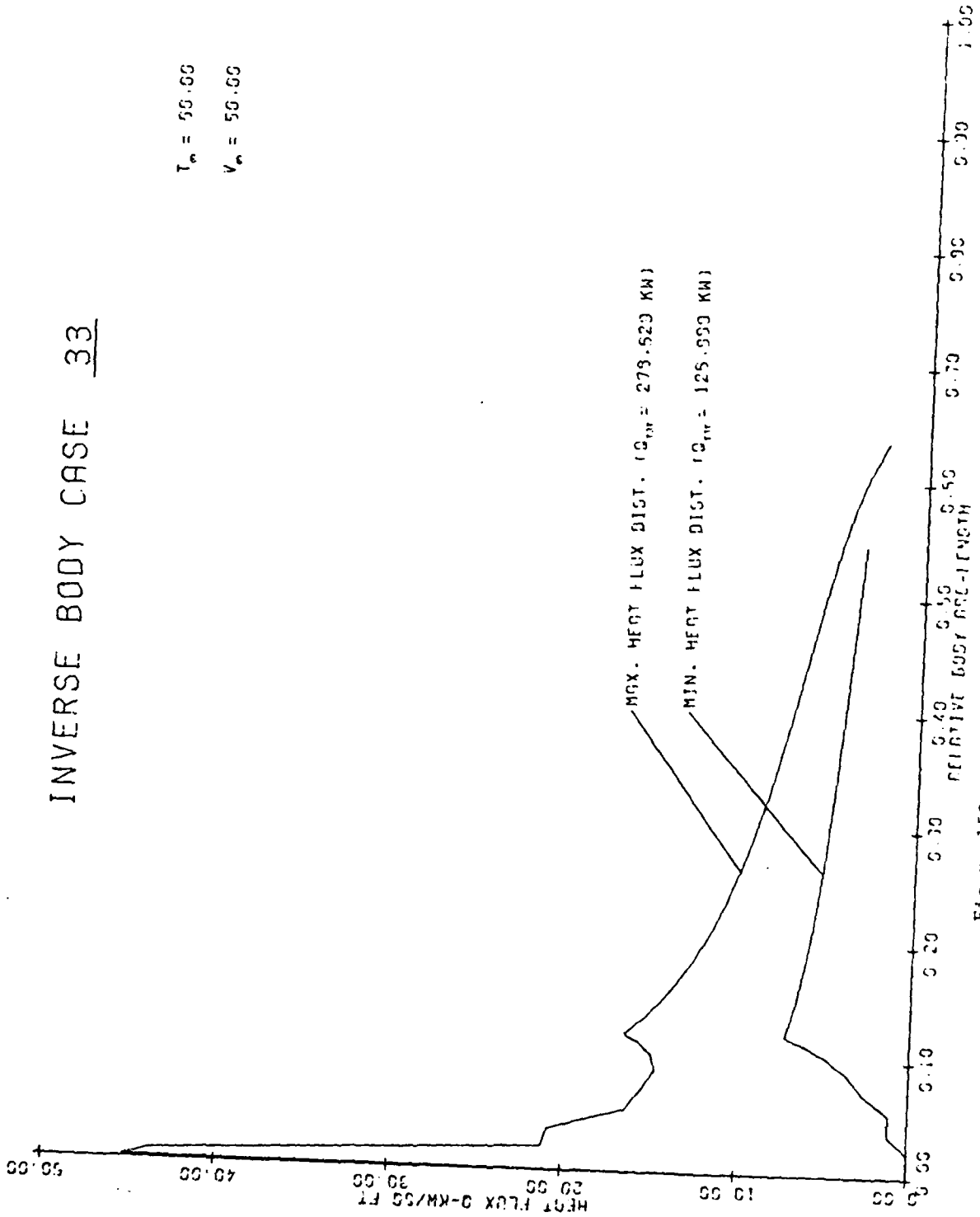


Figure 153. Heat Flux Distributions, Case No. 33.

# INVERSE BODY CASE 34

$T_a = 50.00$

$V_a = 50.00$

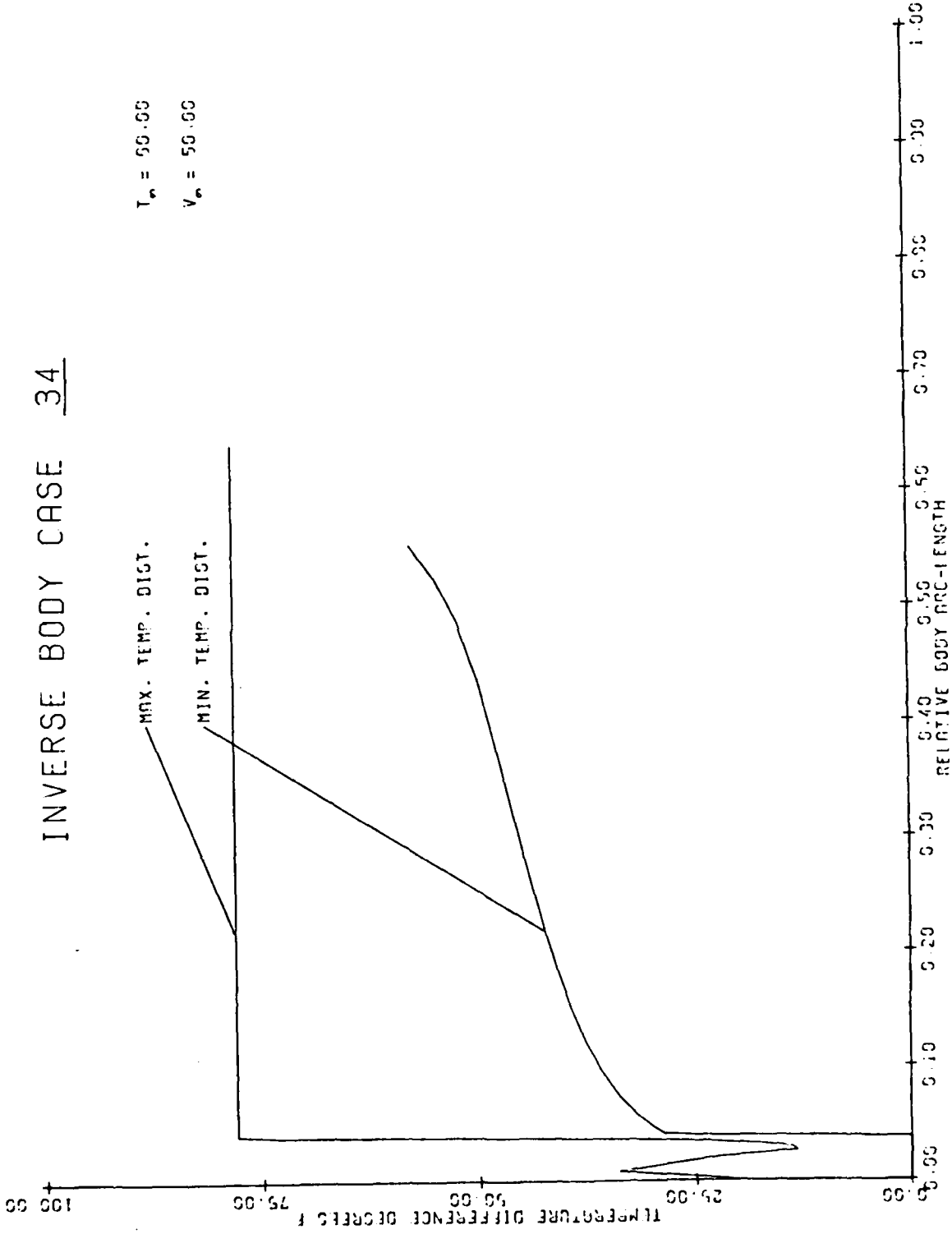


Figure 154. Temperature Distributions, Case No. 34.

INVERSE BODY CASE 34

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

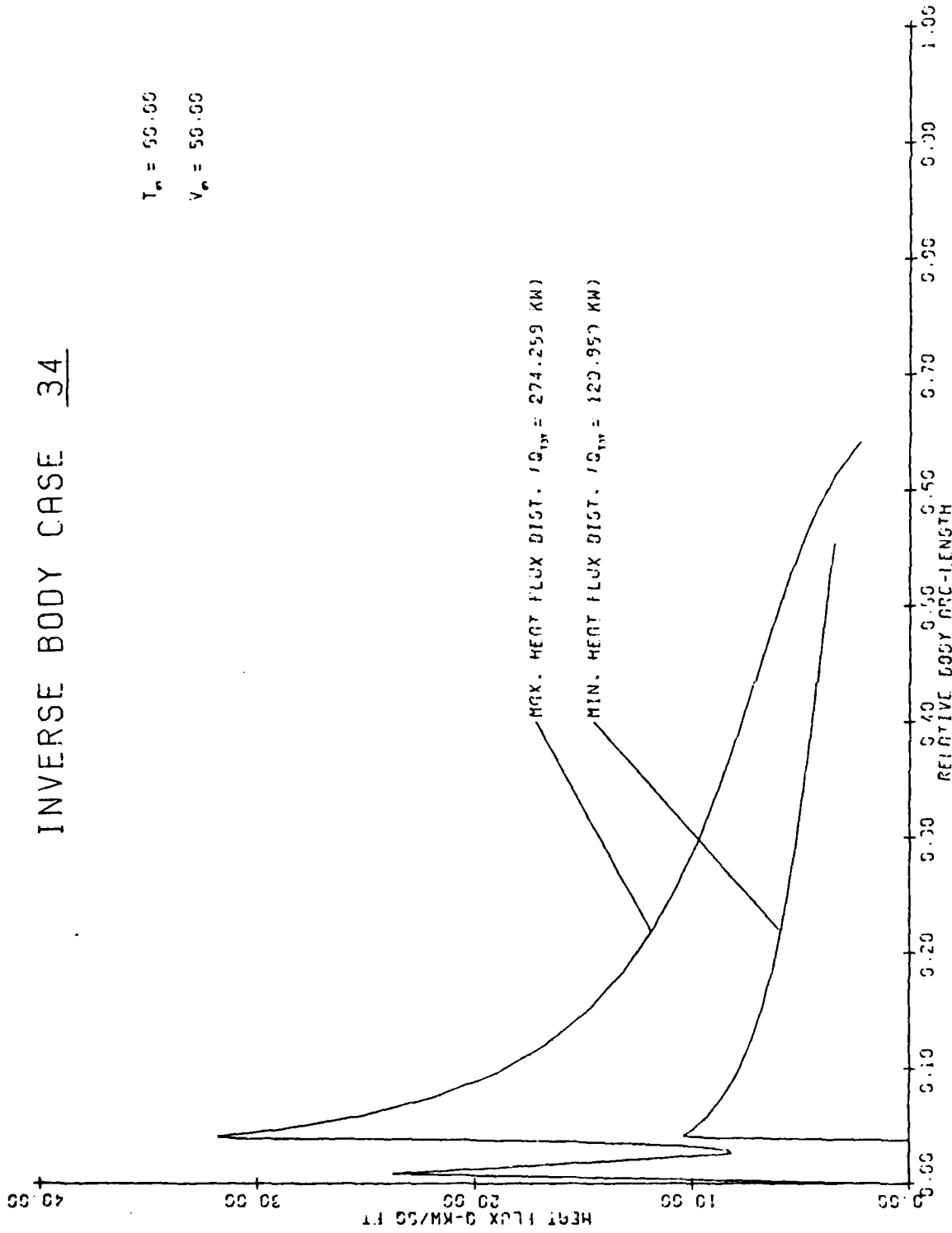
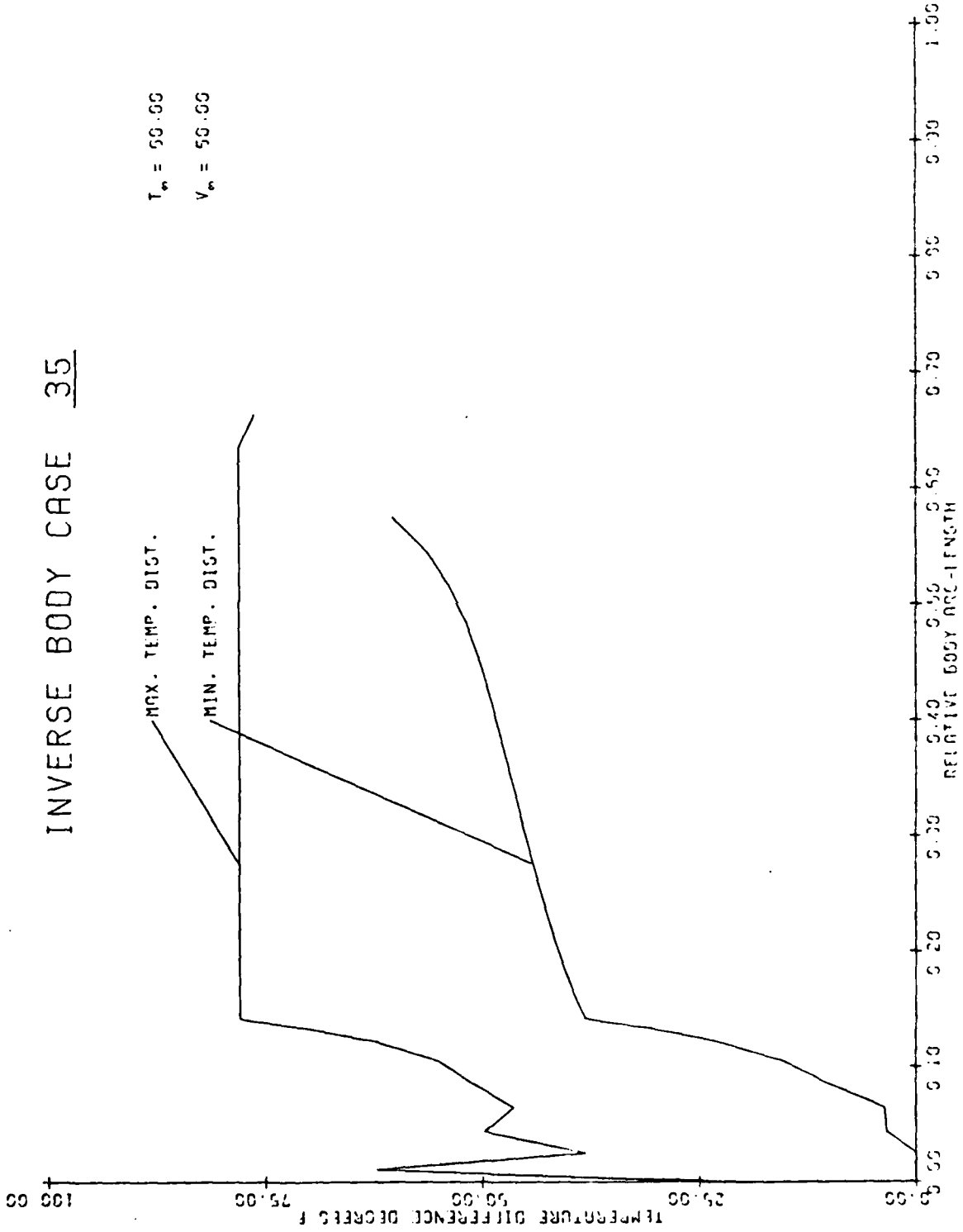


Figure 155. Heat Flux Distributions, Case No. 34.

INVERSE BODY CASE 35

$T_m = 50.00$   
 $V_m = 50.00$



156. Temperature Distributions, Case No. 35.

INVERSE BODY CASE 35

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

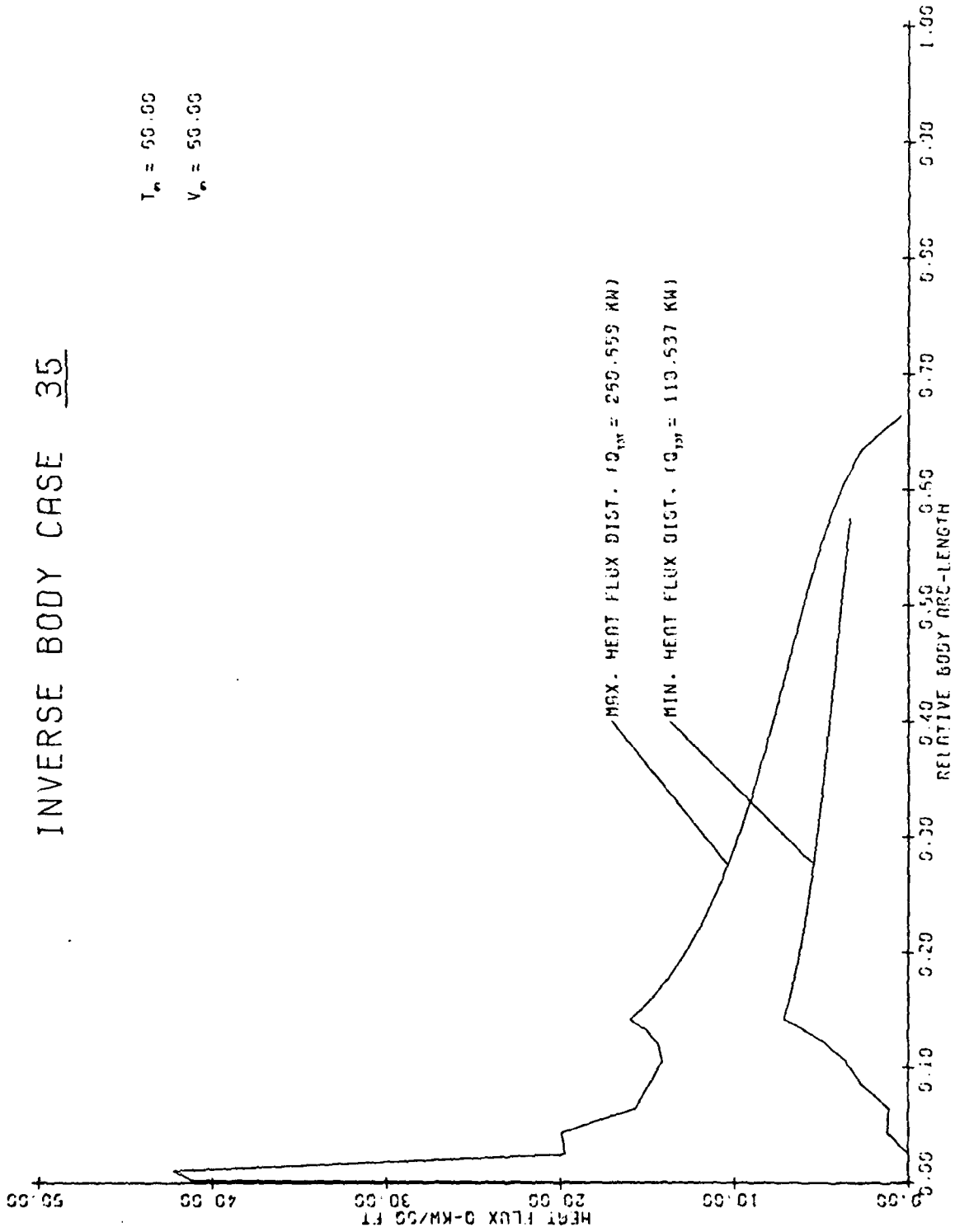


Figure 157. Heat Flux Distributions, Case No. 35.

INVERSE BODY CASE 36

$T_m = 50.00$   
 $V_m = 50.00$

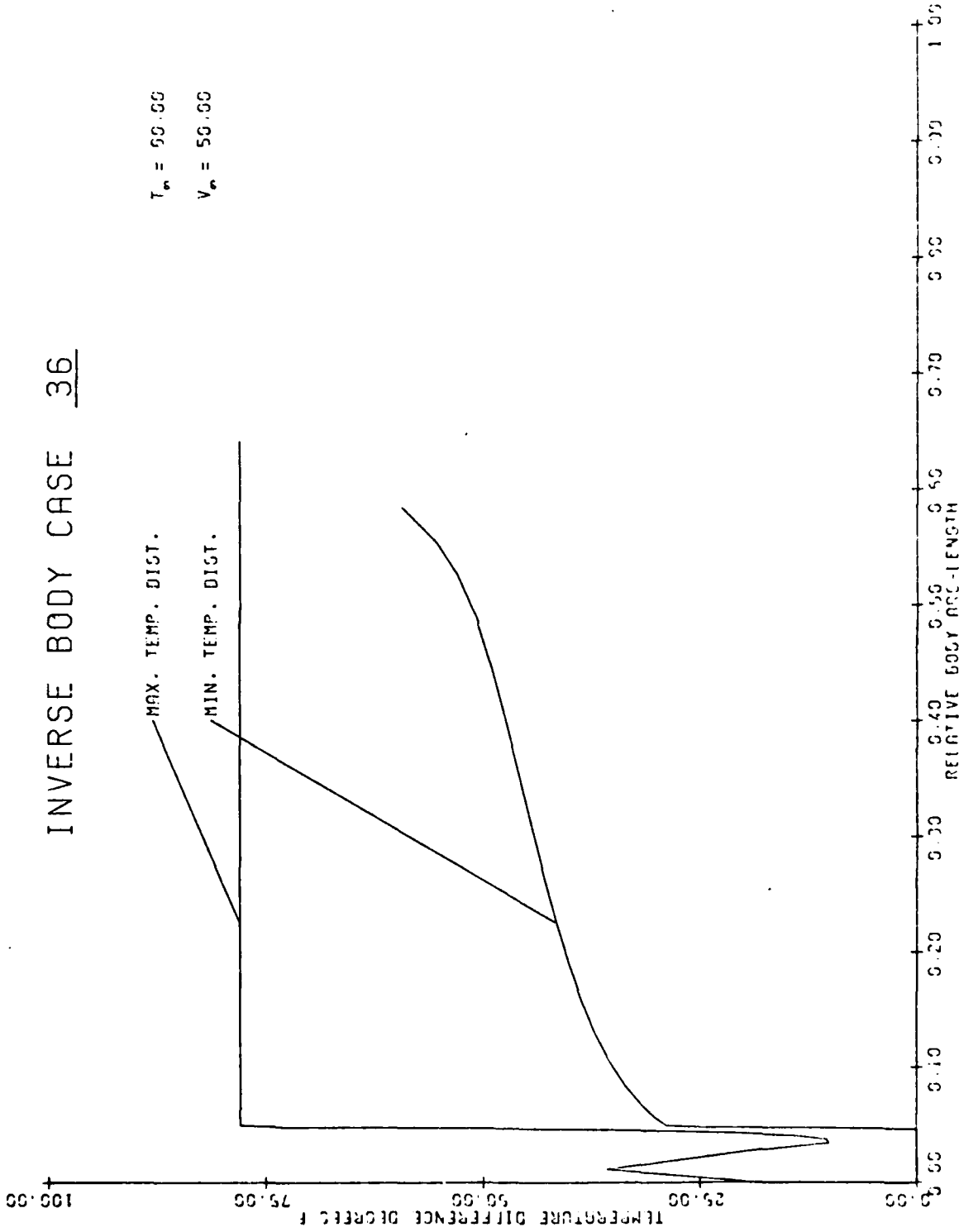


Figure 158. Temperature Distributions, Case No. 36.

INVERSE BODY CASE 36

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

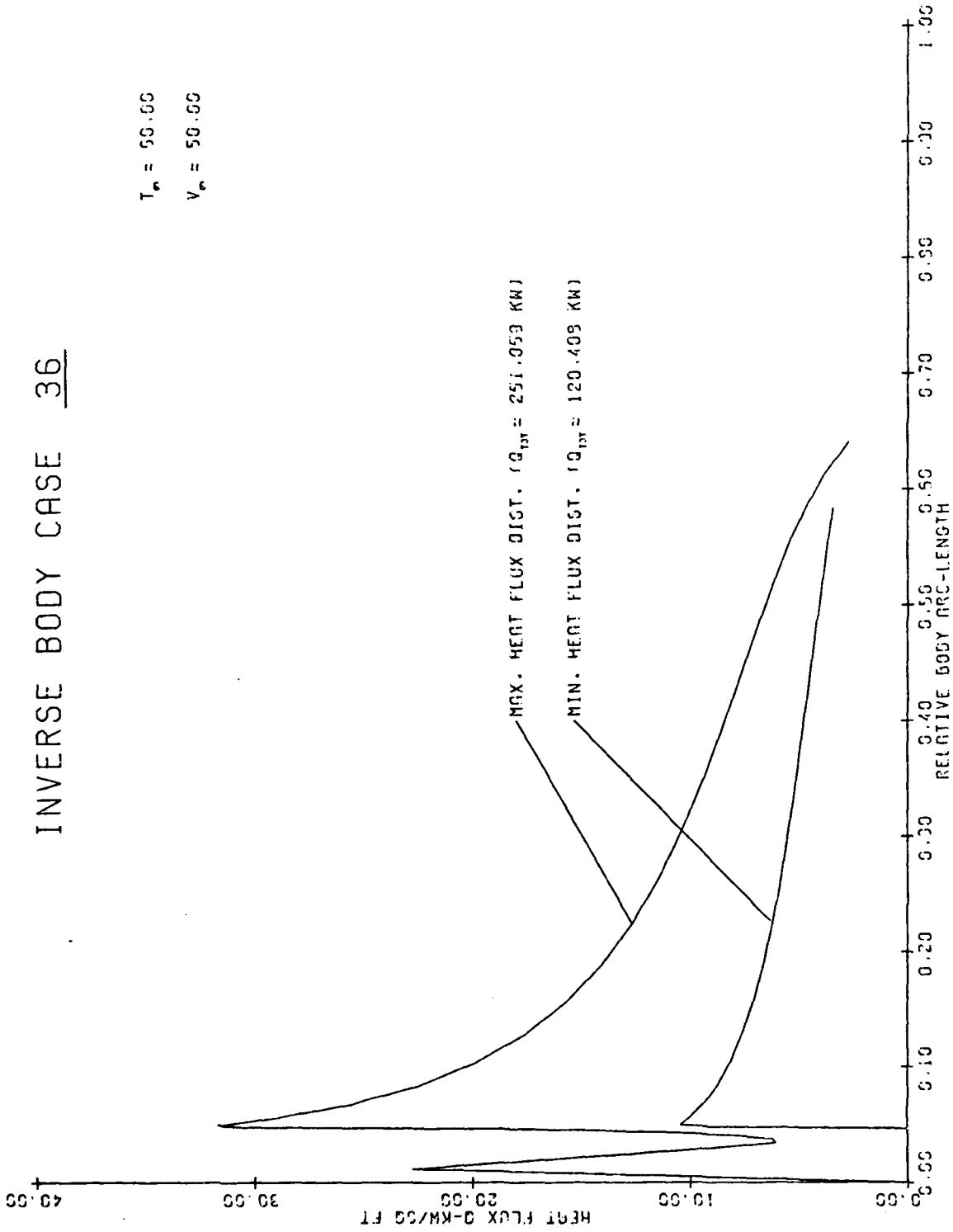


Figure 159. Heat Flux Distributions, Case No. 36.

INVERSE BODY CASE 37

$T_m = 50.00$

$V_m = 50.00$

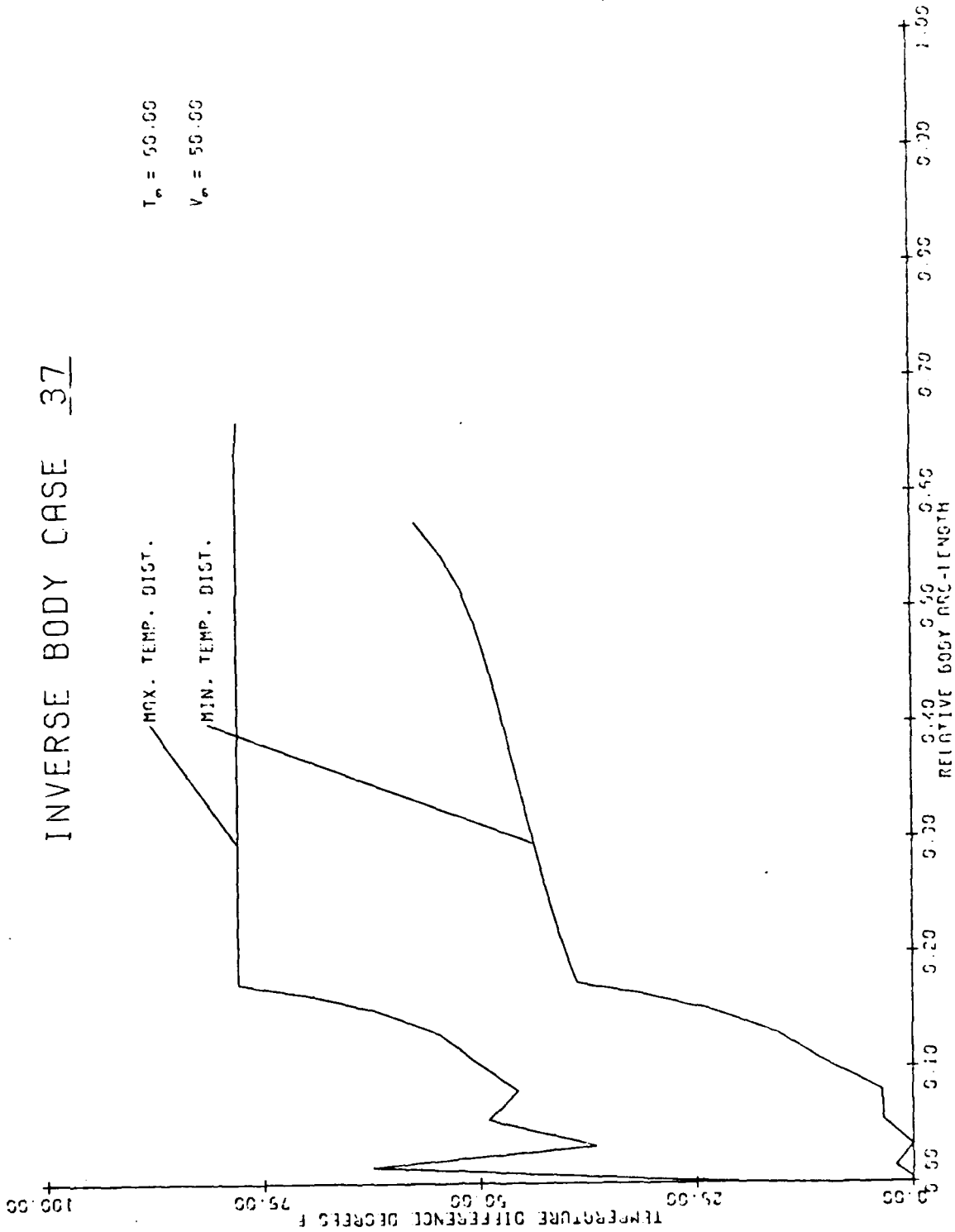


Figure 160. Temperature Distributions, Case No. 37.

INVERSE BODY CASE 37

$T_w = 50.00$

$V_w = 50.00$

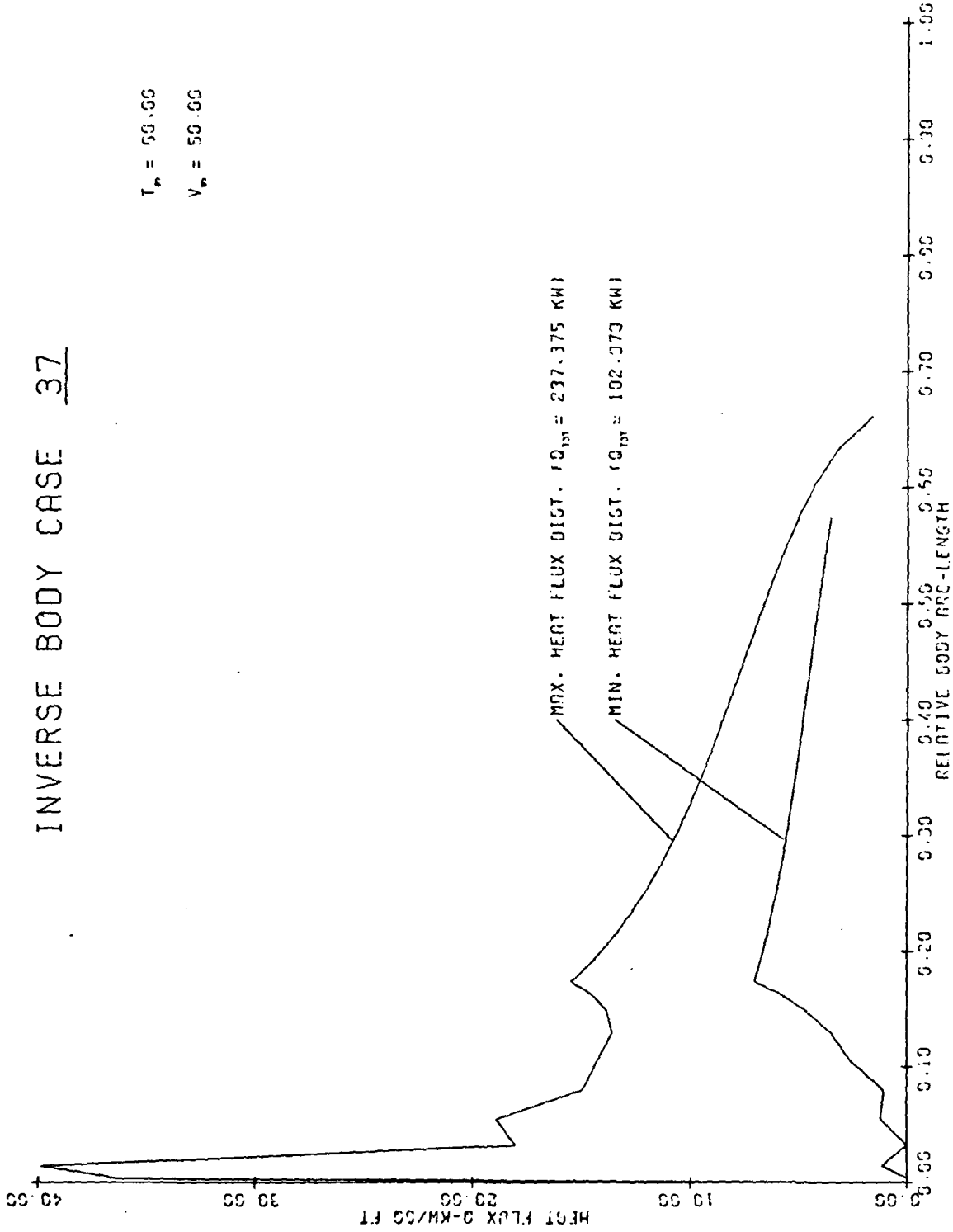


Figure 161. Heat Flux Distributions, Case No. 37.

INVERSE BODY CASE 38

$T_m = 50.00$   
 $V_m = 50.00$

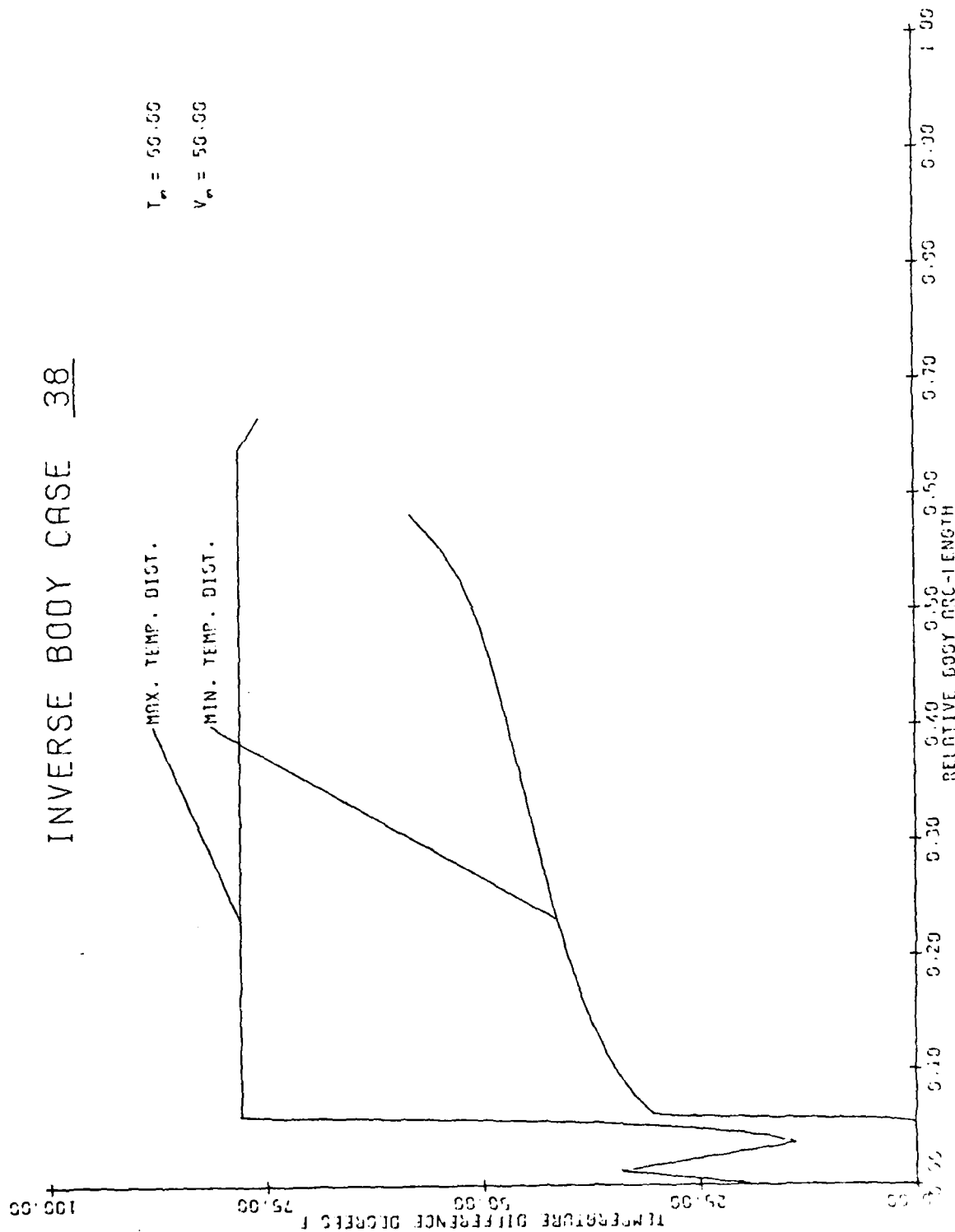


Figure 162. Temperature Distributions, Case No. 38.



INVERSE BODY CASE 38

$T_m = 50.00$

$V_m = 50.00$

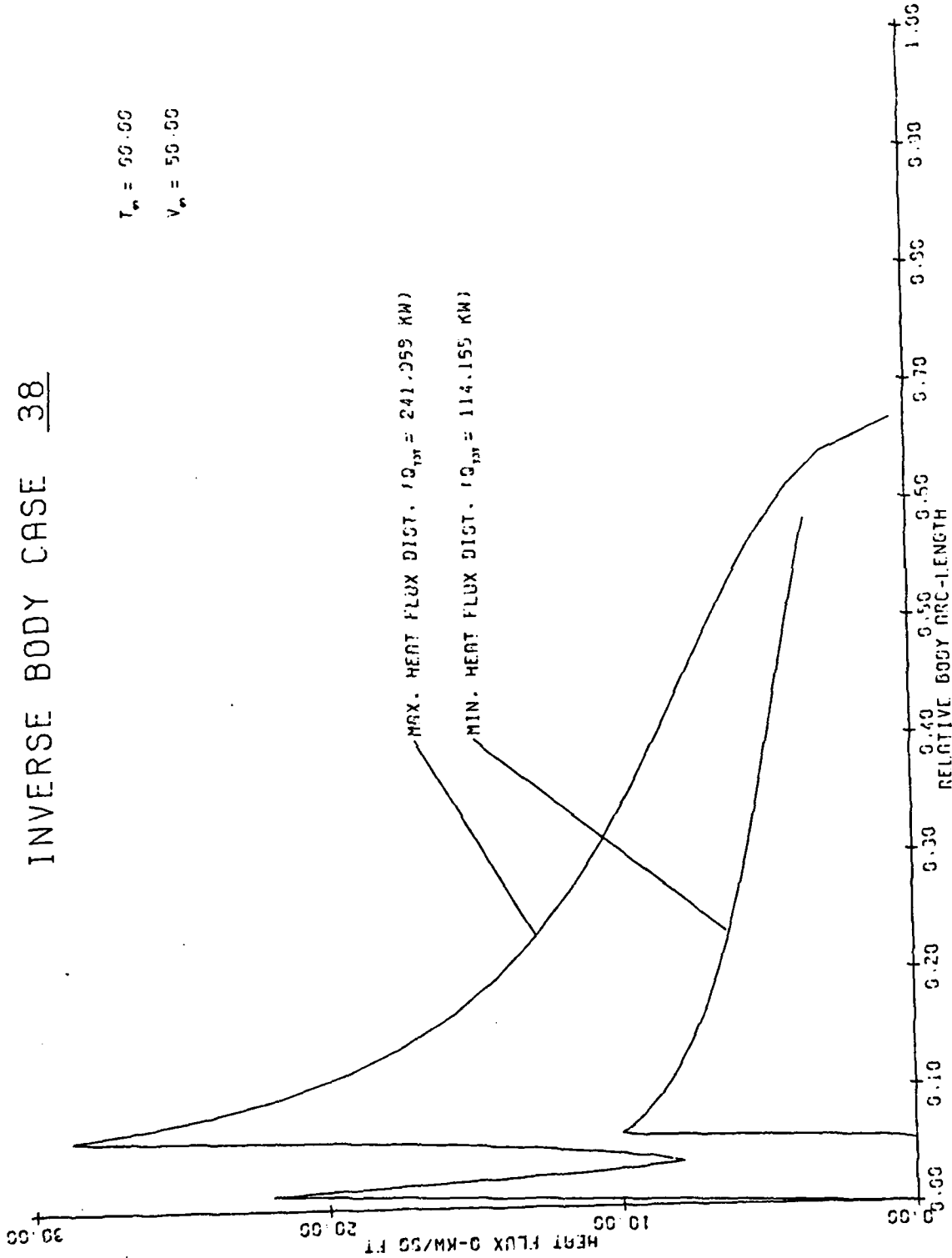


Figure 163. Heat Flux Distributions, Case No. 38.

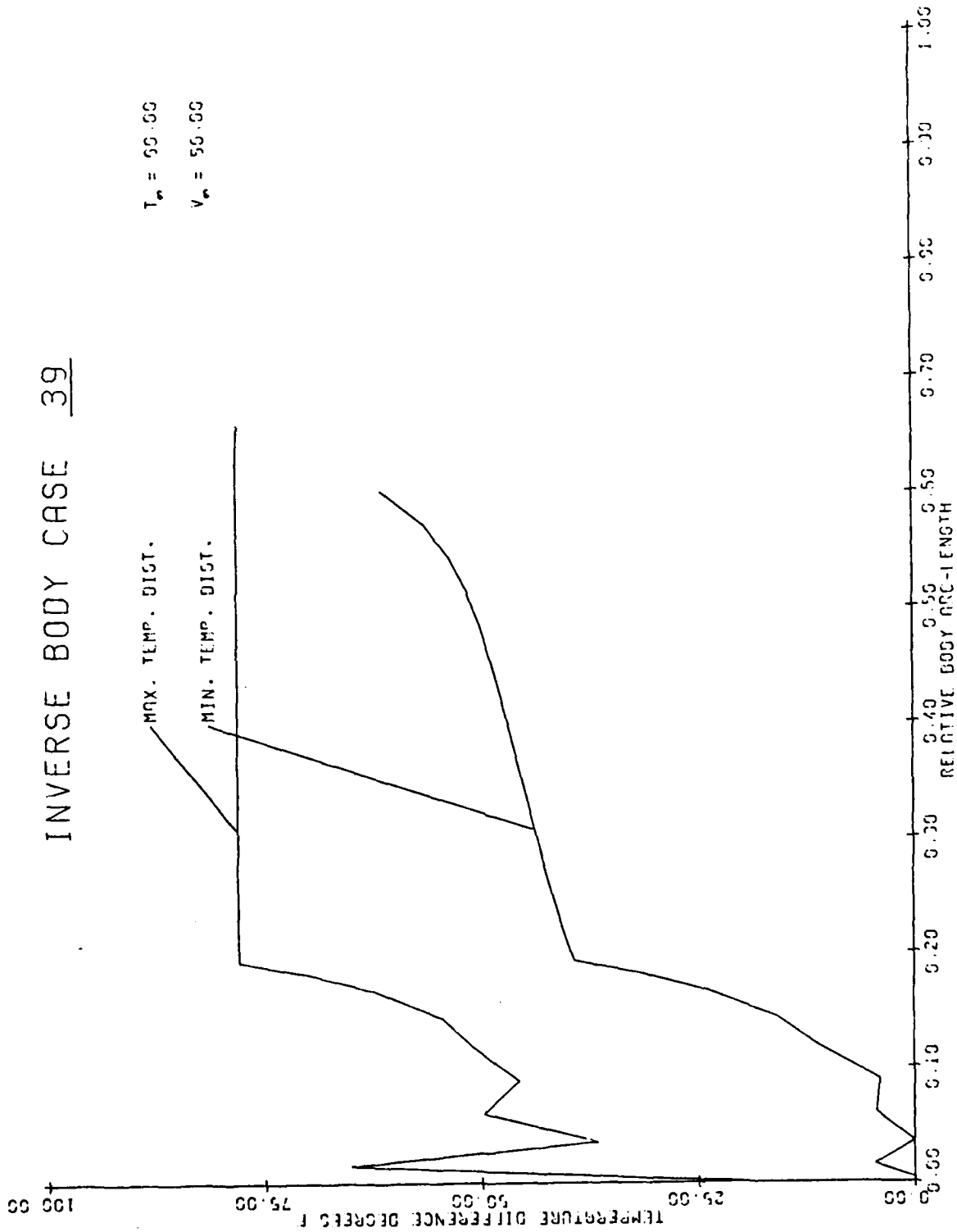


Figure 164. Temperature Distributions, Case No. 39.

INVERSE BODY CASE 39

$T_w = 50.00$

$V_w = 50.00$

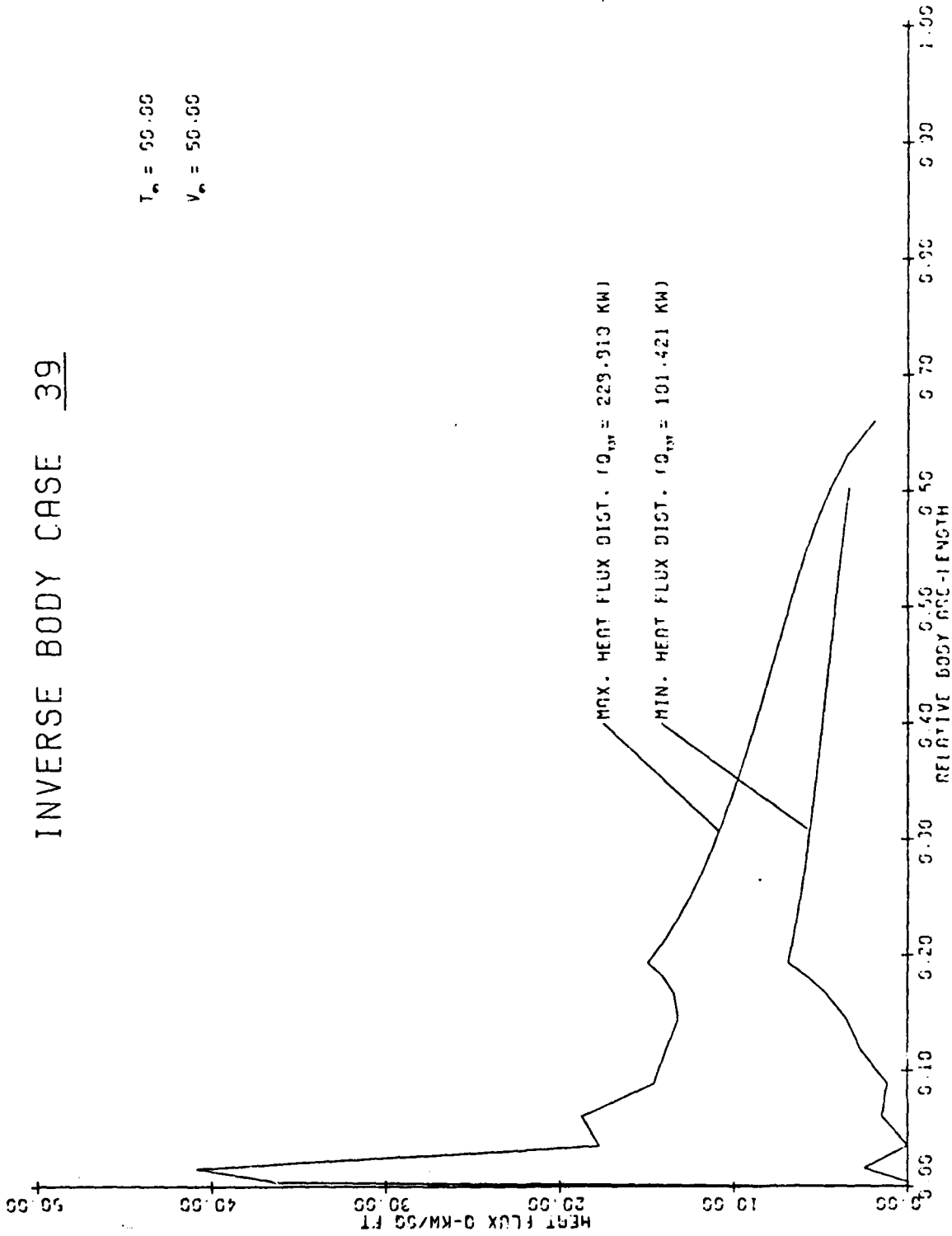


Figure 165. Heat Flux Distributions, Case No. 39.

INVERSE BODY CASE 40

$T_p = 50.00$   
 $V_p = 50.00$

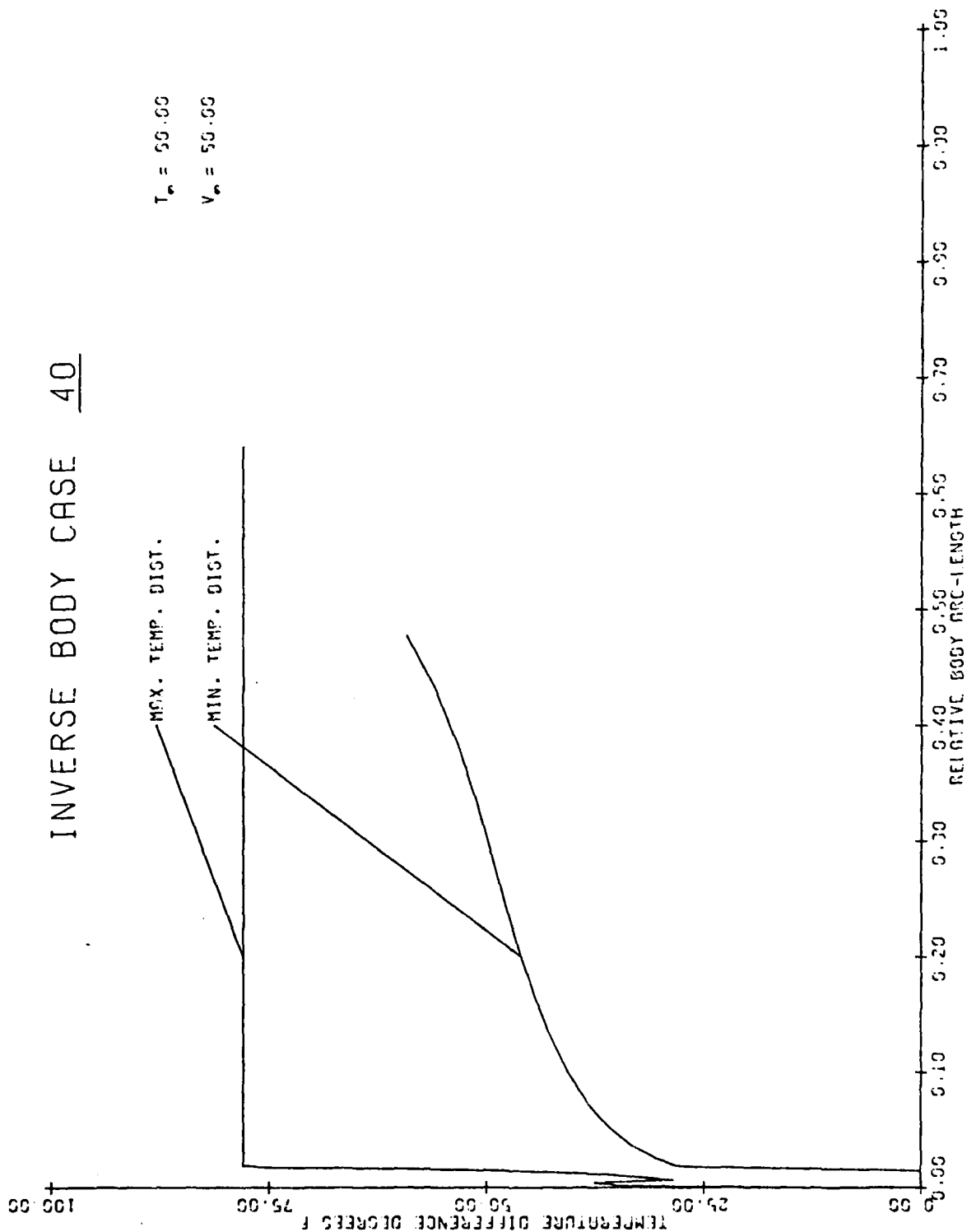


Figure 166. Temperature Distributions, Case No. 40.

INVERSE BODY CASE 40

$T_w = 50.00$

$V_w = 50.00$

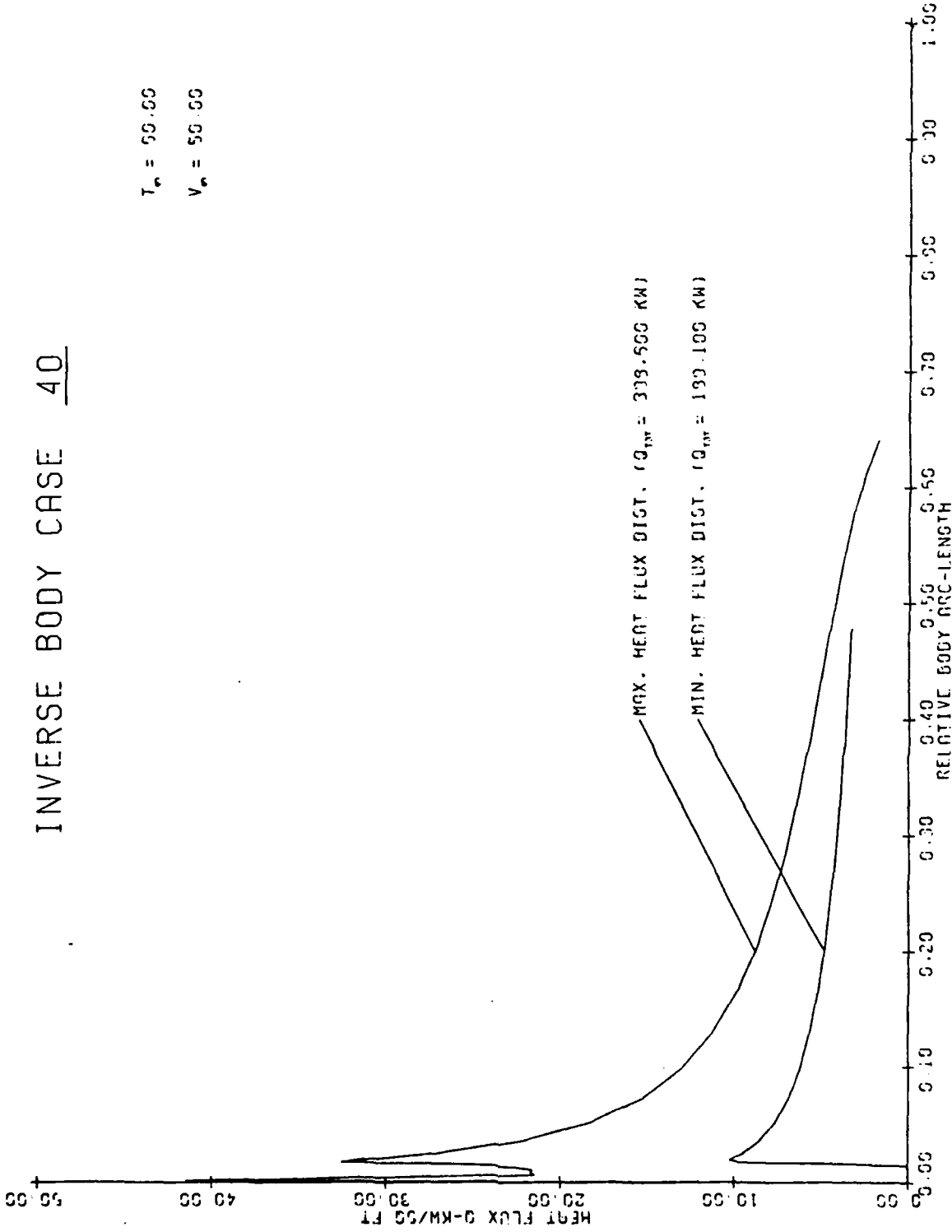


Figure 167. Heat Flux Distributions, Case No. 40.

INVERSE BODY CASE 41

$T_a = 50.00$   
 $V_a = 50.00$

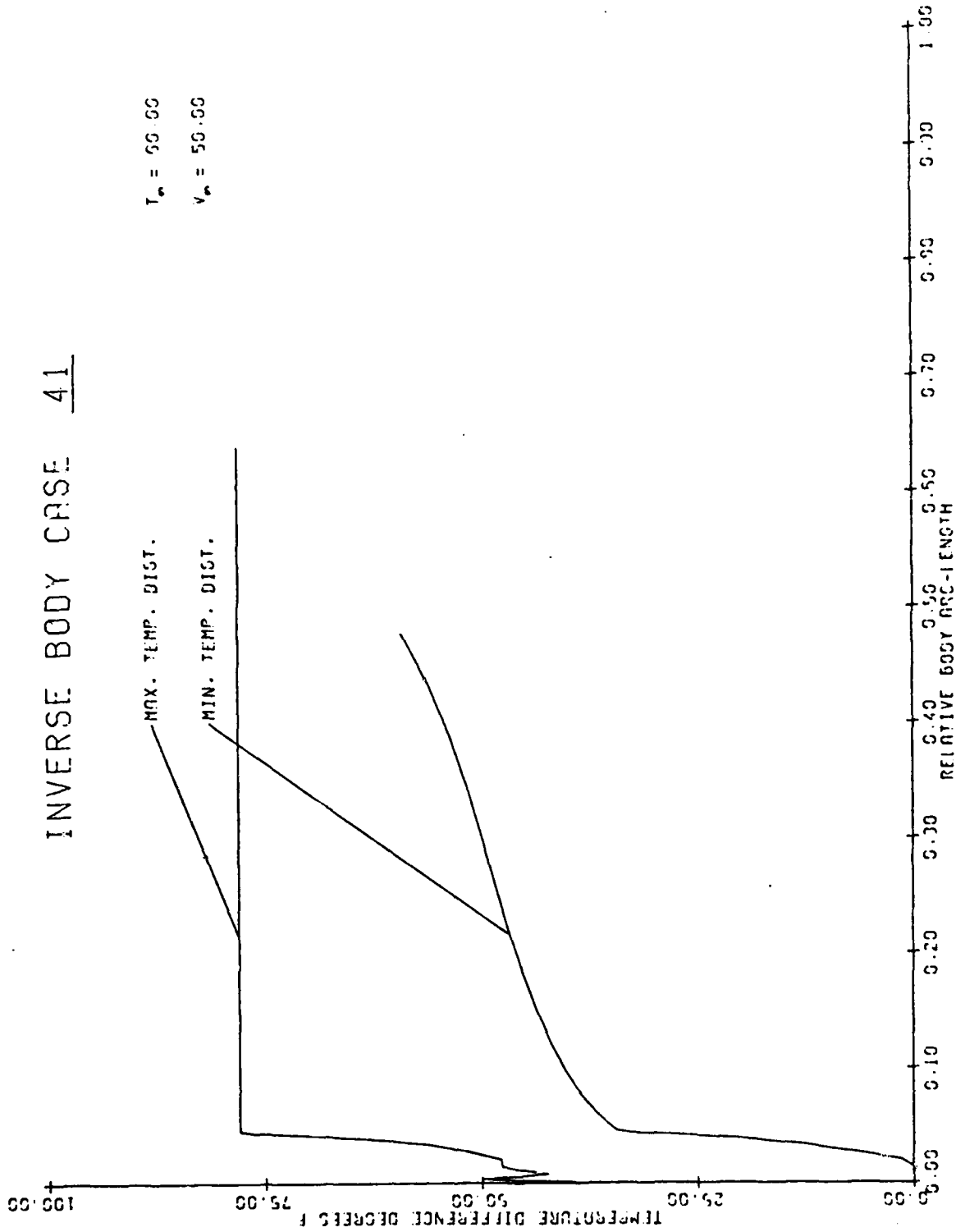


Figure 168. Temperature Distributions, Case No. 41.

INVERSE BODY CASE 41

$T_w = 50.00$   
 $V_w = 50.00$

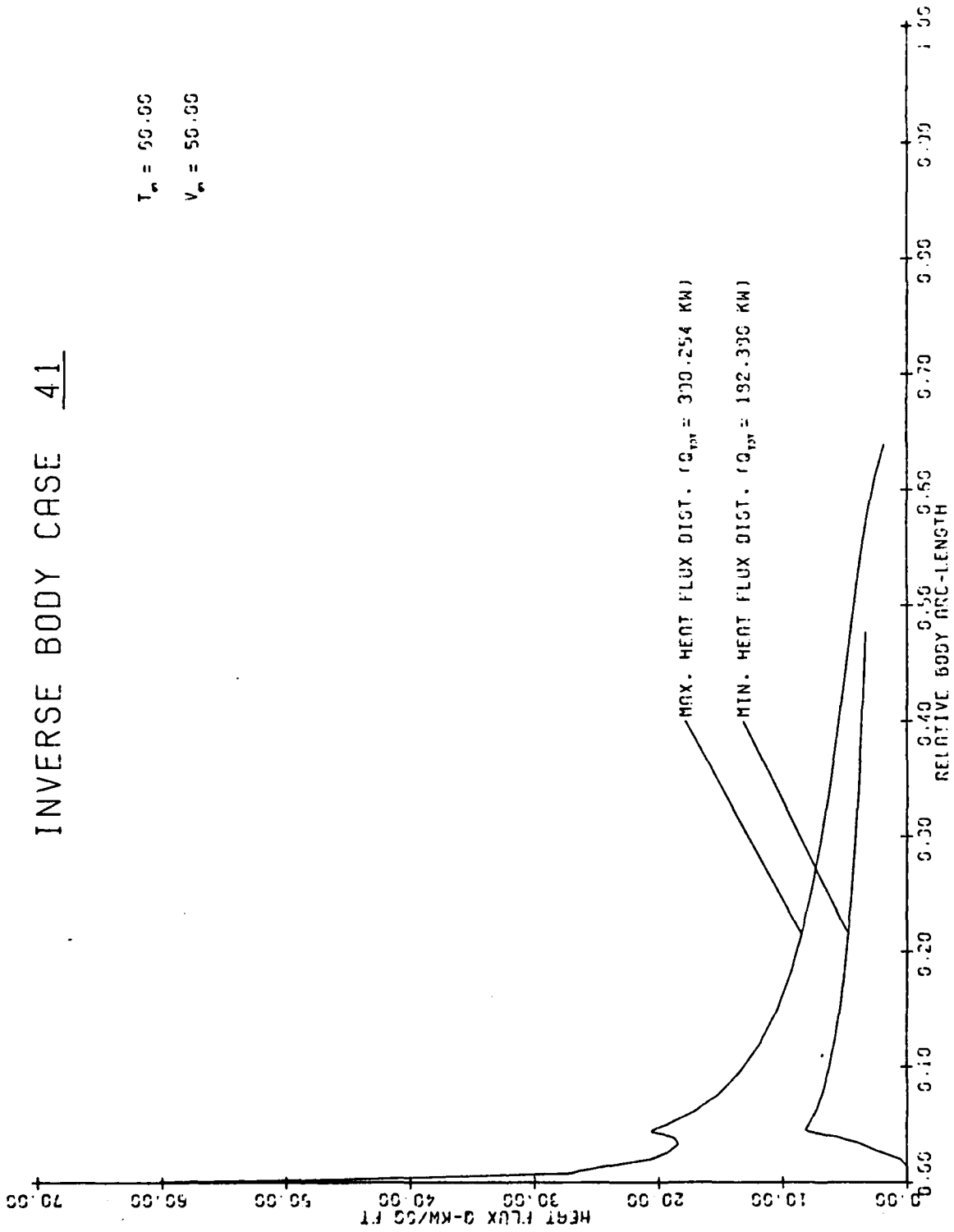


Figure 169. Heat Flux Distributions, Case No. 41.

# INVERSE BODY CASE 42

$T_p = 50.00$   
 $V_p = 50.00$

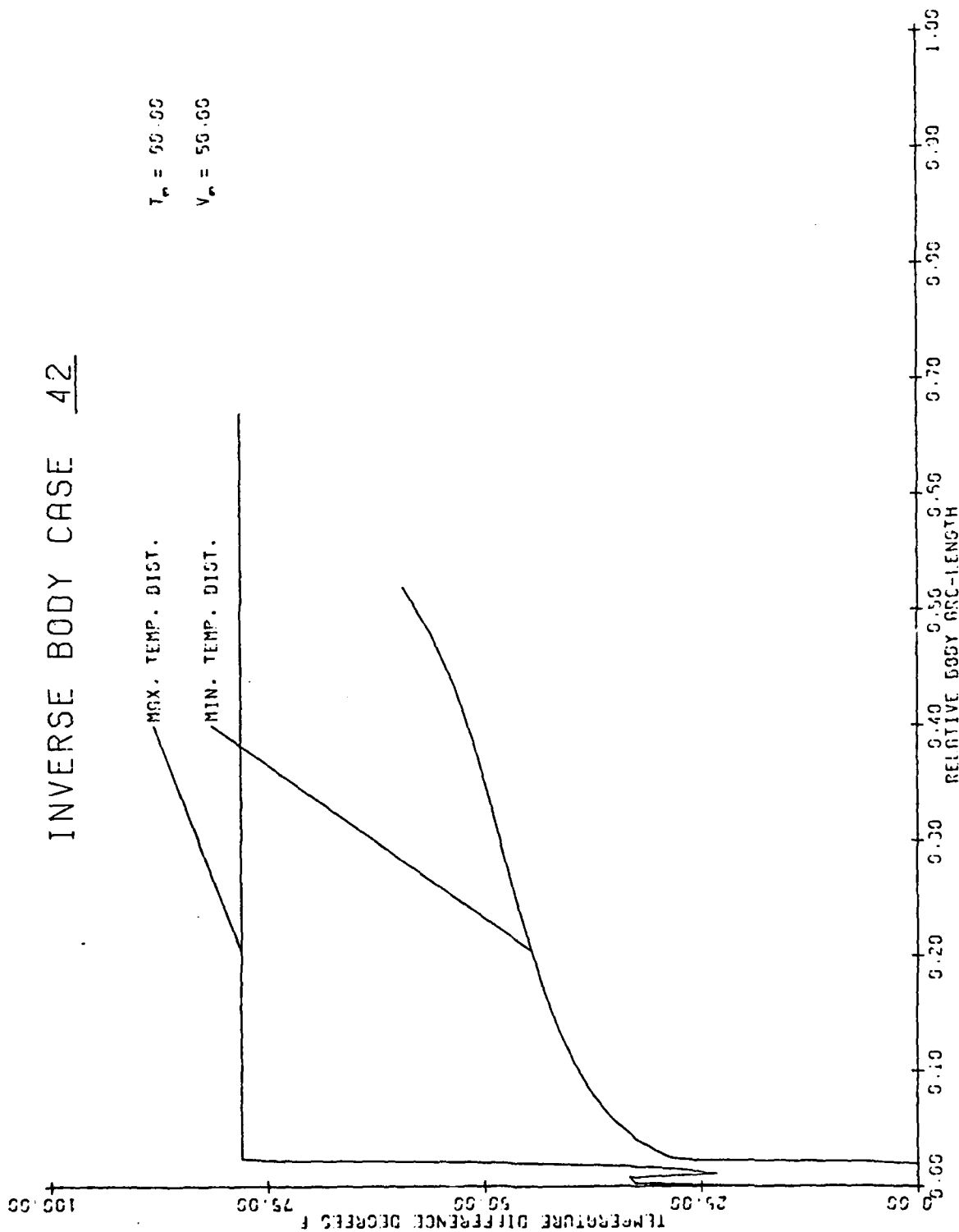


Figure 170. Temperature Distributions, Case No. 42.

INVERSE BODY CASE 42

$T_w = 50.00$

$V_w = 50.00$

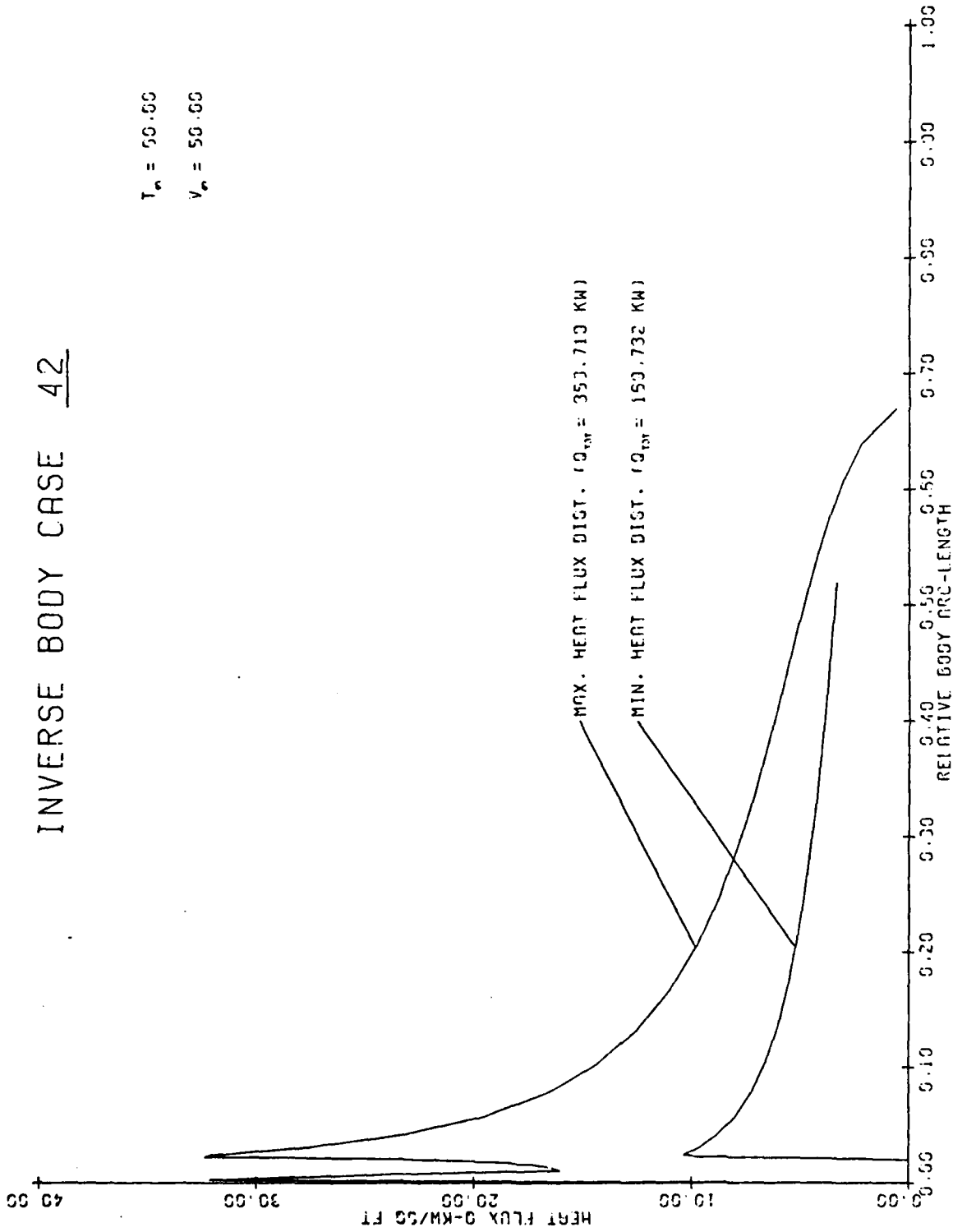


Figure 171. Heat Flux Distributions, Case No. 42.

# INVERSE BODY CASE 43

$T_m = 95.00$

$V_m = 50.00$

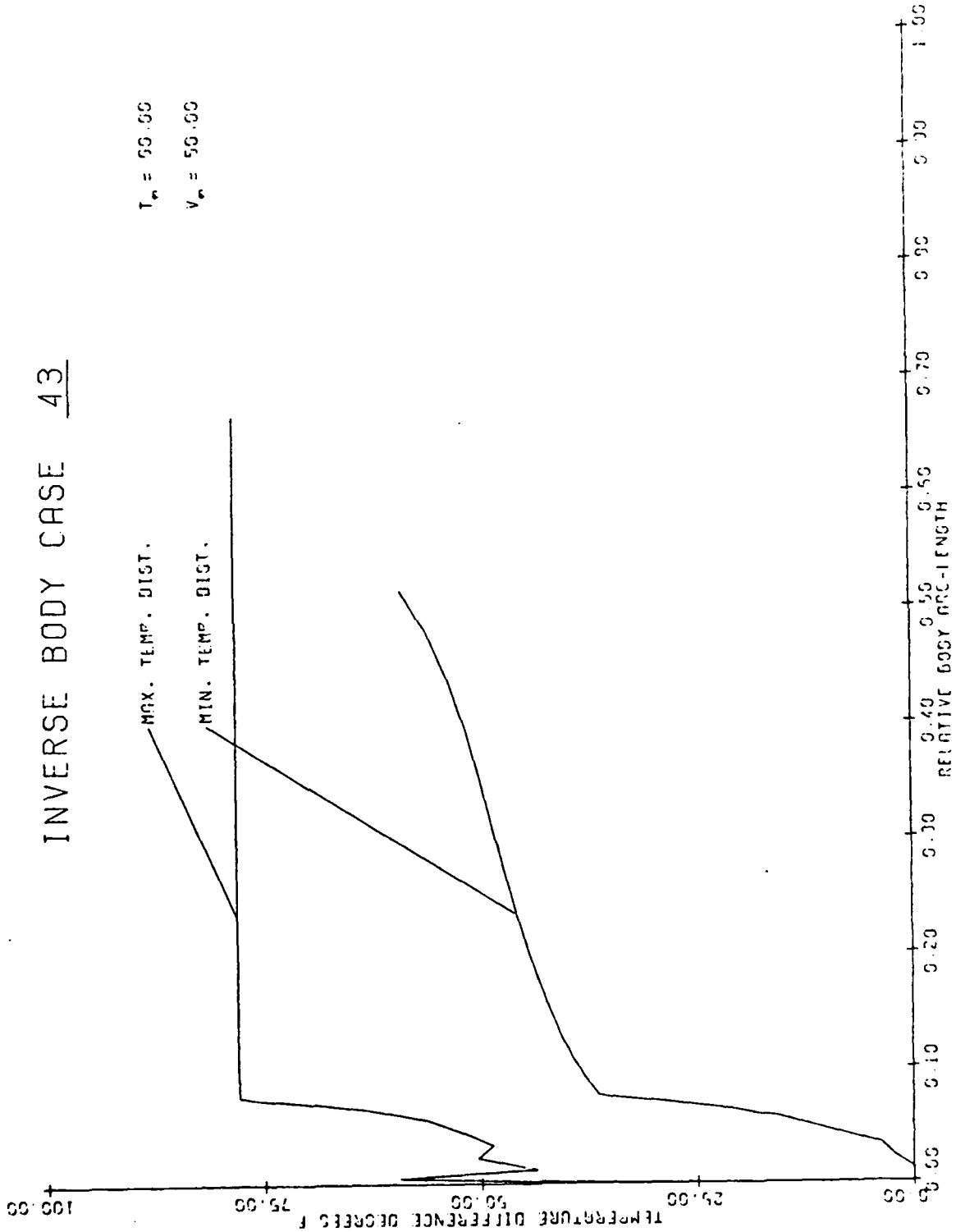


Figure 172. Temperature Distributions, Case No. 43.

INVERSE BODY CASE 43

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

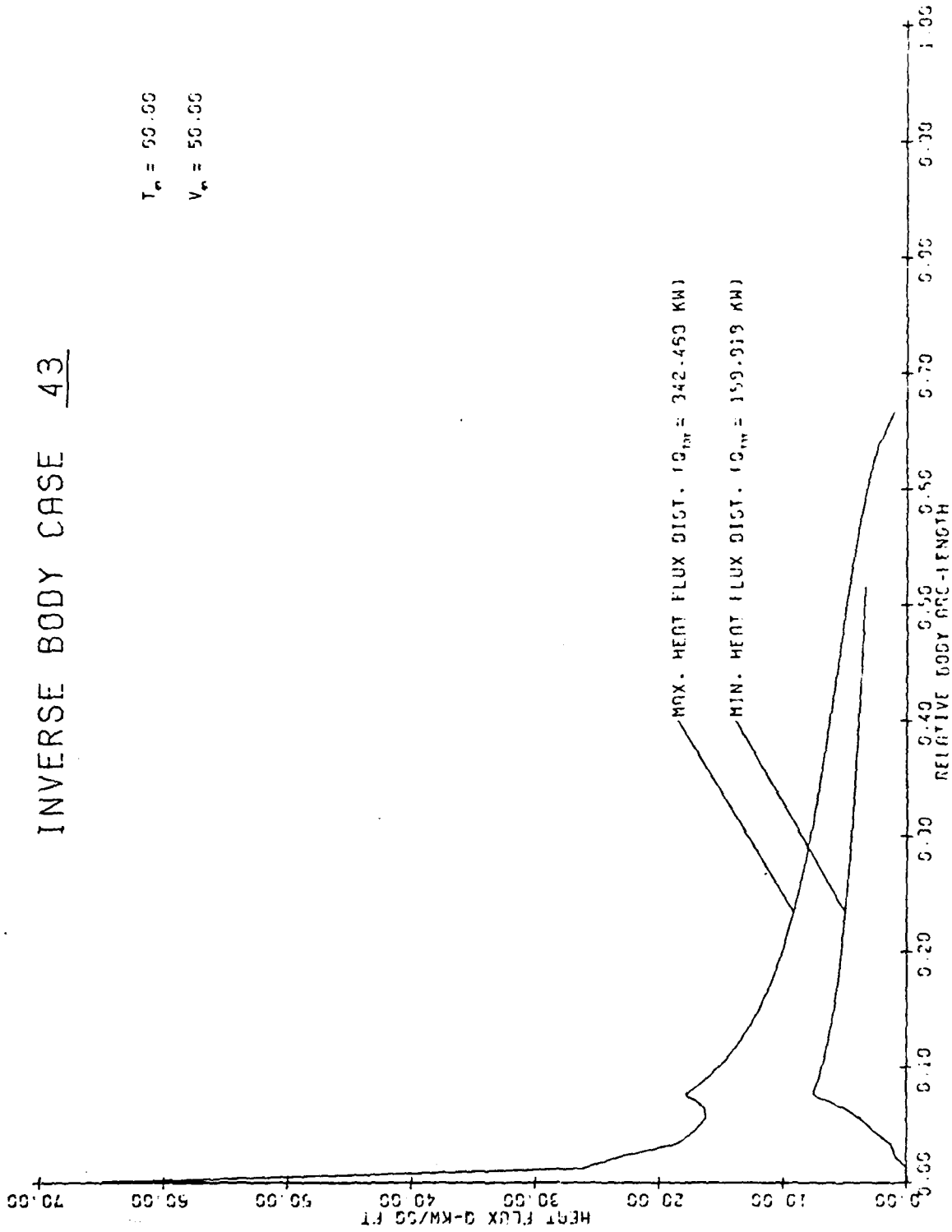


Figure 173. Heat Flux Distributions, Case No. 43.

INVERSE BODY CASE 44

$T_m = 50.00$   
 $V_m = 50.00$

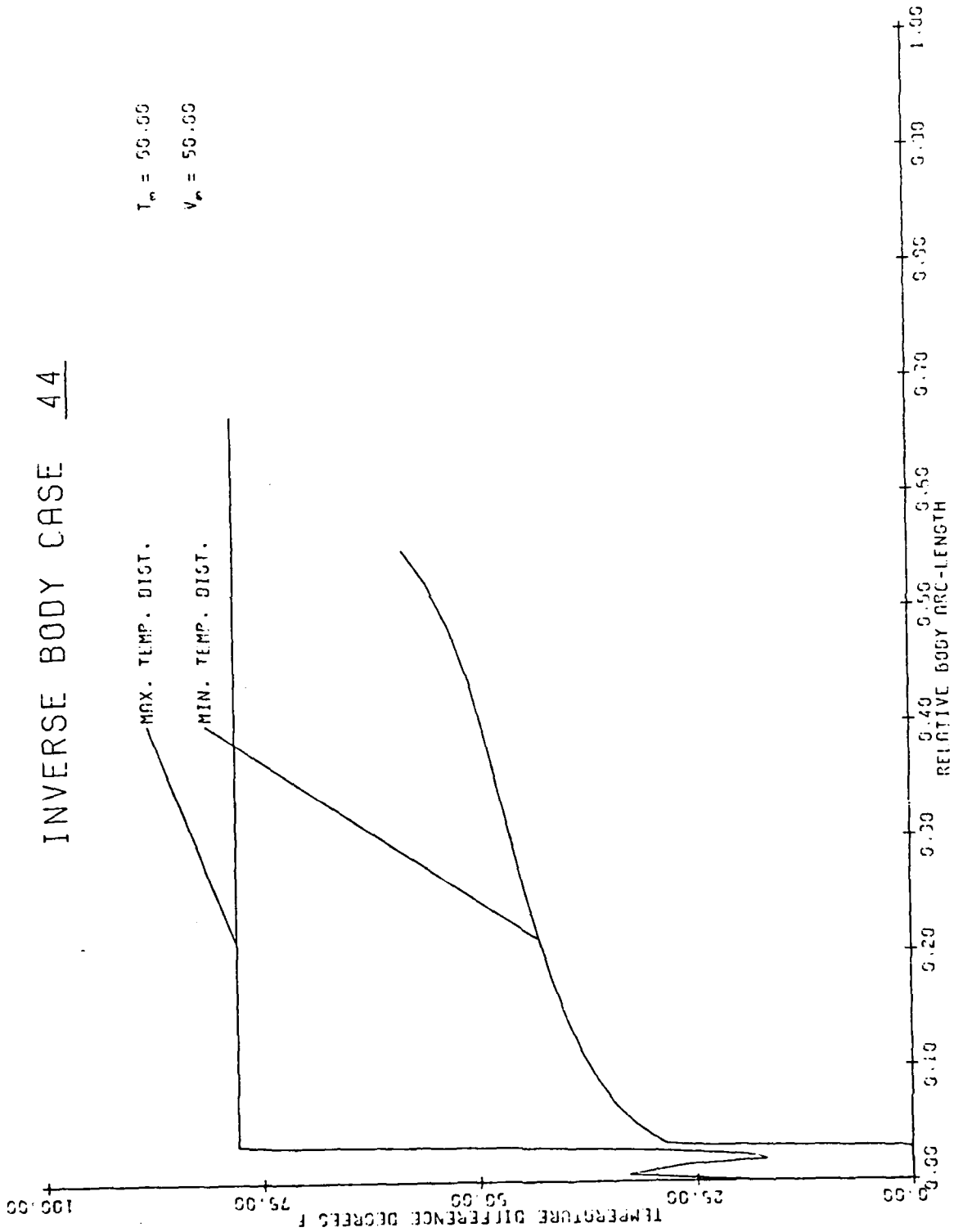


Figure 174. Temperature Distributions, Case No. 44.

INVERSE BODY CASE 44

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

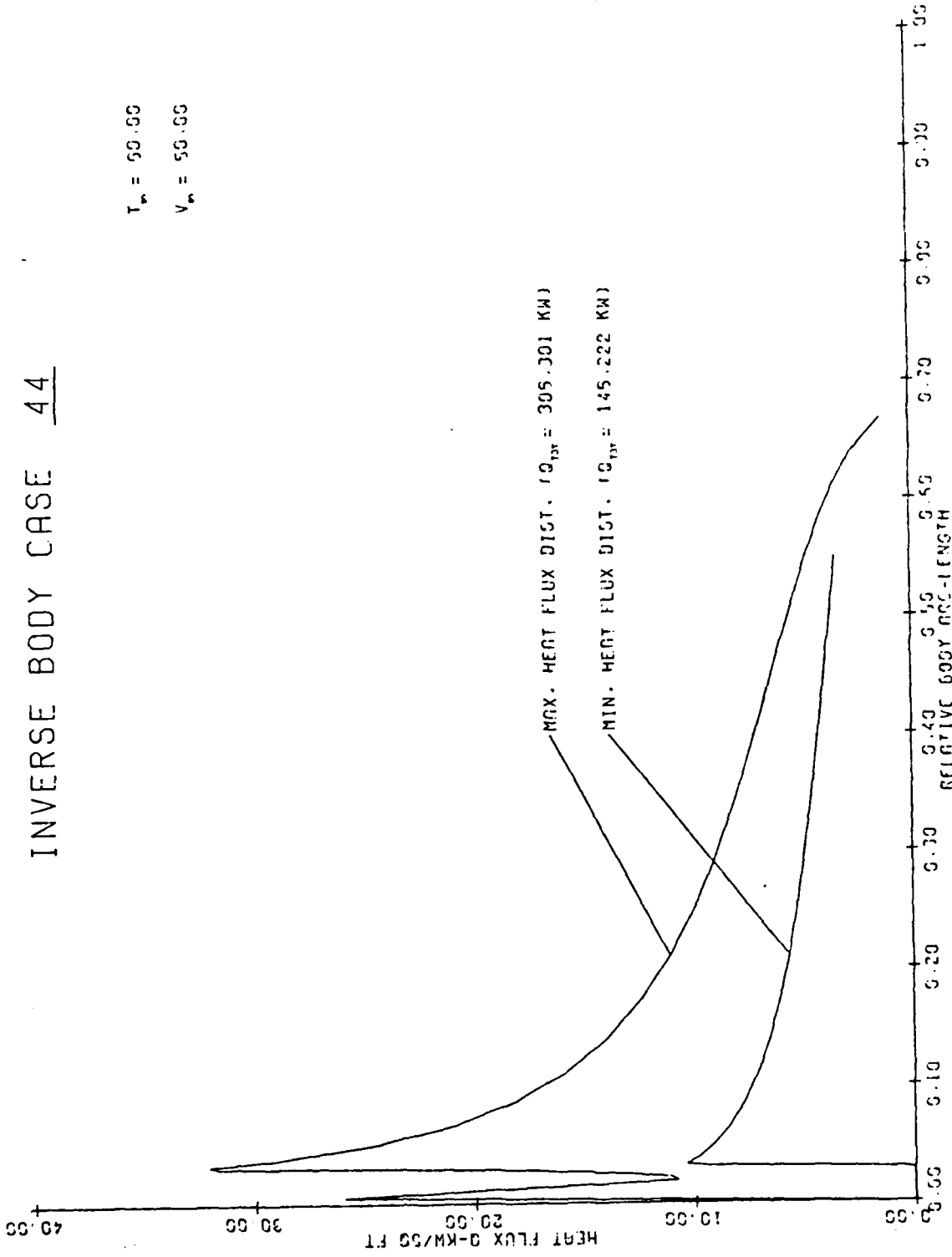


Figure 175. Heat Flux Distributions, Case No. 44.

INVERSE BODY CASE 45

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

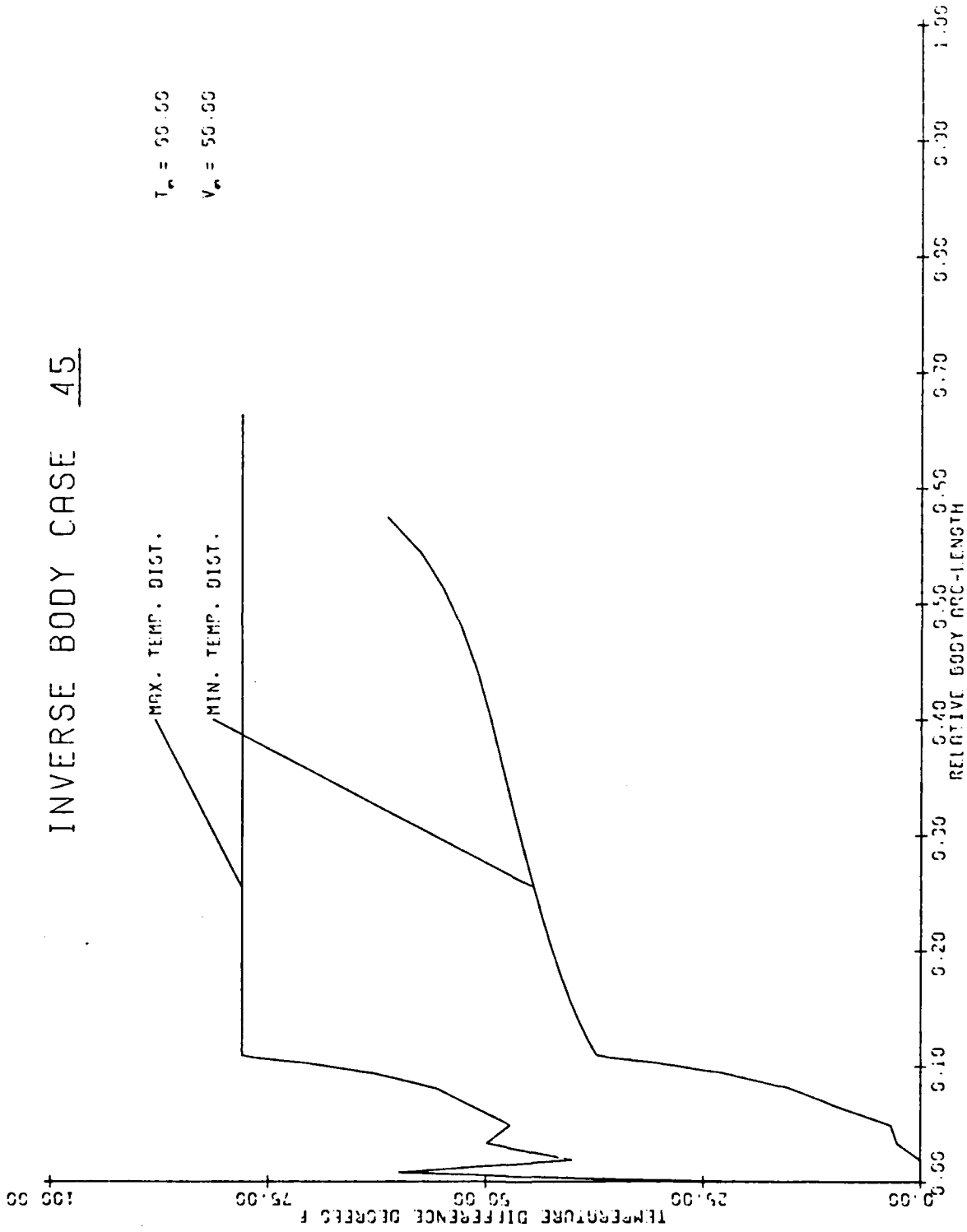


Figure 176. Temperature Distributions, Case No. 45.

INVERSE BODY CASE 45

$T_m = 50.00$   
 $V_m = 50.00$

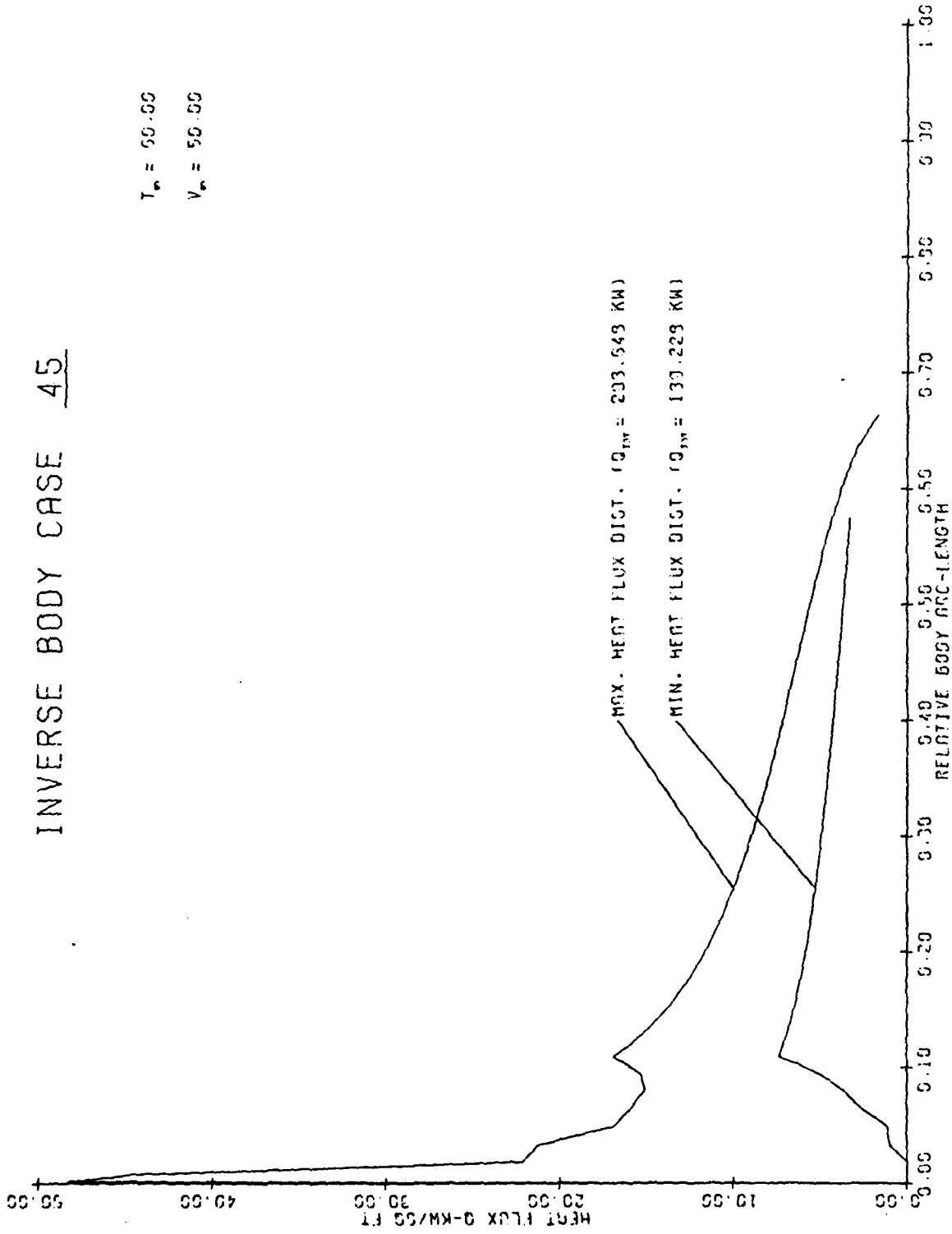


Figure 177. Heat Flux Distributions, Case No. 45.

INVERSE BODY CASE 46

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

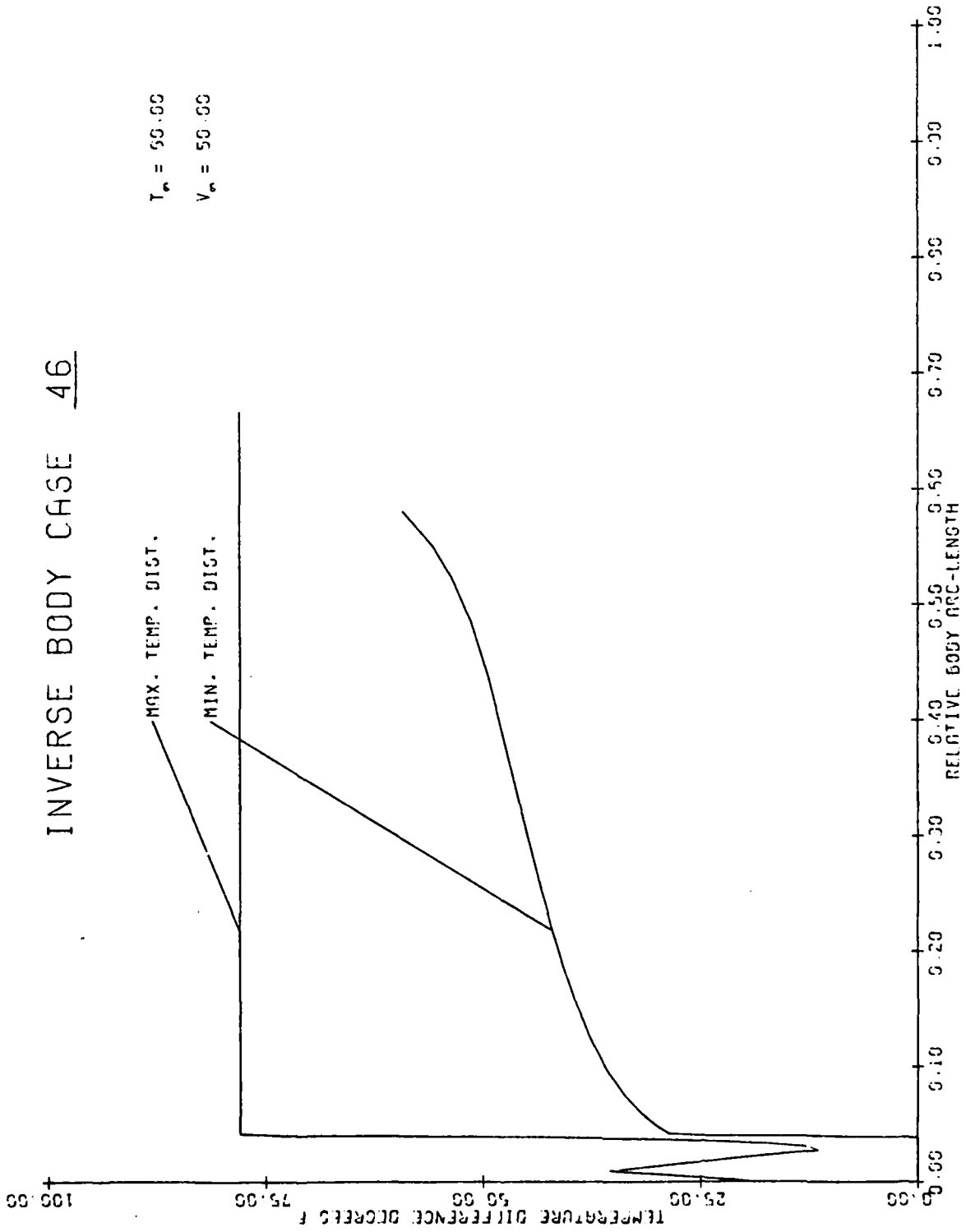


Figure 178. Temperature Distributions, Case No. 46.

INVERSE BODY CASE 46

$T_w = 50.00$

$V_w = 50.00$

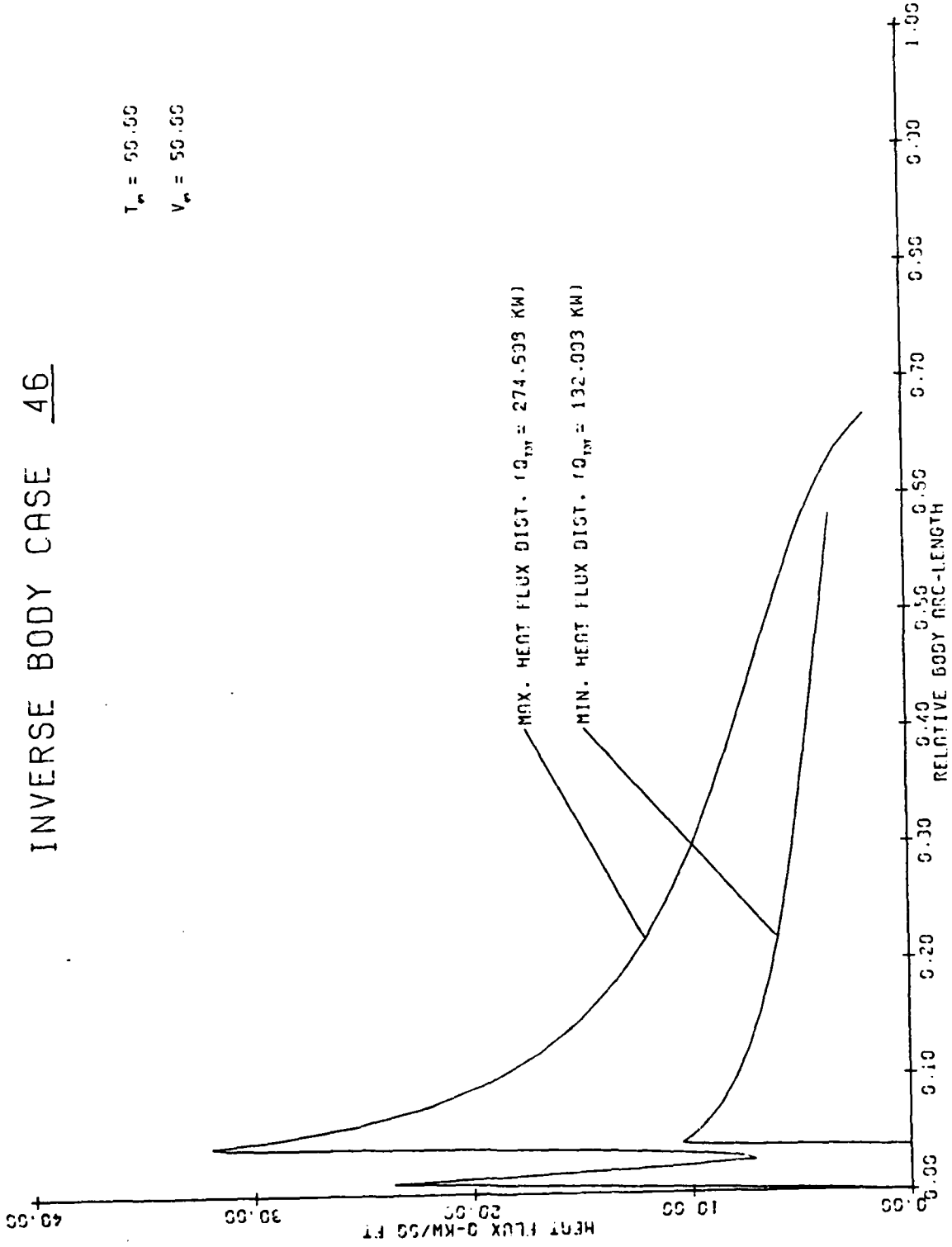


Figure 179. Heat Flux Distributions, Case No. 46.

# INVERSE BODY CASE 47

$T_m = 50.00$

$V_m = 50.00$

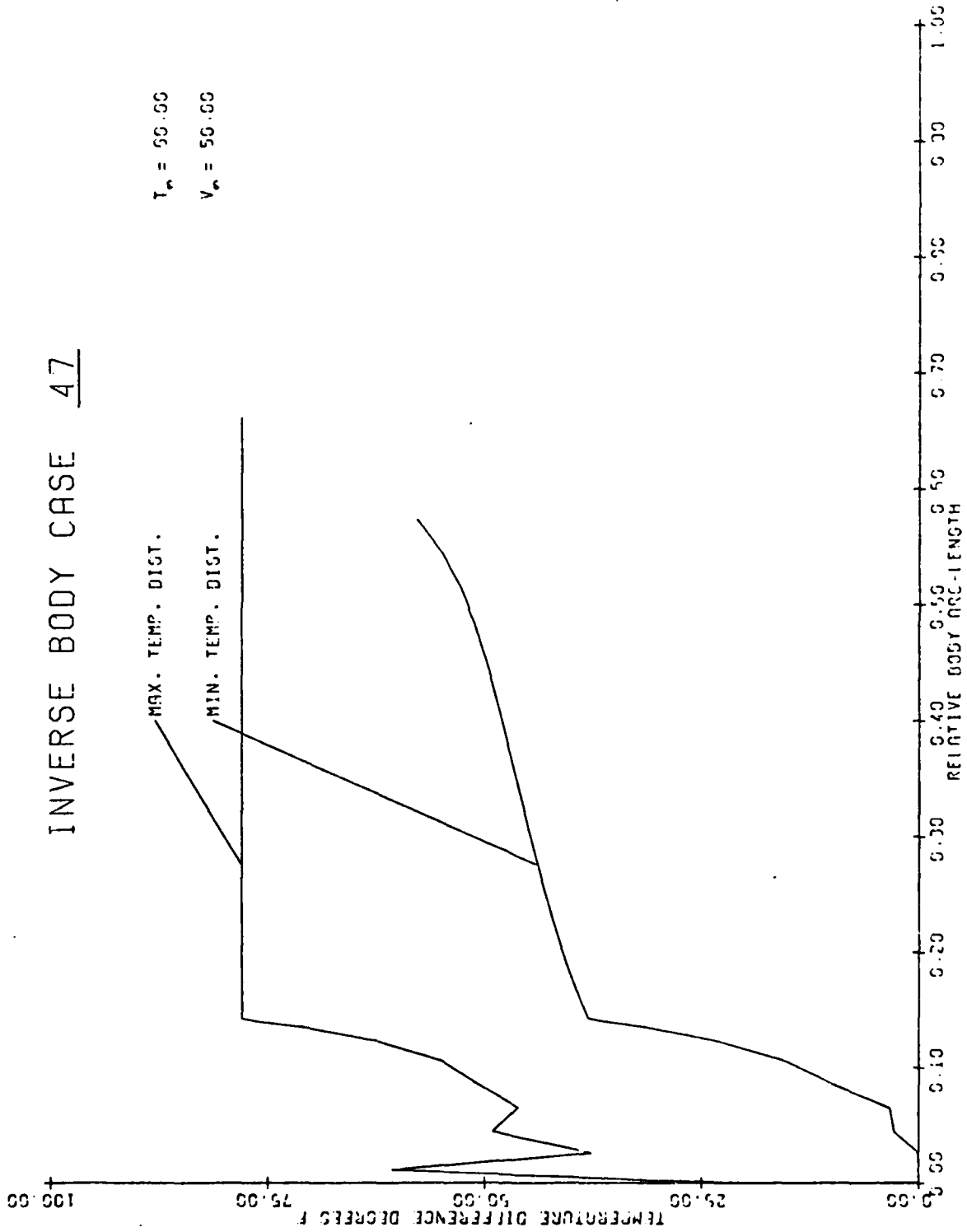


Figure 180. Temperature Distributions, Case No. 47.

INVERSE BODY CASE 47

$T_w = 50.00$

$V_w = 50.00$

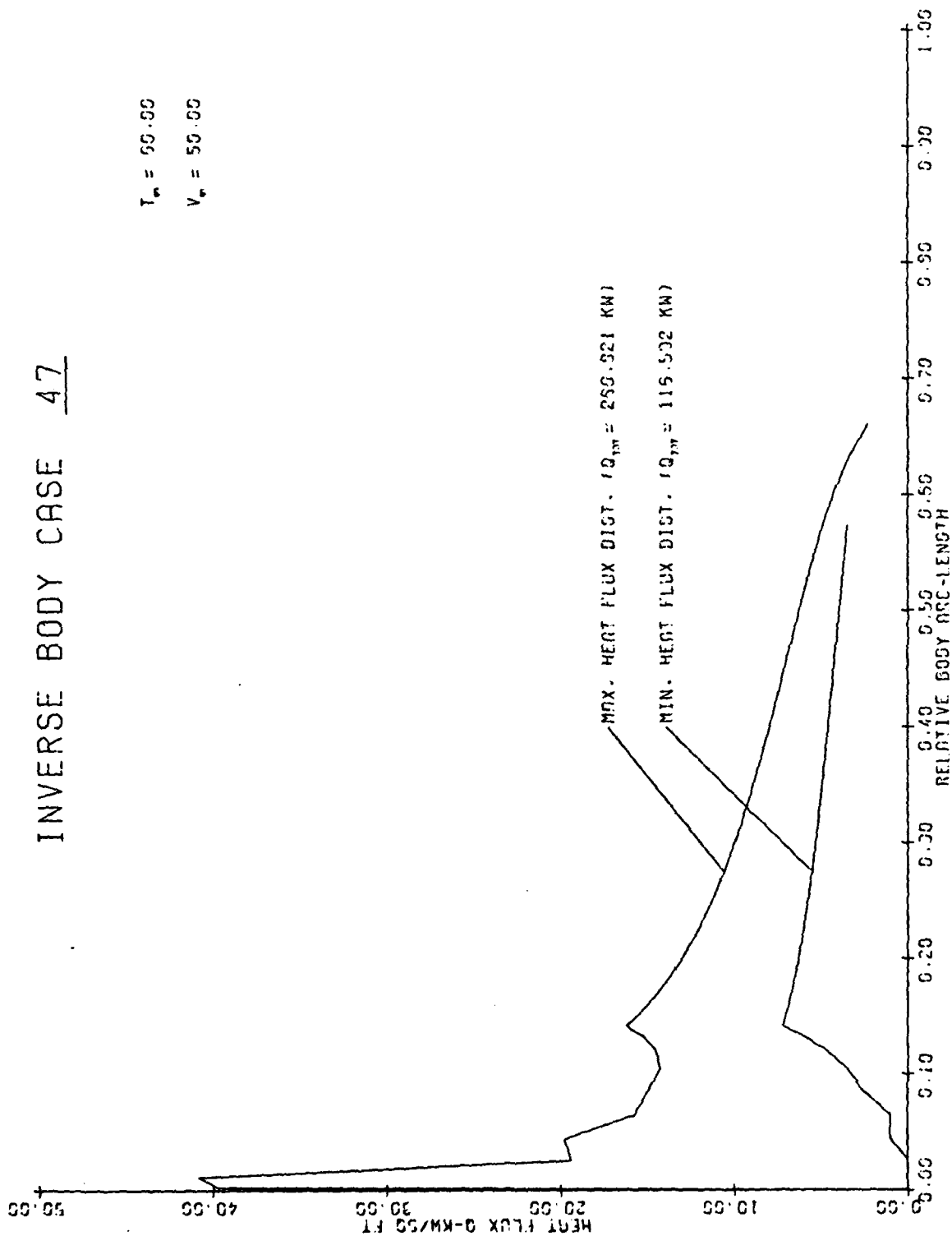


Figure 181. Heat Flux Distributions, Case No. 47.

INVERSE BODY CASE 48

$T_m = 50.00$   
 $V_m = 50.00$

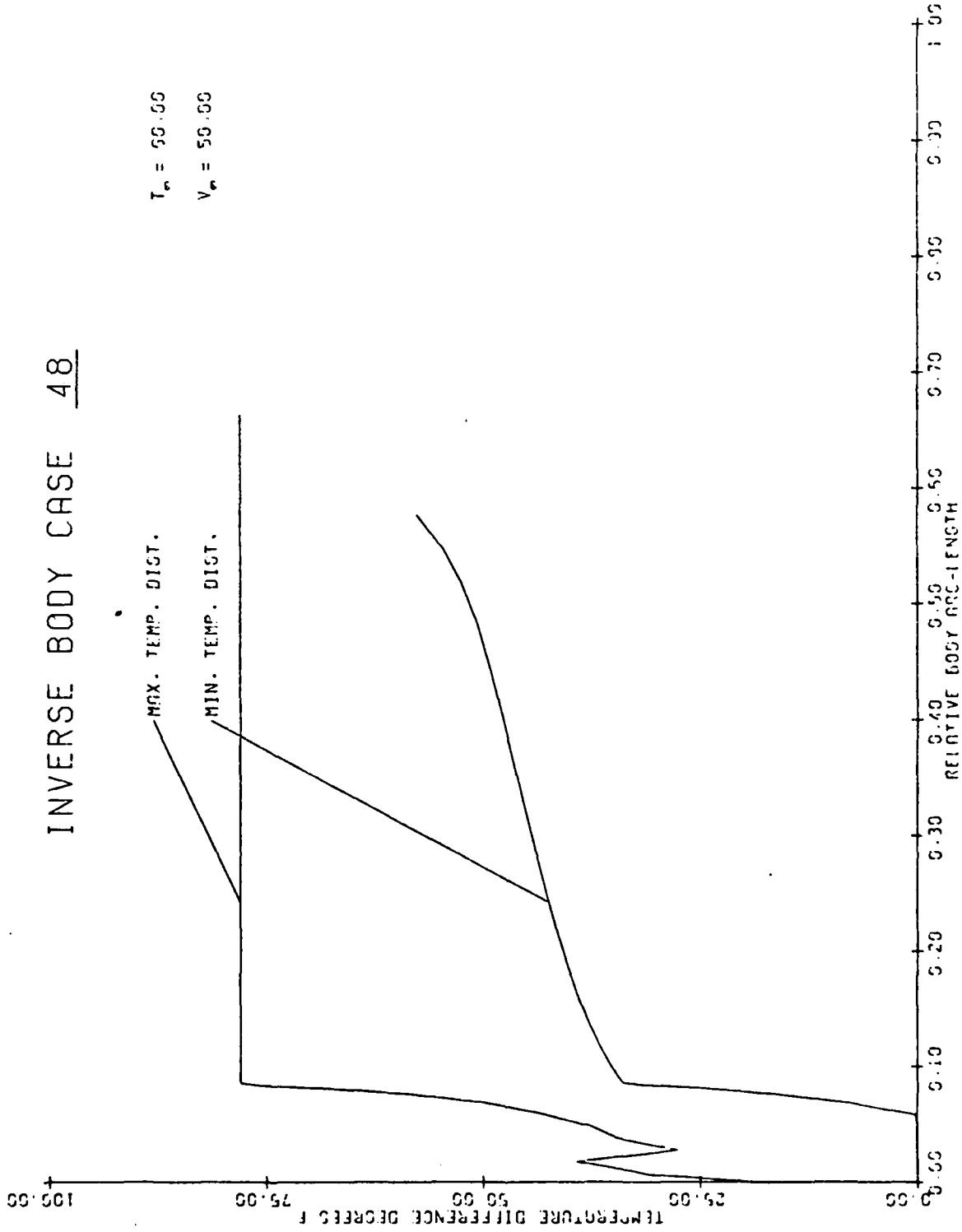


Figure 182. Temperature Distributions, Case No. 48.

INVERSE BODY CASE 48

$T_w = 50.00$

$V_w = 50.00$

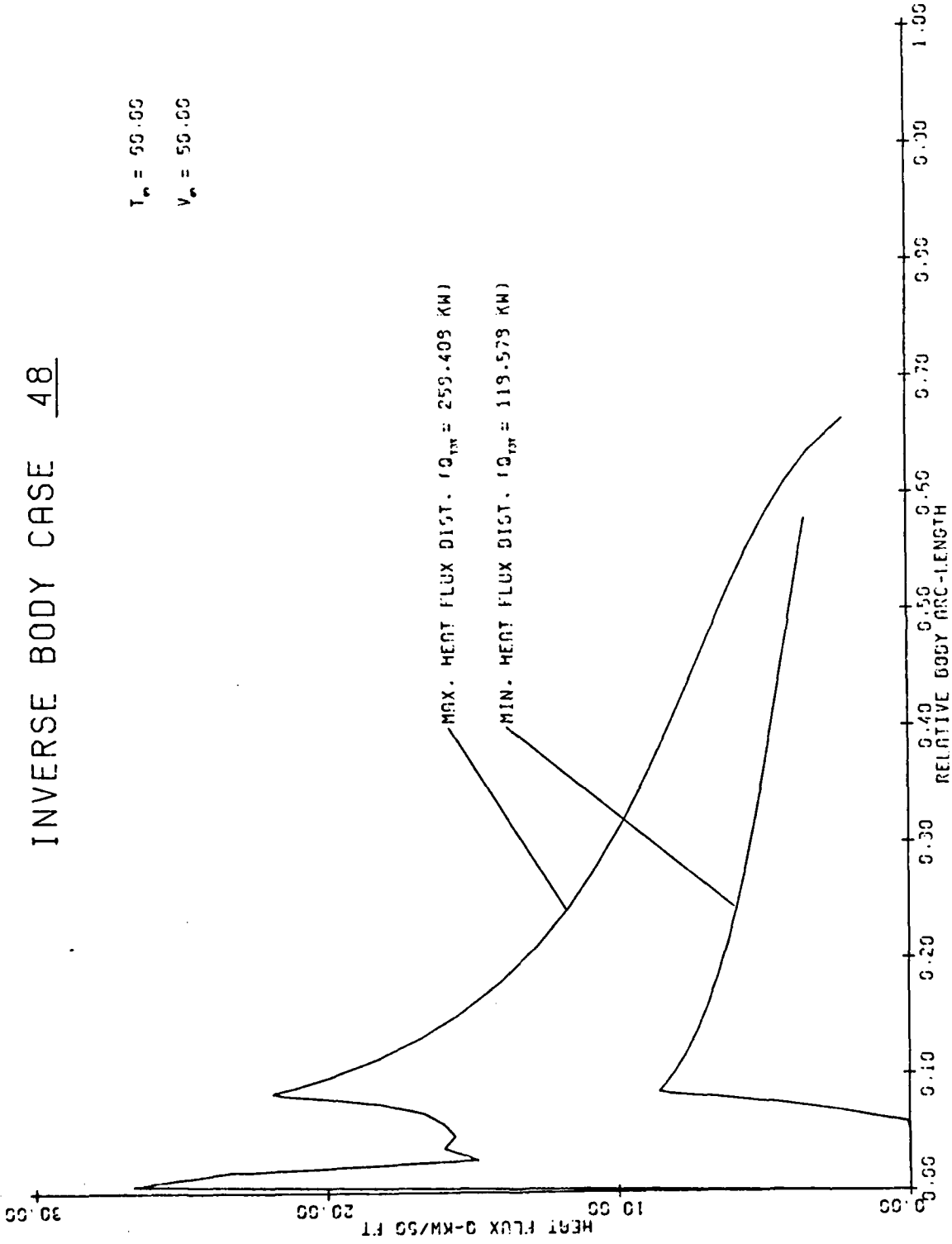


Figure 183. Heat Flux Distributions, Case No. 48.

INVERSE BODY CASE 49

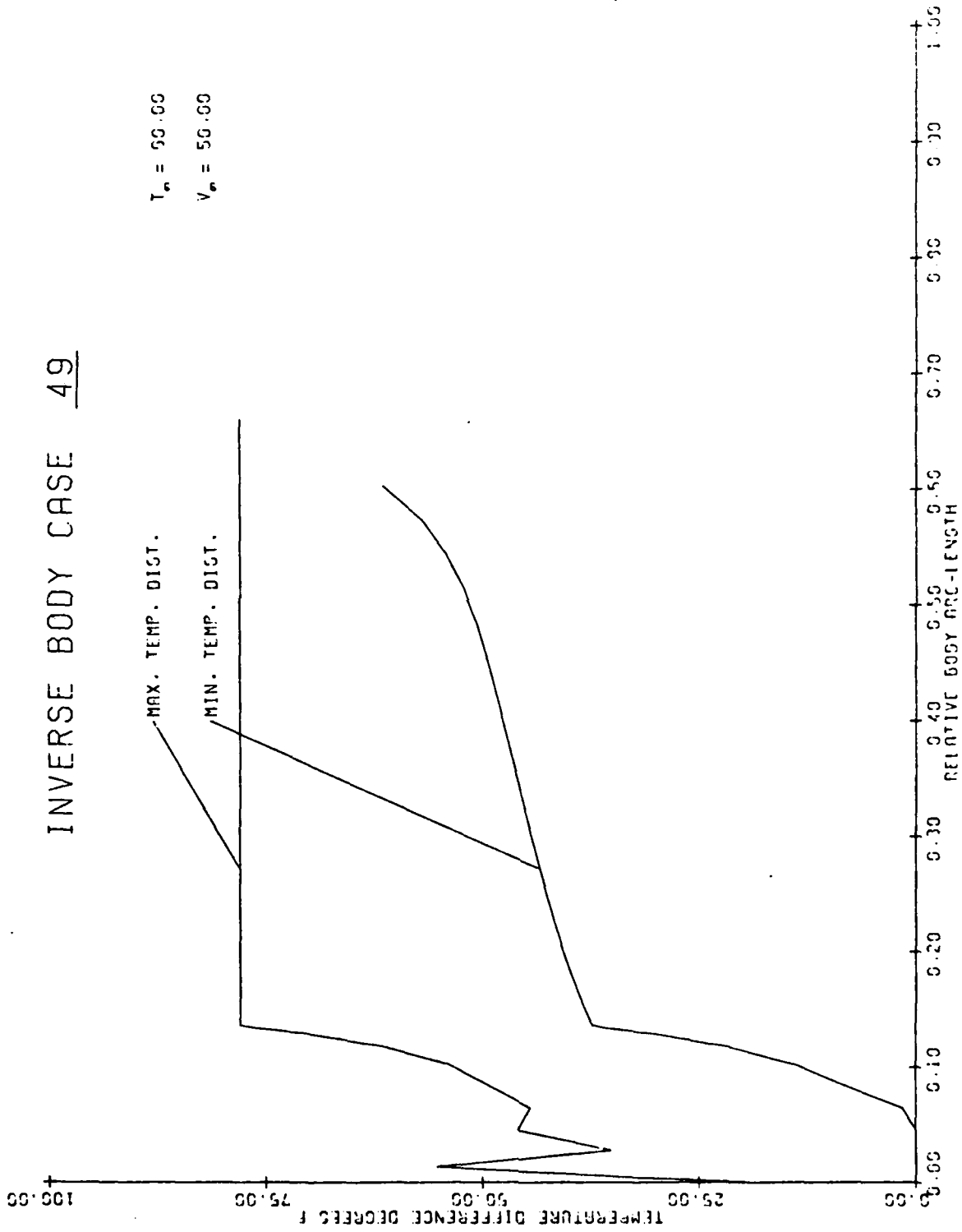


Figure 184. Temperature Distributions, Case No. 49.

INVERSE BODY CASE 49

$T_w = 50.00$

$V_w = 50.00$

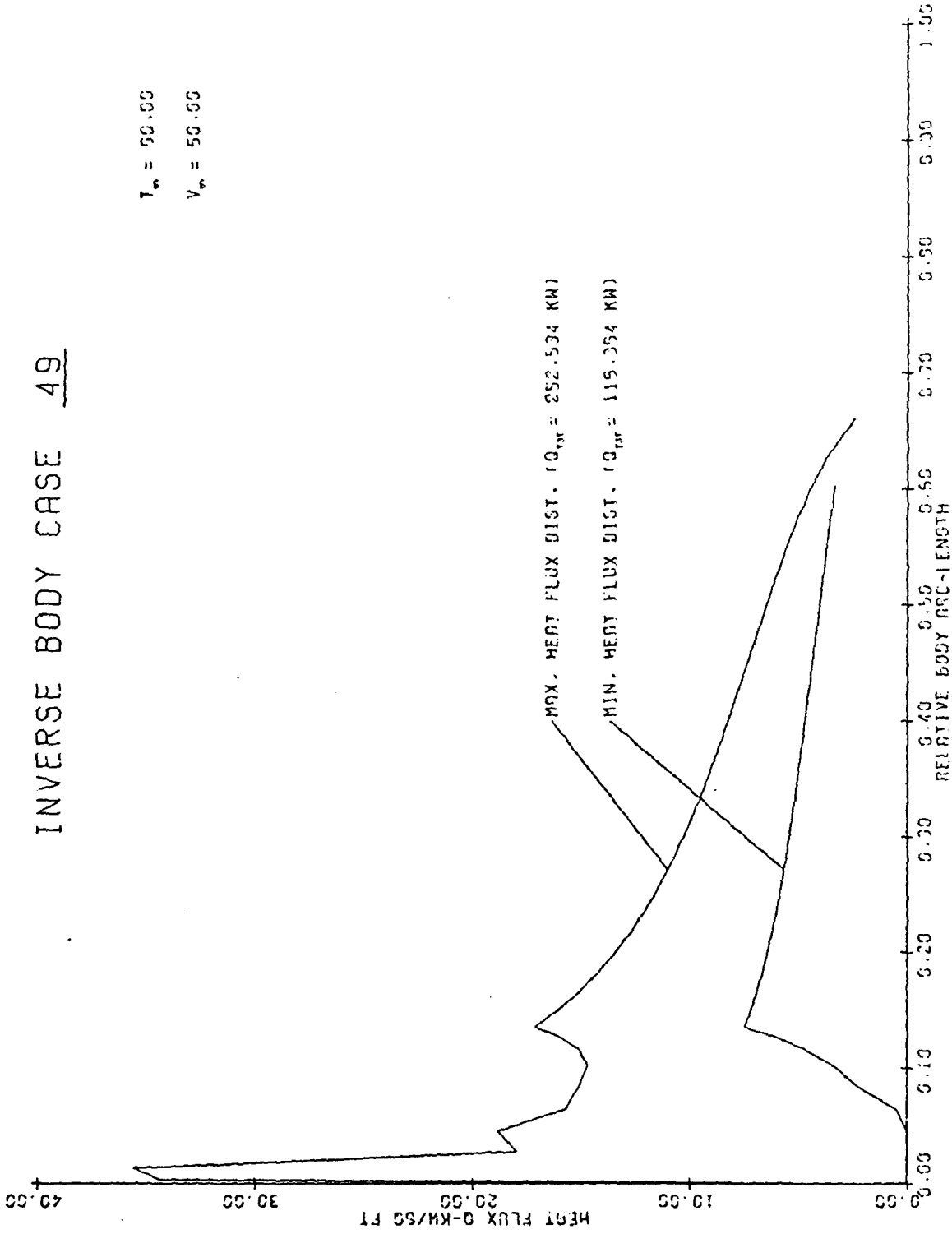


Figure 185. Heat Flux Distributions, Case No. 49.

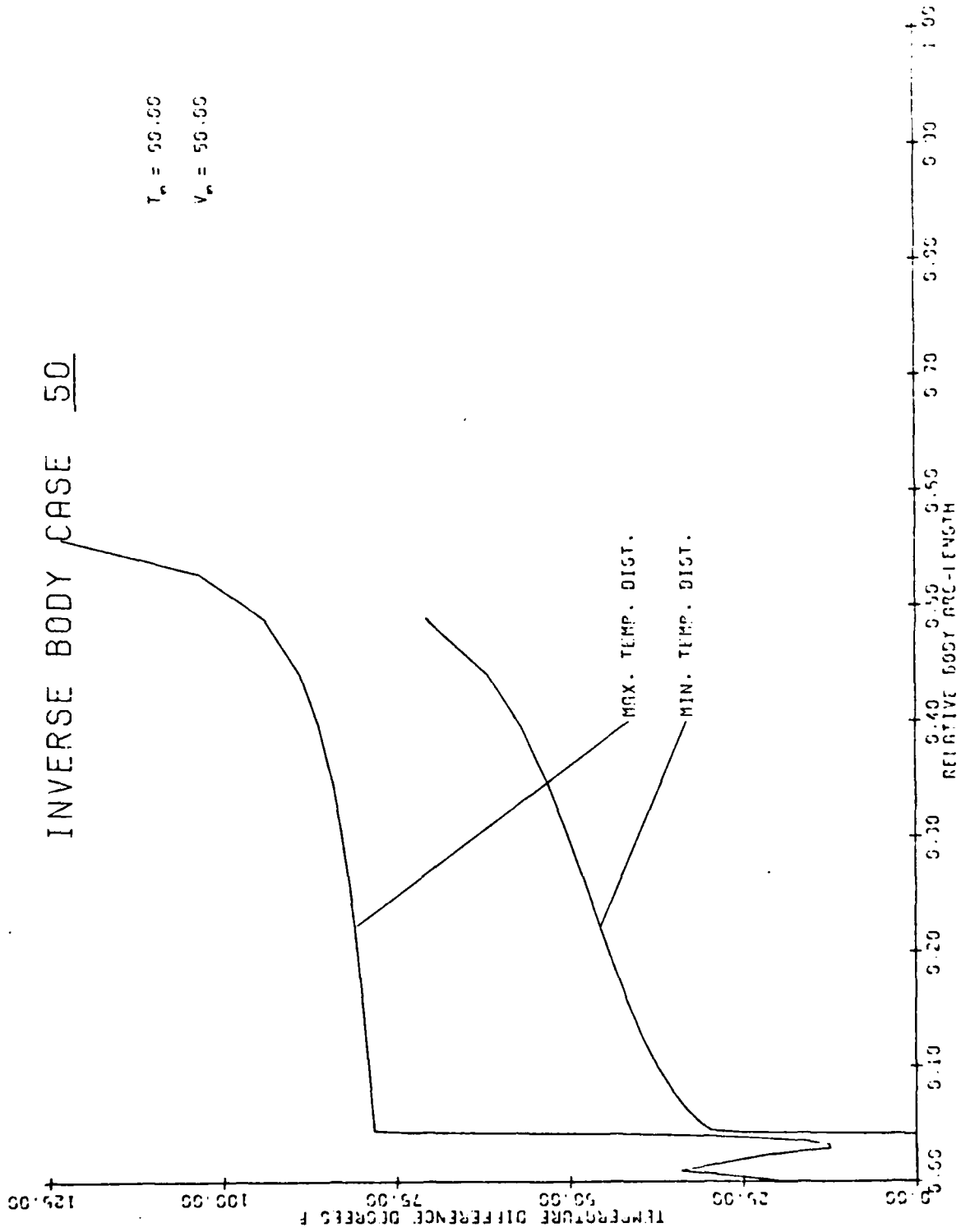


Figure 186. Temperature Distributions, Case No. 50.

INVERSE BODY CASE 50

$T_w = 50.00$

$V_w = 50.00$

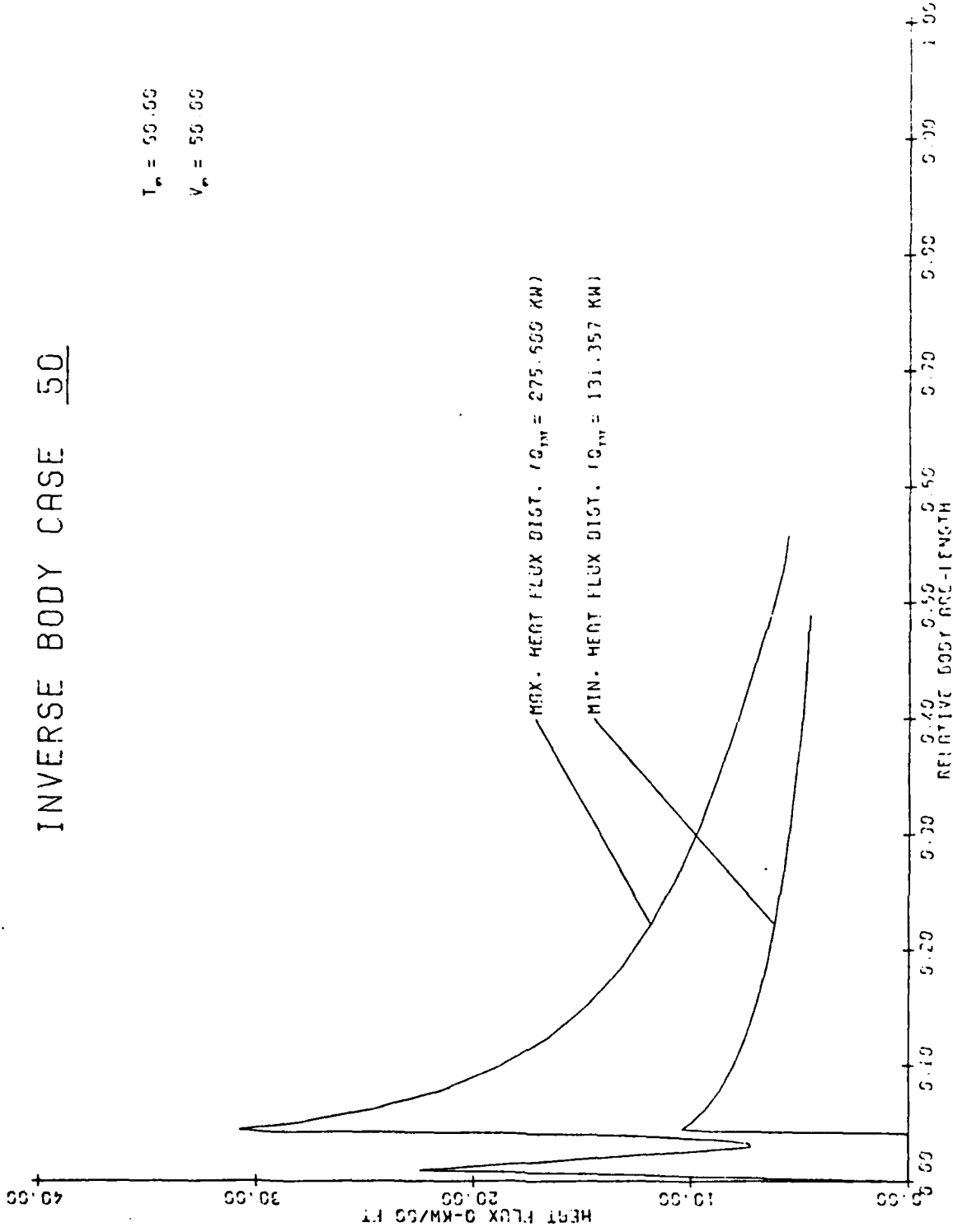


Figure 187. Heat Flux Distributions, Case No. 50.

INVERSE BODY CASE 51

$T_m = 56.66$   
 $V_m = 56.66$

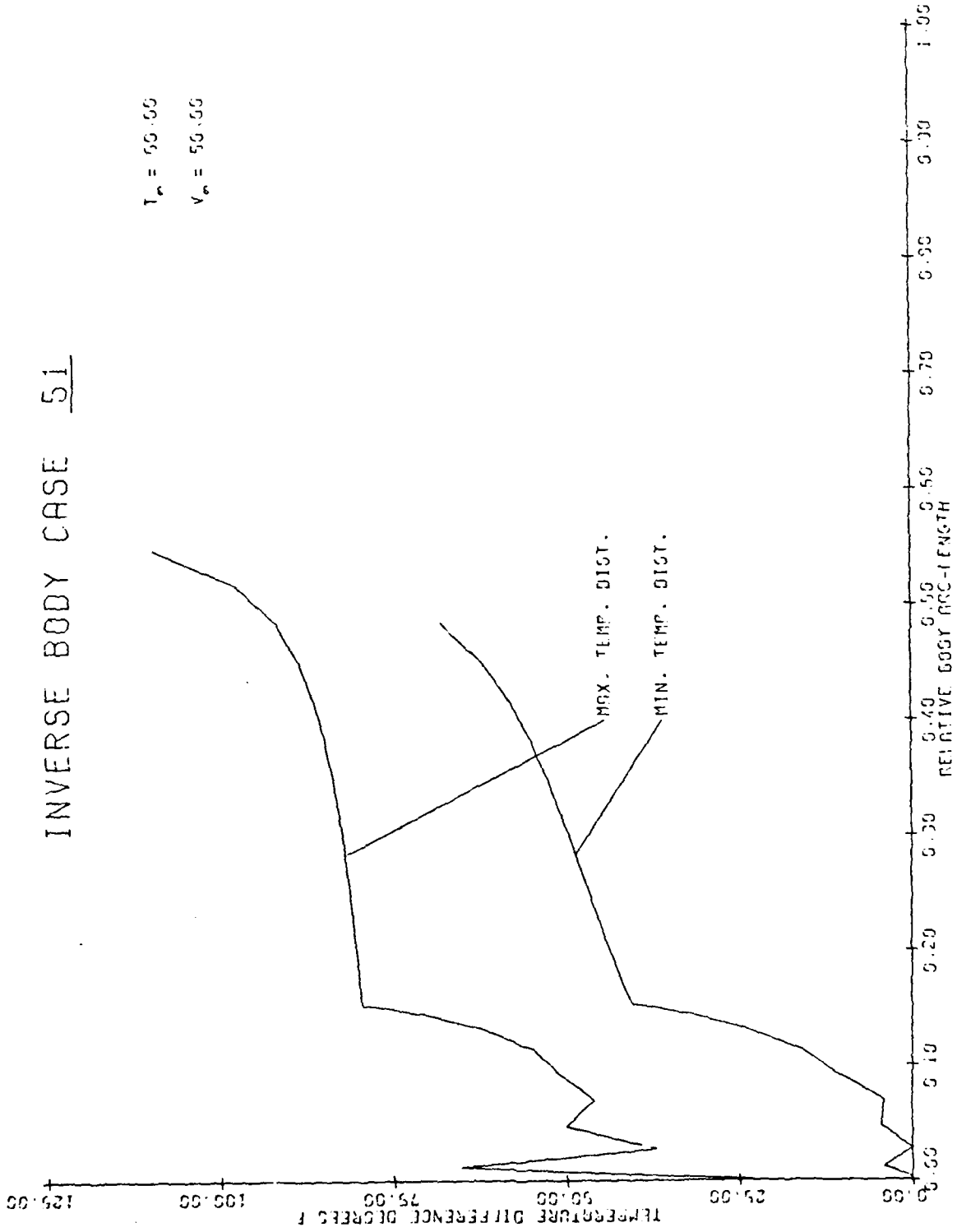


Figure 188. Temperature Distributions, Case No. 51.

INVERSE BODY CASE 51

$T_w = 50.00$

$V_w = 50.00$

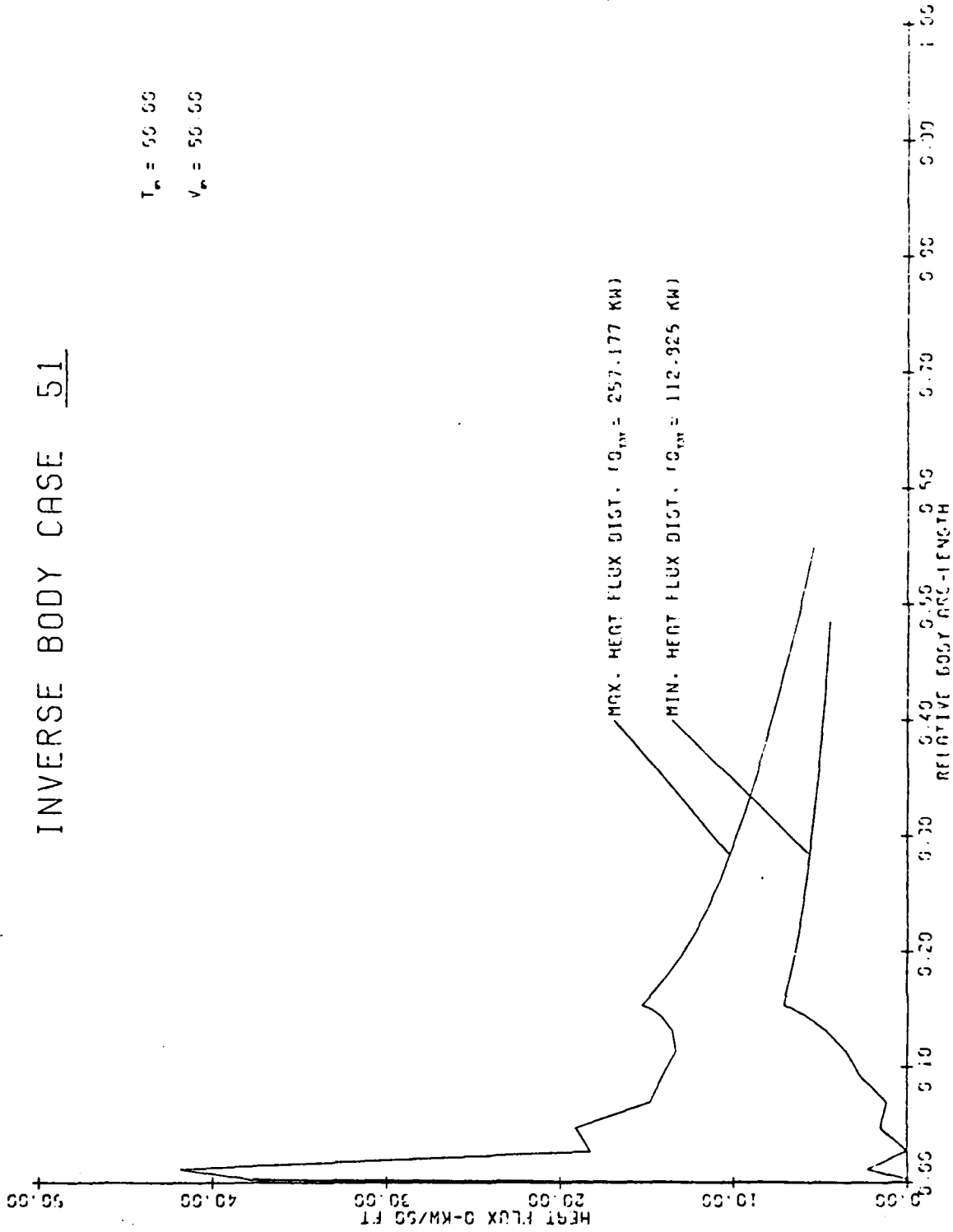


Figure 189. Heat Flux Distributions, Case No. 51.

INVERSE BODY CASE 52

$T_m = 50.00$   
 $V_m = 50.00$

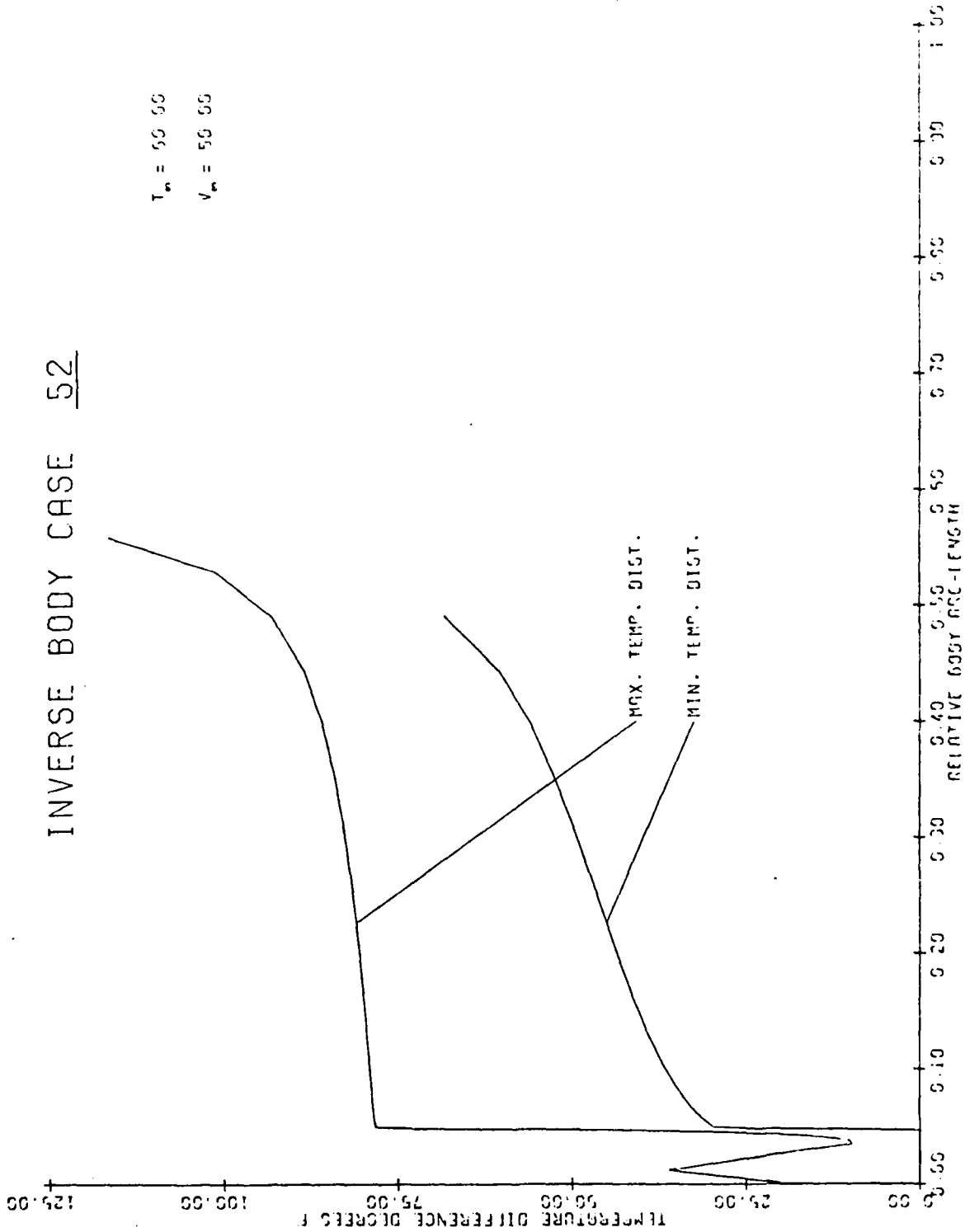


Figure 190. Temperature Distributions, Case No. 52.

INVERSE BODY CASE 52

$T_m = 50.00$   
 $V_m = 50.00$

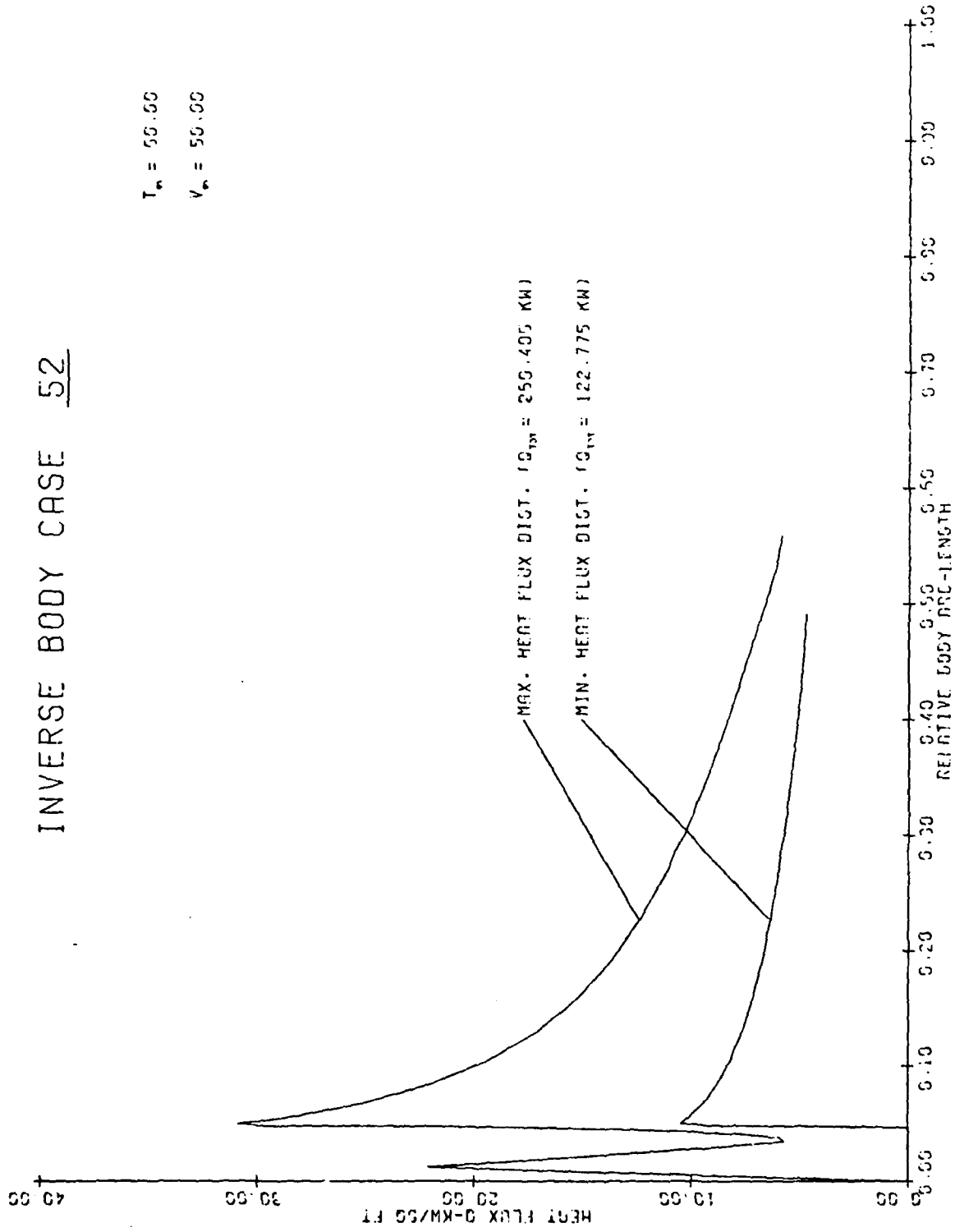


Figure 191. Heat Flux Distributions, Case No. 52.

INVERSE BODY CASE 53

$T_m = 50.00$   
 $V_m = 50.00$

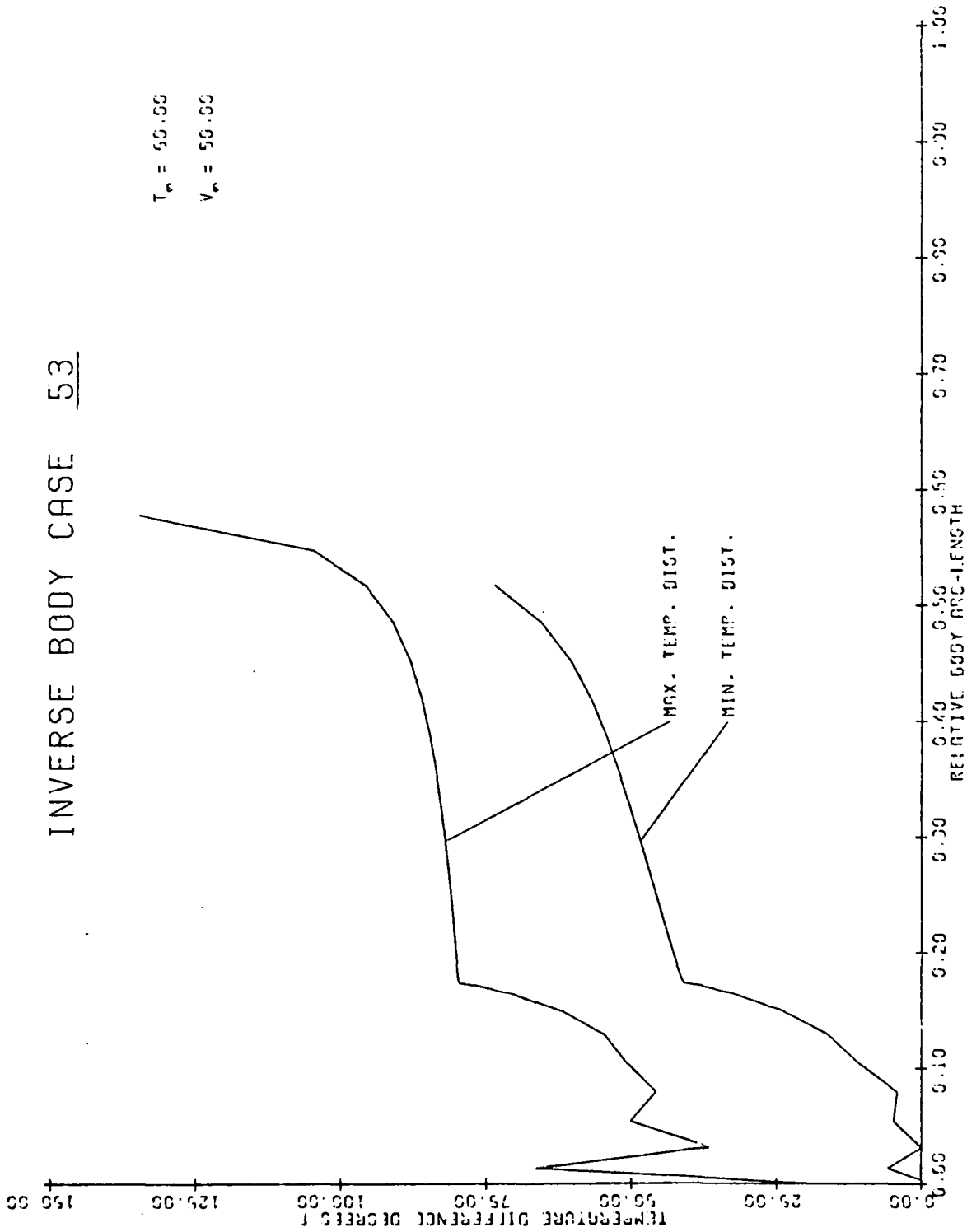


Figure 192. Temperature Distributions, Case No. 53.

INVERSE BODY CASE 53

$T_w = 50.00$   
 $V_w = 50.00$

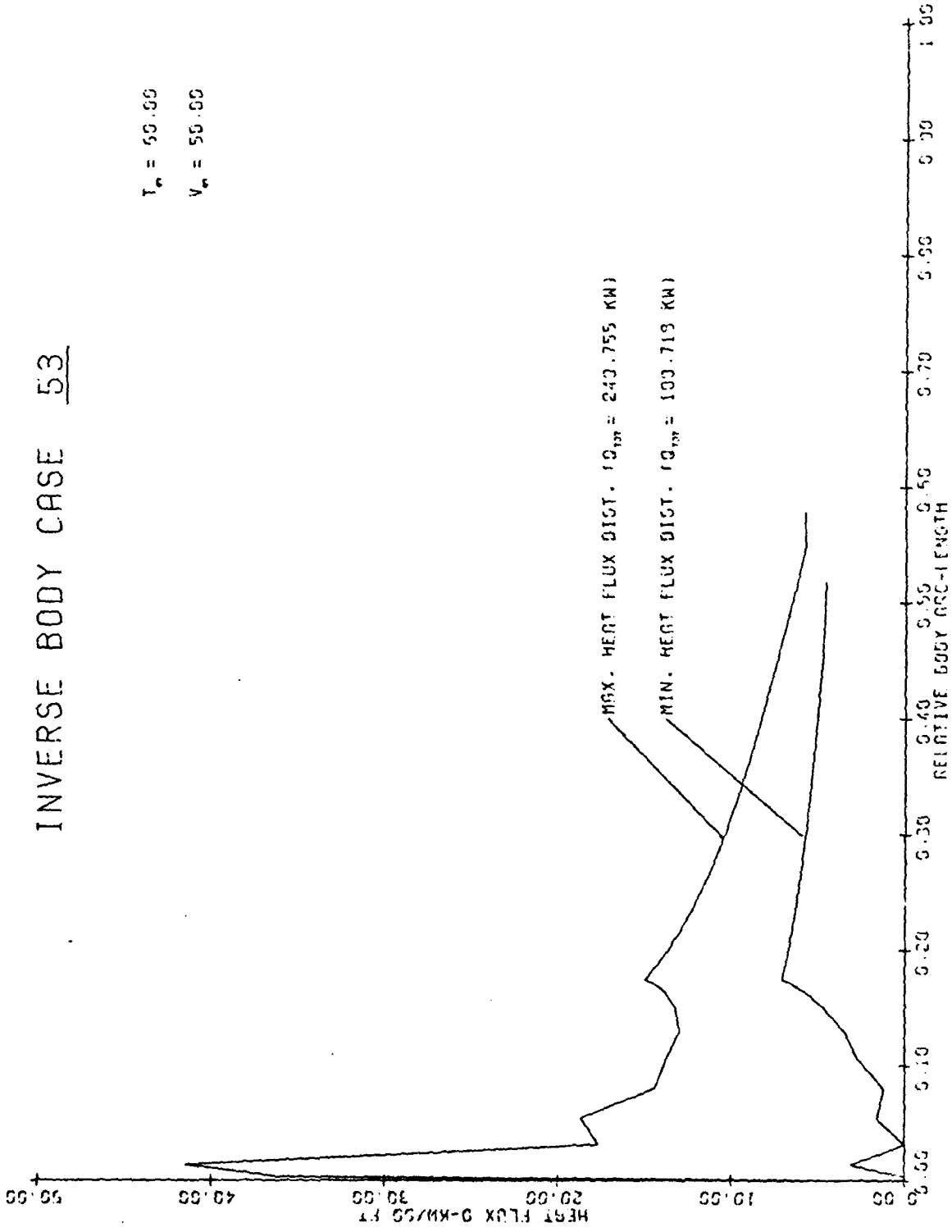


Figure 193. Heat Flux Distributions, Case No. 53.

INVERSE BODY CASE 54

$T_w = 50.00$   
 $V_w = 50.00$

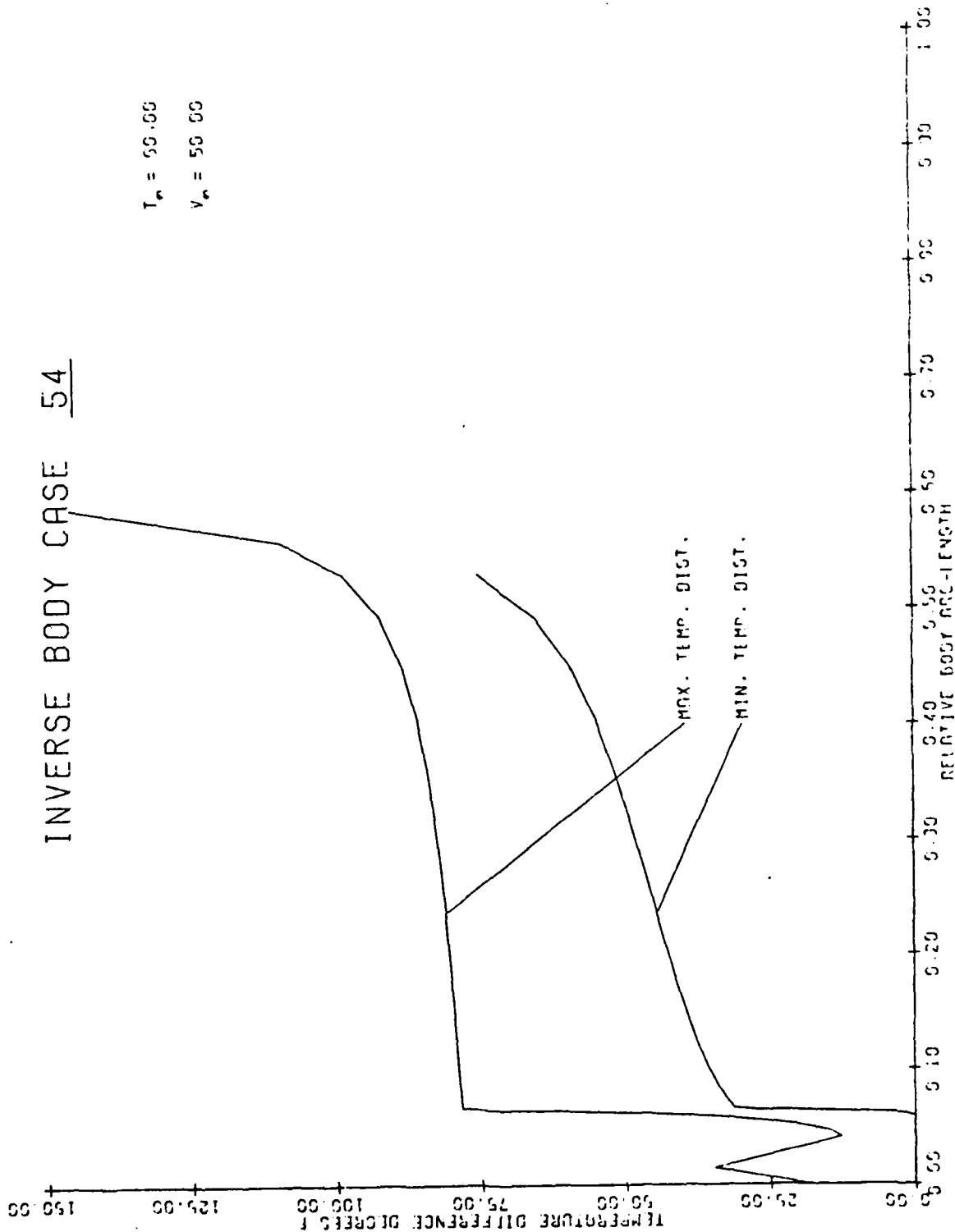


Figure 194. Temperature Distributions, Case No. 54.

INVERSE BODY CASE 54

$T_w = 50.00$

$V_w = 50.00$

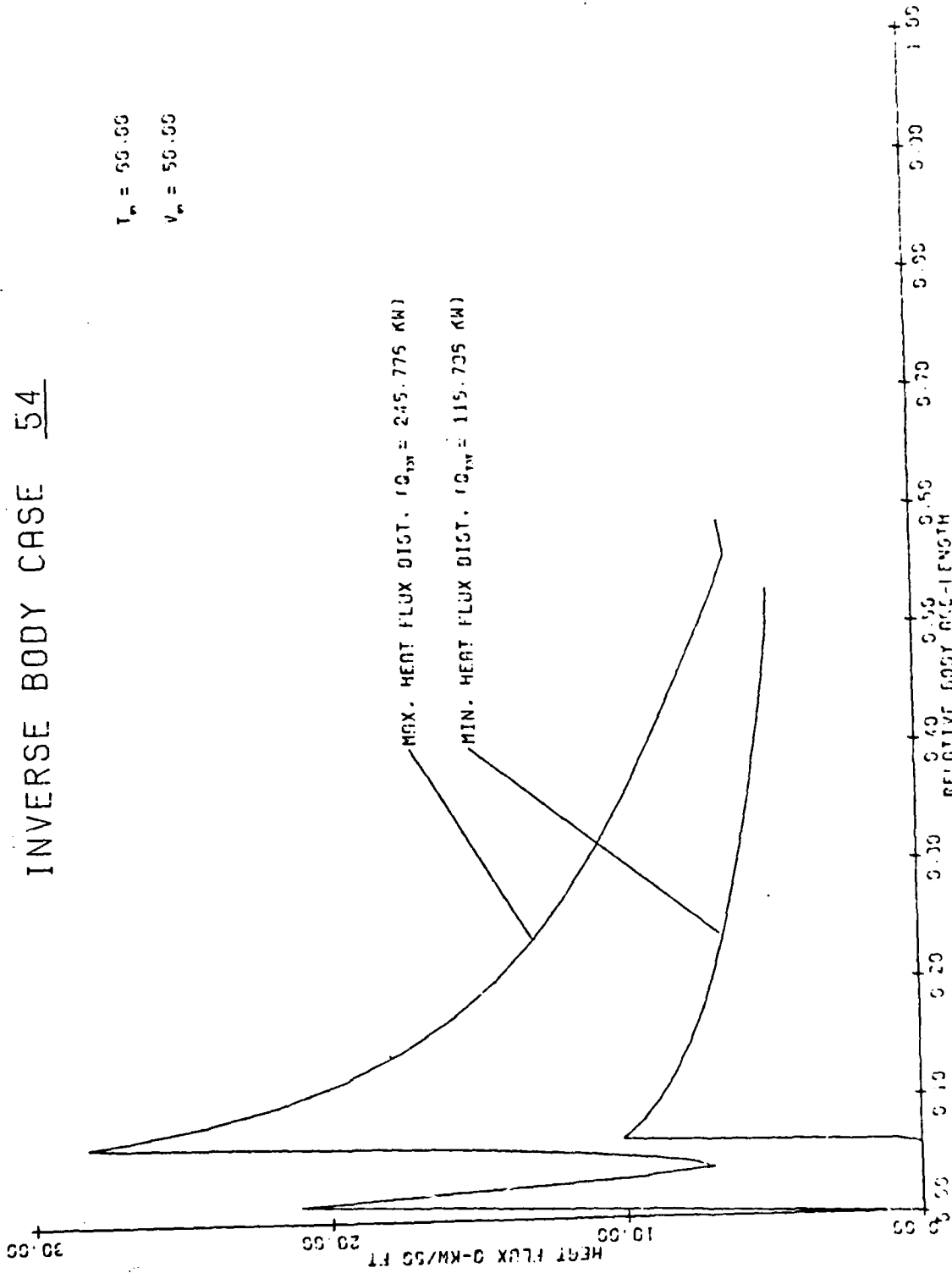


Figure 195. Heat Flux Distributions, Case No. 54.

INVERSE BODY CASE 55

$T_p = 50.00$   
 $V_p = 50.00$

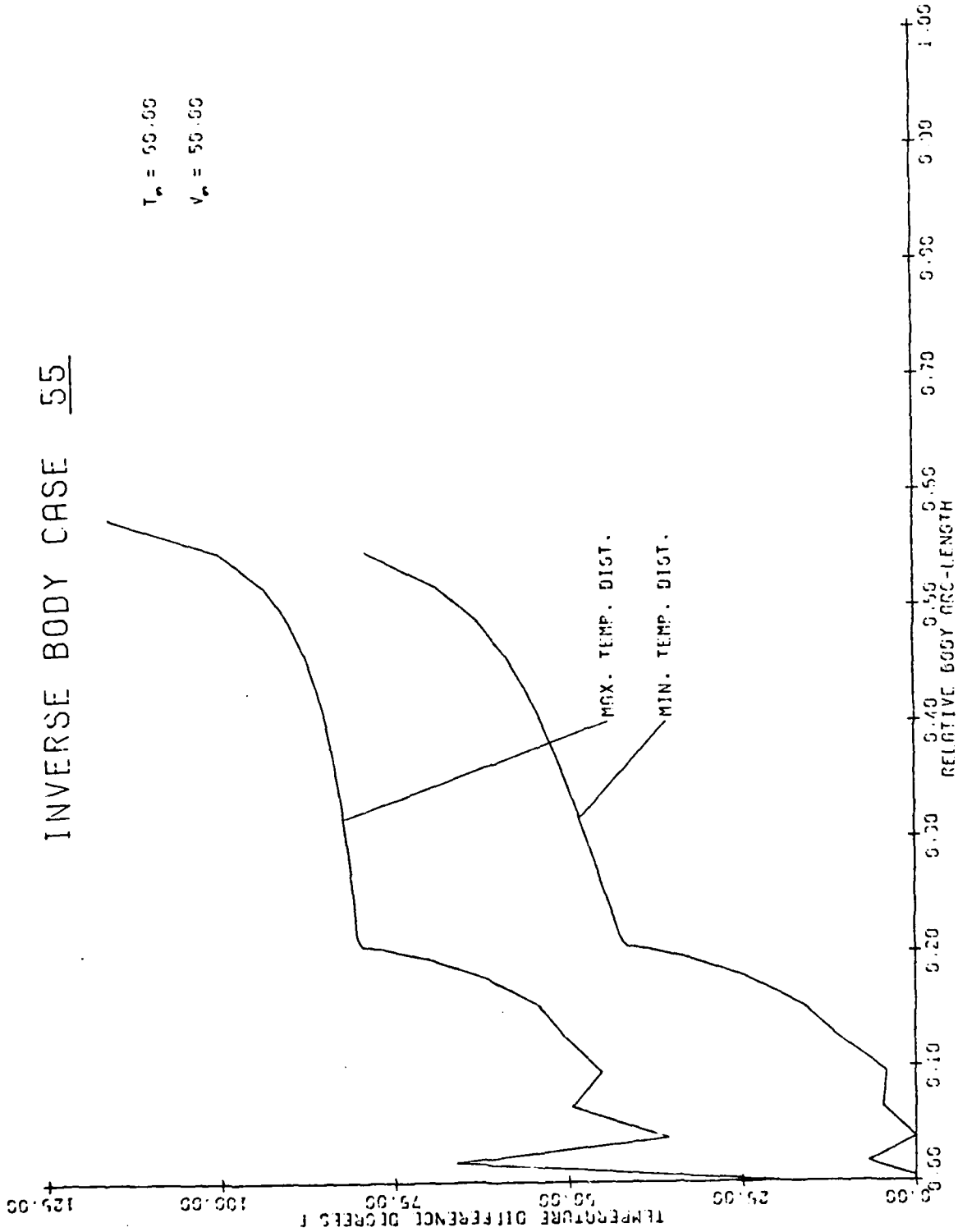


Figure 196. Temperature Distributions, Case No. 55.

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INVERSE BODY CASE 55

$T_w = 99.00$   
 $V_w = 50.00$

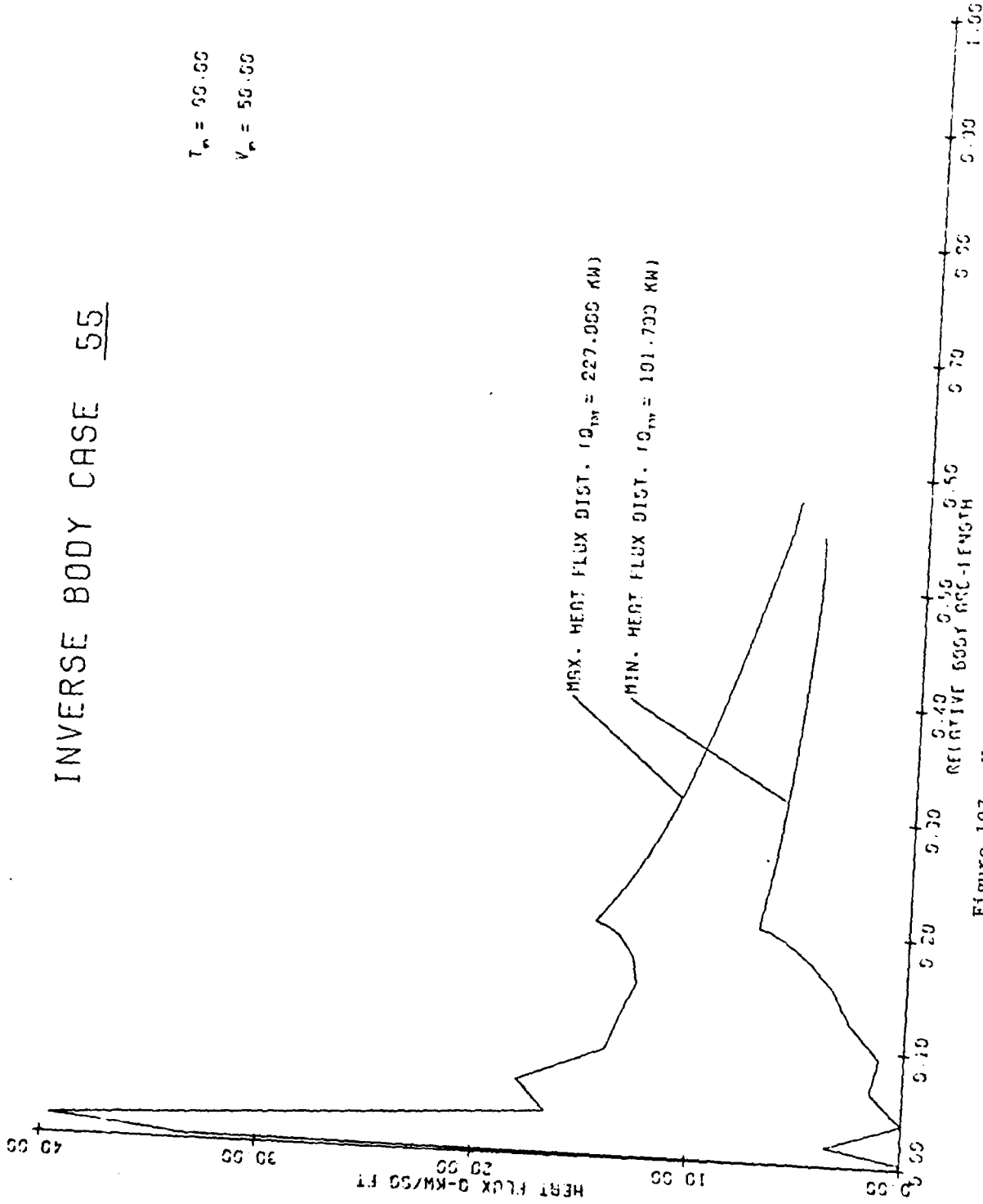


Figure 197. Heat Flux Distributions, Case No. 55.

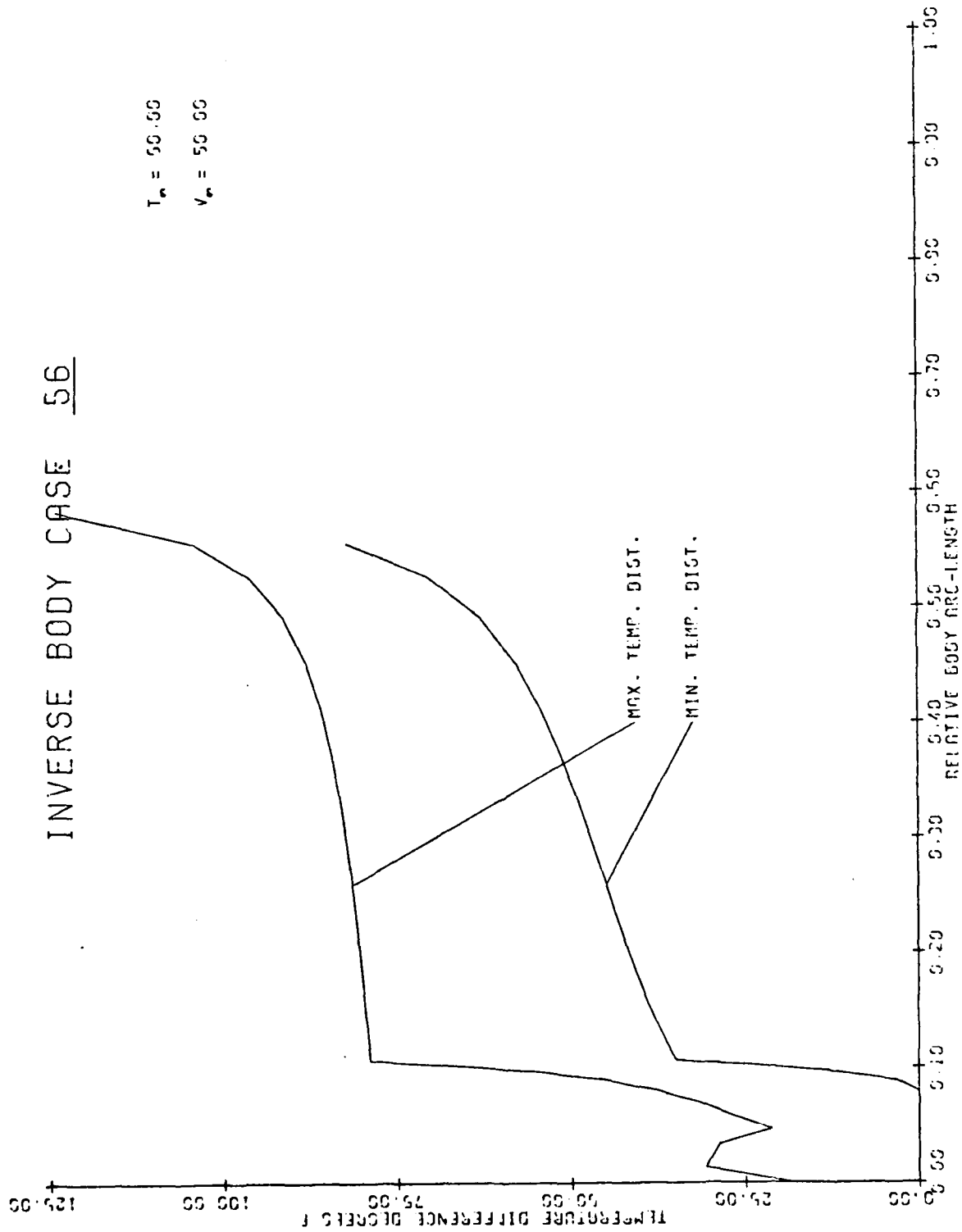


Figure 198. Temperature Distributions, Case No. 56.

# INVERSE BODY CASE 56

$T_w = 50.00$

$V_w = 50.00$

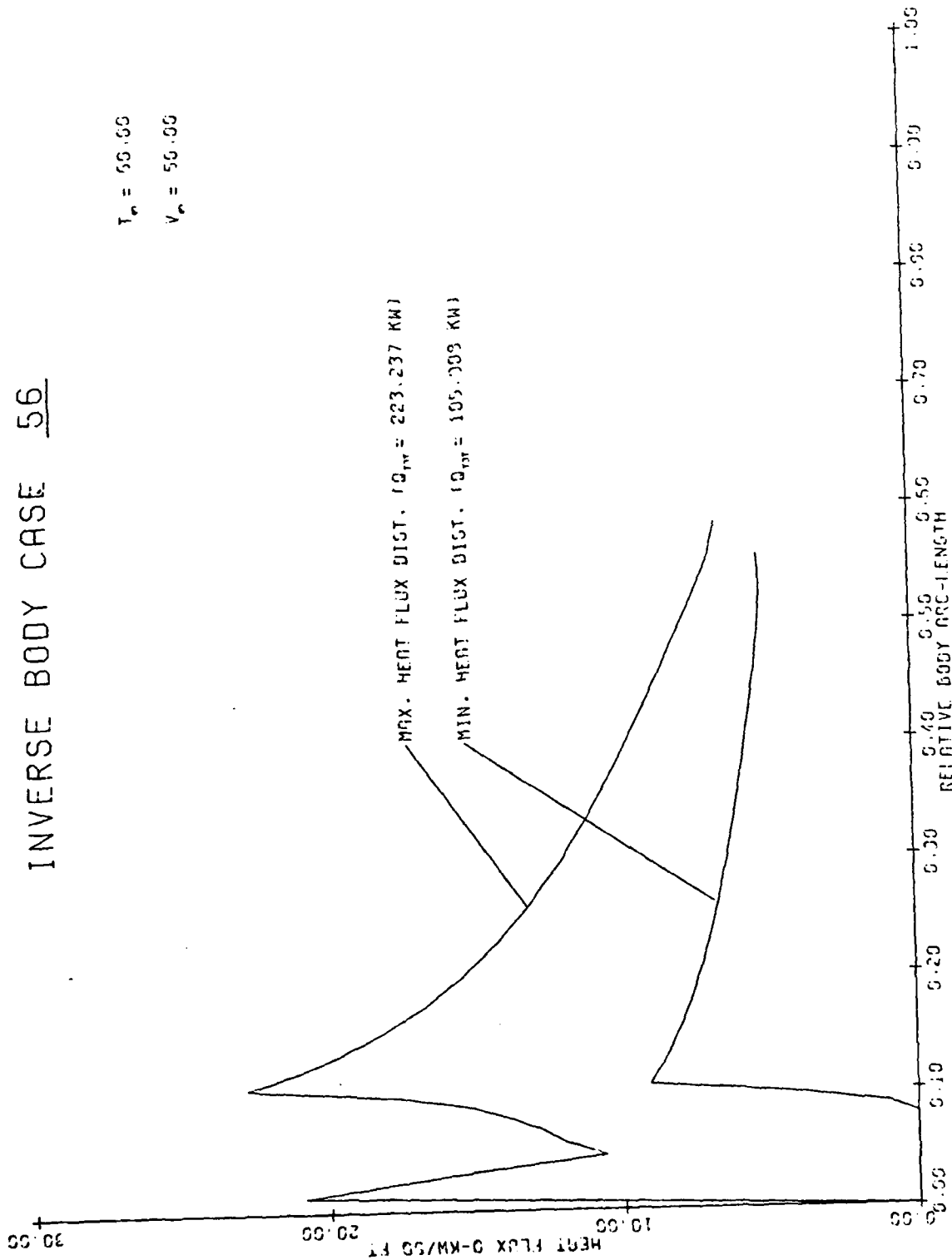


Figure 199. Heat Flux Distributions, Case No. 56.

INVERSE BODY CASE 57

$T_m = 55.00$

$V_m = 50.00$

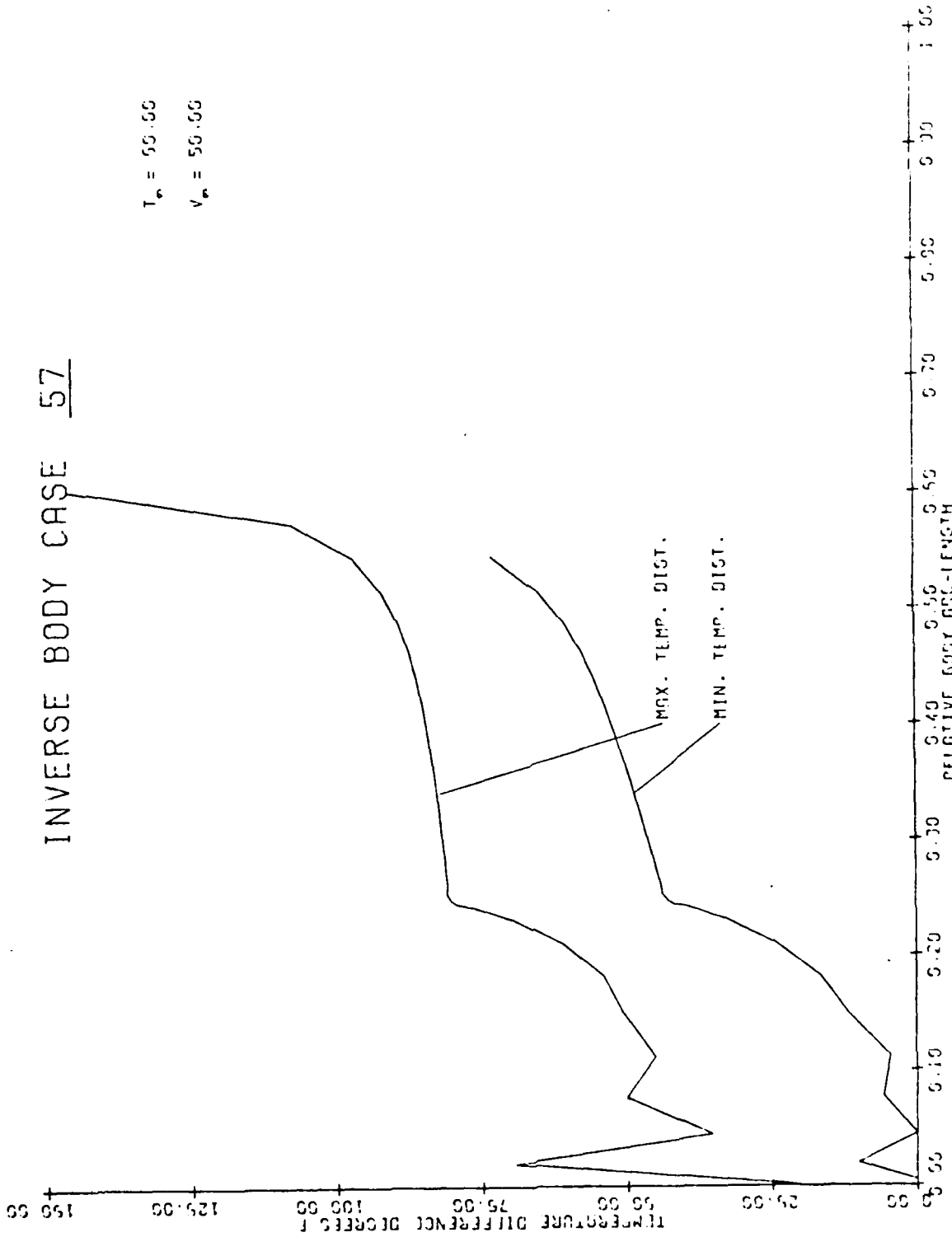


Figure 200. Temperature Distributions, Case No. 57.

INVERSE BODY CASE 57

$T_w = 50.00$   
 $V_w = 50.00$

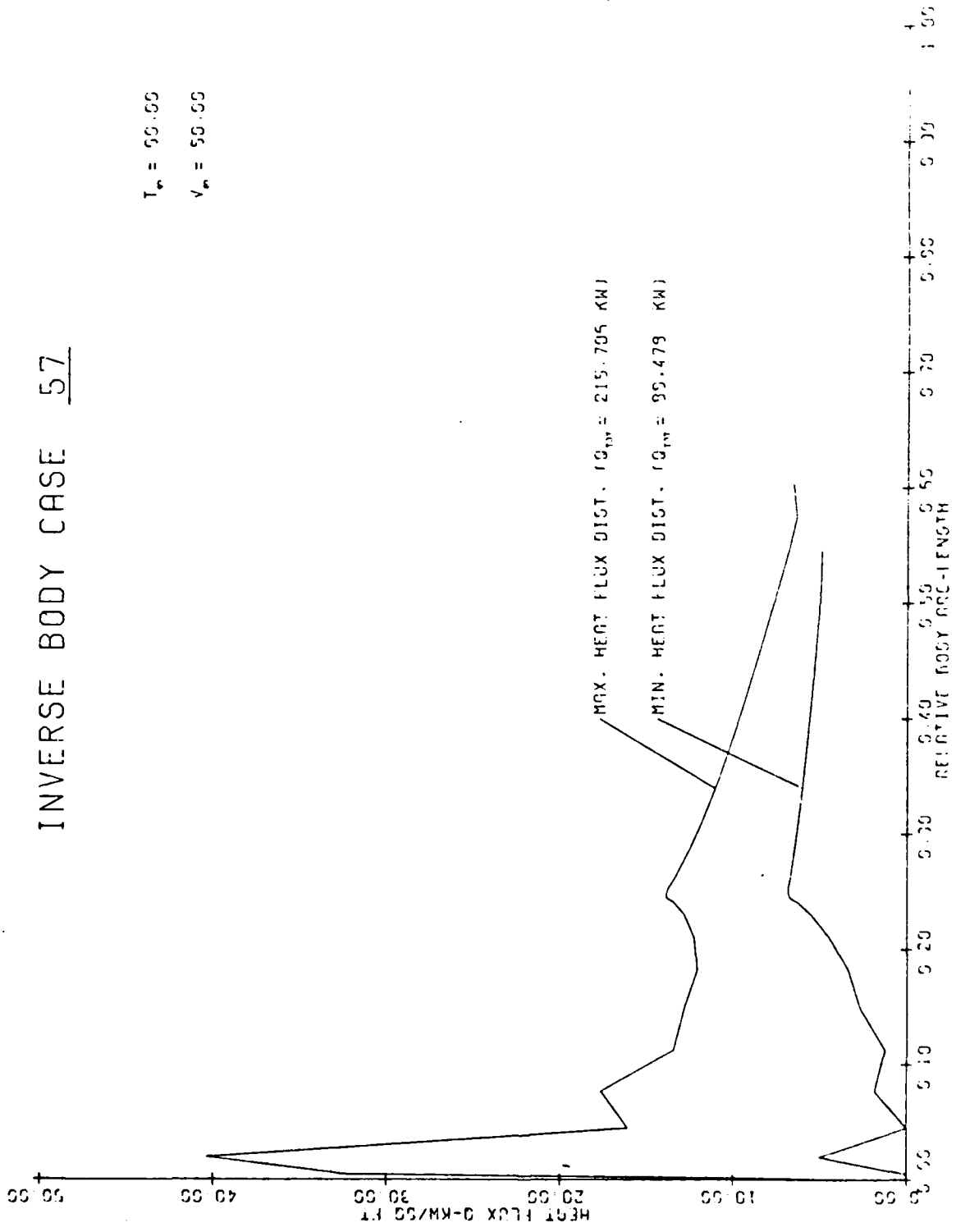


Figure 201. Heat Flux Distributions, Case No. 57.

INVERSE BODY CASE 58

$T_w = 90.00$

$V_w = 50.00$

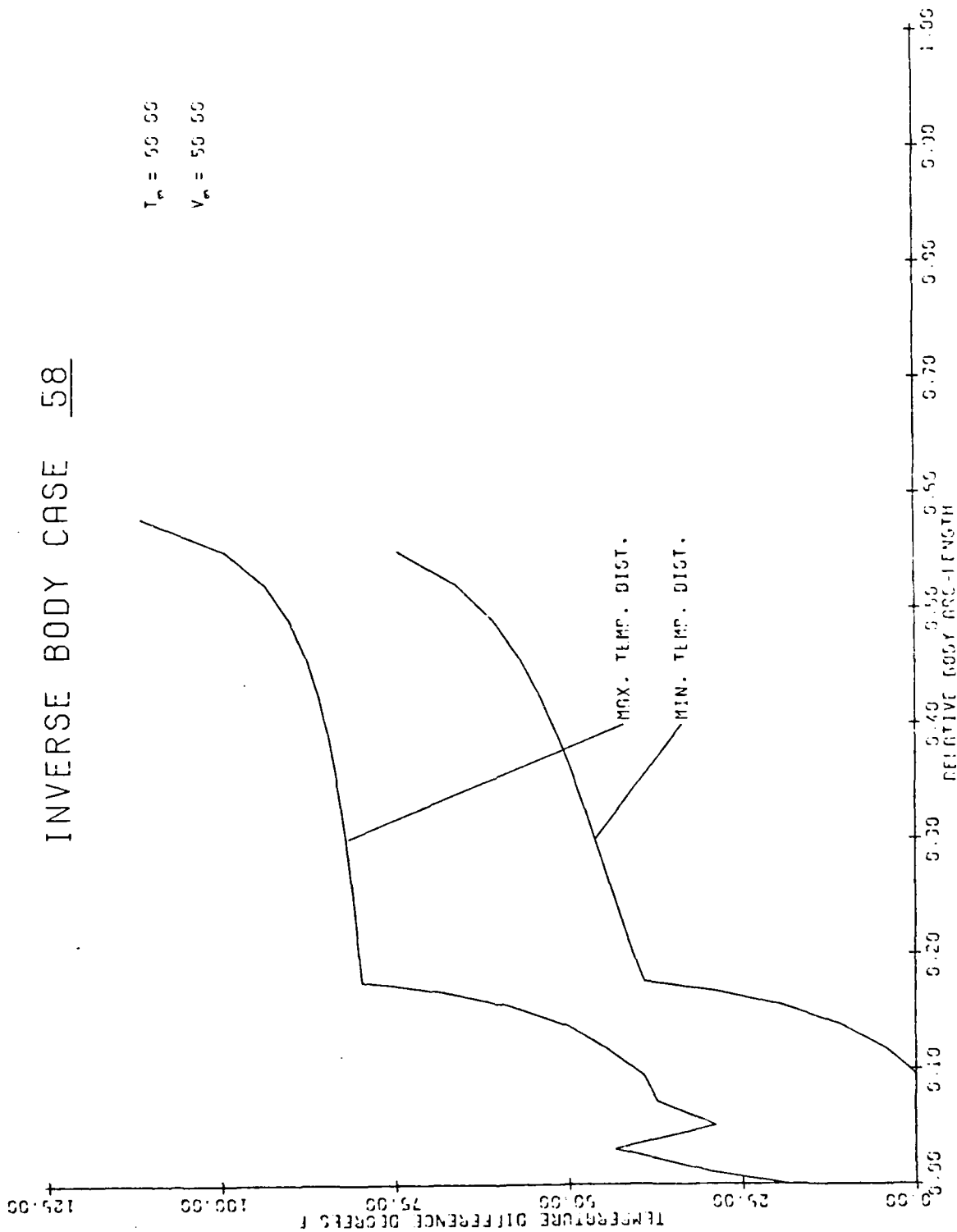


Figure 202. Temperature Distributions, Case No. 58.

INVERSE BODY CASE 58

$T_w = 50.00$   
 $V_w = 50.00$

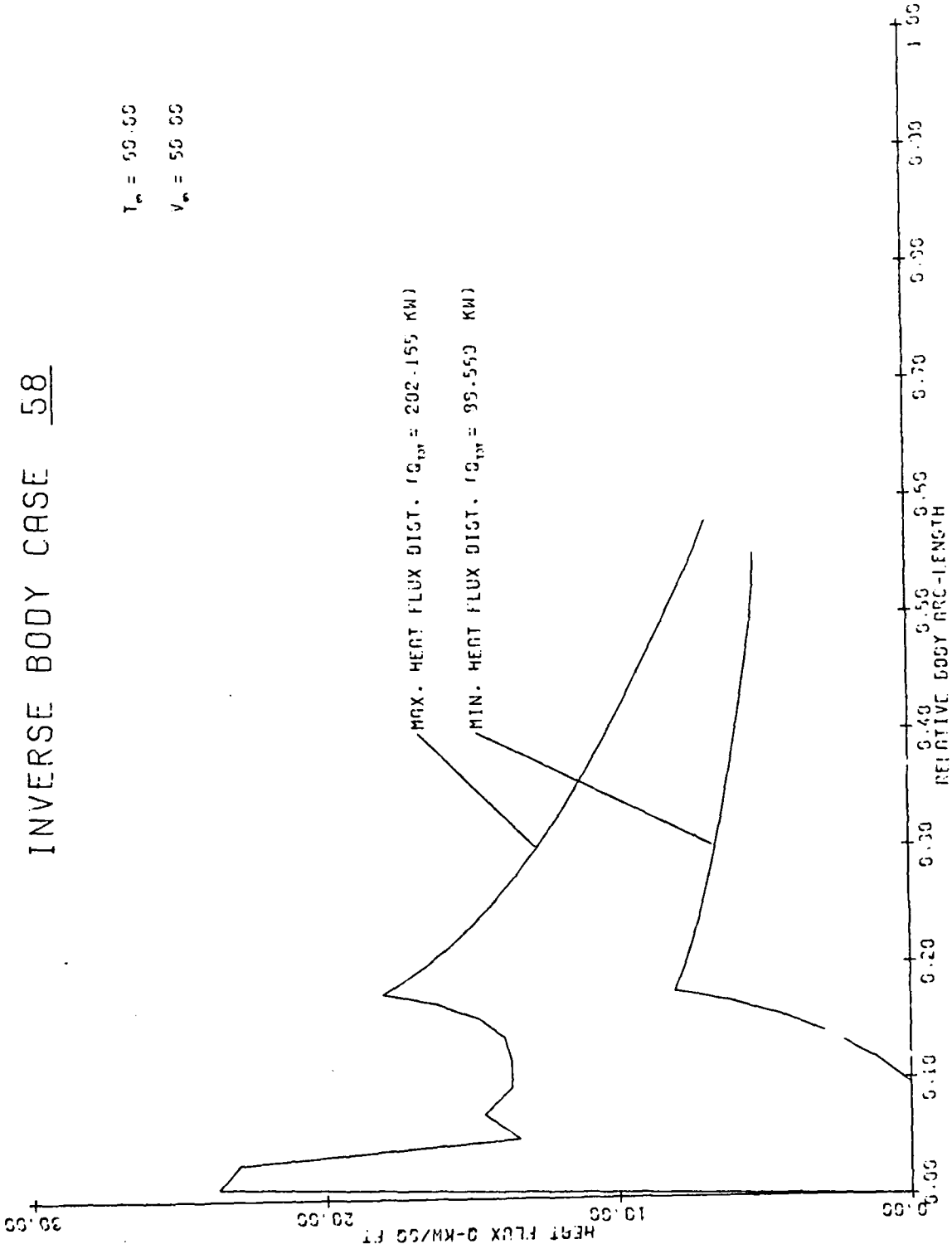


Figure 203. Heat Flux Distributions, Case No. 58.

INVERSE BODY CASE 59

$T_m = 50.00$   
 $V_m = 50.00$

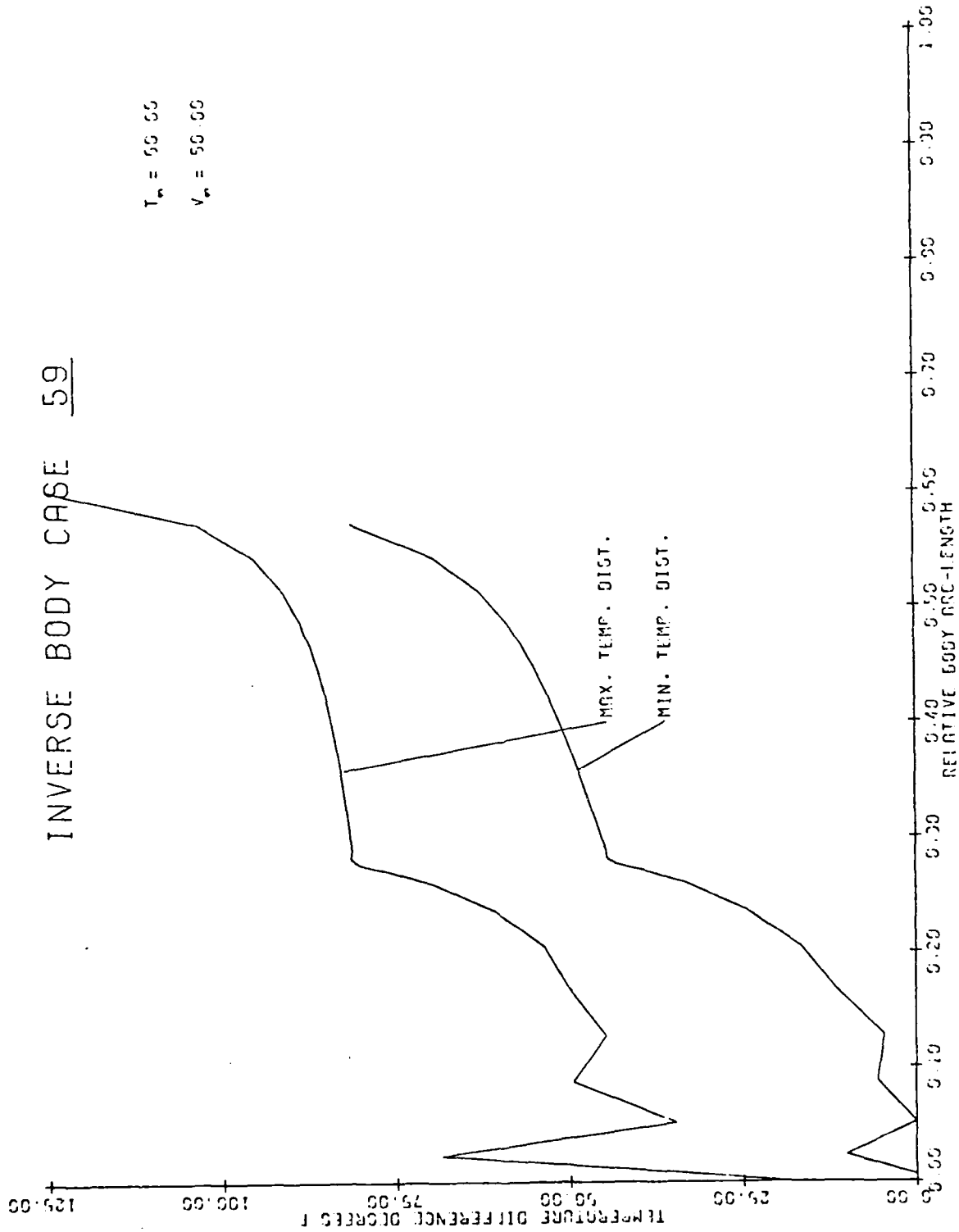


Figure 204. Temperature Distributions, Case No. 59.

INVERSE BODY CASE 59

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

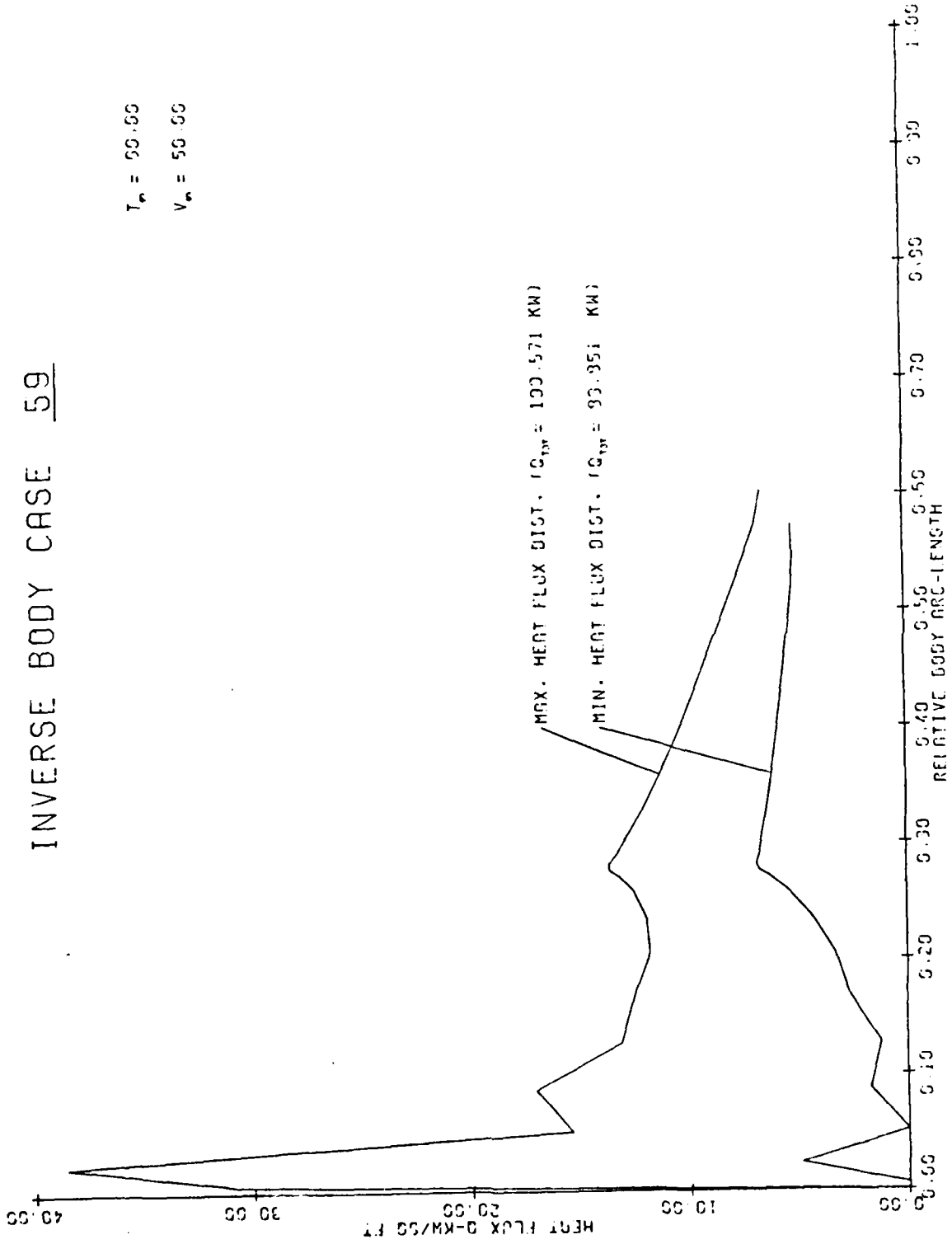


Figure 205. Heat Flux Distributions, Case No. 59.

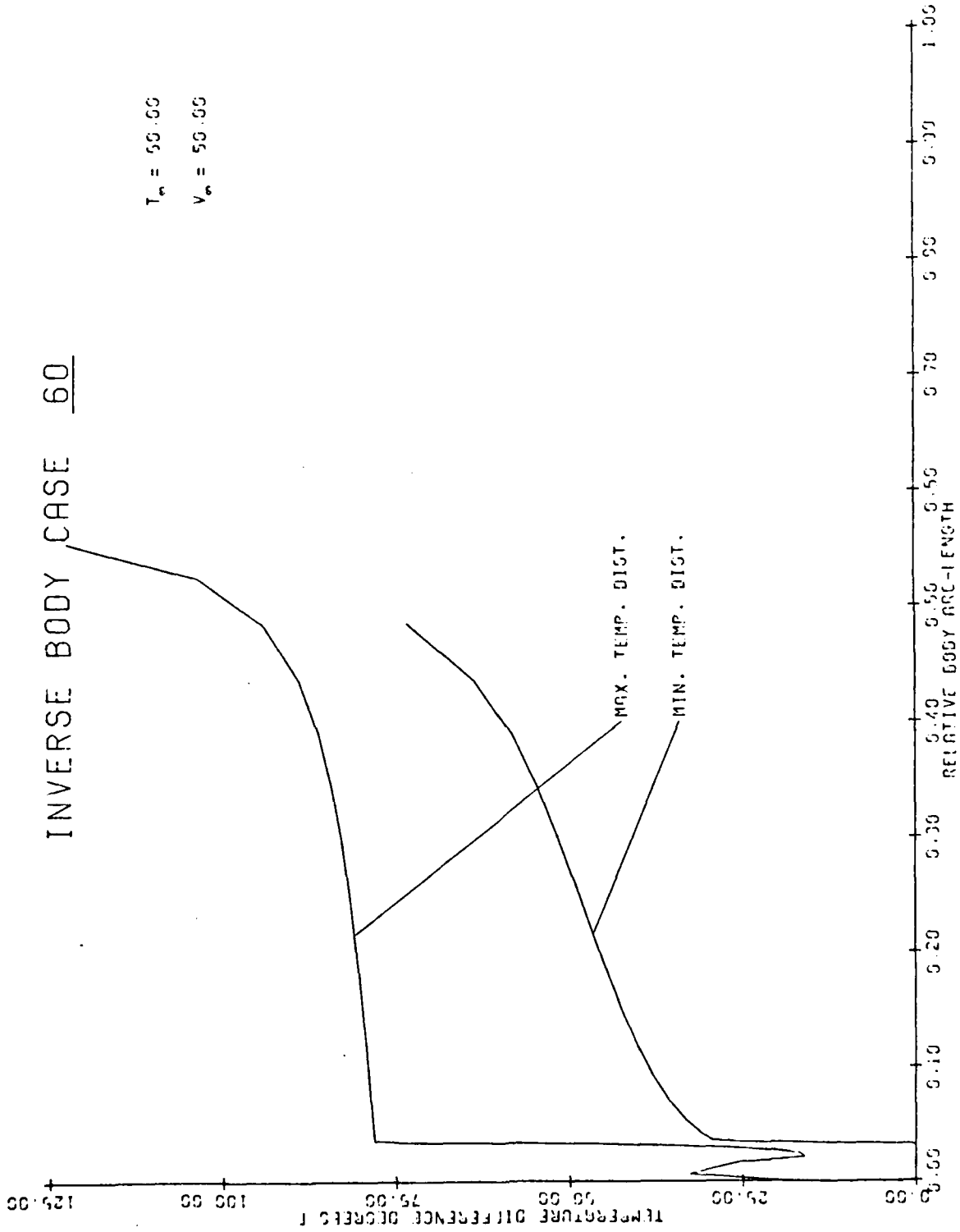


Figure 206. Temperature Distributions, Case No. 60.

INVERSE BODY CASE 60

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

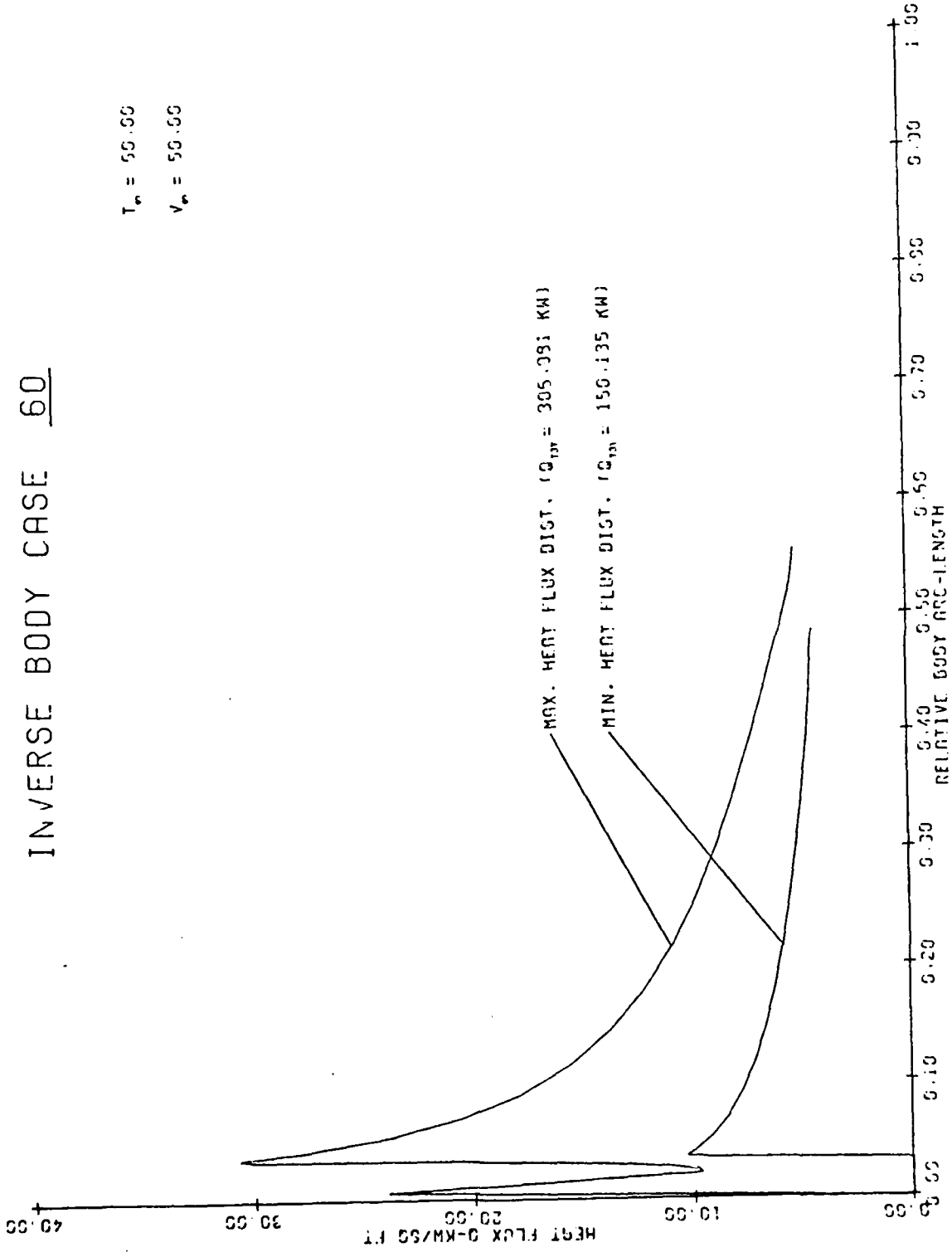


Figure 207. Heat Flux Distributions, Case No. 60.

INVERSE BODY CASE 61

$T_m = 50.00$   
 $V_m = 50.00$

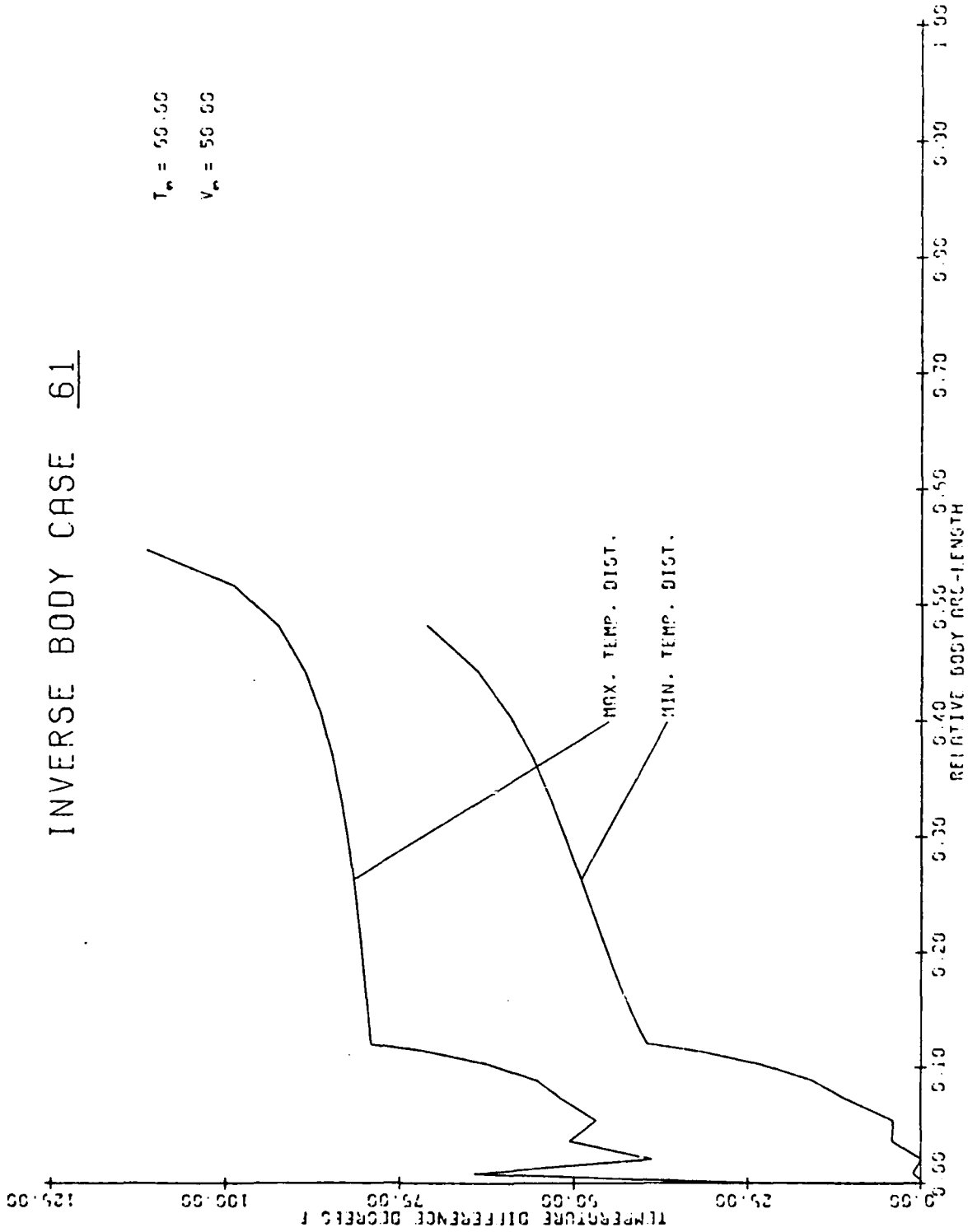


Figure 208. Temperature Distributions, Case No. 61.

INVERSE BODY CASE 61

$T_p = 50.00$   
 $V_p = 50.00$

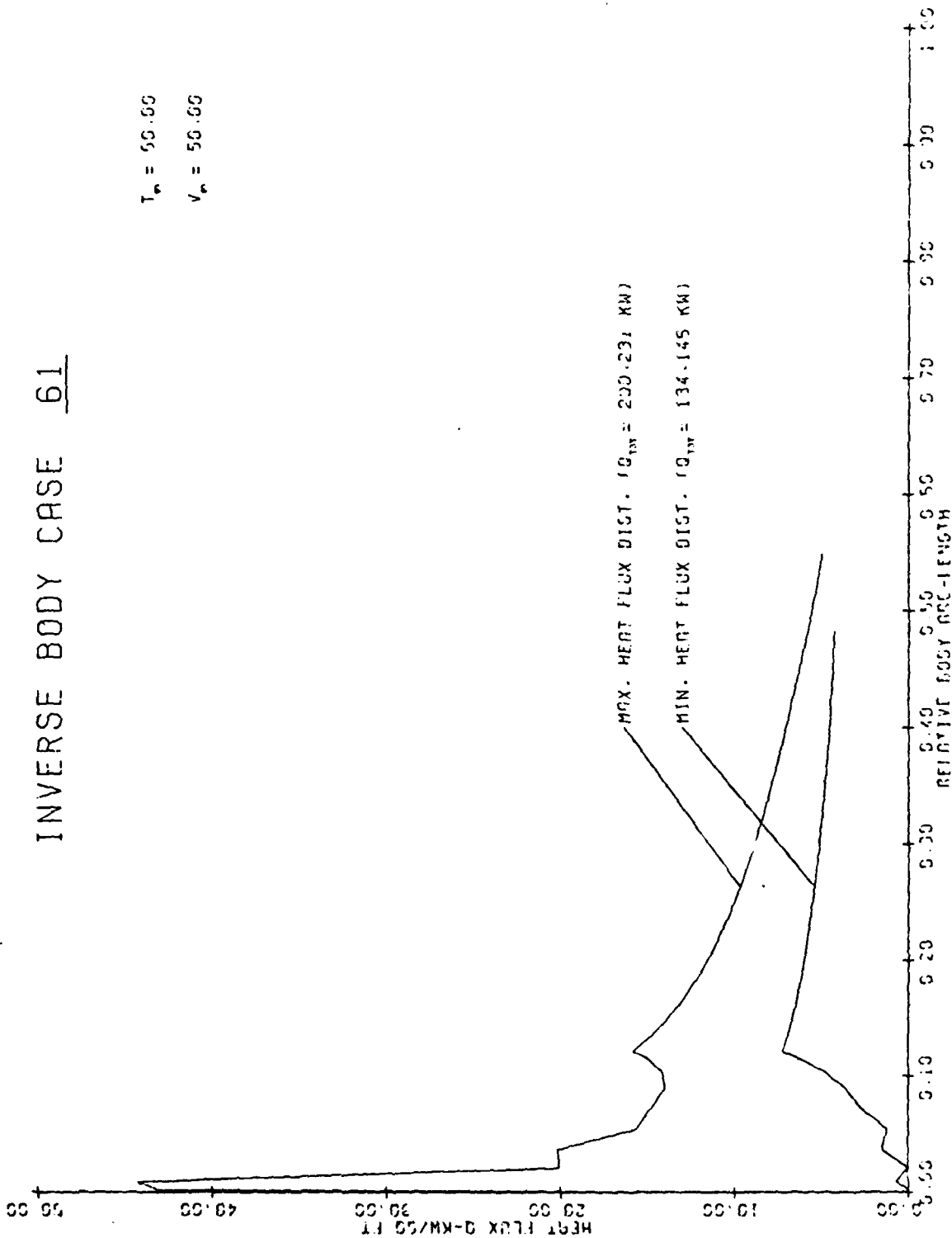


Figure 209. Heat Flux Distributions, Case No. 61.

INVERSE BODY CASE 62

$T_m = 50.00$   
 $V_m = 50.00$

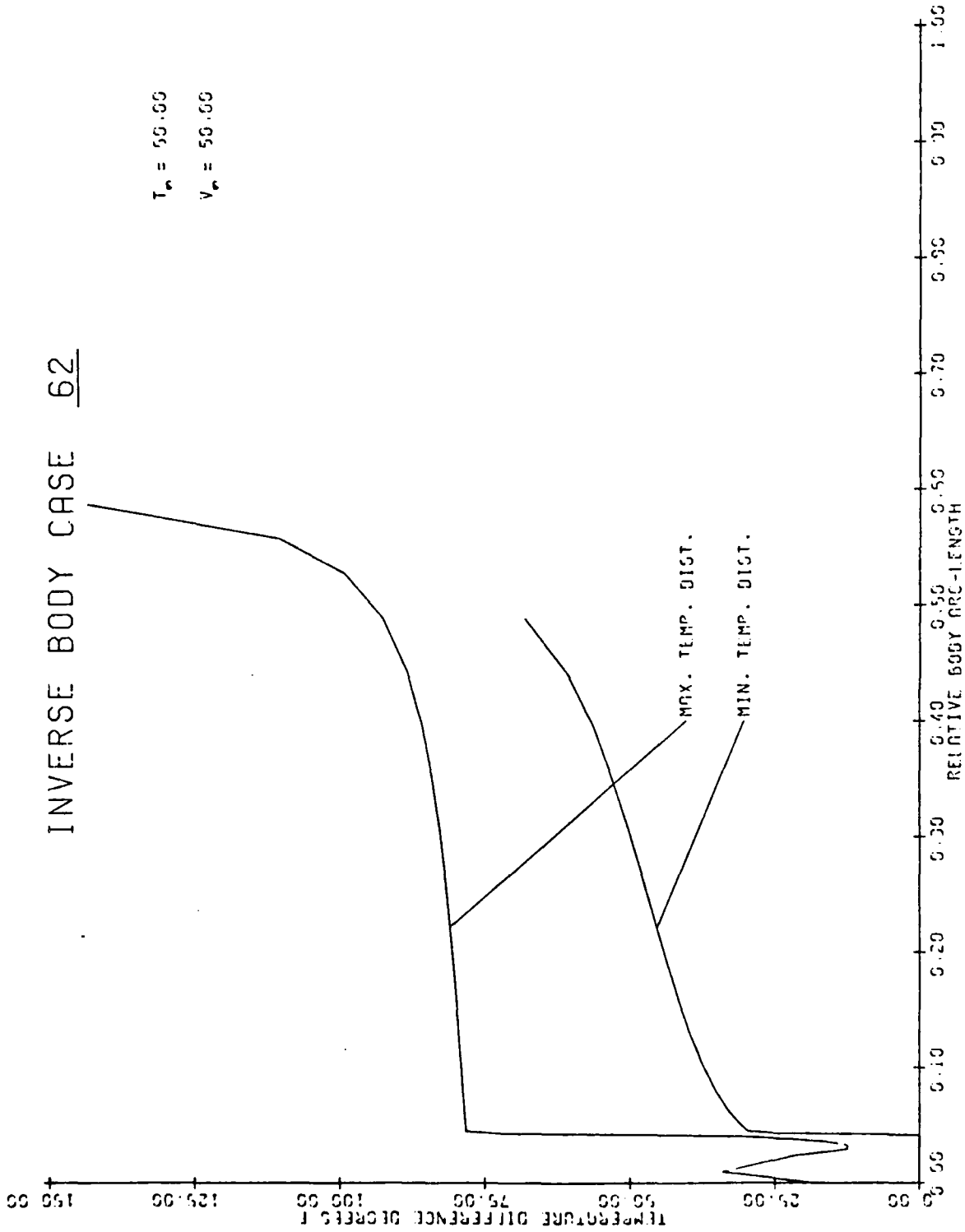


Figure 210. Temperature Distributions, Case No. 62.

INVERSE BODY CASE 62

$T_a = 50.00$

$V_a = 50.00$

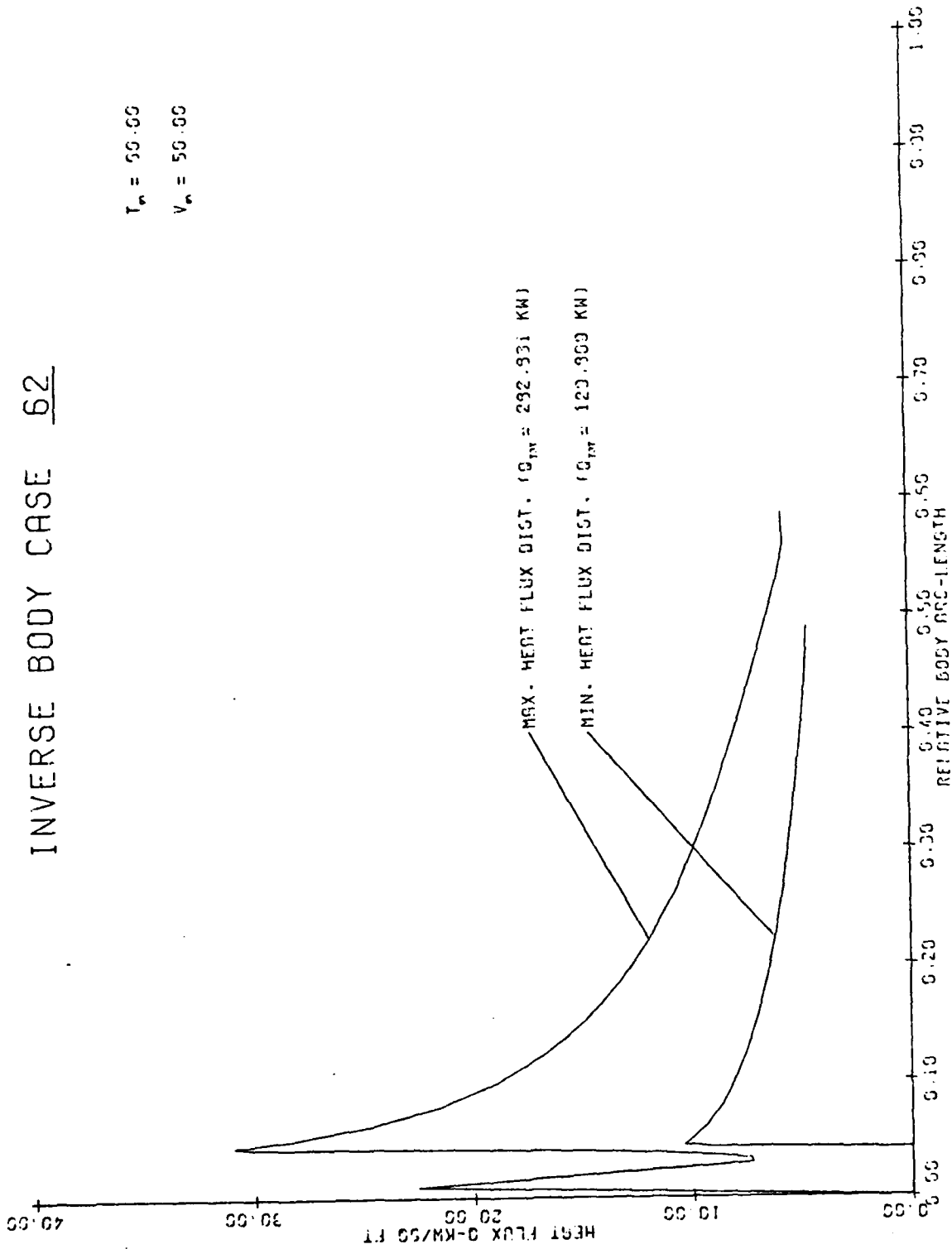


Figure 211. Heat Flux Distributions, Case No. 62.

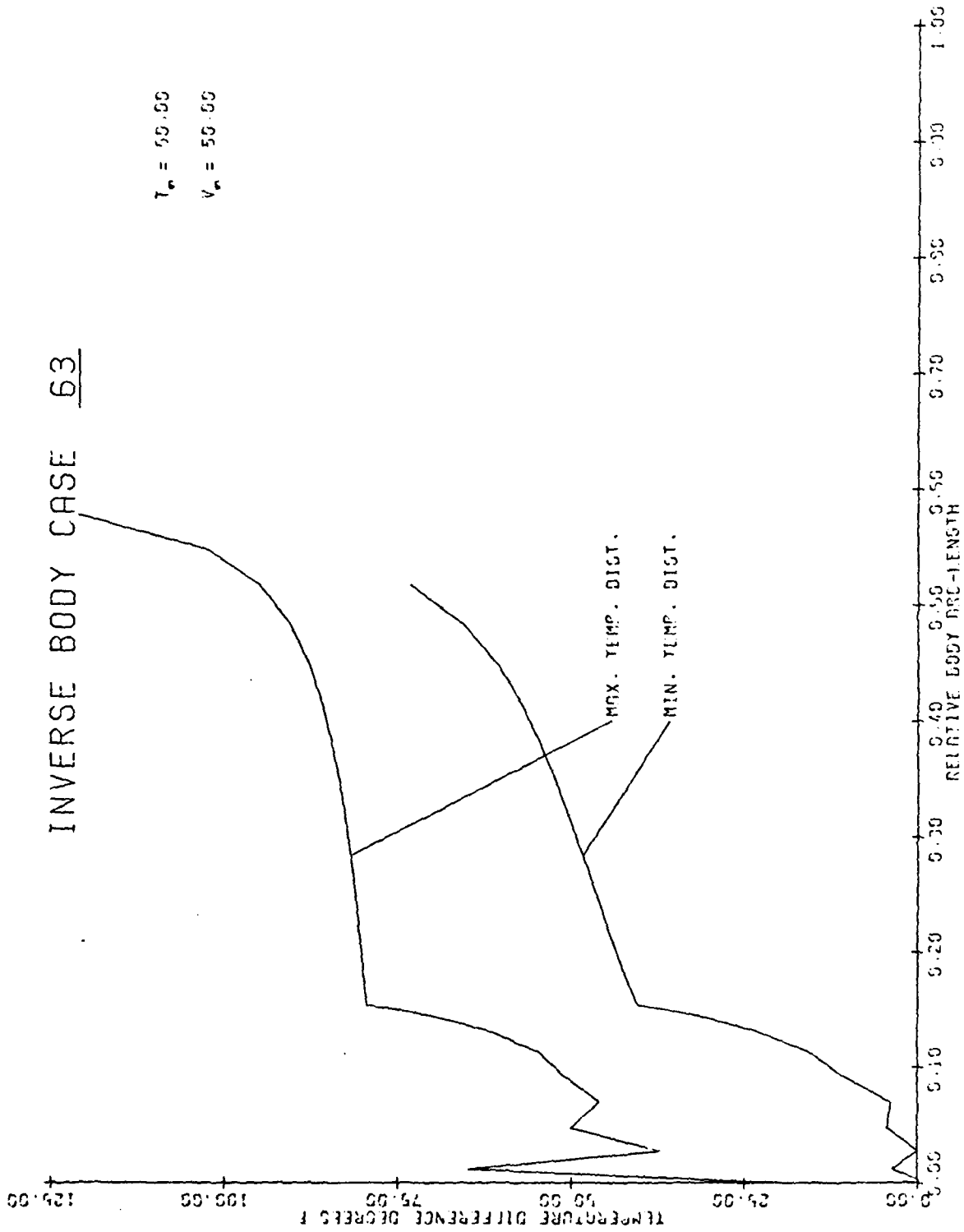


Figure 212. Temperature Distributions, Case No. 63.

INVERSE BODY CASE 63

$T_m = 50.00$

$V_m = 50.00$

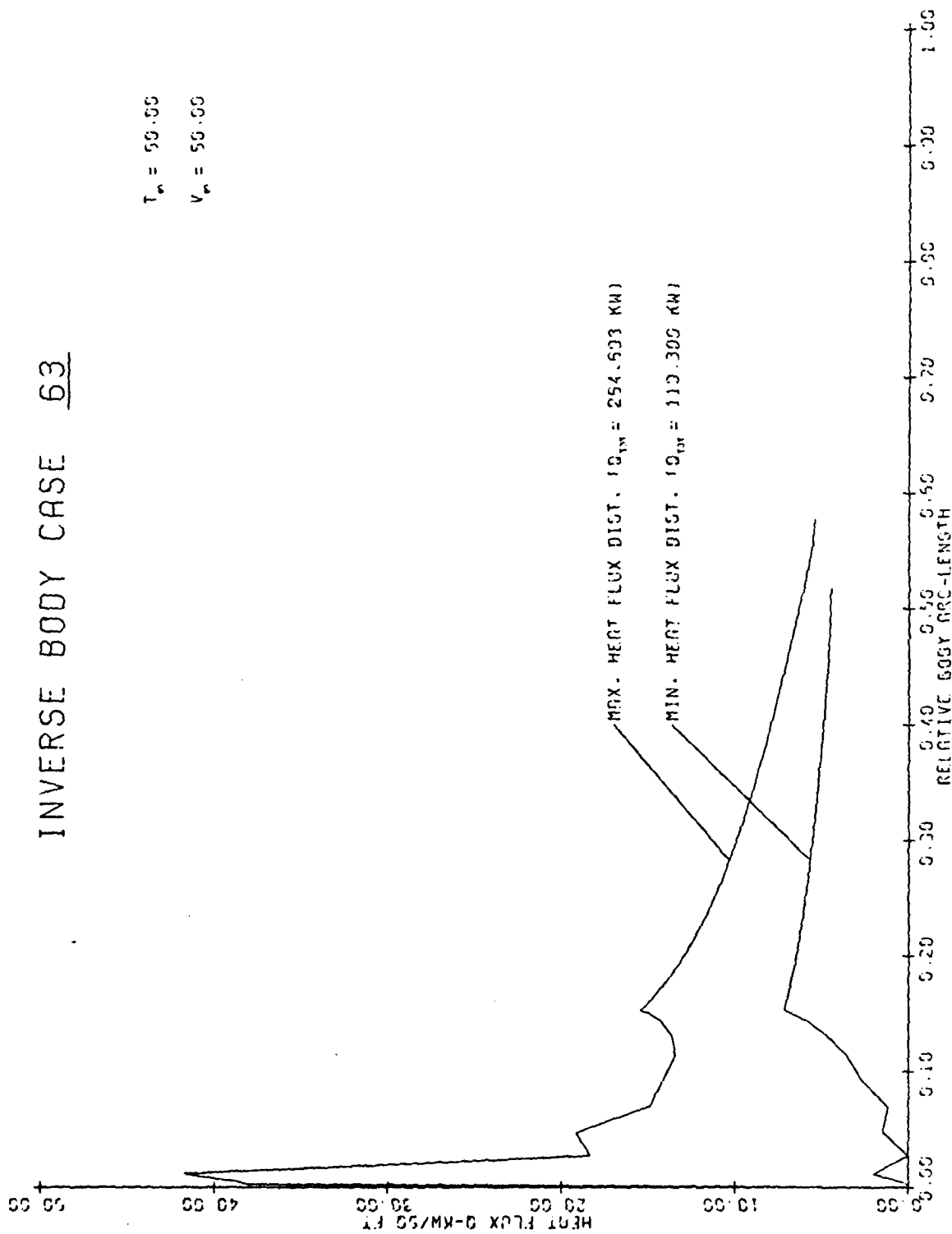


Figure 213. Heat Flux Distributions, Case No. 63.

INVERSE BODY CASE 64

$T_w = 50.00$   
 $V_w = 50.00$

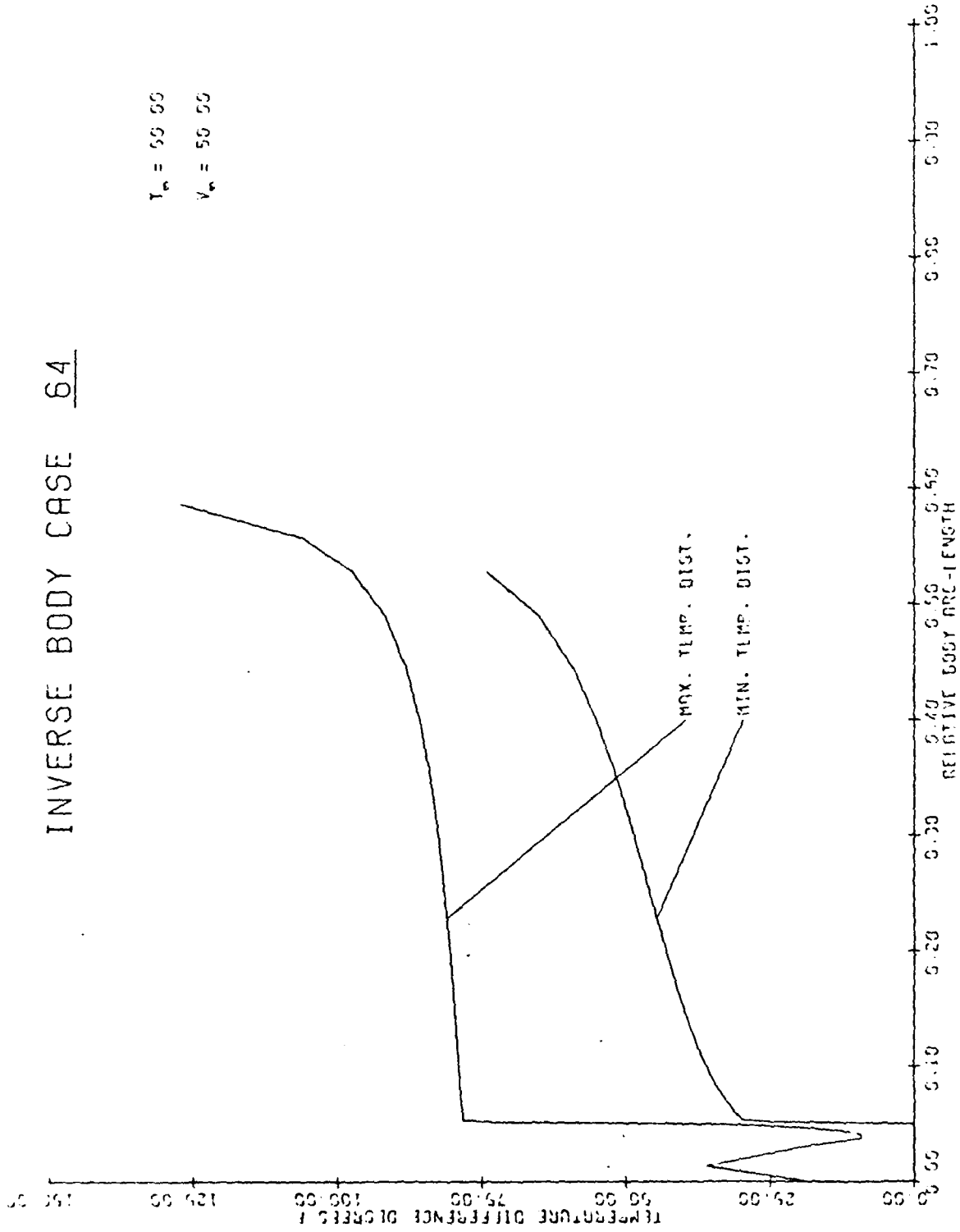


Figure 214. Temperature Distributions, Case No. 64.

INVERSE BODY CASE 64

$T_w = 50.00$   
 $V_w = 50.00$

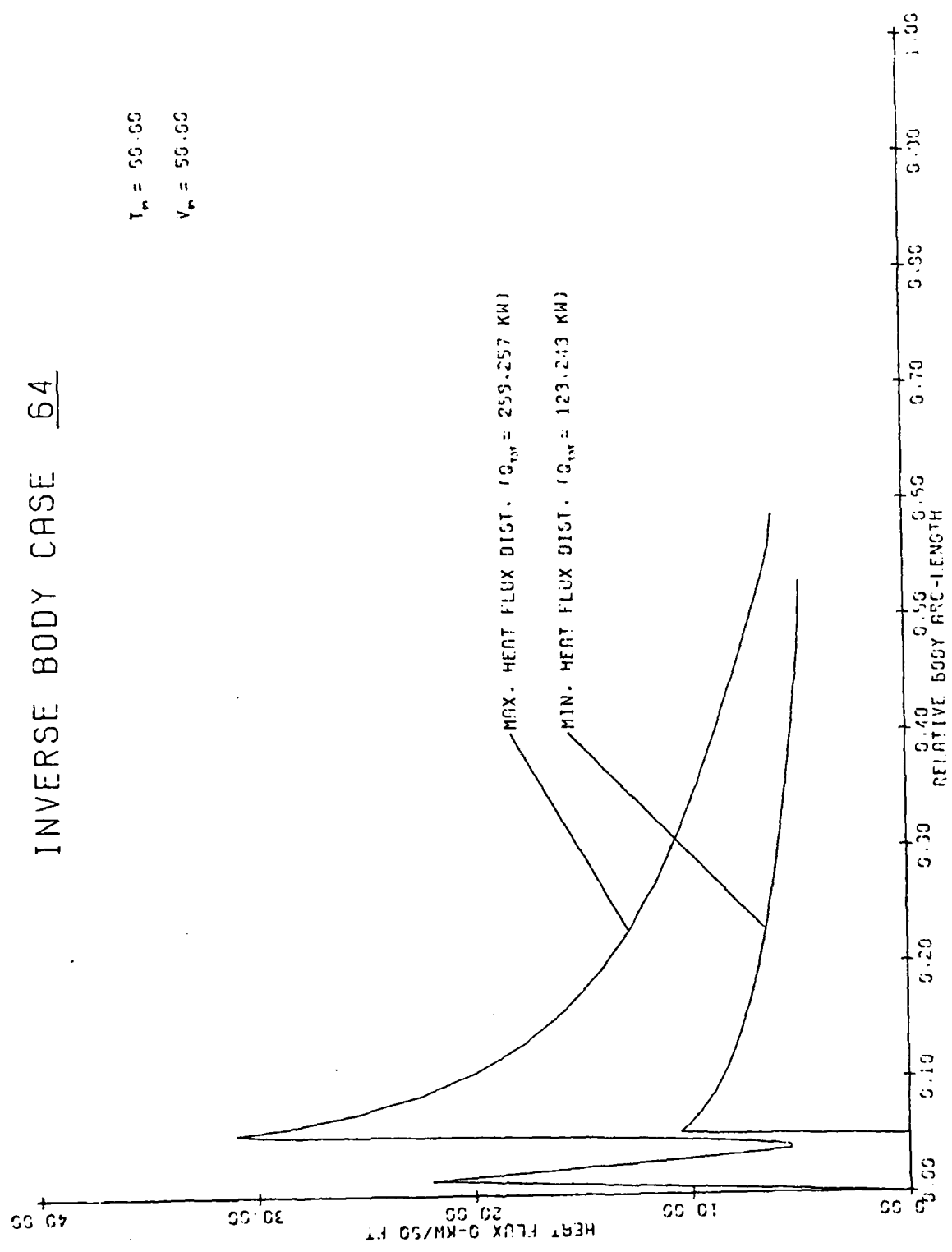


Figure 215. Heat Flux Distributions, Case No. 64.

INVERSE BODY CASE 65

$T_w = 50.00$   
 $V_w = 50.00$

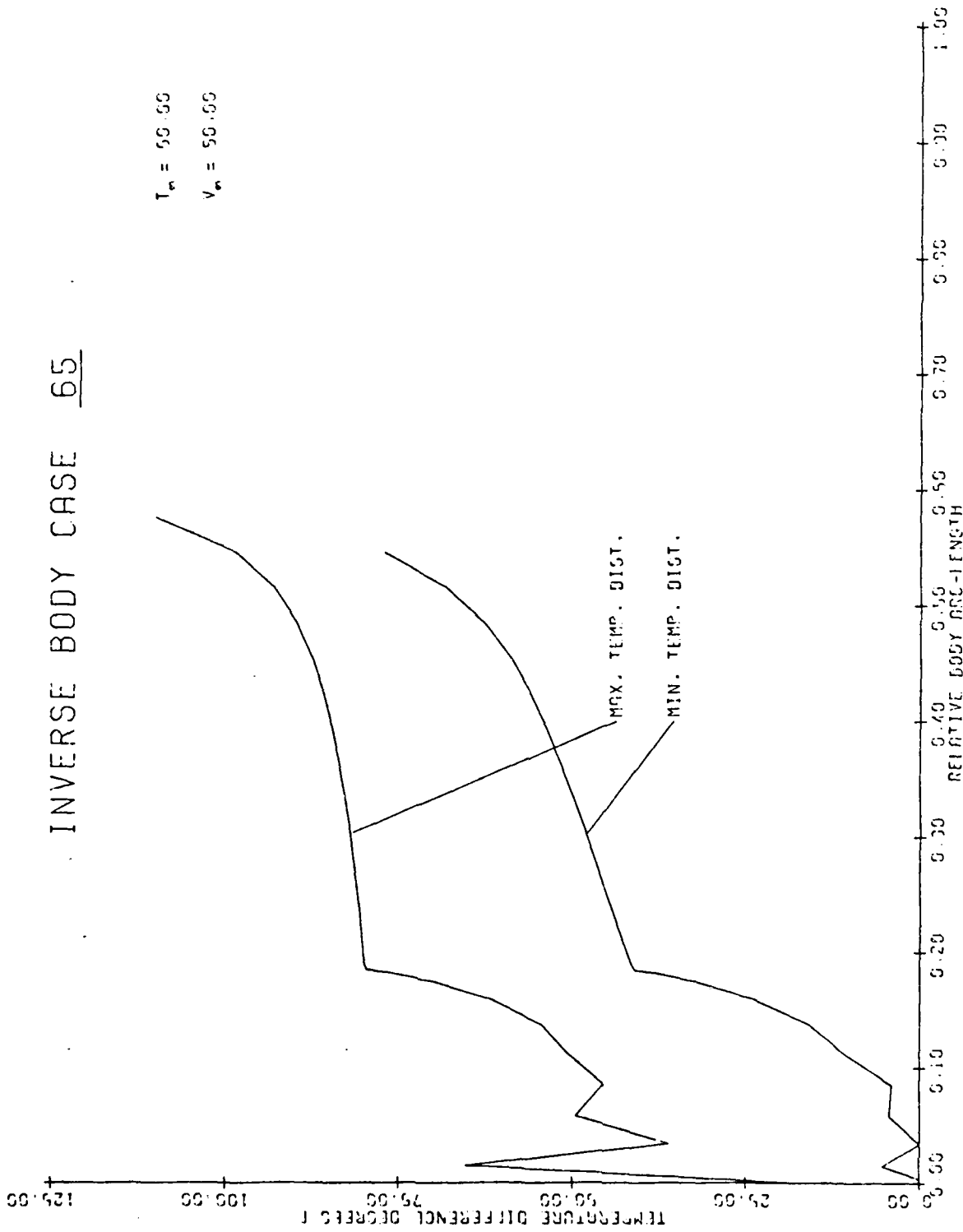


Figure 216. Temperature Distributions, Case No. 65.

INVERSE BODY CASE 65

$T_w = 50.55$

$V_w = 50.55$

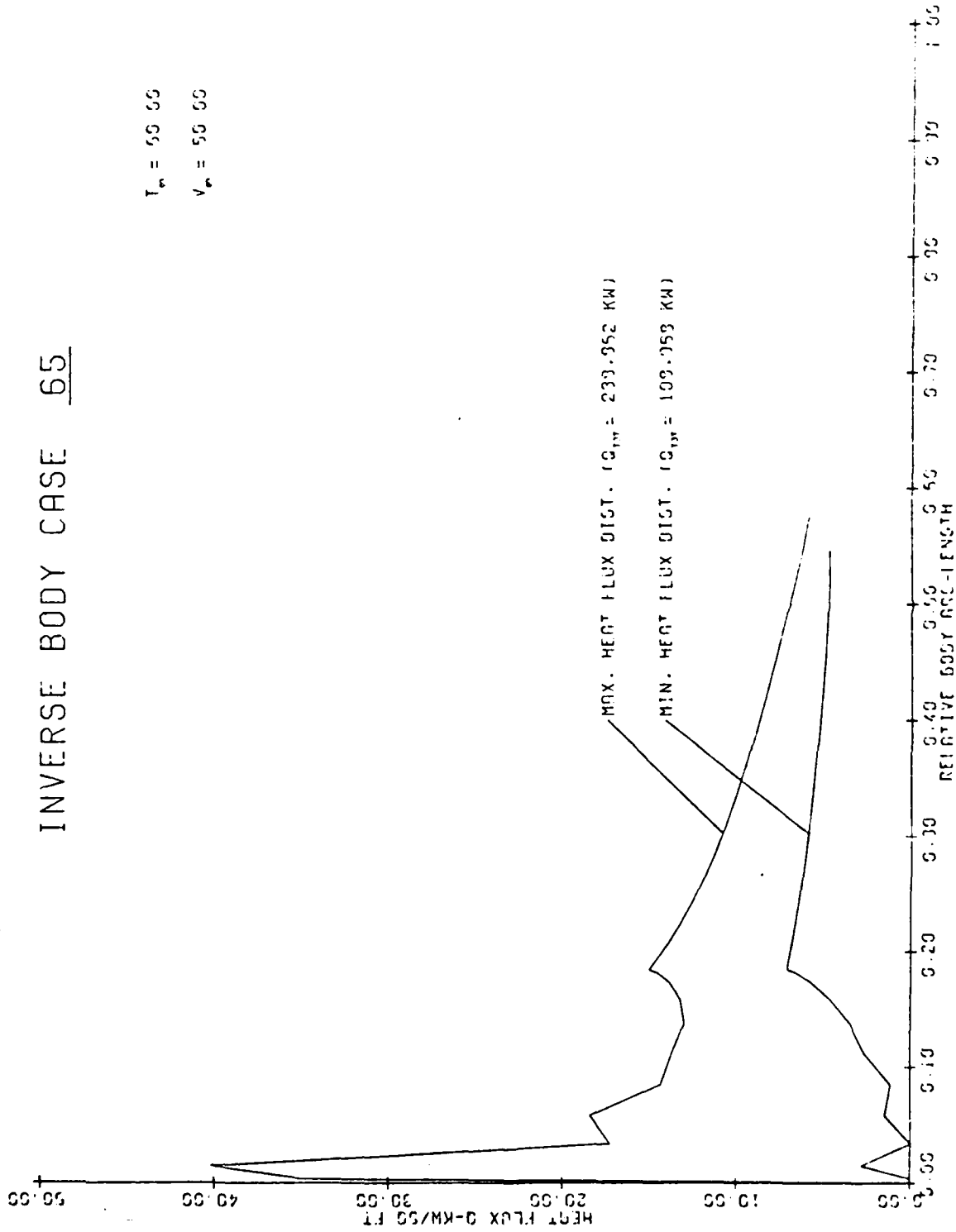


Figure 217. Heat Flux Distributions, Case No. 65.

INVERSE BODY CASE 66

$T_m = 50.55$   
 $V_m = 50.55$

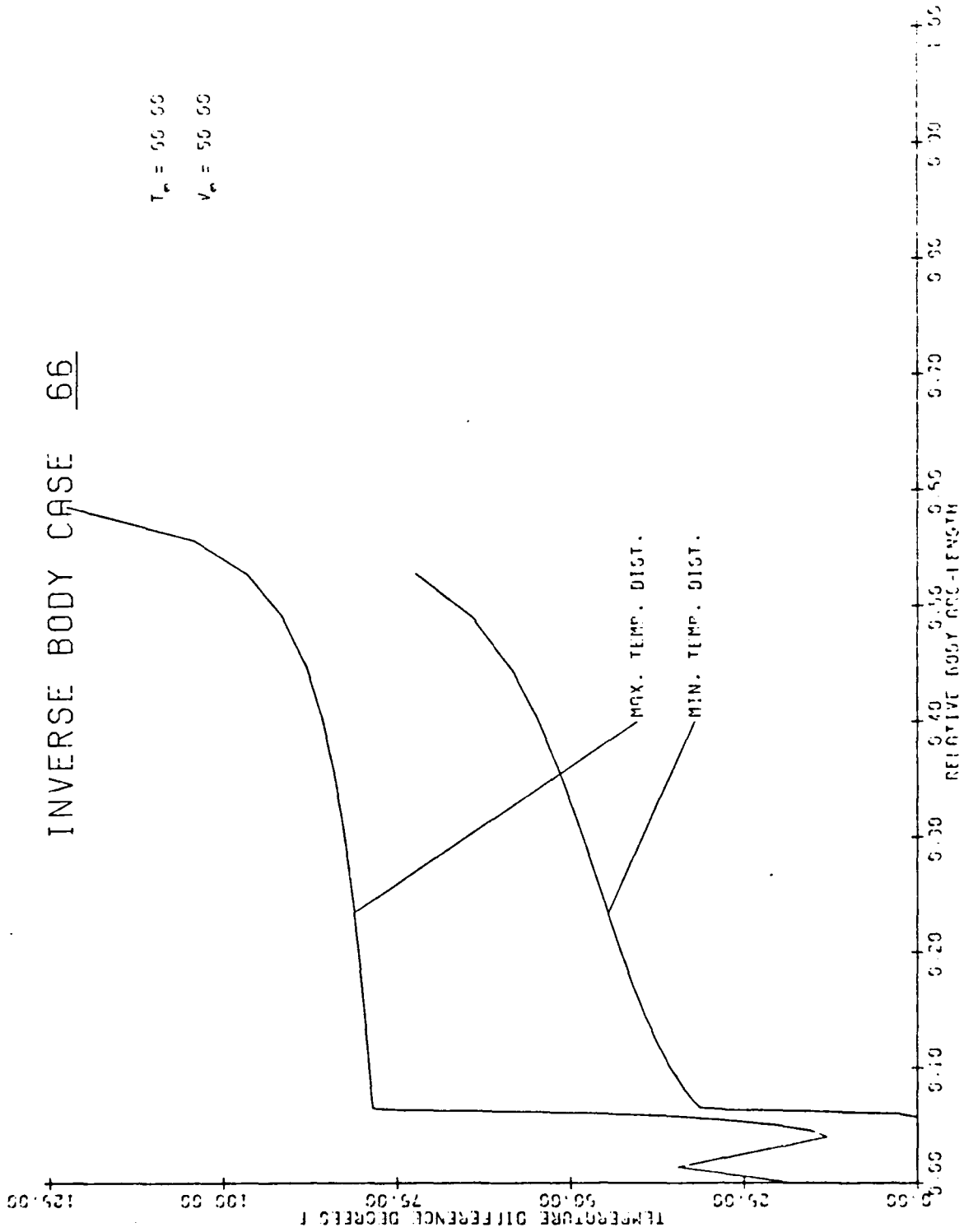


Figure 218. Temperature Distributions, Case No. 66.

INVERSE BODY CASE 66

$T_w = 50.00$

$V_w = 50.00$

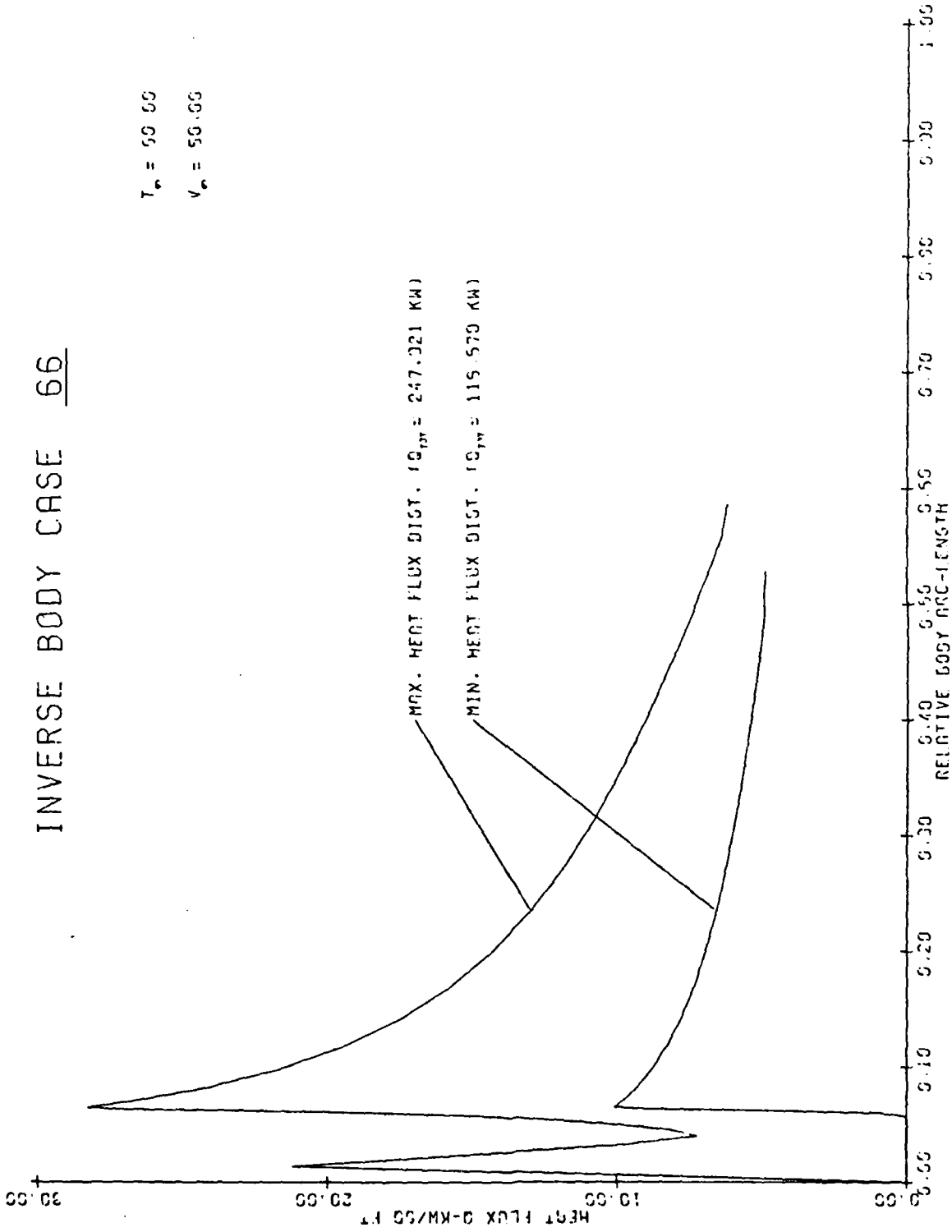


Figure 219. Heat Flux Distributions, Case No. 66.

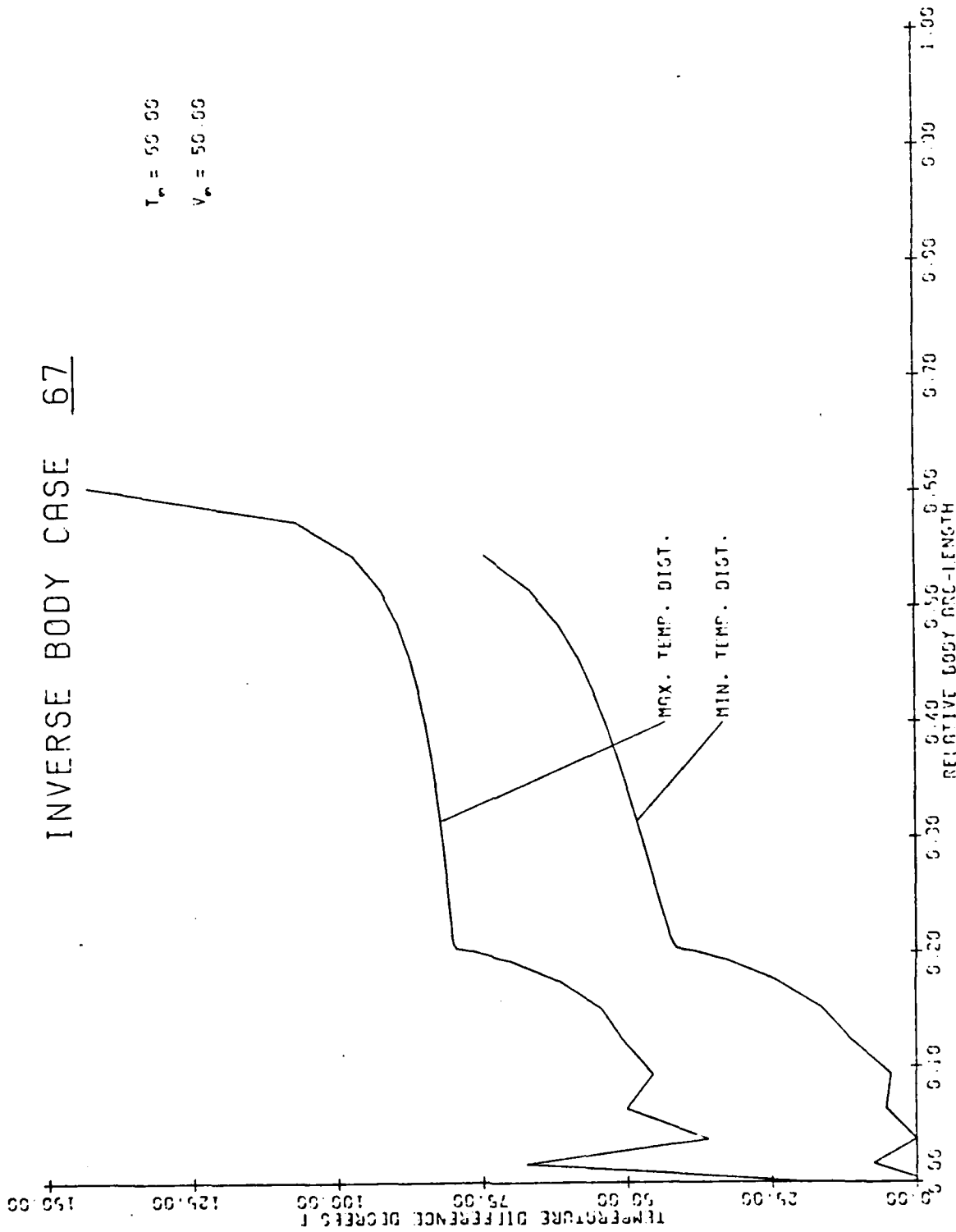


Figure 220. Temperature Distributions, Case No. 67.

INVERSE BODY CASE 67

$T_w = 50.00$   
 $V_w = 50.00$

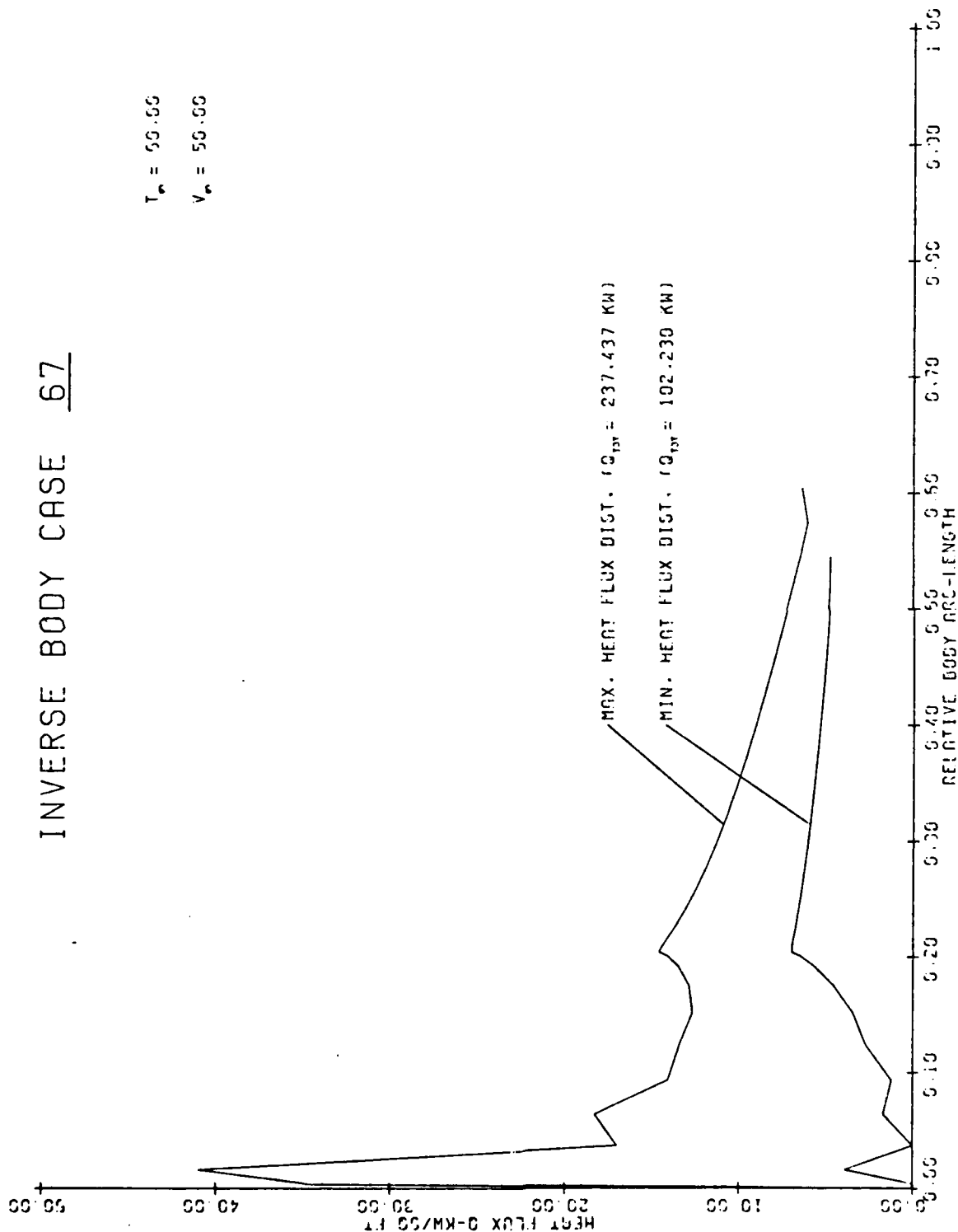


Figure 221. Heat Flux Distributions, Case No. 67.

INVERSE BODY CASE 68

$T_m = 50.00$   
 $V_m = 50.00$

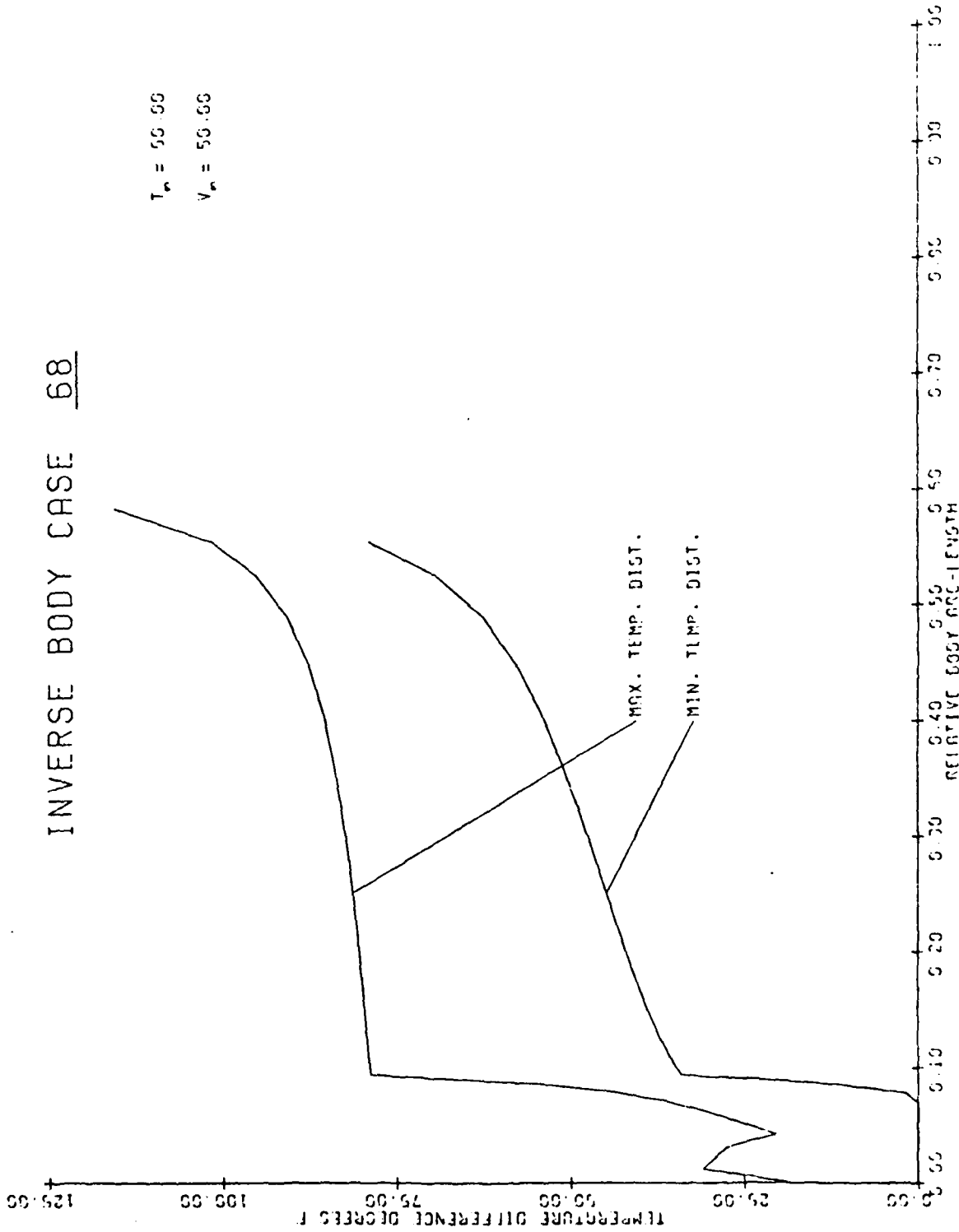


Figure 222. Temperature Distributions, Case No. 68.

INVERSE BODY CASE 68

$T_p = 50.00$

$V_p = 50.00$

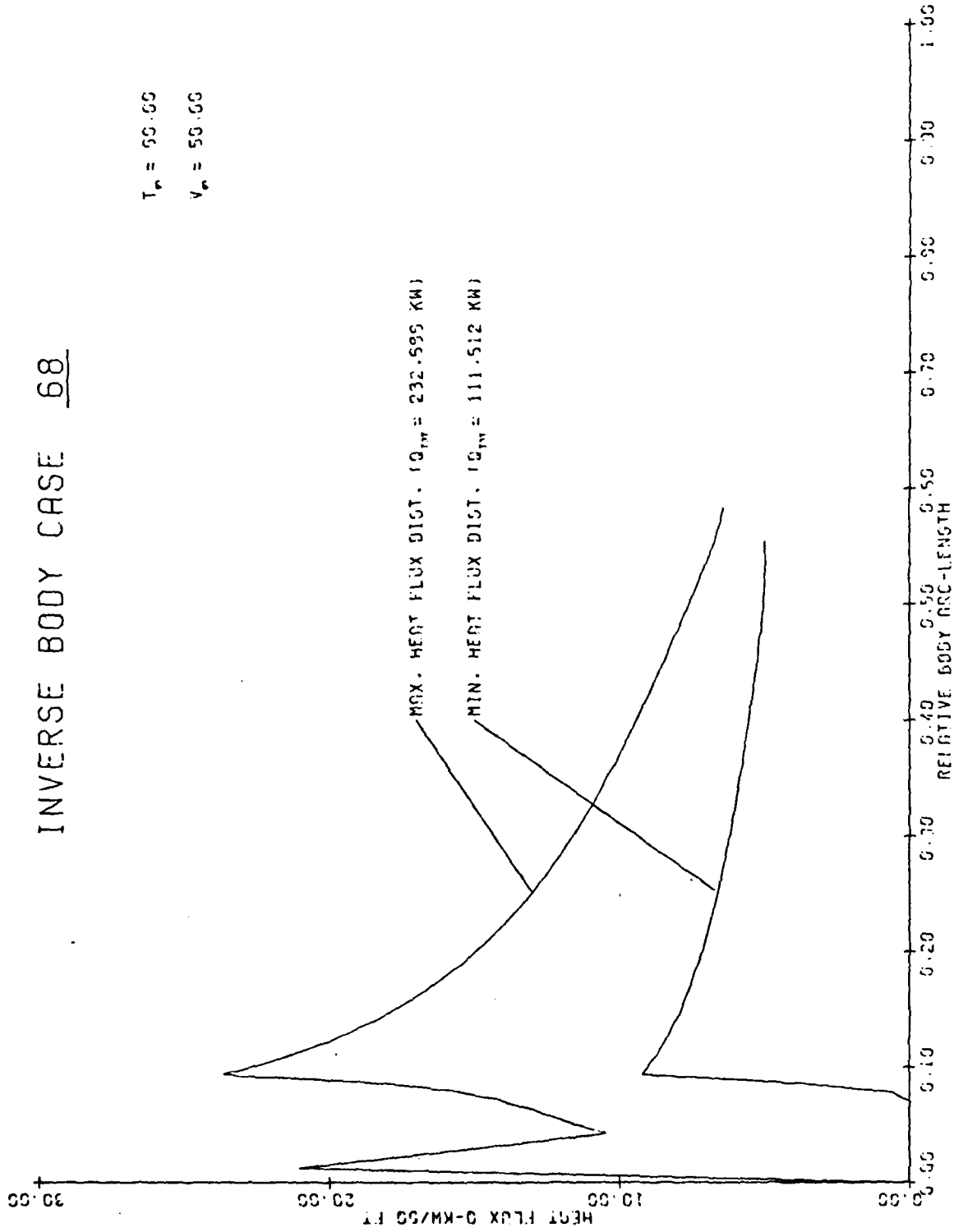


Figure 223. Heat Flux Distributions, Case No. 68.

INVERSE BODY CASE 69

$T_w = 50.00$   
 $V_w = 50.00$

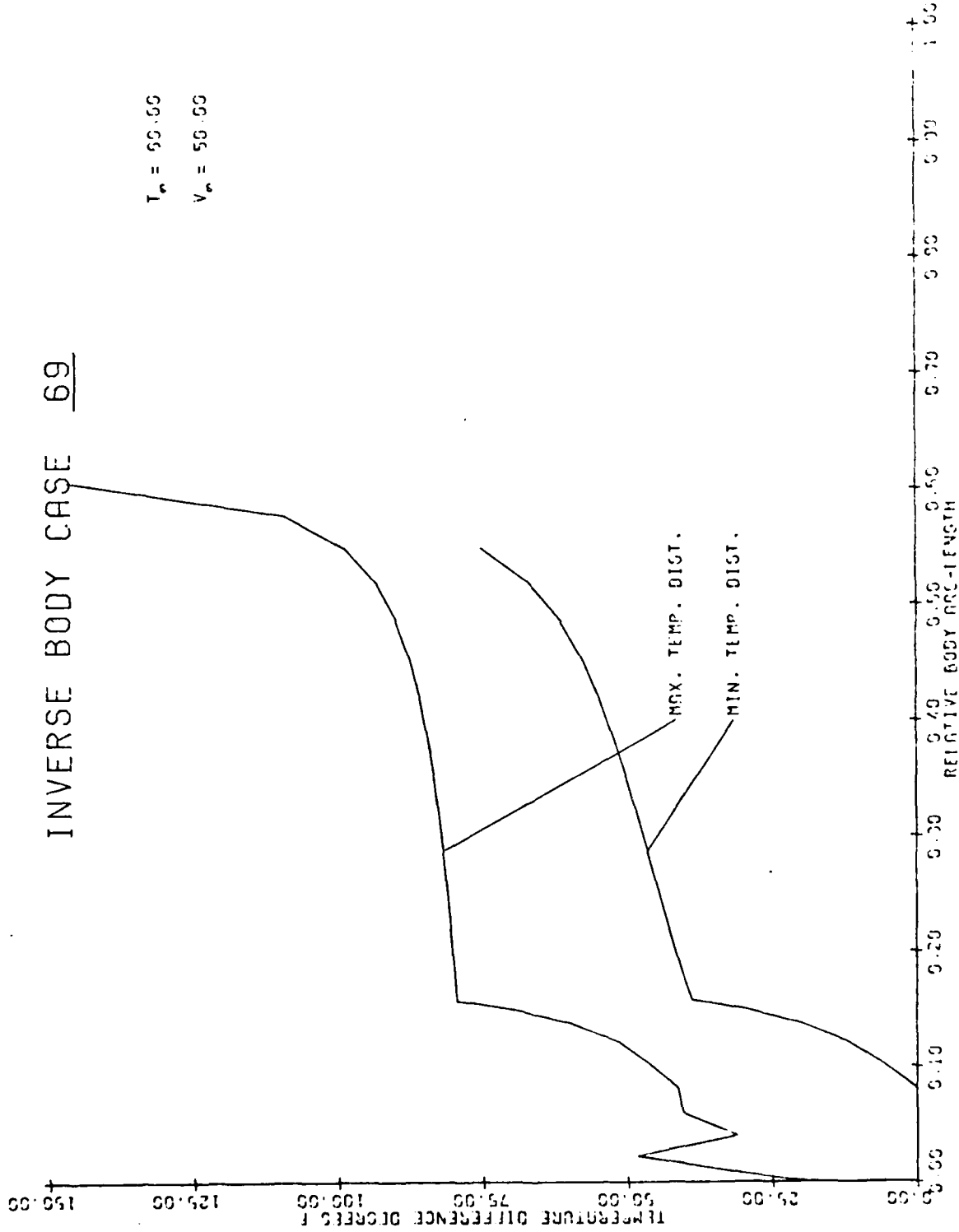


Figure 224. Temperature Distributions, Case No. 69.

INVERSE BODY CASE 69

$T_w = 50.00$

$V_w = 50.00$

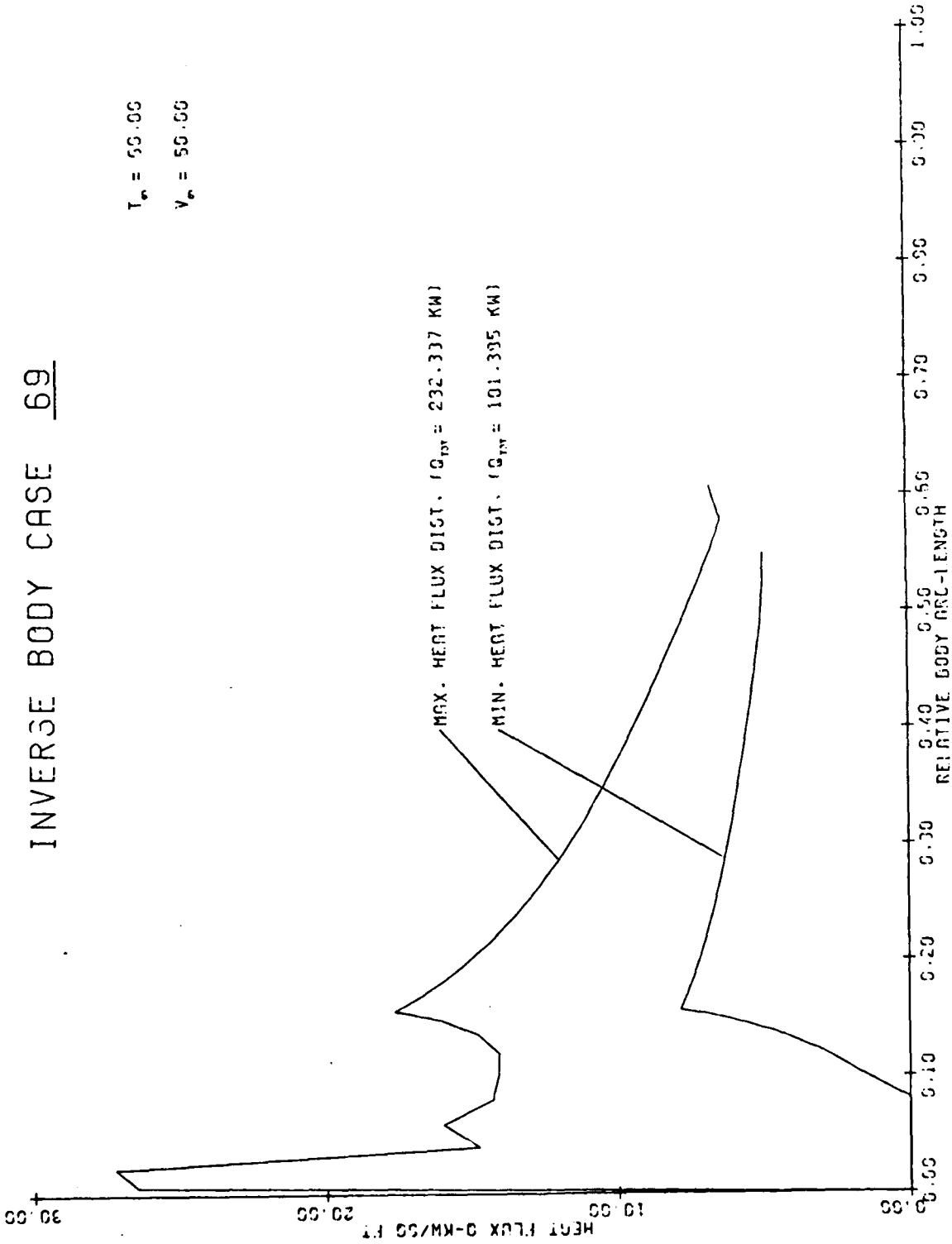


Figure 225. Heat Flux Distributions, Case No. 69.

INVERSE BODY CASE 70

$T_w = 50.00$   
 $V_w = 50.00$

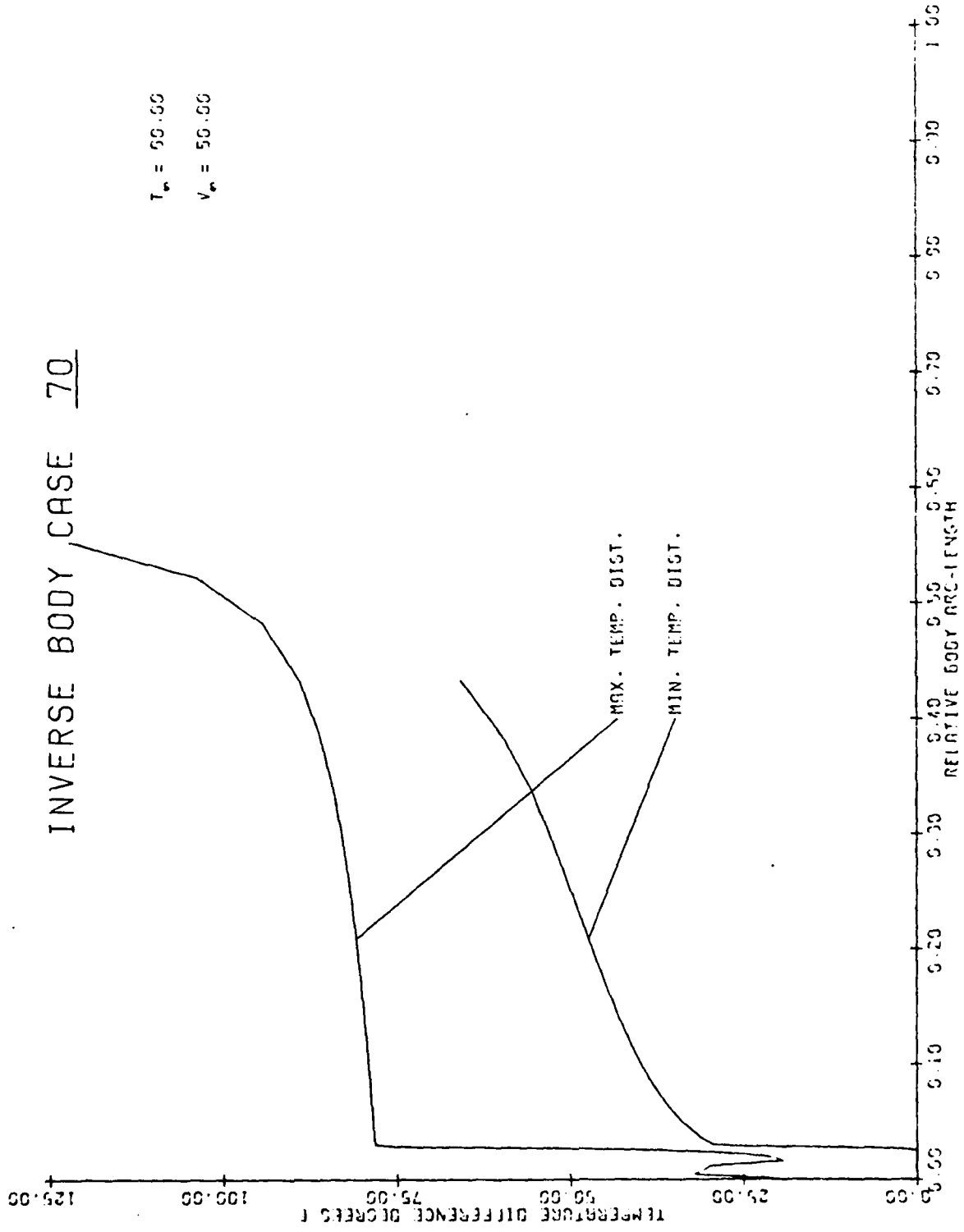


Figure 226. Temperature Distributions, Case No. 70.

INVERSE BODY CASE 70

$T_w = 50.00$

$V_w = 50.00$

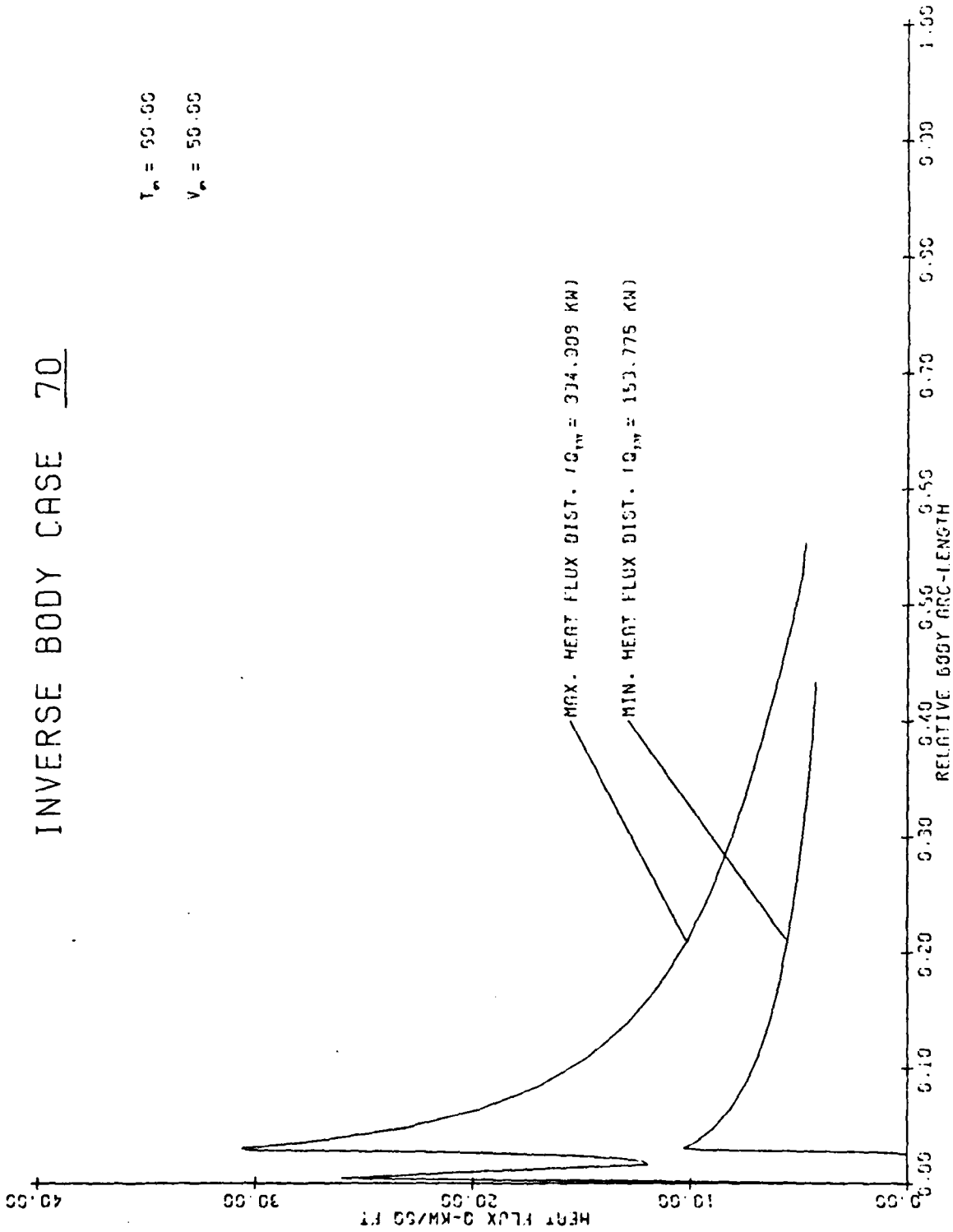


Figure 227. Heat Flux Distributions, Case No. 70.

INVERSE BODY CASE 71

$T_p = 50.00$

$V_p = 50.00$

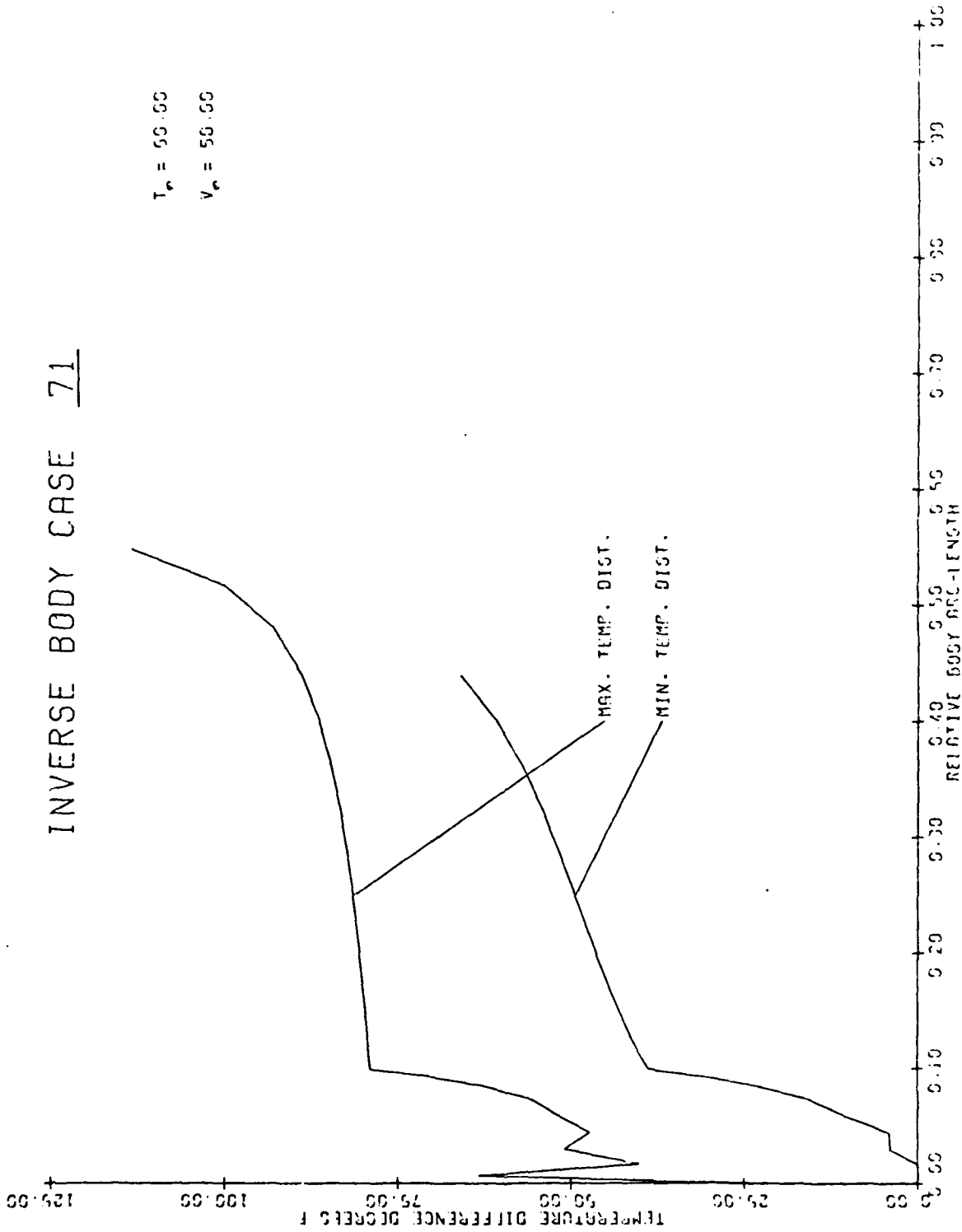


Figure 228. Temperature Distributions, Case No. 71

INVERSE BODY CASE 71

$T_w = 50.00$

$V_w = 50.00$

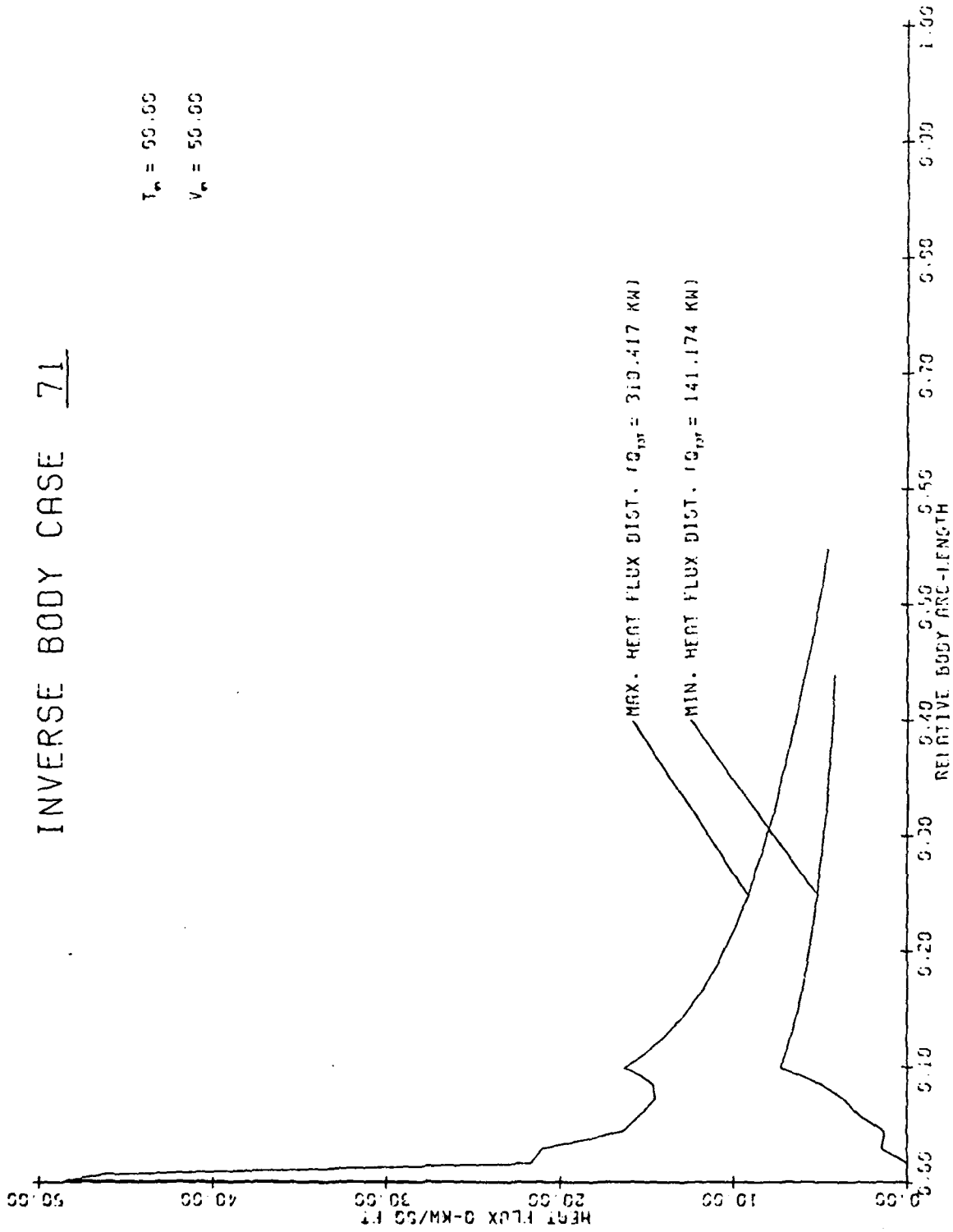


Figure 229. Heat Flux Distributions, Case No. 71.

INVERSE BODY CASE 72

$T_a = 50.00$   
 $V_a = 50.00$

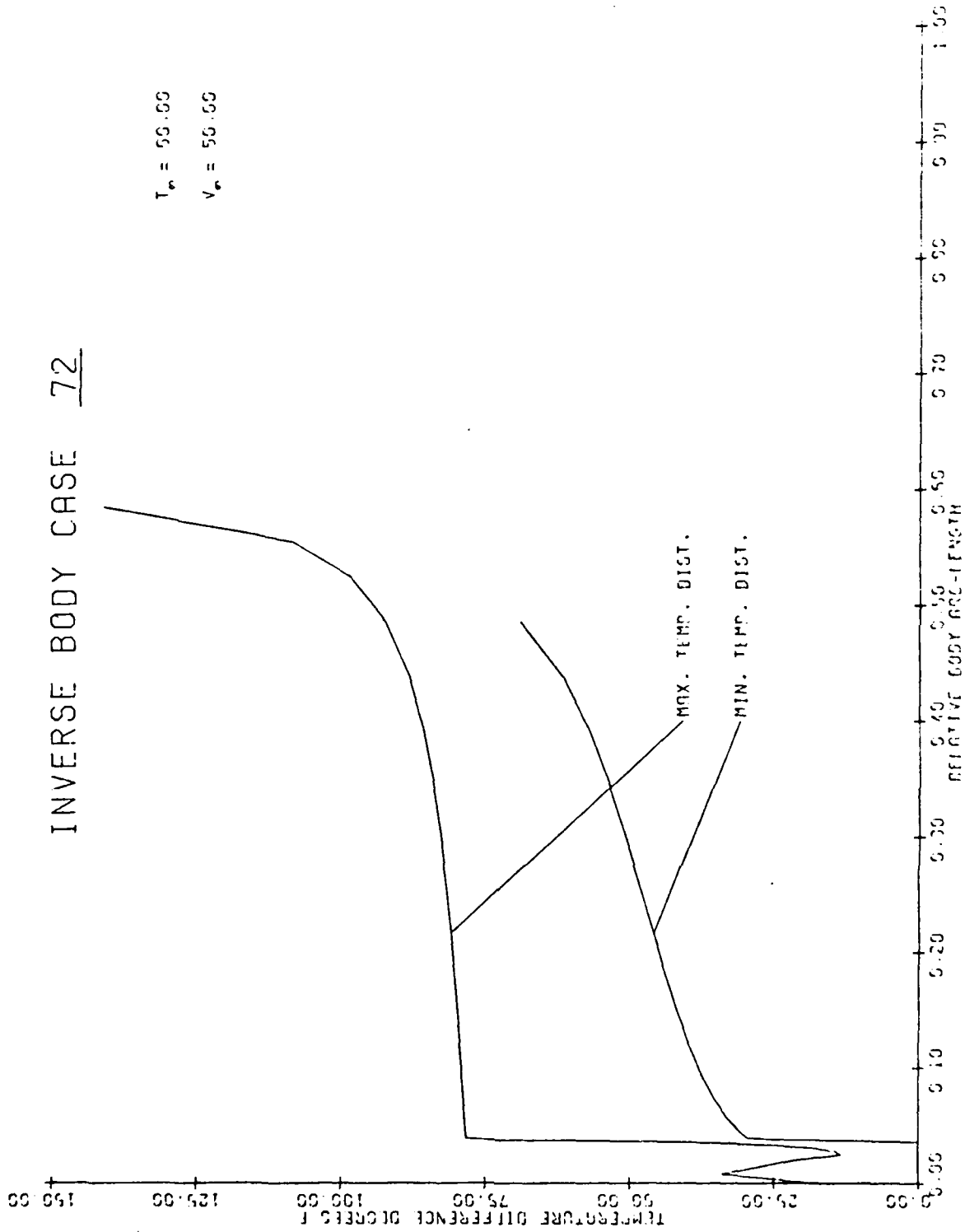


Figure 230. Temperature Distributions, Case No. 72.

INVERSE BODY CASE 72

$T_p = 50.00$

$V_p = 50.00$

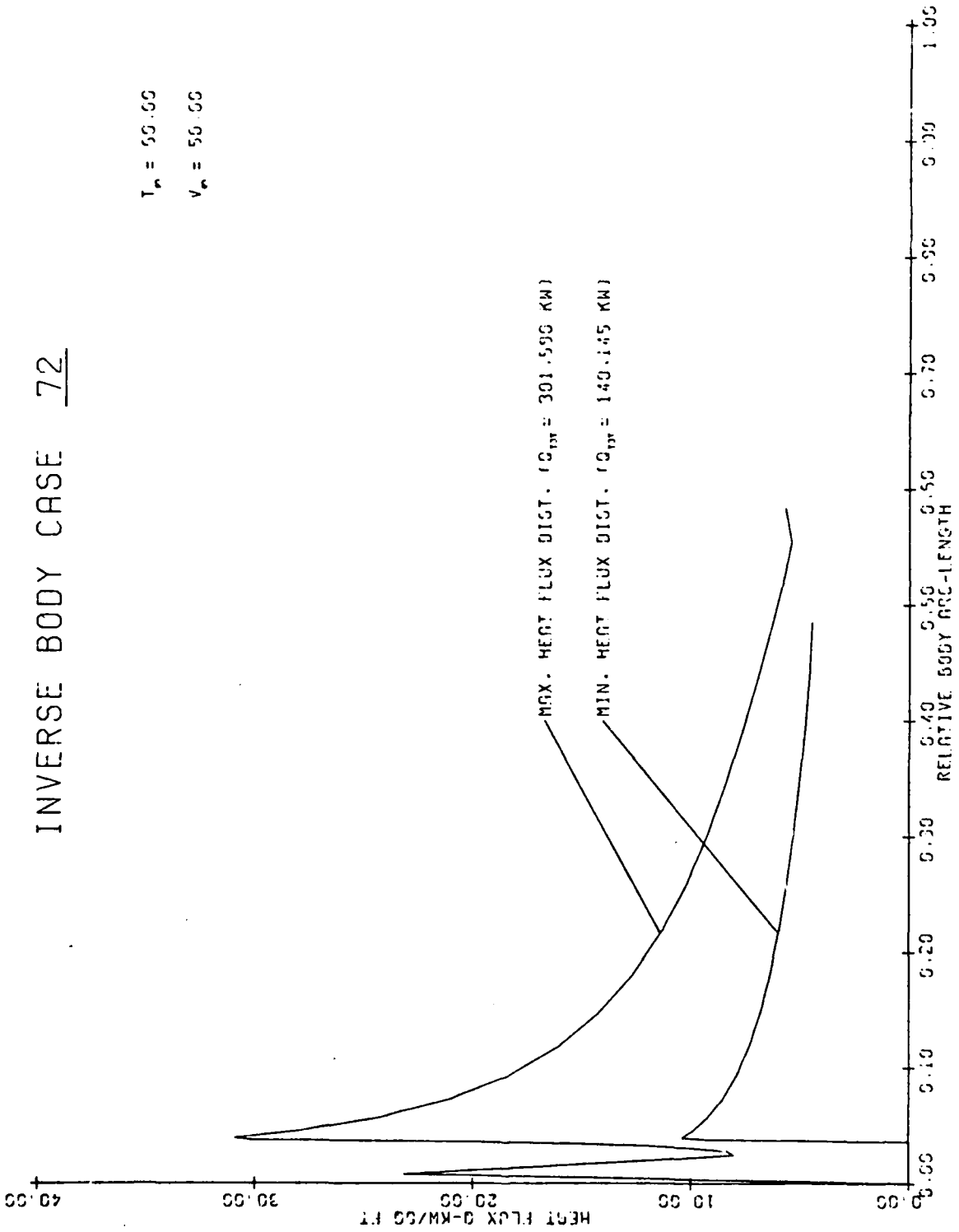


Figure 231. Heat Flux Distributions, Case No. 72.

# INVERSE BODY CASE 73

$T_m = 99.00$   
 $V_m = 50.00$

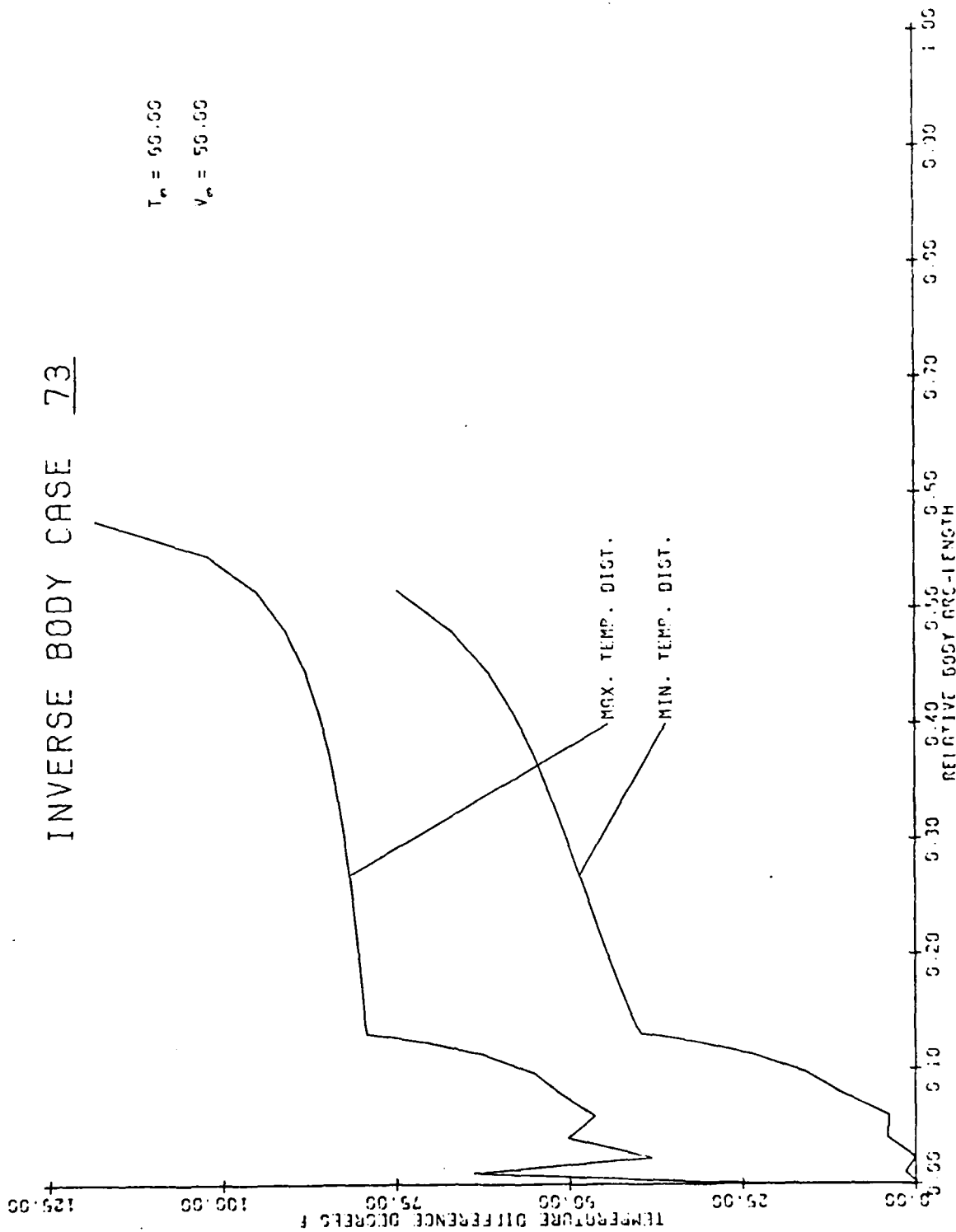


Figure 232. Temperature Distributions, Case No. 73.

INVERSE BODY CASE 73

$T_w = 50.00$

$V_w = 50.00$

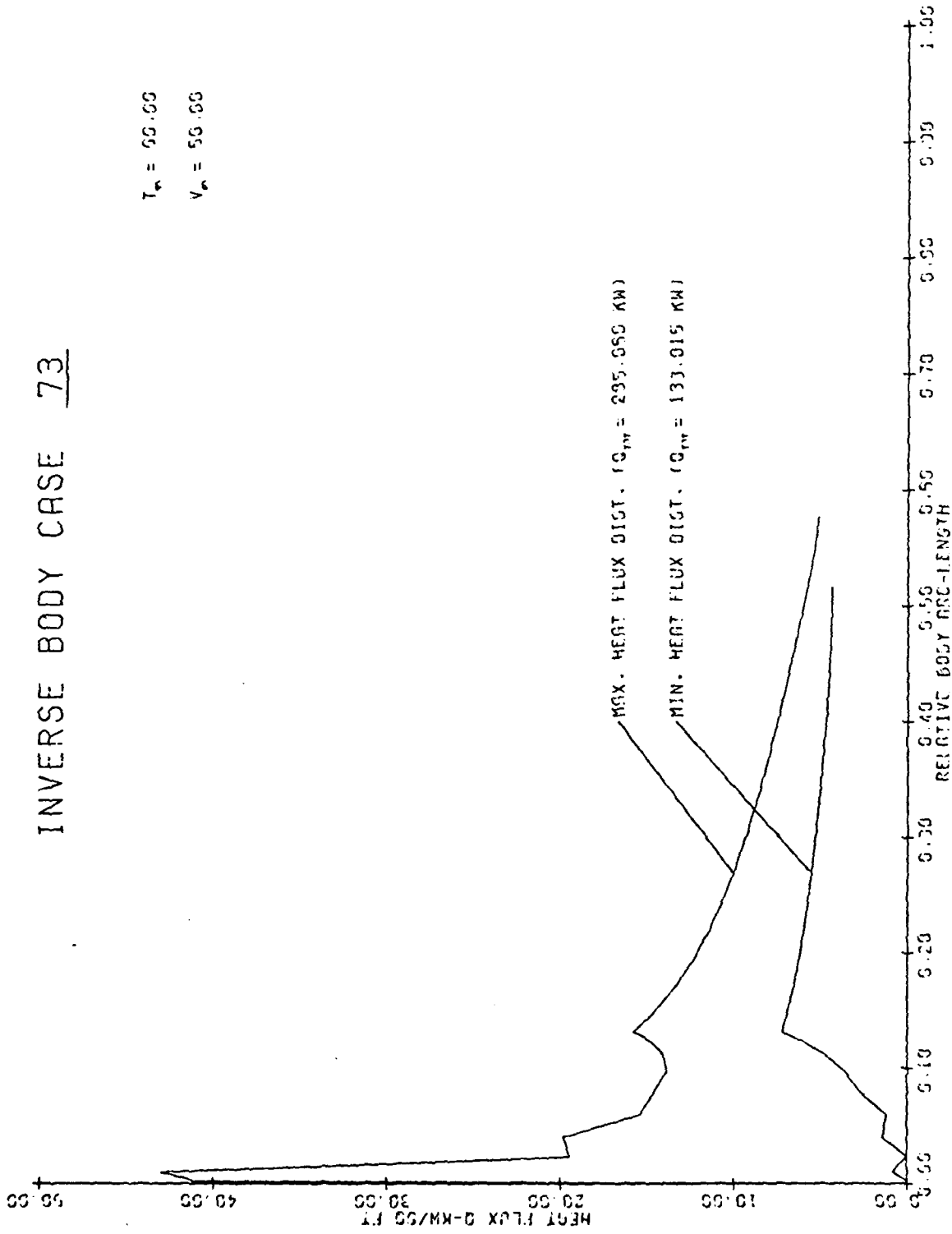


Figure 233. Heat Flux Distributions, Case No. 73.

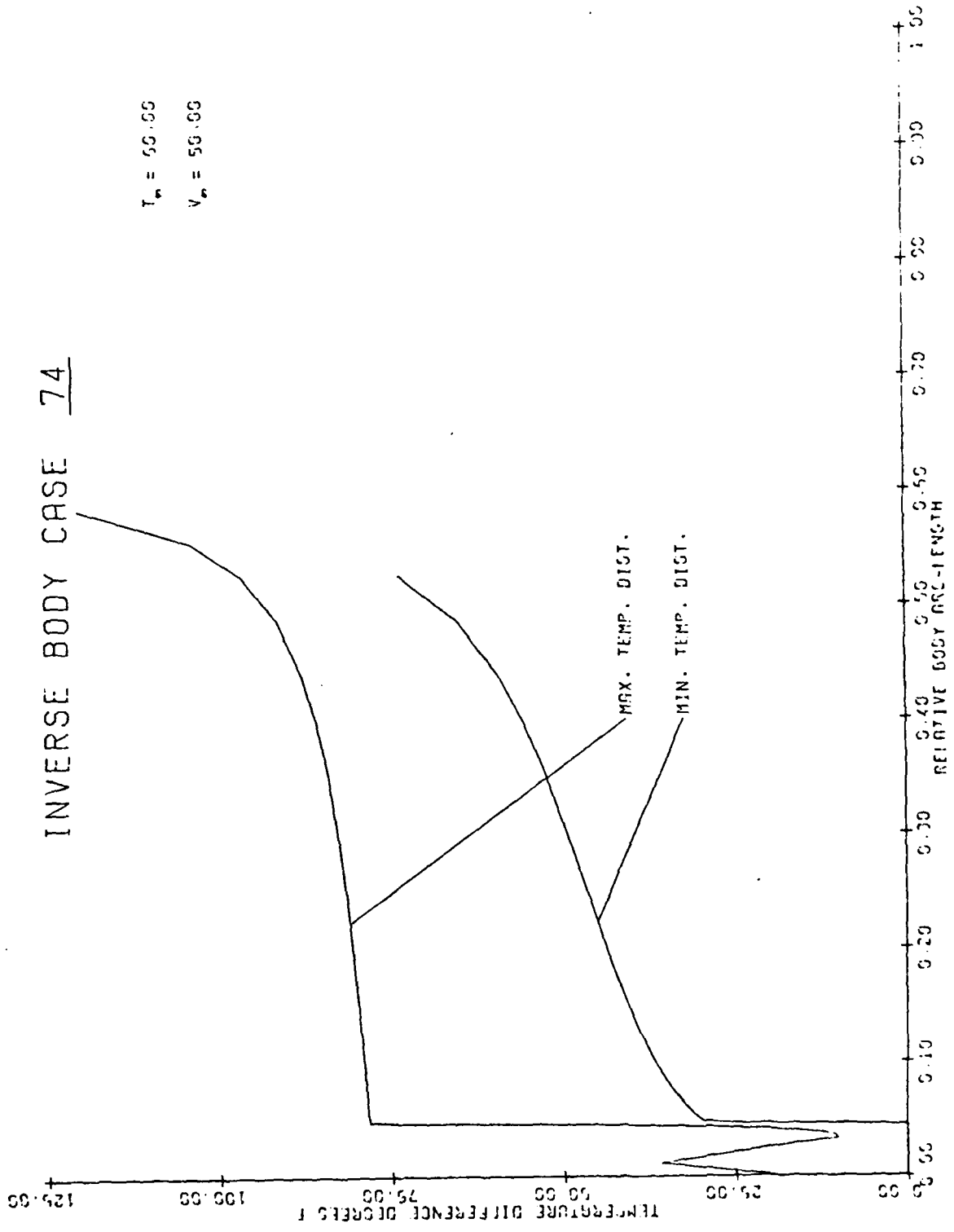


Figure 234. Temperature Distributions, Case No. 74.

INVERSE BODY CASE 74

$T_w = 50.00$

$V_w = 50.00$

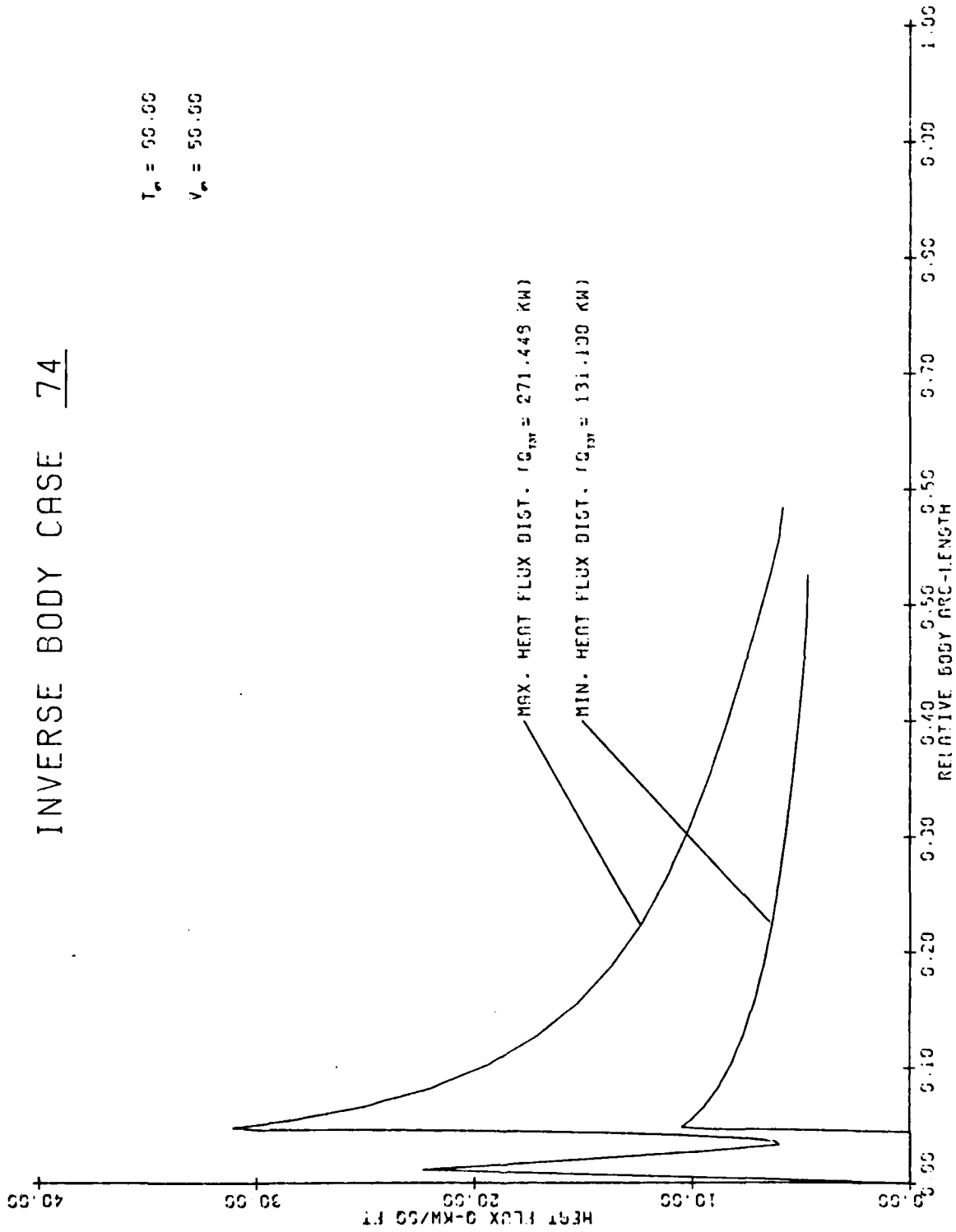


Figure 235. Heat Flux Distributions, Case No. 74.

INVERSE BODY CASE 75

$T_m = 50.00$

$V_m = 50.00$

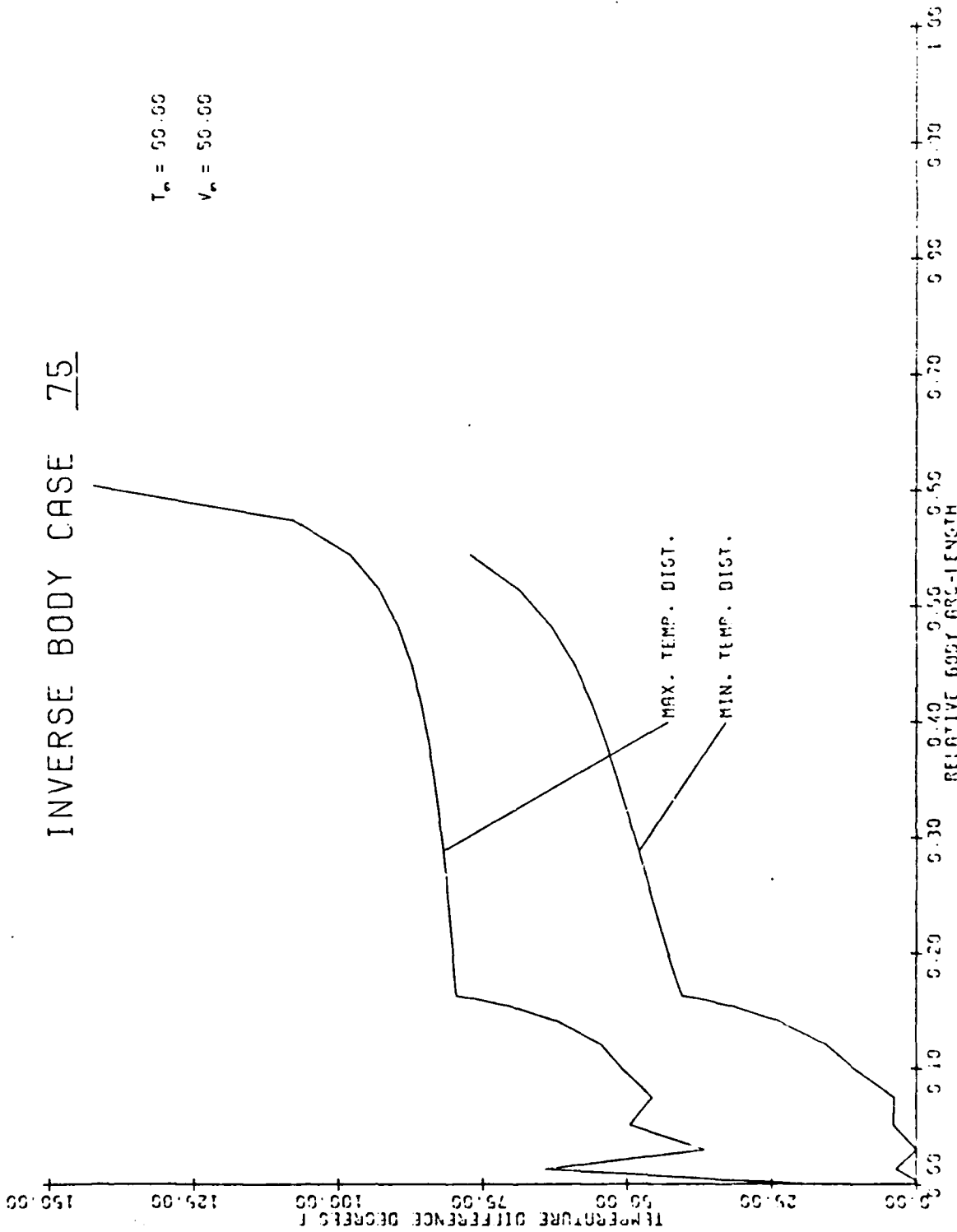


Figure 236. Temperature Distributions, Case No. 75.

INVERSE BODY CASE 75

$T_w = 50.00$   
 $V_w = 50.00$

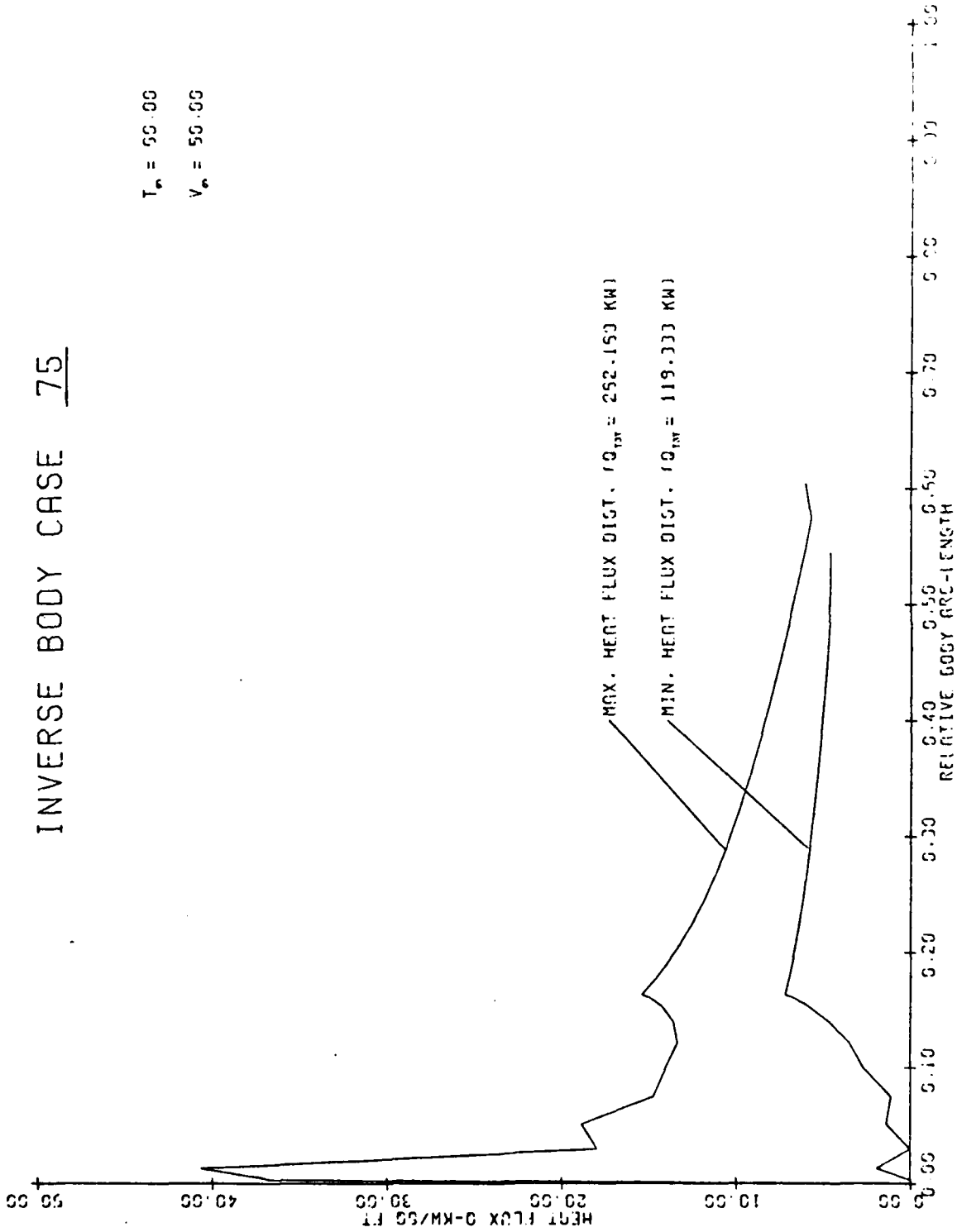


Figure 237. Heat Flux Distributions, Case No. 75.

INVERSE BODY CASE 76

$T_w = 50.00$   
 $V_w = 50.00$

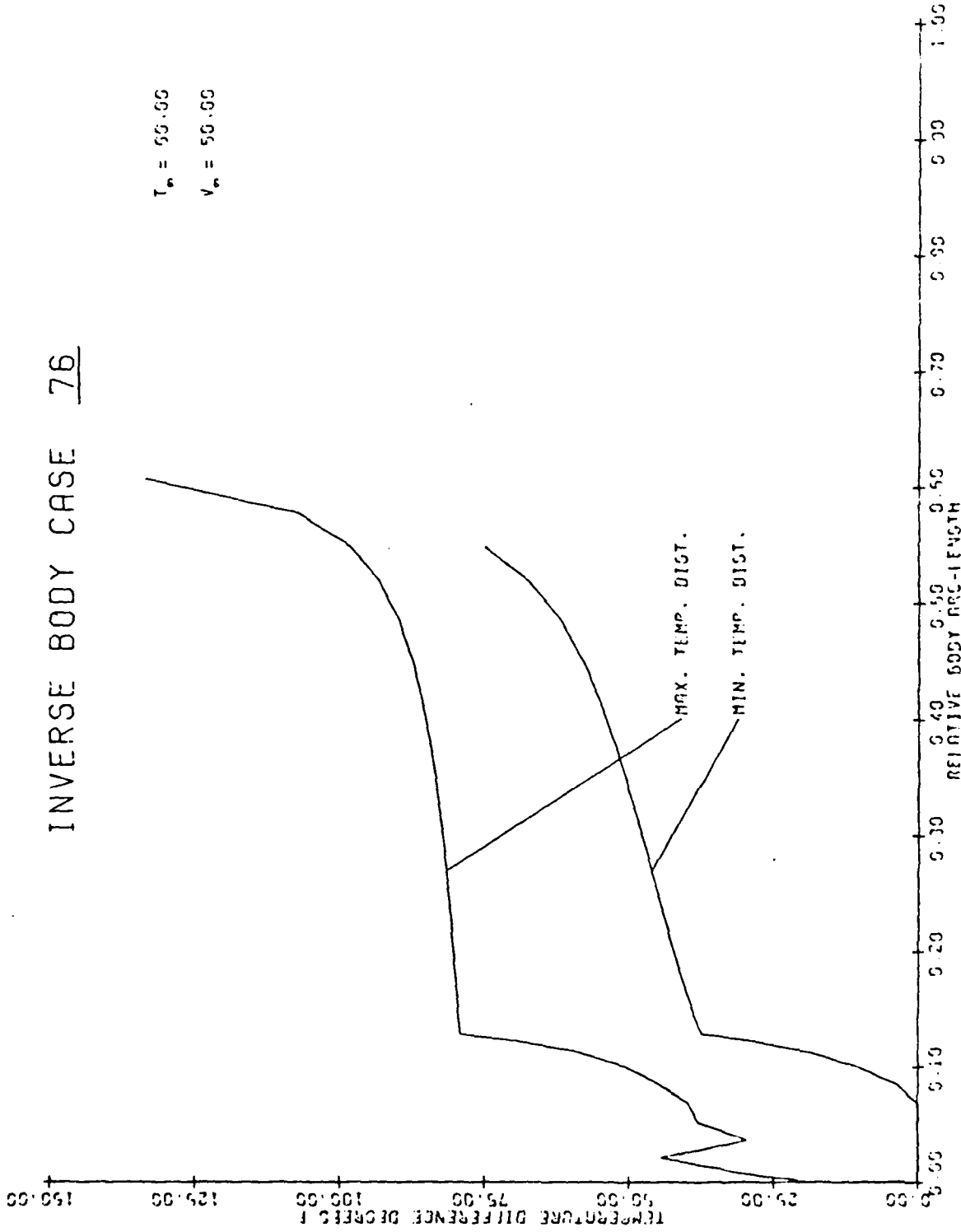


Figure 238. Temperature Distributions, Case No. 76.

# INVERSE BODY CASE 76

$T_w = 60.00$   
 $V_w = 50.00$

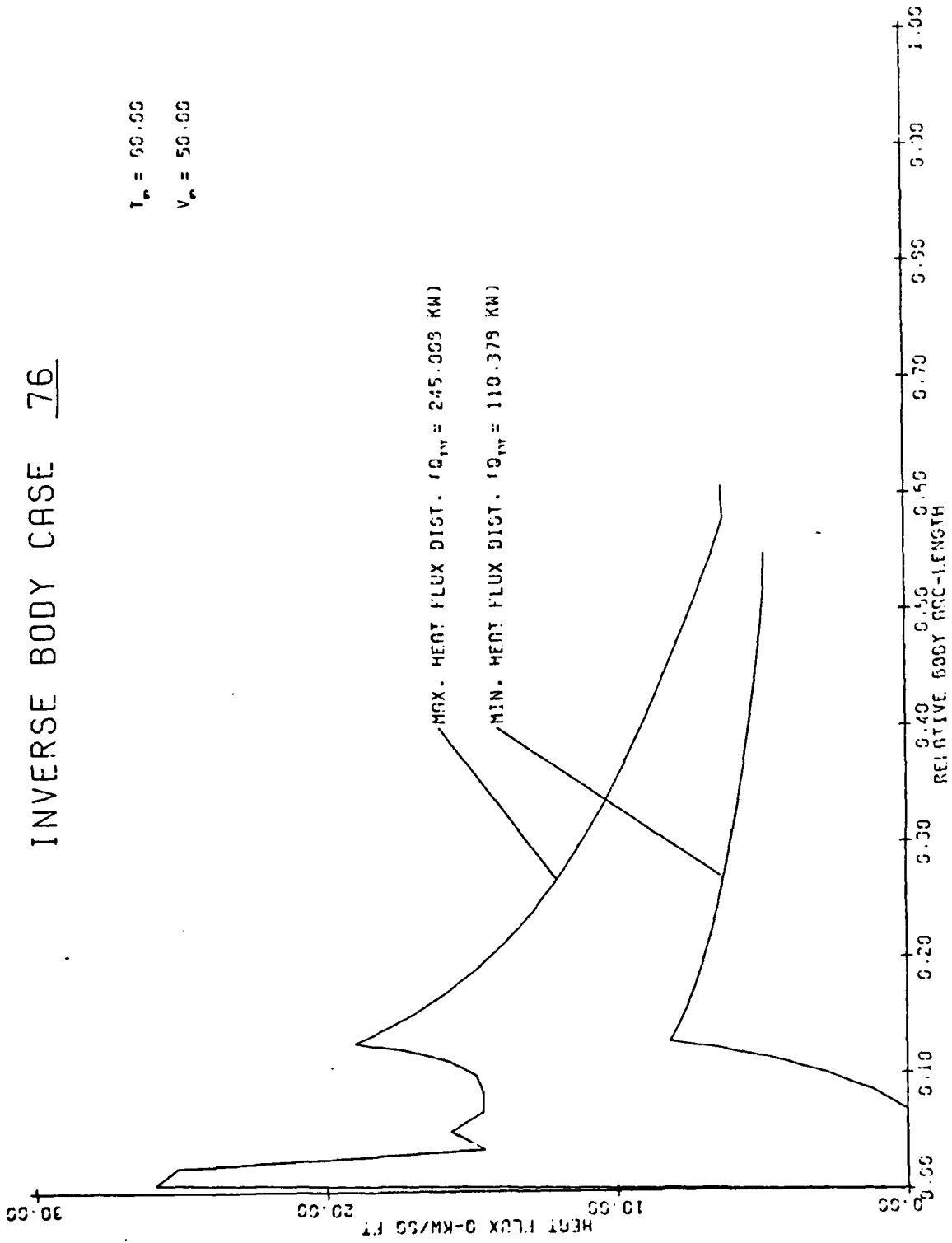


Figure 239. Heat Flux Distributions, Case No. 76.

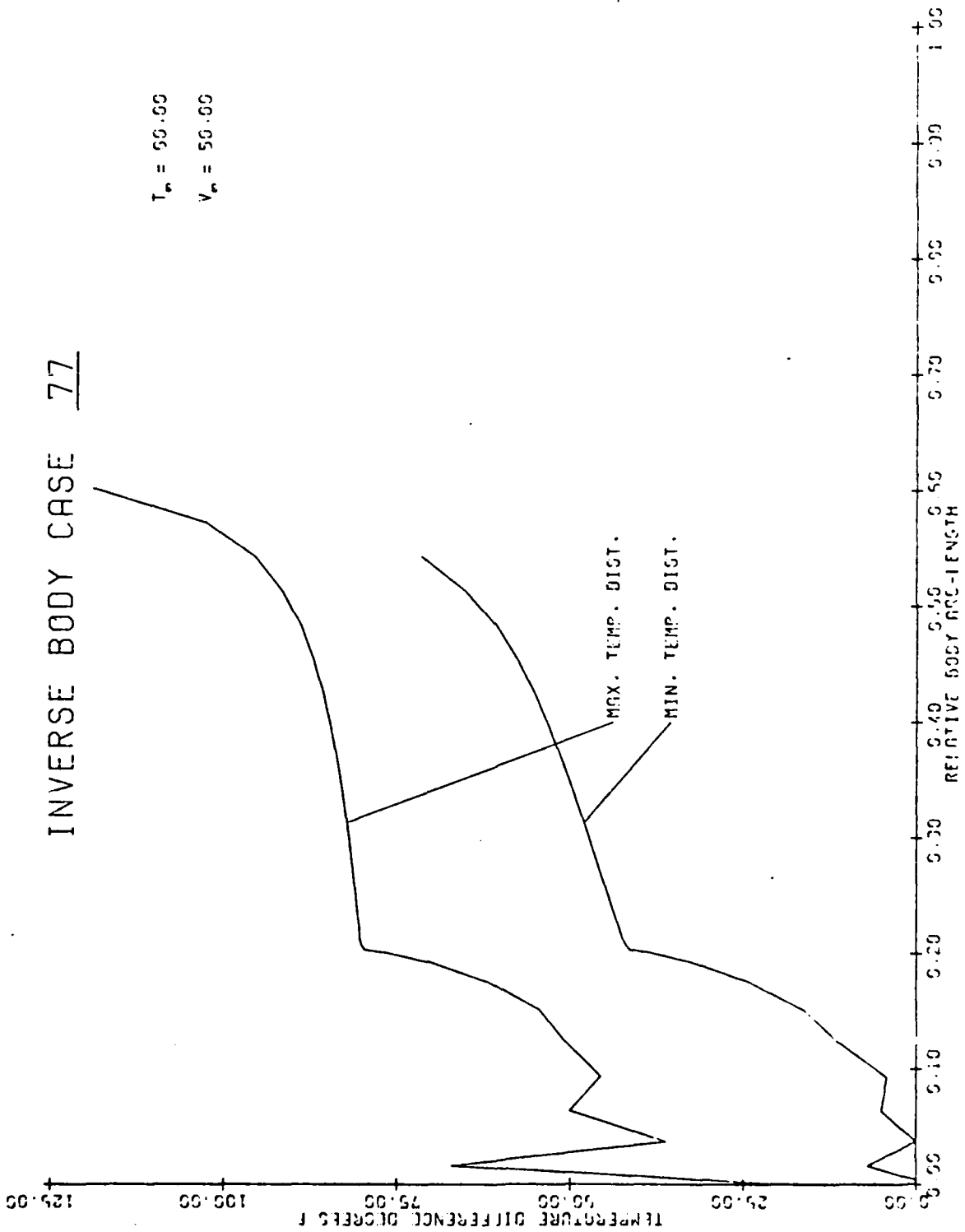


Figure 240. Temperature Distributions, Case No. 77.

INVERSE BODY CASE 77

$T_w = 50.00$   
 $V_w = 50.00$

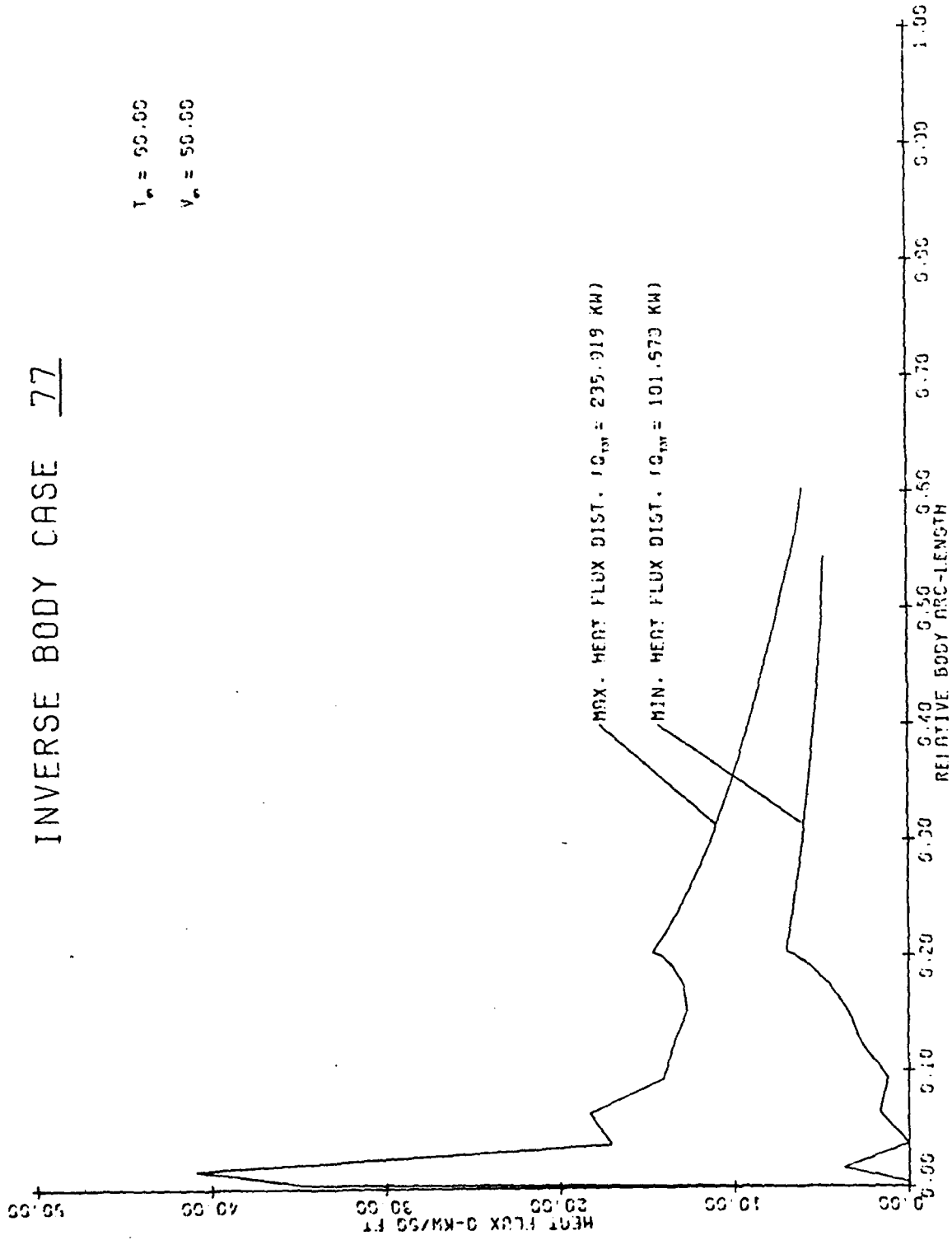


Figure 241. Heat Flux Distributions, Case No. 77.

# INVERSE BODY CASE 22

$T_{\infty} = 50.00$

$V_{\infty} = 30.00$

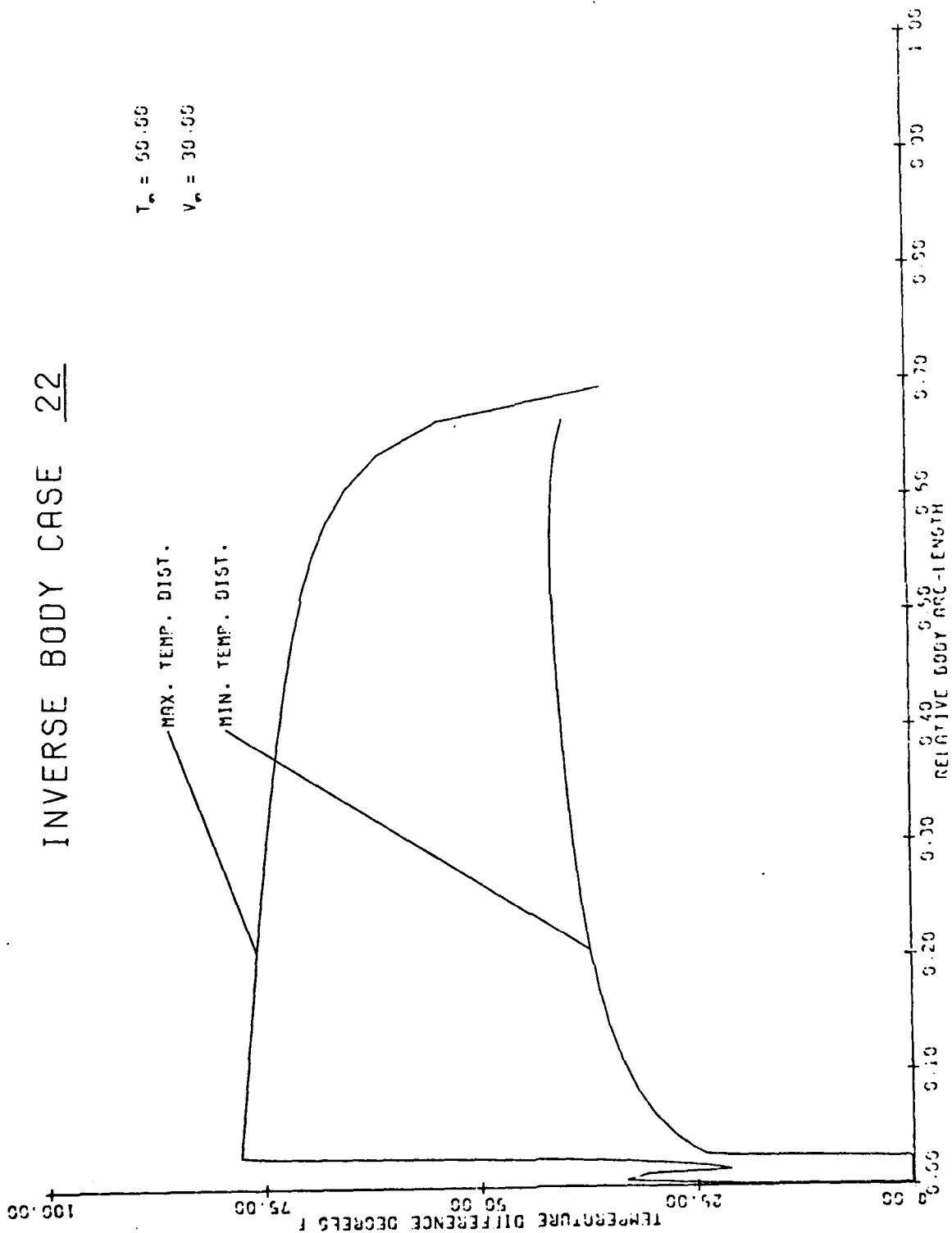


Figure 242. Temperature Distributions, Case No. 22, ( $V_{\infty} = 30$  fps,  $D = 21$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$

$V_{\infty} = 30.00$

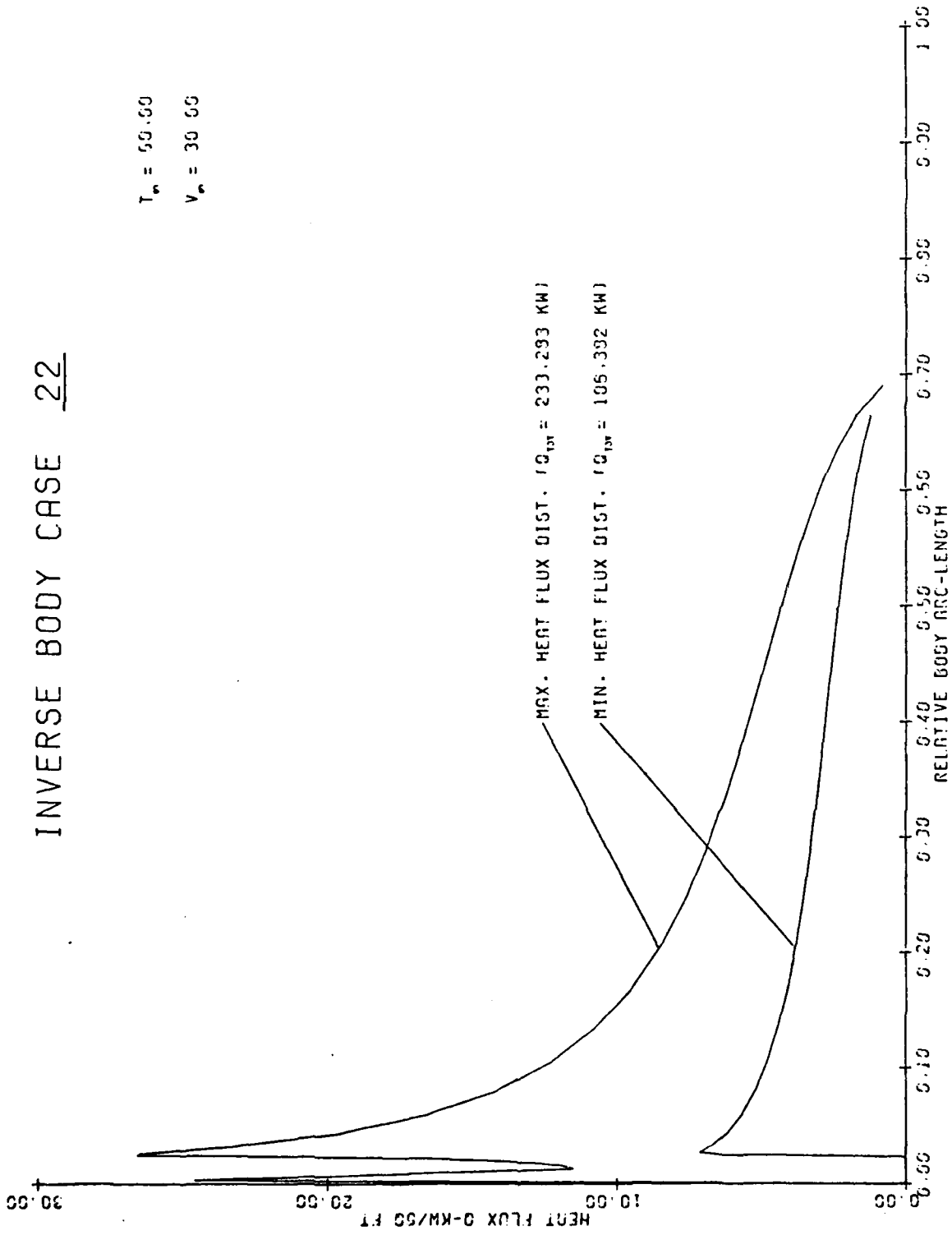


Figure 243. Heat Flux Distributions, Case No. 22, ( $V_{\infty} = 30$  fps,  $D = 21$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$   
 $V_{\infty} = 40.00$

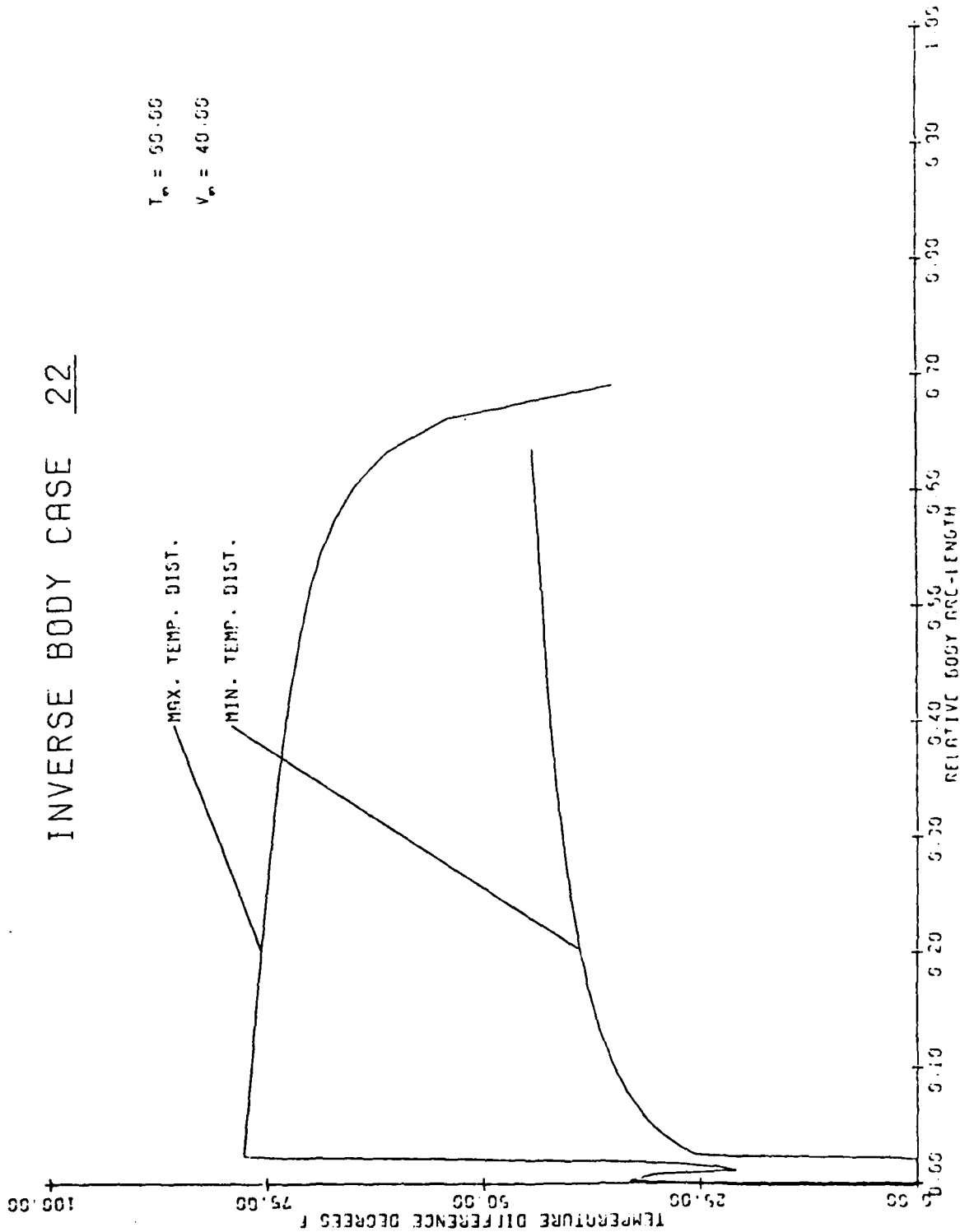


Figure 244. Temperature Distributions, Case No. 22, ( $V_{\infty} = 40$  fps,  $D = 21$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 60.60$

$V_{\infty} = 40.00$

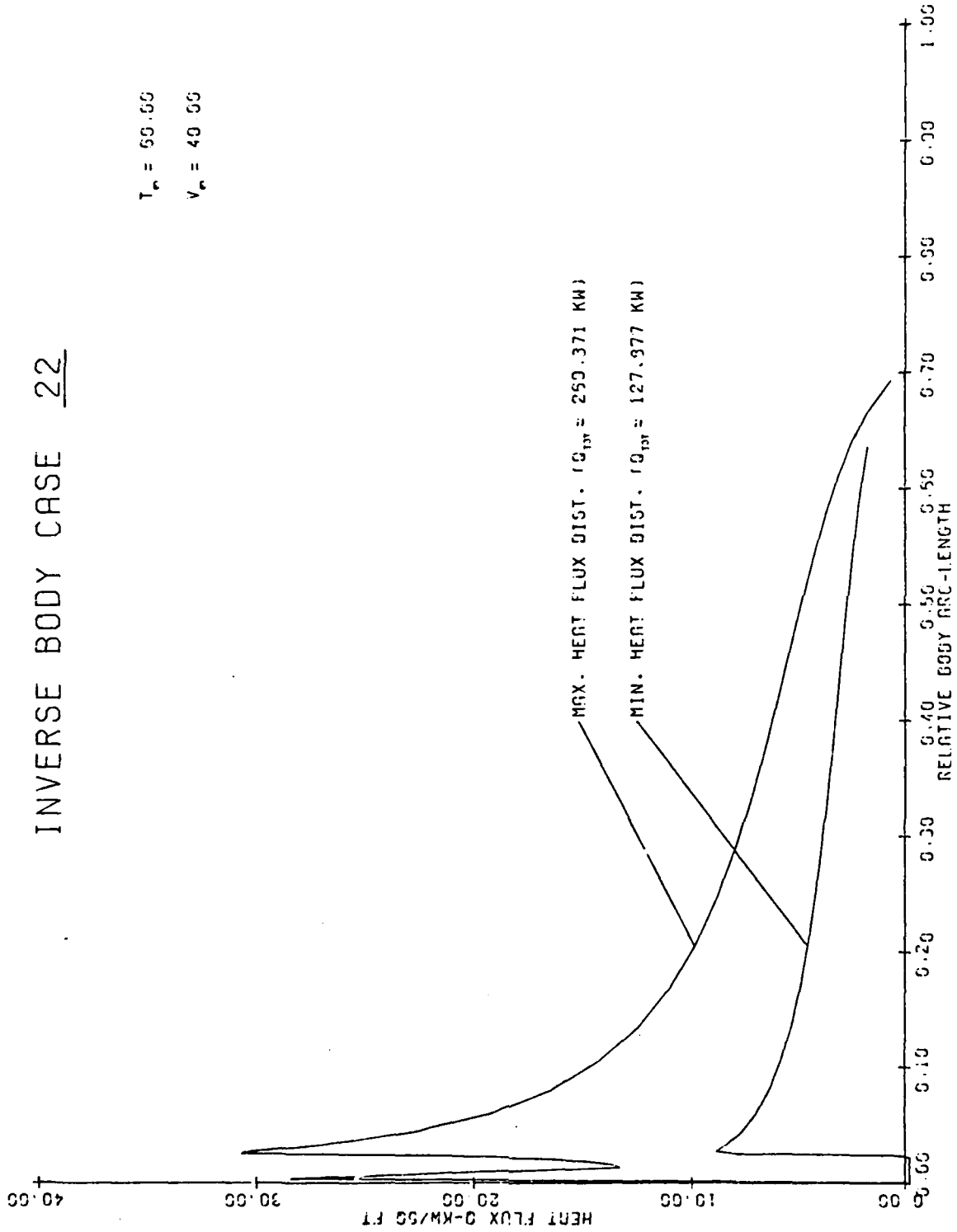


Figure 245. Heat Flux Distributions, Case No. 22, ( $V_{\infty} = 40$  fps,  $D = 21$  in.).

# INVERSE BODY CASE 22

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

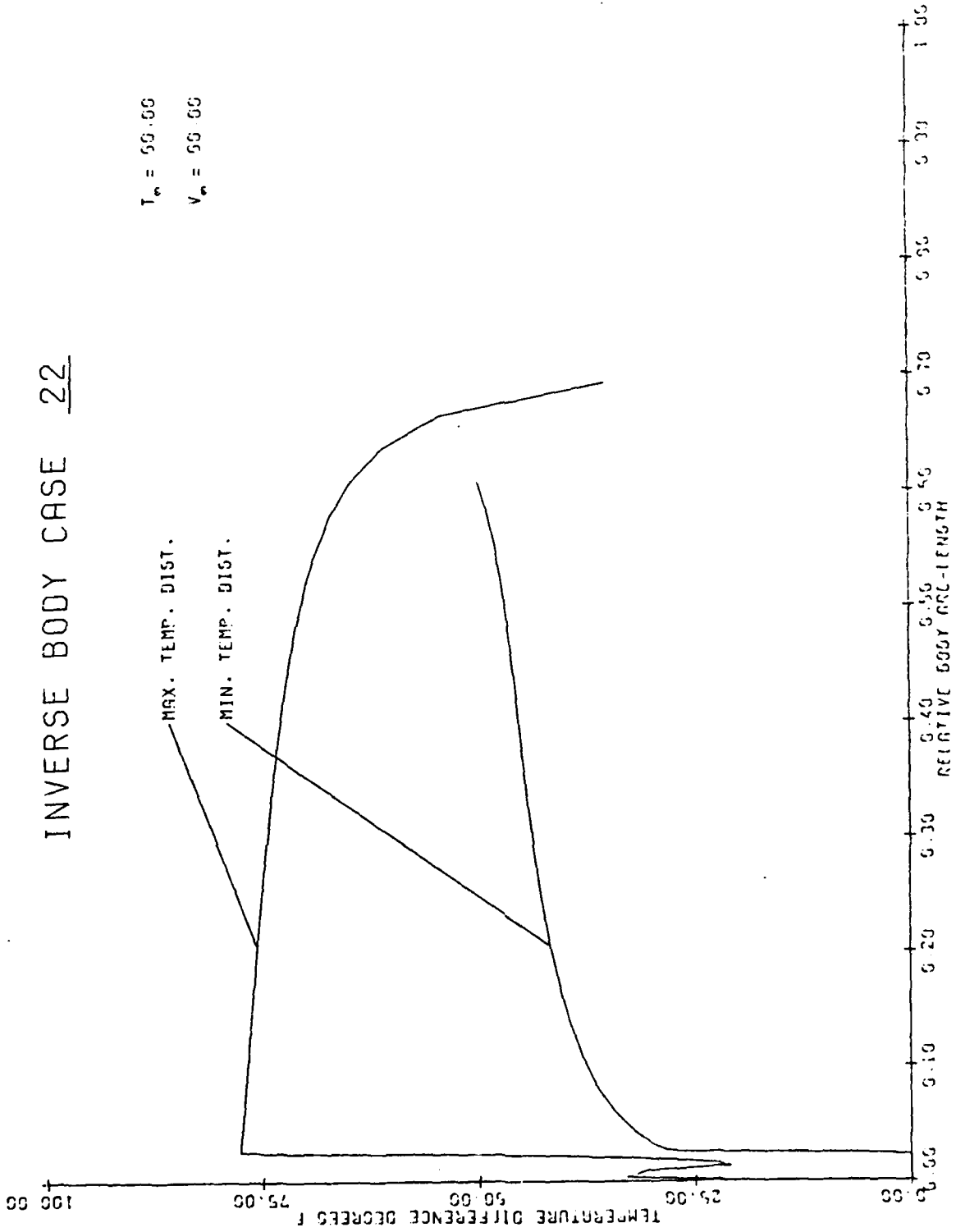


Figure 246. Temperature Distributions, Case No. 22, ( $V_{\infty} = 60$  fps,  $D = 21$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

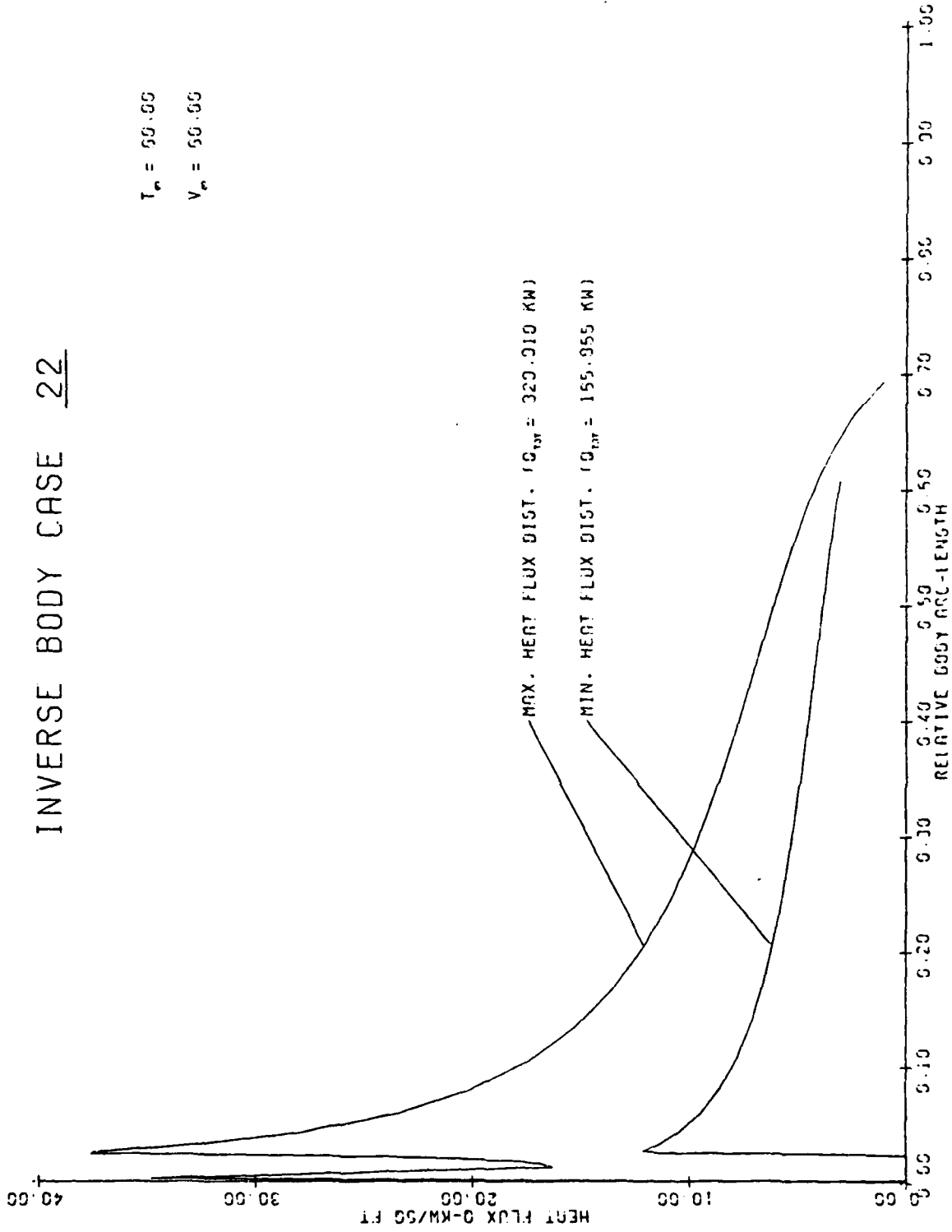


Figure 247. Heat Flux Distributions, Case No. 22, ( $V_{\infty} = 60$  fps,  $D = 21$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

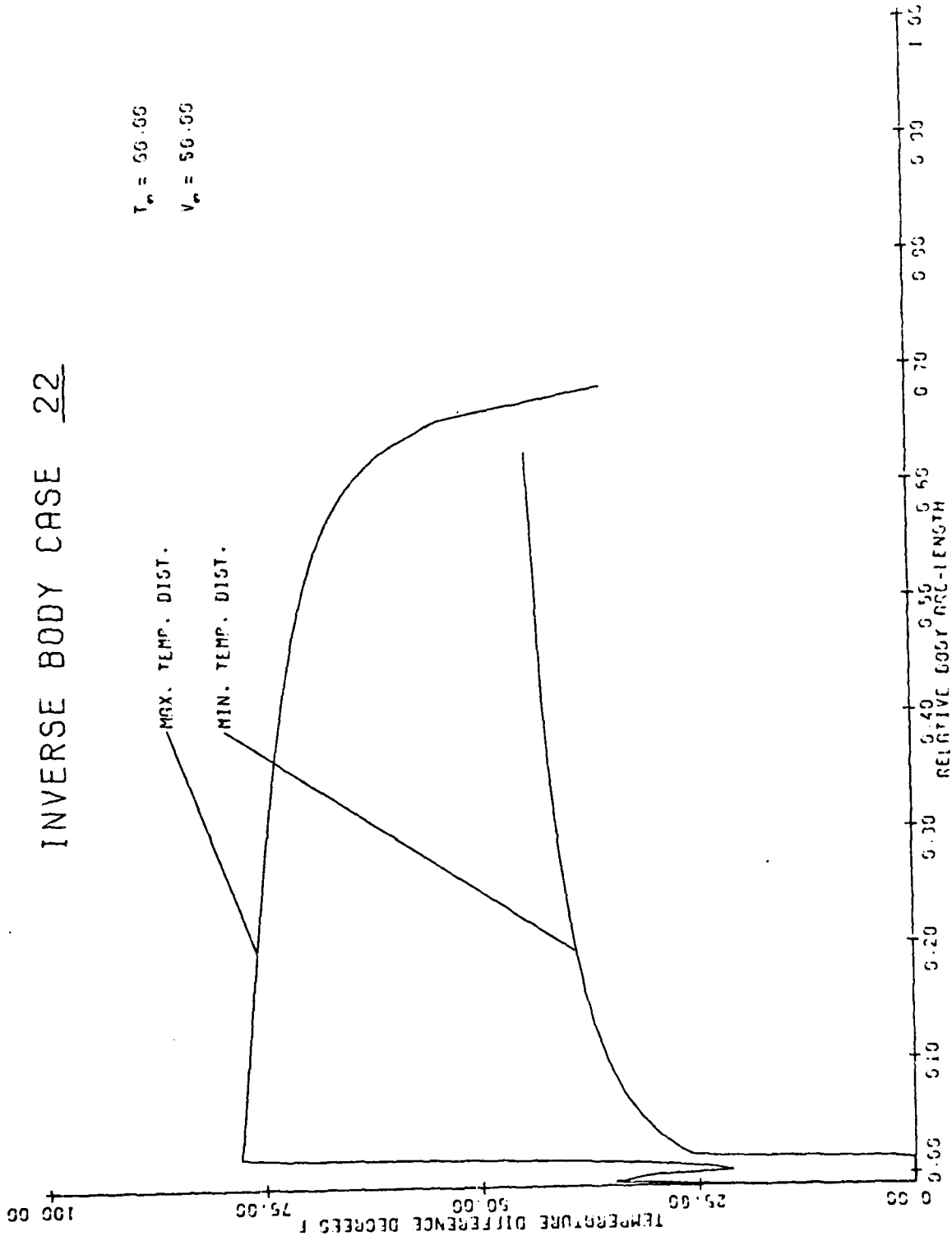


Figure 248. Temperature Distributions, Case No. 22, ( $V_{\infty} = 50$  fps,  $D = 16.5$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$

$V_{\infty} = 50.00$

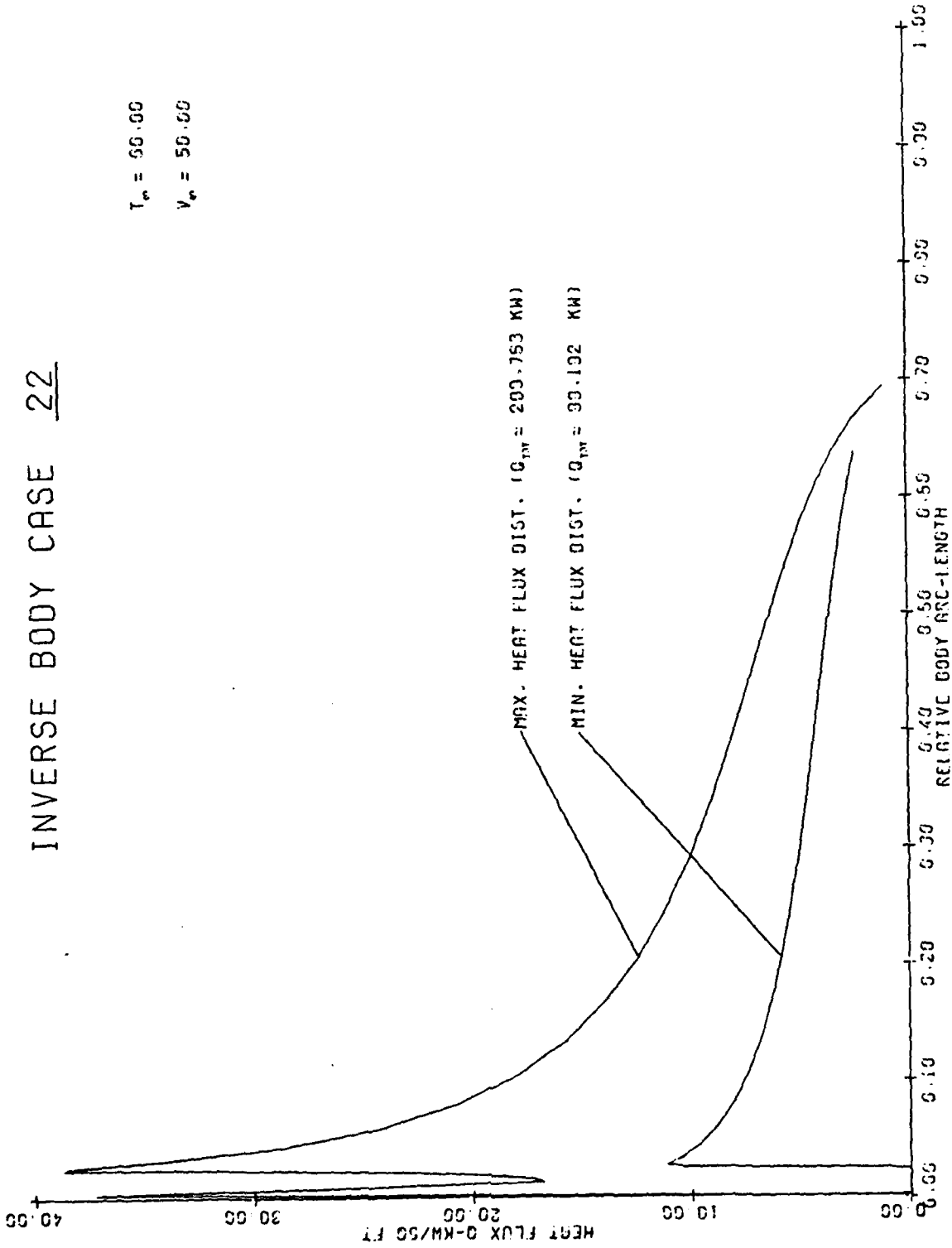


Figure 249. Heat Flux Distributions, Case No. 22, ( $V_{\infty} = 50$  fps,  $D = 16.5$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

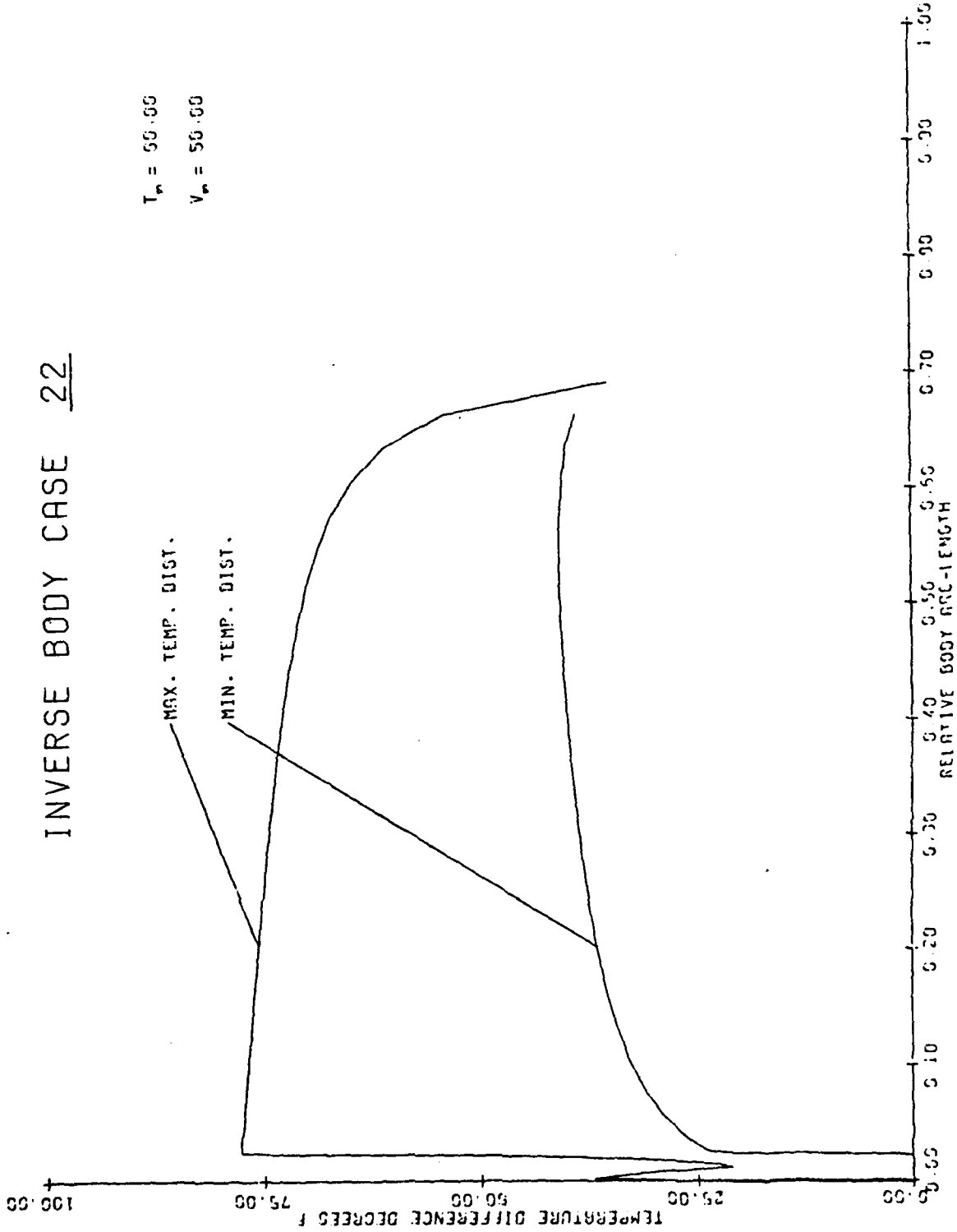


Figure 250. Temperature Distributions, Case No. 22, ( $V_{\infty} = 50$  fps,  $D = 12$  in.).

INVERSE BODY CASE 22

$T_{\infty} = 50.00$   
 $V_{\infty} = 50.00$

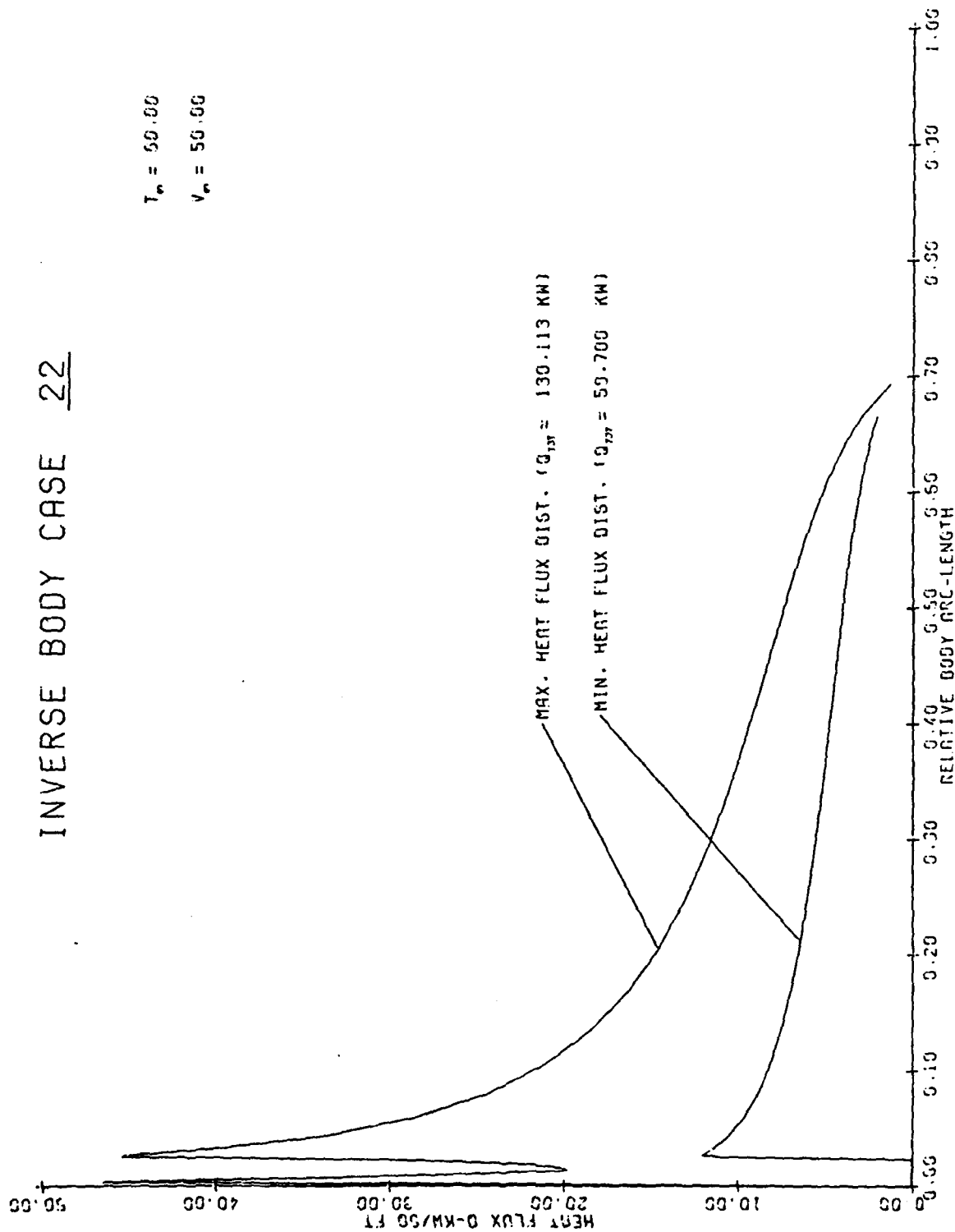


Figure 251. Heat Flux Distributions, Case No. 22, ( $V_{\infty} = 50$  fps,  $D = 12$  in.).

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