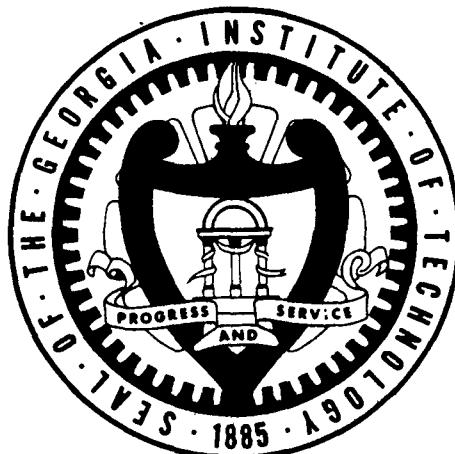


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GEORGIA INSTITUTE OF TECHNOLOGY
School of Mechanical Engineering
Atlanta, Georgia

SIMPLIFIED ANALYSIS AND OPTIMIZATION
OF
SPACE BASE AND SPACE SHUTTLE HEAT
REJECTION SYSTEMS



Contract No. NAS 9-10415

by

Wolfgang Wulff

Sponsored by the
Power Generation Branch
Manned Spacecraft Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Houston, Texas



April 1972

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GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF MECHANICAL ENGINEERING
ATLANTA, GEORGIA

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I

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FOREWORD

This report covers part of the work performed during the second year phase of a two year research project, at the School of Mechanical Engineering at the Georgia Institute of Technology in Atlanta, Georgia, for the NASA Manned Spacecraft Center, Houston, Texas. The contract designation is NAS 9-10415 and the project title is "Study of Design Parameters of Space Base and Shuttle Heat Rejection Systems." The project was monitored by Dr. W.E. Simon of the Power Generation Branch of NASA MSC, Houston, Texas, and was performed by Dr. W.Z. Black and Dr. W. Wulff as Co-Investigators. The project resulted in one Annual Report [2]* and two Final Reports, the first one of which covers a detailed and rigorous space radiator simulation analysis [1] and includes a computer program users manual. The second Final Report is this report.

Although the study of system parameters and the system optimization were originally conceived to be performed on the basis of the rigorous radiator system simulation [1], the growing complexity of this simulation soon gave rise to the need for a simplified analysis. The simplified system simulation was later expanded into systematic optimization procedures. Both the simplified simulation and the optimization procedures serve to supplement and support the originally intended system parameter study [1].

The work presented here was supported by the contributions of computer coding by Mr. Richard J. Huntley and Mr. Wallace W. Carr, both Graduate Research Assistants and M.S. Candidates.

*Numbers in brackets refer to the Bibliography at the end of this report.

SUMMARY

A simplified radiator system analysis was performed to predict steady-state radiator system performance. The system performance was found to be describable in terms of five non-dimensional system parameters. The governing differential equations are integrated numerically to yield the enthalpy rejection for the coolant fluid.

The simplified analysis was extended to produce firstly the derivatives of the coolant exit temperature with respect to the governing system parameters and secondly a procedure to find the optimum set of system parameters which yields the lowest possible coolant exit temperature for either a given projected area or a given total mass. The process can be inverted to yield either the minimum area or the minimum mass, together with the optimum geometry, for a specified heat rejection rate.

The major accomplishments of the simplified radiator system analysis are:

- (1) the reduction of the number of necessary systems parameters from twelve or more to six,
- (2) the graphical representation of system performance in terms of non-dimensional groups, suitable to aid in the design of radiative heat rejection systems, and
- (3) an efficient computer code suitable for preliminary performance prediction.

The accomplishments of the systematic optimization analysis are two computer codes which perform iterative optimizations processes leading to the maximum heat rejection for either a given projected fin-plus-tube area or a given total system mass.

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NOMENCLATURE

A^*	Normalized projected radiator area, Eq. 38
\tilde{A}	Coefficient matrix in Eq. 49
A_{ij}	Elements of coefficient matrix \tilde{A}
a_i	Coefficients of power polynomial
$B_{ij} = \partial^2 \theta_b / \partial x_i \partial x_j$	Second-order derivatives of θ_b
c	Constant in Nusselt number relation, Eq. 35
c_p	Coolant fluid specific heat (Btu/(lbm R))
d	Tube diameter (ft)
$d^* = d/L_o$	Normalized tube diameter
F_{fs}	Fin to sink view factor, Eq. 15
f	Blockage coefficient, defined by Eq. 16
H	Fin height, from base to tip (ft)
$H^* = H/L_o$	Normalized fin height
\bar{h}_c	Average convective film coefficient for convection from fluid to tube (Btu/(hr ft ² R))
i	Number of radiatively active sides
k	Thermal conductivity (Btu/(hr ft R)) of structural material
k_f	Thermal conductivity (Btu/(hr ft R)) of coolant fluid
L	Tube length (ft)
L_o	Reference length (ft), defined by Eq. 37
$L^* = L/L_o$	Normalized tube length
M	Parameter, defined by Eq. 12 (viewfactor augmentation)
M	Structural mass, per fin-tube element (lbm)
$M_o = \rho L_o^3$	Reference mass (lbm)

M_f	Coolant fluid mass (lbm)
$M^* = M / (M_o \phi_1)$	Normalized structural mass
$M_f^* = M_f / (M_o \phi_1)$	Normalized coolant mass
$M_{tot}^* = M_f^* + M^*$	Normalized total mass
m	Exponent on N_{Re} in Nusselt number relation, Eq. 35
\dot{m}	Coolant mass flow rate (lbm/hr)
N	Tube to sink view factor, Eq. 17
$N_c = \bar{N}_c \theta_b^3$	Conduction parameter, Eq. 14
\bar{N}_c, N_c^*	Reference conduction parameter, defined by Eqs. 20 and 58*
N_{Gr}, N_{Gr}^*	Graetz number, Eqs. 23 and 55
N_{Nu}, N_{Nu}^*	Nusselt number, Eqs. 8, 9, 10, 35 and 57*
N_{Pr}	Prandtl number, Eq. 7
N_{Re}, N_{Re}^*	Reynolds number, Eqs. 6 and 56*
n	Number of coolant channels
n	Exponent on N_{Pr} in Nusselt number relation, Eq. 35
p	Exponent on d/L-ratio in Nusselt number relation, Eq. 35
q''	Incident radiant heat flux ($\text{Btu}/(\text{hr ft}^2)$)
r	Number of constraints
T	Absolute temperature (R)
t	Fin panel thickness (ft)
$t^* = t / L_o$	Normalized fin panel thickness
U	System parameter, defined by Eq. 22
V	System parameter, ratio of convective to radiative resistances, Eq. 21
\tilde{x}	Vector whose components are the system parameters x_i

*Superscripted stars on symbol N indicate non-dimensional groups evaluated by replacing all dimensions L, H, d and t by L_o .

x_i	General system parameters, $x_1 = U$, $x_2 = V$, $x_3 = \bar{N}_c$, $x_4 = \lambda$
$\Delta \tilde{x}$	Computed changes of \tilde{x} , in iteration process
Y	Generalized distance from optimum, defined by Eqs. 49 and 50
y_i	Components of \tilde{Y} , defined by Eqs. 50
z	Distance along the tube (ft)

GREEK SYMBOLS

α_s	Solar absorptance
δ	Incremental component vector defining a neighborhood about potential optimum, Eq. 47
ϵ	Surface emittance
$\zeta = Z/L_o$	Normalized axial distance
η	Effectiveness of unobstructed fin
$\bar{\eta}$	Combined fin and tube effectiveness
$\theta = T/T_o$	Normalized temperature
$\lambda = 4H/d$	
σ	Stefan Boltzmann constant $\sigma = 0.1714 \times 10^{-8} \text{ Btu}/(\text{hr ft}^2 \text{ R}^4)$
μ	Dynamic viscosity (lbm/(sec ft))
ρ	Structural material density (lbm/ft ³)
ρ_f	Fluid density (lbm/ft ³)
ϕ_1	Parameter, defined by Eq. 42
ϕ_2	Parameter, defined by Eq. 44
ϕ_3	Parameter, defined by Eq. 63
ψ_i	Constraints, Eqs. 39, 40, 41 and 46

SUBSCRIPTS

b	Fin base
c	Conduction

e Channel exit
f Fluid, bulk property
i,j Component subscripts
k Iteration step counting index
m at optimum
s sink
w Fluid, at tube wall
o Channel inlet

I. INTRODUCTION

A large-scale, complete and rigorous computer simulation of space radiator systems was developed under the same contract as the work presented here [1].* The computer code consists of over fifty program units and is capable of simulating transient as well as steady-state radiator system performances under prescribed time-dependent operational and environmental conditions. The program accommodates both gaseous and liquid coolant fluids with any consistently prescribed set of thermodynamic and transport properties. In principle, this large-scale computer program could serve to not only predict radiator system performance but also to optimize certain design parameters via enumeration of performance characteristics, associated with selected parameter combinations.

Any large computer simulation must be tested during its development; the greater the number of independent verification modes the greater will be the confidence in the program performance. In addition to the tests described in Reference [1], a simplified radiator system analysis was developed to verify the large-scale computer program performance. This simplified analysis served later (1) to extend the rigorous analysis to a wider class of radiator geometries and operating conditions [1] than would have been possible otherwise and (2) to develop systematic optimization procedures in support of system parameter studies on the basis of the rigorous computer simulation.

The essence of the simplified analysis lies in the recognition of the dominant performance characteristics and in the parameter reduction through normalization of the governing differential equations. The optimization is based on standard requirements of extrema subject to suitable constraints. These requirements are imposed on the governing differential equations prior to their numerical integration.

Chapter II below is a discussion of the simplified analysis and is followed by the presentation of the optimization analysis in Chapter III.

*Numbers in brackets refer to the Bibliography.

II. SIMPLIFIED RADIATOR SYSTEM ANALYSIS

A. Objective and Background

The purpose of this analysis is to provide an efficient process of least complexity which serves to describe the steady-state performance of a space radiator system. The radiator system is described in detail in the following chapter.

The analysis is intended to accommodate the essential features of the radiator system performance but to require less computational effort than the rigorous system simulation described in Reference [1]. Finally, the simplified analysis should serve as the basis for systematic optimization of the radiator system.

A first simplified analysis was developed during the first year of the contract period [2], also in support of the rigorous computer analysis, and for the purpose of treating approximately some radiator system geometries which deviate from the basic geometry underlying the rigorous system analysis, such as cylindrical shell radiator structures, asymmetrically loaded coolant channels etc. [1]. This analysis was based on two global energy balances, one for the coolant fluid and one for the radiator panel, and included the two thermal resistances associated with the energy transfer from the fluid to the tube and from the radiator into space. The mean tube wall temperature (and with it, the fin base temperature) was obtained from a single, transcendental equation (Eq. D.11, [2]) and the cooling capacity was found explicitly in terms of the mean tube wall temperature (Eq. 1.1 or 3, [2]). Agreement between this simplified analysis and the full-scale computer simulation was found to be approximately 4%.

The search for an optimum radiator geometry on the basis of the first simplified analysis lead to the conclusion that for optimum radiator geometries neighboring coolant channels should be expected to be close enough to each other so as to obstruct each other's, and the fin panel's, view of space. Moreover, the rigorous computer simulation indicated that the tube wall temperature changes significantly in the direction of the flow even though conduction parallel to the flow direction, both in the fluid, in the

tube wall and in the fin, is negligible. These effects are not accounted for in the first simplified analysis.

The new simplified analysis presented here, for the prediction of steady-state radiator heat rejection performance, takes into account

- (i) temperature variations within the fluid, tube and fin, along the direction of the flow,
- (ii) temperature variation within the fin, normal to the direction of the flow,
- (iii) direct radiative interaction between fin panel and space, tube and space, fin and tubes, tube and neighboring tubes (by approximation),

but does not take into account

- (i) thermal conduction in the direction of the coolant flow, both in the fin-tube structure and the fluid
- (ii) temperature variation of thermal properties,
- (iii) end effects at the coolant fluid manifold,
- (iv) cross-sectional changes in the fin panel,
- (v) secondary reflections of radiant heat.

The analysis reduces to an initial value problem consisting of two ordinary, first-order, coupled differential equations, with one of its initial conditions given through a transcendental equation. The new formulation is suitable for optimization.

B. Description of Radiator System

The radiator system considered here consists of a given number of parallel coolant channels, equally spaced in one plane, and connected by rectangular fin panels which have constant thickness and are symmetric with respect to the plane through the tube areas.

The coolant channels are taken to be thin-walled tubes of circular cross-section, with diameter d and length L . Substitution of the hydraulic diameter for the diameter permits readily the inclusion of channels with non-circular cross-sections, except for possible effects from radiative interaction between tube, fin and environment.

Let the distance between tube centers be designated by $d + 2H$ and the fin panel thickness by t . Then the radiator can be considered to consist of the given number n of identical fin elements as shown in Figure 1.

The coolant fluid enters the channel at $z = 0$ with time-invariant temperature $T_f = T_o$. Both the fluid temperature $T_f(z)$ and the fin base temperature $T_b(z)$ decrease along the tube provided the equivalent sink temperature T_s is less than T_o . The coolant fluid emerges from the radiator at $z = L$ with the exit temperature T_e .

The objective of the analysis is to predict the rate of heat rejection $\dot{m} c_p (T_o - T_e)$ per tube for a given mass flow rate \dot{m} per tube and given fluid properties, namely density ρ , specific heat c_p , thermal conductivity k_f , dynamic viscosity μ , and given properties of the fin, that is, surface emittance ϵ , solar absorptance α_s , and thermal conductivity k .

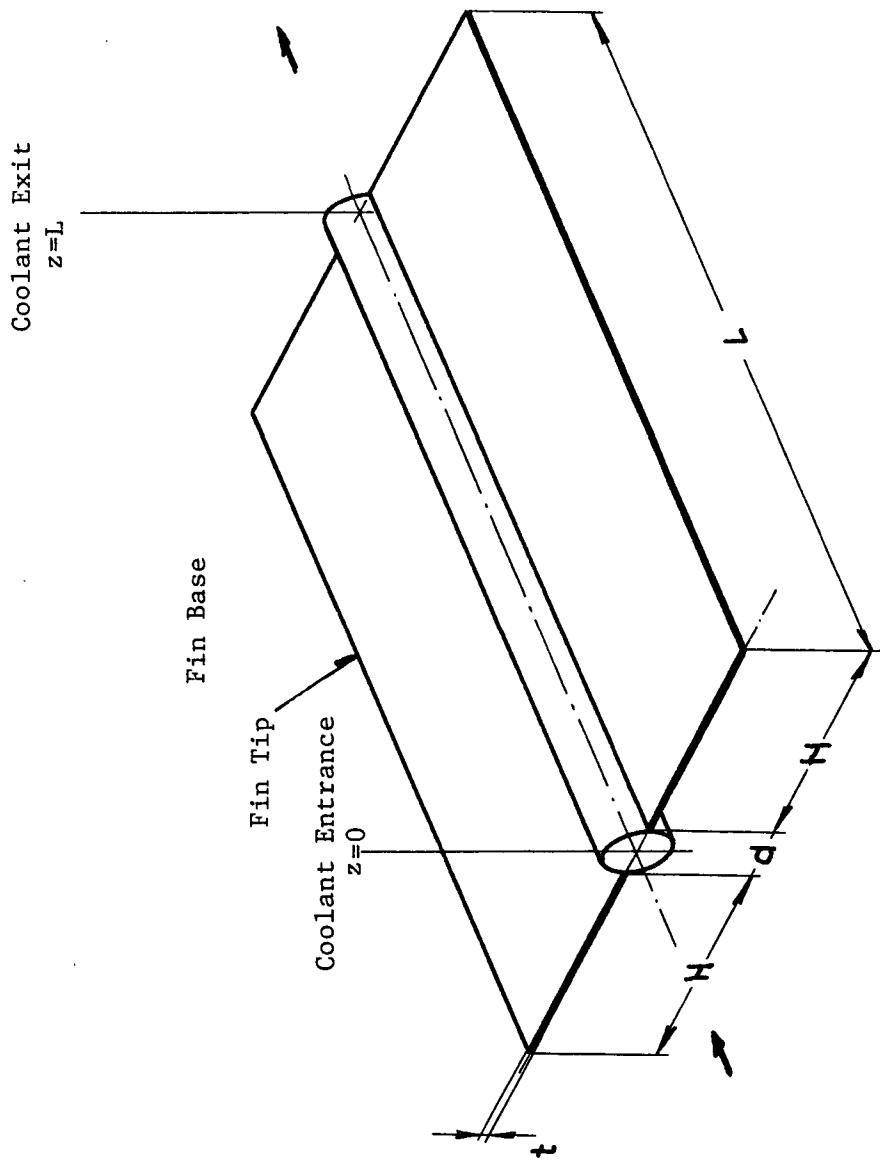


Figure 1. Geometry of Fin System Element

C. Governing Equations

1. Conservation of Energy

Setting the local change of the fluid enthalpy flux first equal to the local heat exchange per unit tube length between fluid and tube wall, and then equal to the radiative heat rejection per unit tube length one obtains, for i effective sides of the radiator:

$$-\dot{m} c_p \frac{dT_f}{dz} = \pi \bar{h}_c (T_f - T_b) \quad (1)$$

$$\pi \bar{h}_c (T_f - T_b) = 2iH\varepsilon\sigma\bar{\eta}(T_b^4 - T_s^4) \quad (2)$$

where \bar{h}_c and σ represent, respectively, the convective film coefficient and the Stefan-Boltzmann constant. The symbol $\bar{\eta}$ represents the overall tube-and-fin effectiveness and is evaluated in Section 3. The convective film coefficient is computed from the Nusselt number N_{Nu}

$$\bar{h}_c = N_{Nu} \frac{k_f}{d} \quad (3)$$

the evaluation of which is deferred to Section 2. The equivalent sink temperature T_s is computed from the known incident normal radiant heat flux q''' by

$$T_s = \sqrt[4]{\frac{\alpha_s}{\varepsilon} \frac{q'''}{\sigma}} \quad (4)$$

The first-order differential equation, Eq. 1, is subject to the initial condition at $z = 0$

$$T_f(0) = T_o \quad (5)$$

Equations 1 and 2 determine the two dependent variables $T_f(z)$ and $T_b(z)$. Integration of Eq. 1 from $z = 0$ to $z = L$ gives the unknown fluid exit temperature T_e .

2. Convective Film Coefficient

The Nusselt number N_{Nu} in Eq. 3 depends on the Reynolds number N_{Re} , the Prandtl number N_{Pr} and the d/L ratio.

$$N_{Re} = \frac{4m}{\pi d \mu} \quad (6)$$

$$N_{Pr} = \frac{\mu_c p}{k_f} \quad (7)$$

For laminar flow, $N_{Re} \leq 2300$, of non-metallic fluids, $N_{Pr} \geq 0.1$, Hausen [3] established the relation

$$N_{Nu} = \left[3.65 + \frac{0.0668 N_{Re} N_{Pr} \frac{d}{L}}{1 + 0.045(N_{Re} N_{Pr} \frac{d}{L})^{2/3}} \right] \left(\frac{\mu_f}{\mu_w} \right)^{0.14} \quad (8)$$

The nomogram in Figure 2, taken from the VDI Waermeatlas*, facilitates the estimate of the Nusselt number in accordance with Eq. 8.

For turbulent flow, $N_{Re} > 2300$, of non-metallic fluids, $N_{Pr} \geq 0.1$, similarity considerations lead to

$$N_{Nu} = 0.116 \left[1 + \left(\frac{d}{L} \right)^{2/3} \right] (N_{Re}^{2/3} - 125) N_{Pr}^{1/3} \left(\frac{\mu_f}{\mu_w} \right)^{0.14} \quad (9)$$

which is also presented in a nomogram in Figure 3.

Liquid metal convective heat transfer in tubes, $N_{Pr} < 0.1$, may be represented by the result of the work by Seban and Shimazaki [4] which is

*VDI-Verlag GMBH, Düsseldorf, West Germany

valid for $(N_{Re} N_{Pr}) > 100$ and $L/d > 60$

$$N_{Nu} = 5.0 + 0.025 (N_{Re} N_{Pr})^{0.8} \quad (10)$$

Other Nusselt number relationships may be more suitable in a particular case. Their selection does not affect the ensuing analysis because the Nusselt number calculation is part of the input data preparation, prior to the numerical evaluation of the solution.

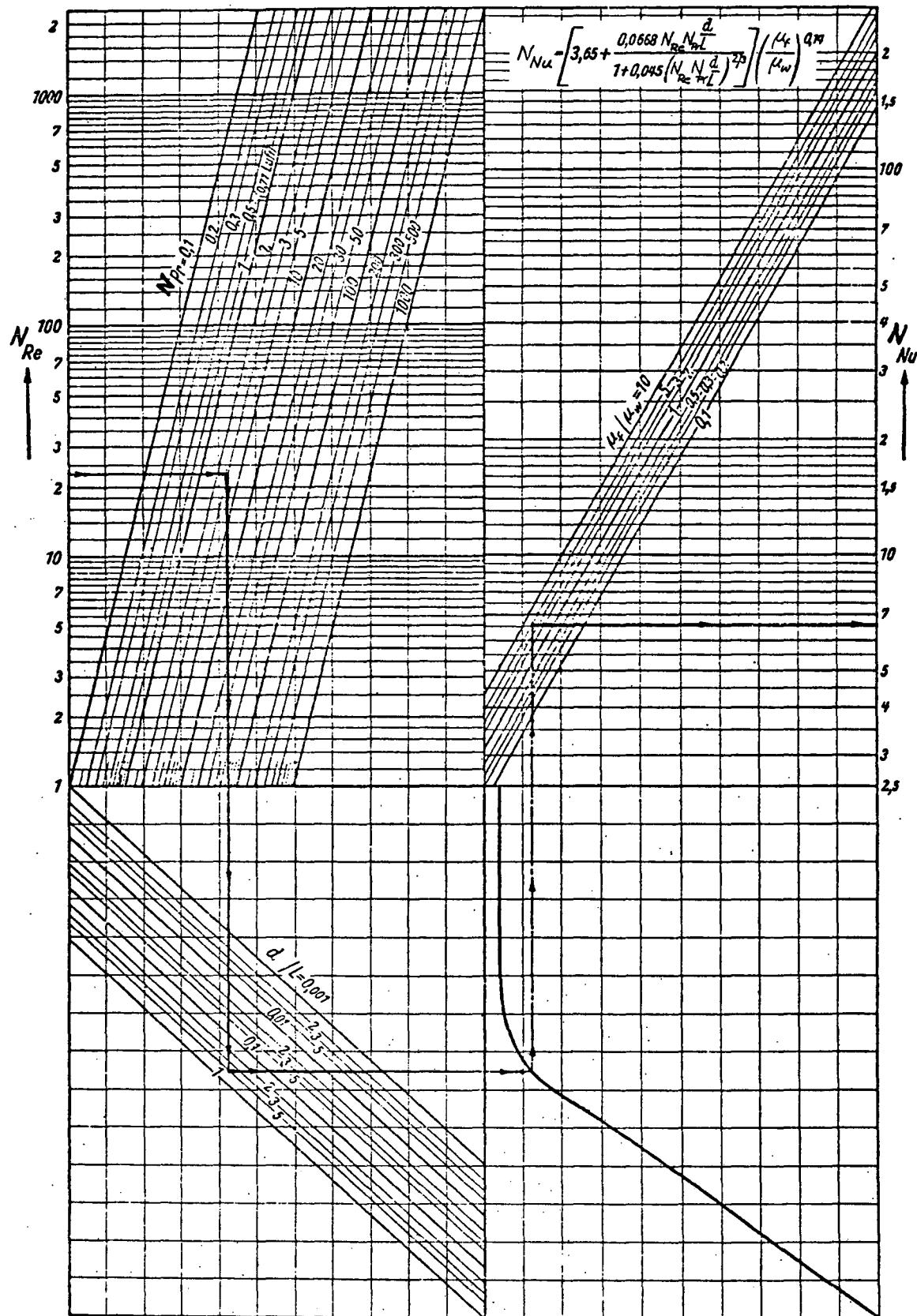


Figure 2. Nusselt Number Nomogram for Laminar Flow of Non-Metallic Coolant Fluids, Eq. 8. (VDI Waermeatlas)

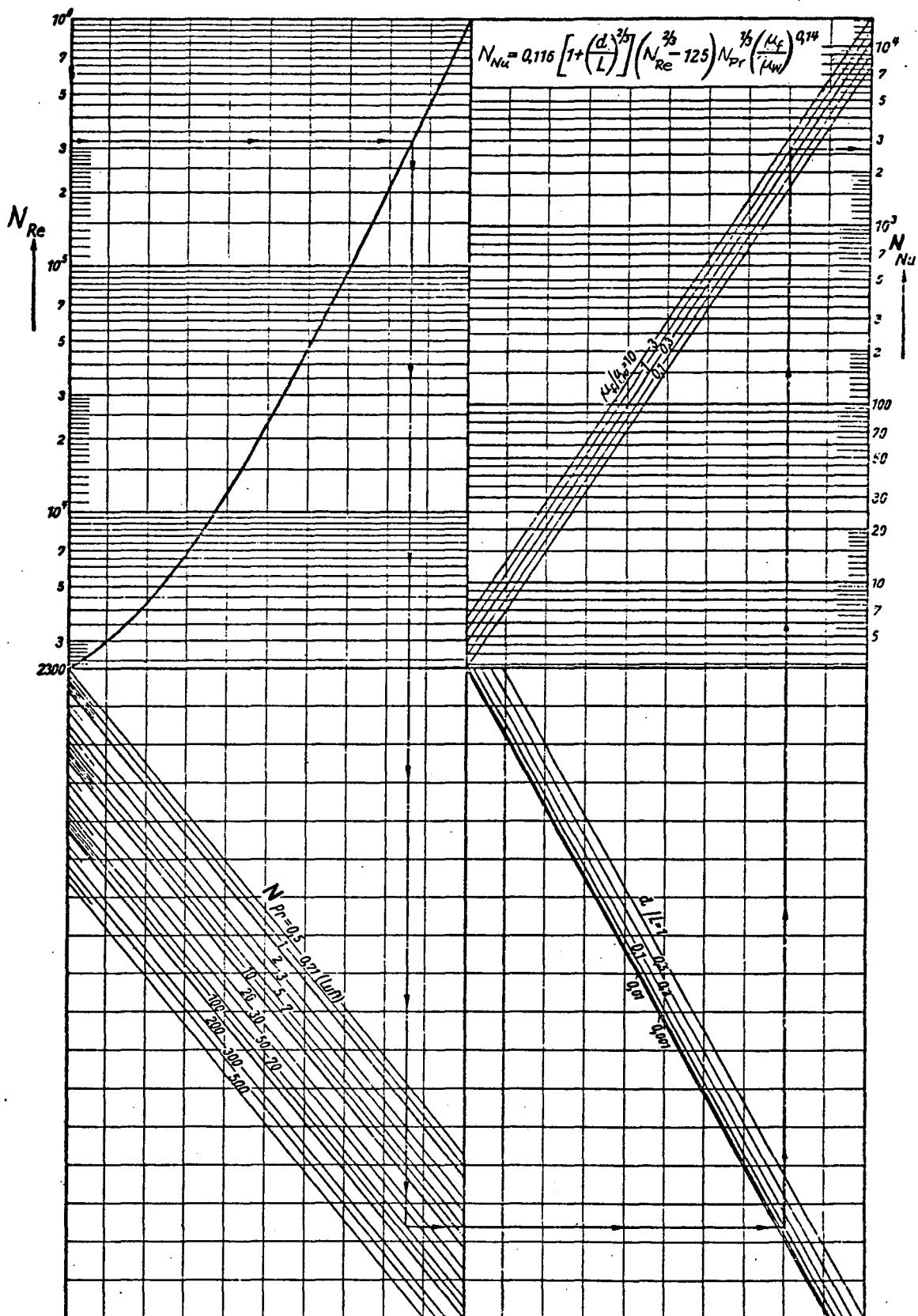


Figure 3. Nusselt Number Nomogram for Turbulent Flow of Non-Metallic Coolant Fluids, Eq. 9. (VDI Waermeatlas).

3. Total Fin-Tube Effectiveness

The symbol $\bar{\eta}$ in Eq. 2 denotes the overall radiative fin-and-tube effectiveness and accounts not only for the non-uniform temperature distribution within the fin and normal to the flow direction, but also for the effects on the radiative heat transfer from the tube. These effects are due to the additional radiating tube area and the partial blockage of emission from the fin and the tubes by the tubes of the neighboring fin elements. Adding the contributions from the tube to that of the fin, one obtains

$$\bar{\eta}(z) = M(z) \cdot \eta(z) + N \quad (11)$$

Here, $\eta(z)$ is the radiative fin effectiveness of the unobstructed fin, Eqs. 32, [5,6,7] and varies with the fin base temperature $T_b(z)$. The factor M is the product of the shape factor of the fin with respect to the sink, F_{fs} , and the corrective term f on η for the temperature profile distortion resulting from the tube-fin interaction [8]:

$$M = F_{fs}(\lambda) \cdot f(\lambda, N_c) \quad (12)$$

where

$$\lambda = \frac{4H}{d} \quad (13)$$

and

$$N_c = \frac{2\epsilon\sigma H^2}{kt} [T_b(z)]^3 \quad (14)$$

which is the well-known conduction parameter. Hottel's crossed-string method yields

$$F_{fs}(\lambda) = \left(\sqrt{\lambda(\lambda + 2)} + \arcsin \frac{1}{1+\lambda} - \pi/2 \right) / \lambda \quad (15)$$

and the curve fit of data in Reference [8] resulted in

$$f(\lambda, N_c) = 1 - (N_c/\lambda)(0.1460 N_c - 0.02866) . \quad (16)$$

Finally, the symbol N in Eq. 11 represents the radiative heat rejection contributed by the tubes and is the shape factor of the tube with respect to the sink, multiplied by the tube-to-fin area ratio

$$N(\lambda) = \pi \left[1/2 + \left[\lambda + 2 - \sqrt{\lambda(\lambda + 2)} - \arcsin \frac{1}{\lambda + 1} \right] / \pi \right] / \lambda \quad (17)$$

This completes the description of the overall fin-and-tube effectiveness. In summary it should be emphasized that axial conduction, radial tube wall temperature variation, kinetic and potential coolant energies, and end effects are ignored, that radiative interaction between tube and fin and between tubes is only approximate and that the representation of Eq. 16 is limited to $T_s < 0.8 T_b$ (but could be extended, in principle).

D. Scaling Parameters

Effective analysis, numerical integration, graphical representation of numerical results and, ultimately, the system optimization makes the reduction of parameters mandatory. Introduce the non-dimensional

$$\text{axial distance} \quad \zeta = \frac{z}{L} \quad (18)$$

$$\text{temperature} \quad \theta = T/T_0 \quad (19)$$

$$\text{reference conduction parameter} \quad \bar{N}_c = \frac{2\epsilon\sigma T_0^3 H^2}{kt} \quad (20)$$

$$\text{ratio of convective to radiative resistance} \quad V = \frac{i}{\pi} \frac{t}{H} \frac{k}{k_f} \frac{\bar{N}_c}{N_{Nu}} \quad (21)$$

$$\text{convection number} \quad U = \pi N_{Nu} / N_{Gz} \quad (22)$$

where the Graetz number N_{Gz} is defined by

$$N_{Gz} = (c_p \dot{m}) / (k_f L) = \frac{\pi}{4} \frac{d}{L} N_{Re} N_{Pr} \quad (23)$$

With these parameters and the λ defined by Eq. 13 one may recast the problem as previously established by Eqs. 1, 2 and 5 as given by Eqs. 24 through 26:

$$\frac{d\theta_f}{d\zeta} = -U(\theta_f - \theta_b) \quad (24)$$

$$\theta_f - \theta_b = V \bar{\eta} (\theta_b^4 - \theta_s^4) \quad (25)$$

subject to the initial condition at $\zeta = 0$

$$\theta_f(0) = 1 . \quad (26)$$

Integration of Eq. 24 subject to Eqs. 25 and 26 yields the coolant fluid exit temperature θ_e sought

$$\theta_e = \theta_f(1) \quad (27)$$

and, consequently, this coolant fluid exit temperature is a function of five parameters

$$\theta_e = \theta_e(U, V, \bar{N}_c, \lambda; \theta_s) . \quad (28)$$

The first four parameters correspond to the geometrical dimensions L, H, t and d of the radiator system and θ_s represents the environment.

E. Solution

Equation 25 is transcendental because of $\bar{\eta}(\theta_b)$ and would require iterative solutions at every step of the numerical integration of Eq. 24. It is more economical to derive a second differential equation for θ_b by differentiating Eq. 25

$$\frac{d\theta_b}{d\zeta} = \frac{-U}{\frac{1}{\theta_f - \theta_b} + \frac{1}{\bar{\eta}} \frac{d\bar{\eta}}{d\theta_b} + \frac{4\theta_b^3}{\theta_b^4 - \theta_s^4}} \quad (29)$$

and to obtain the initial condition for Eq. 29 through a single iterative process (Newton Raphson method) from

$$V\bar{\eta}(\theta_b^4 - \theta_s^4) + \theta_b = 1 \quad \text{at } \zeta = 0 \quad (30)$$

The derivative $d\bar{\eta}/d\theta_b$ is obtained from Eqs. 11 and 16

$$\begin{aligned} \frac{d\bar{\eta}}{d\theta_b} &= \frac{d\bar{\eta}}{dN_c} \frac{dN_c}{d\theta_b} = 3 \bar{N}_c \theta_b^2 \frac{\partial}{\partial N_c} (M\eta) \\ &= 3\bar{N}_c \theta_b^2 \left\{ \eta F_{fs} \left[0.02866 - 0.2920 \bar{N}_c \theta_b^3 \right] / \lambda \right. \\ &\quad \left. + M \frac{d\eta}{dN_c} \right\} \end{aligned} \quad (31)$$

which can be evaluated once the fin effectiveness $\eta(N_c)$, that is the ratio of the actual power loss from an unobstructed (tubless) fin panel to the power loss from an ideal, unobstructed fin of infinite thermal conductivity, is represented by a power polynomial:

$$n(N_c) = \sum_{i=0}^6 a_i (N_c)^i \quad (32a)$$

where

$$\begin{aligned} a_0 &= 1.000\ 000 \\ a_1 &= -1.163\ 143 \\ a_2 &= 1.478\ 836 \\ a_3 &= -1.267\ 550 \\ a_4 &= 0.632\ 522\ 3 \\ a_5 &= -0.162\ 706\ 7 \\ a_6 &= 0.016\ 542\ 23 \end{aligned}$$

Equation 32 is valid for $0 \leq N_c \leq 2.5$. For greater values, $N_c > 2.5$

$$n(N_c) = 0.686\ 609\ 5 e^{-0.229\ 771\ 8} \quad (32b)$$

Equations 24 and 29 have been integrated by a fourth-order Runge-Kutta procedure [2], subject to initial conditions given by Eqs. 26 and 30. The result of the integration yields primarily Θ_e in the form of Eq. 28.

F. Results

A typical computer print-out of the results is shown in Figure 4. First are presented the five parameters $\{\theta_s; U, V, \bar{N}_c, \lambda\}$ of Eq. 28, as read-in. Following that is a table in which are listed, as functions of axial distance measured from the coolant fluid inlet, the fluid temperature $\theta_f = \text{THETA}F$, the fin base temperature $\theta_b = \text{THETAB}$, next the local conduction parameter $N_c = NC$, the local total fin-plus-tube effectiveness $\bar{\eta} = ETABAR$, the local fin effectiveness $\eta = ETA$, the nondimensional axial position $\zeta = ZETA$ and, finally, the number of integration steps required to reach the particular axial position. The number of integration steps depends on the chosen error limits and the rates of variable changes.

The time rate of heat rejection per fin element (tube) is to be computed from

$$\dot{m} c_p (T_o - T_e) = \dot{m} c_p T_o (1 - \theta_e) \quad (32)$$

Parameter studies are presented in Figures 5 through 9. The non-dimensional fluid exit temperature is plotted versus non-dimensional fin panel area with the temperature θ_s (Fig. 5), the non-dimensional tube spacing λ (Figs. 6 and 7) and the reference conduction parameter \bar{N}_c (Figs. 8 and 9) as parameters.

	THETA-S =	V =	E =	LAMBDA =
②	.30000	.100000+01	.200000+01	.200000+01
				.250000+02

	THE TAF	THE TAT	NC	ETABAR	ETA	2ETA	STEP-N0
1.	.000000	.83159	.117762	.964240	.RA1311	.01	1
	.284461	.835315	.116568	.965251	.RA2615	.11	2
	.976137	.837677	.115468	.966145	.RA3569	.21	4
	.956977	.837231	.114453	.967148	.RA4452	.31	5
	.914765	.827954	.135118	.967846	.RA5267	.41	6
	.933555	.825862	.112656	.968553	.RA6020	.51	7
	.923216	.823916	.111051	.969263	.RA6716	.61	8
	.913659	.821213	.111128	.969492	.RA7359	.71	9
	.900875	.820443	.110453	.970473	.RA7953	.81	10
	.890765	.814898	.109830	.971109	.RA8501	.91	11
	.0E9284	.817467	.109255	.971505	.RA9008	1.01	12

FIGURE 4. TYPICAL COMPUTER PRINT-OUT FOR RADIATOR SYSTEM PERFORMANCE

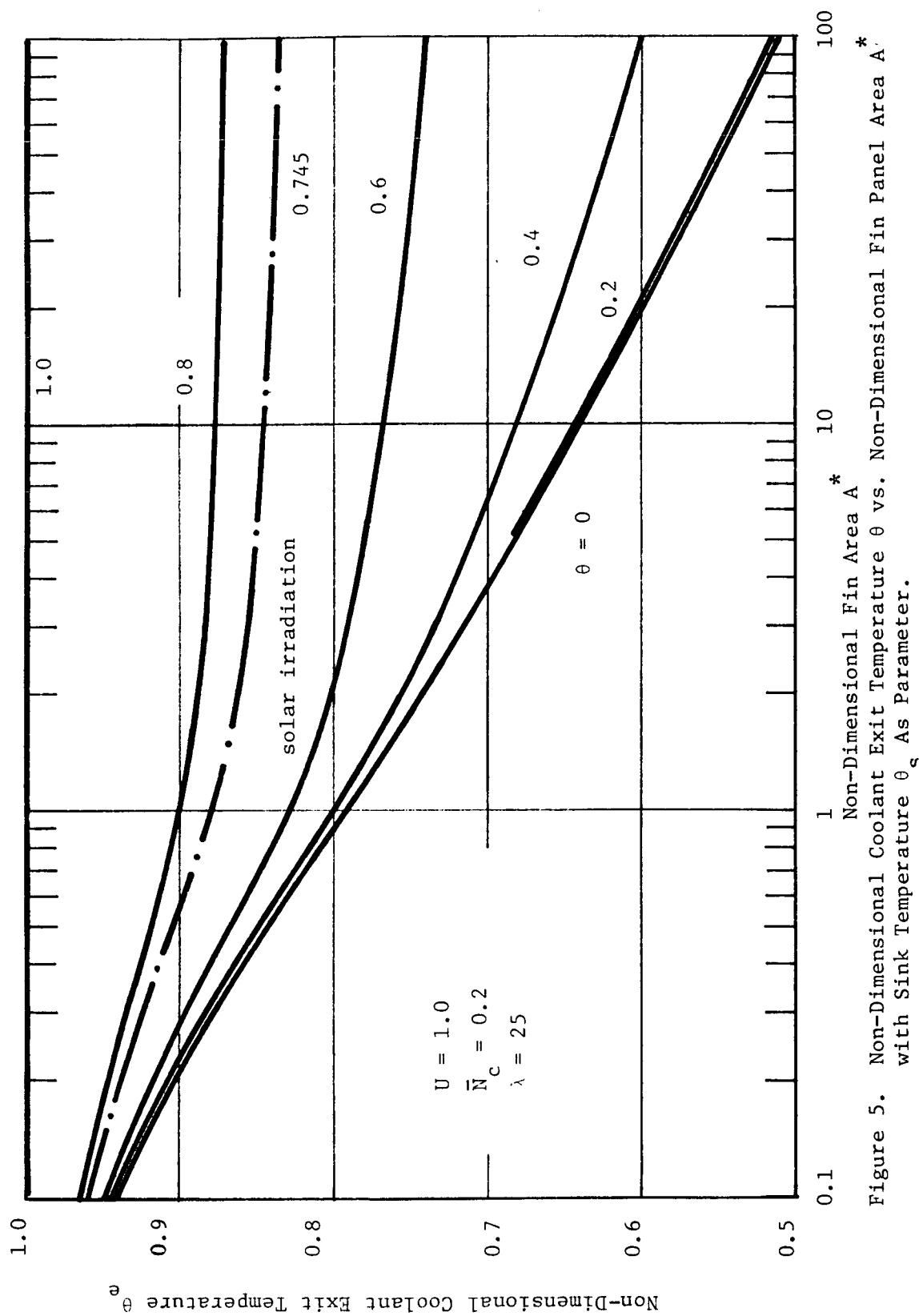


Figure 5. Non-Dimensional Coolant Exit Temperature θ_e vs. Non-Dimensional Fin Panel Area A^* with Sink Temperature θ_s As Parameter.

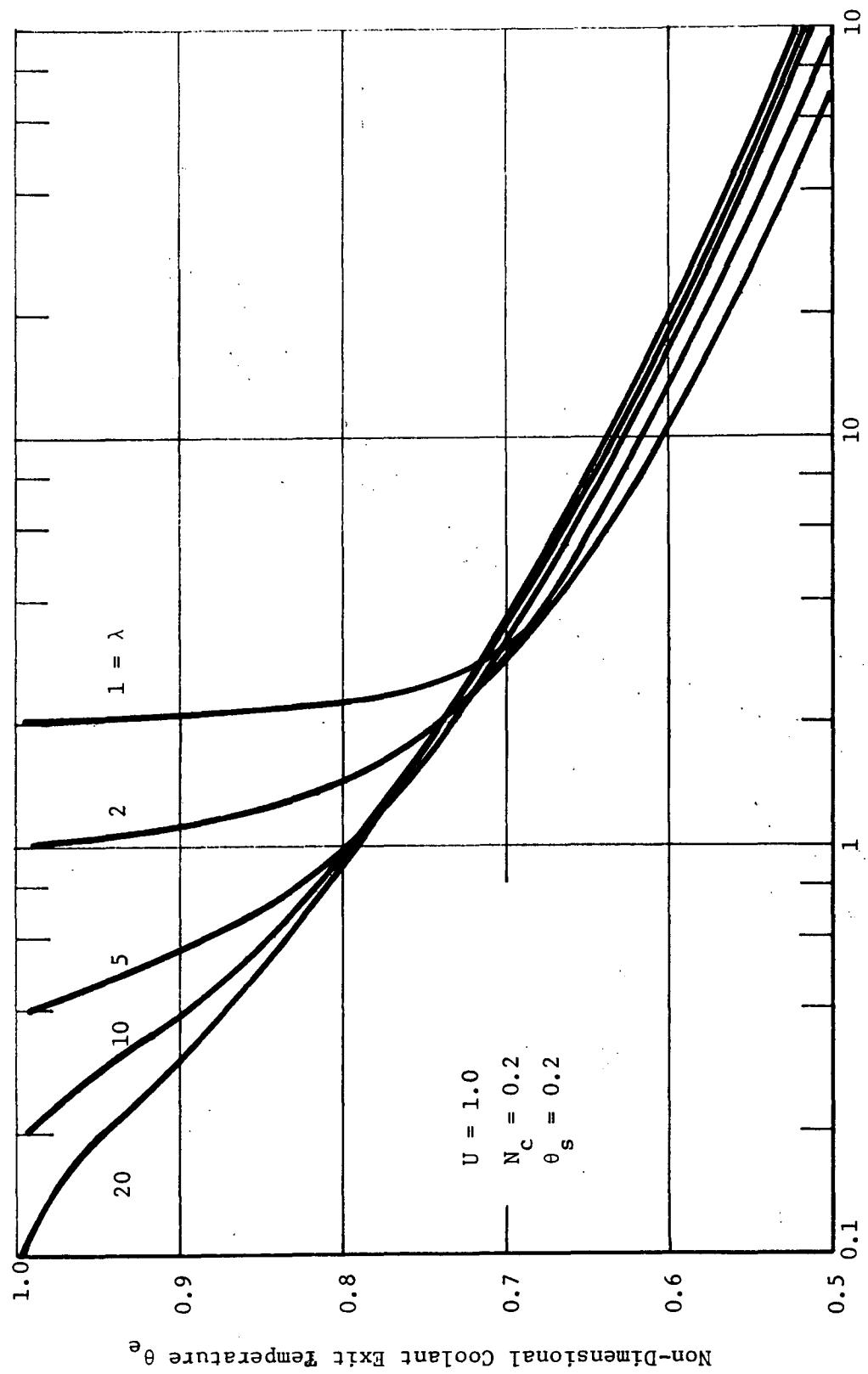


Figure 6. Non-Dimensional Coolant Exit Temperature vs. Non-Dimensional Fin Area For Constant U and Varying λ

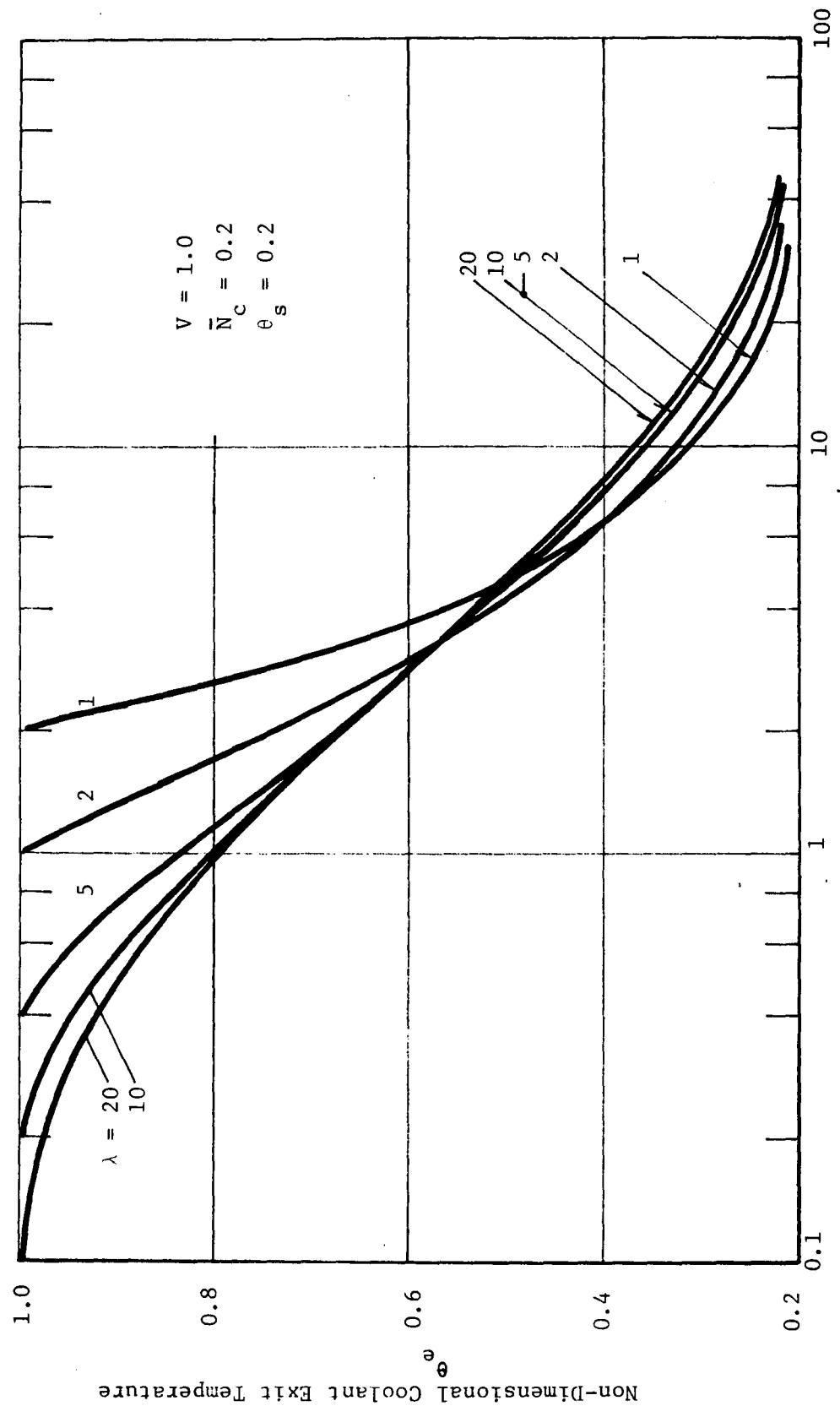


Figure 7. Non-Dimensional Coolant Exit Temperature vs. Non-Dimensional Fin Area
For Constant V and Varying λ

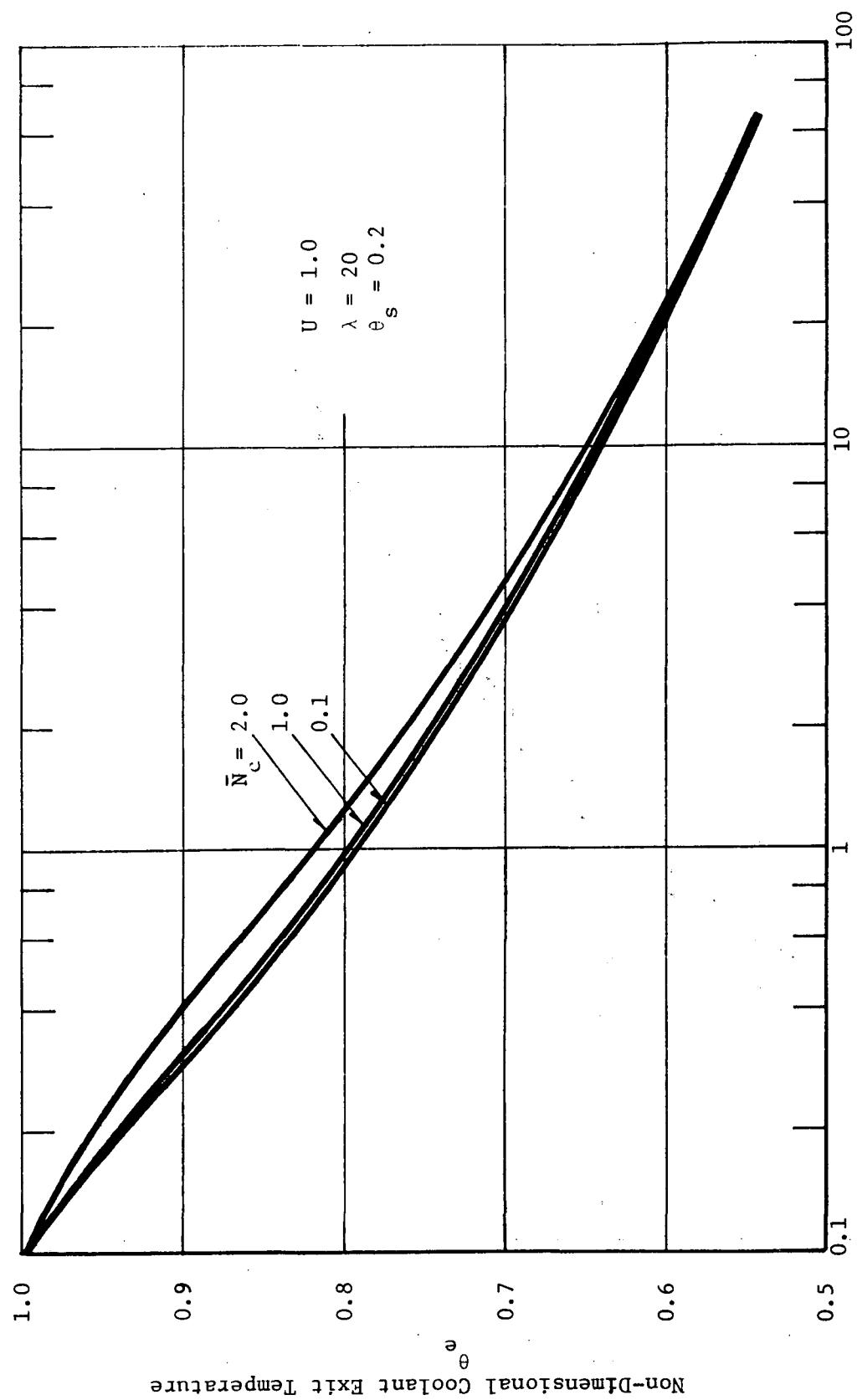


Figure 8. Non-Dimensional Coolant Exit Temperature VS. Non-Dimensional Fin Area For Varying Conduction Parameter and Long Fins.

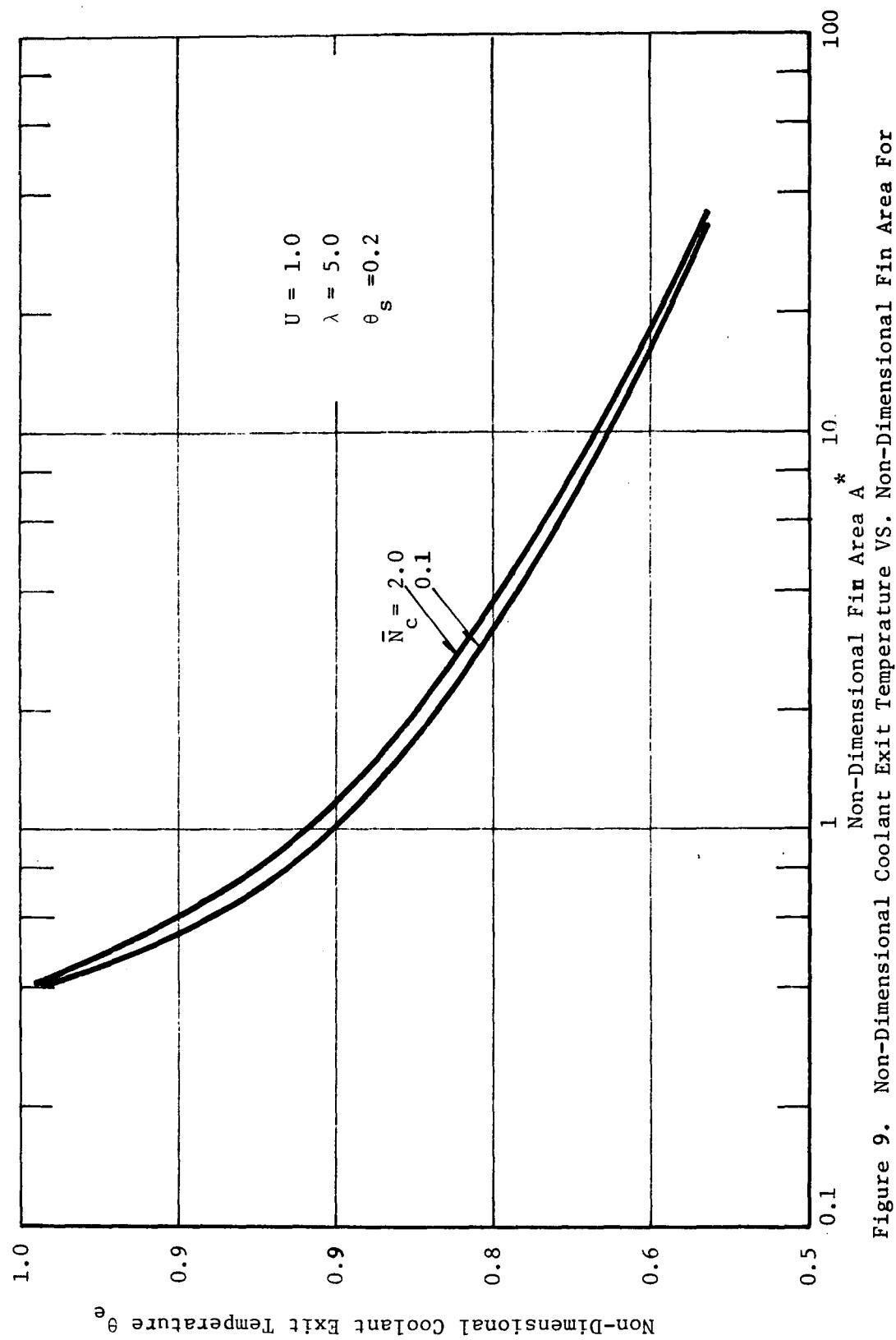


Figure 9. Non-Dimensional Coolant Exit Temperature VS. Non-Dimensional Fin Area For Varying Conduction Parameter and Short Fins

III. OPTIMIZATION OF THE RADIATOR SYSTEM

A. Purpose

In the design of the radiator system all parameters describing the system objectives and the system environment are prescribed beforehand while, at some occasions and within certain limits, the geometry of the system may be selected in the process of the design. This possible freedom of choice leads to the optimization of the radiator system geometry.

The primary purpose of the radiator system is to lower the coolant fluid temperature. For a given set of constraints the radiator with the lowest fluid exit temperature is considered here to be an optimum radiator system.

The set of constraints to be imposed on the optimum radiator system must be selected for a particular set of circumstances. In this analysis two sets out of many possible constraints were selected, that is, weight (or volume) and projected area of the radiator are considered to be prescribed.

The process of optimization proposed here, namely to find the minimum coolant fluid exit temperature for either a fixed radiator area or a fixed mass may be inverted to yield the minimum radiator area or weight for a prescribed cooling rate.

The optimization process can be outlined in the following steps:

(i) select, for given coolant exit temperature

$$\theta_e = \theta_e \{U, V, \bar{N}_c, \lambda; \theta_s\} \quad (28)$$

that optimum set $\{U, V, \bar{N}_c, \lambda\}$ of geometric parameters which constitutes, under selected constraints, the system geometry for the lowest possible coolant exit temperature,

(ii) transform the non-dimensional groups U , V and \bar{N}_c into suitable, non-dimensional radiator length L^* , fin height H^* and panel thickness t^* ,

(iii) calculate the physical dimensions L, H, t and d of the optimum radiator system.

If all fin elements operate under optimum conditions then the radiator as a whole operates under optimum conditions.

B. Problem Formulation

1. General

Of the five parameters U , V , \bar{N}_c , λ and θ_e which define θ_e only the first four can be considered independent while θ_s is determined by the incident radiant flux. For simplicity let us introduce the vector \tilde{X} with components $x_1 = U$, $x_2 = V$, $x_3 = \bar{N}_c$ and $x_4 = \lambda$. The minimum coolant fluid exit temperature $\theta_e(\tilde{X})$, subject to $r \leq 3$ constraints may be obtained from the necessary conditions for a relative extremum

$$\frac{\partial \theta_e}{\partial x_i} = 0 \quad i = 1, \dots, (4 - r) \quad (33)$$

and the r constraints

$$\varphi_j(\tilde{X}) = 0 \quad j = i, \dots, r. \quad (34)$$

This problem formulation implies that the r constraint equations can be solved explicitly for r components of \tilde{X} which can be substituted into Eqs. 33 to yield $(4 - r)$ equations for the remaining $(4 - r)$ components. This was in effect achieved by replacing the Nusselt number relationships given in Eqs. 8 and 9 by a simpler relation of the form

$$N_{Nu} = c N_{Re}^m N_{Pr}^n (d/L)^p \quad (35)$$

with appropriate constants $c = 0.023$, $m = 0.8$, $n = 1/3$, $p = 0$, for $N_{Re} \geq 2,300$; and $c = 1.86$, $m = n = p = 1/3$ for $N_{Re} < 2,300$. The method of Lagrangian multipliers, however, permits the retention of the original constraints at the expense of additional, computational efforts in the case of fixed-mass constraints, since Eqs. 34 need not to be solved explicitly for \tilde{X} .

Two sets of constraints have been considered. Both sets have in common four sets of bounds

$$\left. \begin{array}{l}
 U_{\min} \leq x_1 \leq U_{\max} \\
 V_{\min} \leq x_2 \leq V_{\max} \\
 (\bar{N}_c)_{\min} \leq x_3 \leq (\bar{N}_c)_{\max} \\
 \lambda_{\min} \leq x_4 \leq \lambda_{\max}
 \end{array} \right\} \quad (36)$$

which represent practical limits of the design parameters x_i , $i = 1, \dots, 4$. Should the search procedure lead to the intersection of any of the above limits, then their appropriate equalities would enter the set of constraints. The other two constraints, namely of fixed volume or of fixed area, are discussed below.

2. Area Constraint

Introduce the characteristic length of a single fin element

$$L_o = \sqrt{\frac{m c_p}{i \epsilon \sigma T_o^3}} \quad . \quad (37)$$

which may be interpreted as the length of a square fin element whose effectiveness is unity and which reduces the fluid temperature to zero. Dividing the physical dimensions L , H , t and d by the reference length L_o one obtains the non-dimensional geometric quantities L^* , H^* , t^* and d^* , respectively. The normalized projected fin element area is (for $t \ll d$)

$$A^* = A/L_o^2 = [2HL + dL]/L_o^2 \quad . \quad (38)$$

Consequently, the constraint of "fixed area," the first of Eq. 34, becomes

$$\varphi_1 = 2H^*L^*[1 + 2/\lambda] - A^* = 0 \quad (39)$$

or

$$\varphi_1(x_1, x_2, x_4) = x_1x_2(1 + 2/x_4) - A^* = 0 \quad (40)$$

This constraint equation can be solved explicitly for any one of its arguments, regardless of applicable Nusselt number relationship (see comments following Eq. 34).

The constant area constraint may be supplemented by an additional constraint reflecting the preference for a particular fin panel thickness, arising from manufacturing considerations. A fixed panel thickness t , or equivalently t^* would require

$$\varphi_2(X) = t^* - \phi_1 x_2^2/x_3 \cdot N_{Nu}^2(X) = 0 \quad (41)$$

where ϕ_1 is known beforehand

$$\phi_1 = (1/2i) (\pi k_f/k)^2 k^2 / (im c_p \epsilon \sigma T_o^3) \quad (42)$$

Equation 41 depends on the Nusselt number relationship used. It becomes a necessary constraint when the optimization tends toward panel thicknesses which approach the tube diameter.

3. Volume Constraint

The volume constraint is stipulated by the desire to design a radiator system of minimum mass. The coolant mass may (liquids) or may not (gases) contribute significantly to the total mass.

The mass of one fin element is, under the assumption of a tube wall thickness, equal to the fin panel thickness

$$M^* = \frac{M}{\phi_1 M_o} = L^* t^* [2H^* + \pi(d^* - t^*)] \approx \frac{UV^3}{N_c} \left[1 + \frac{2\pi}{\lambda} \right] N_{Nu}^2 \quad (43)$$

provided $t^* \ll d^*$. Here $M_o = \rho L_o^3$ is the reference mass and M the physical mass of the structure. With

$$\phi_2 = 2i(\rho_f/\rho)(k/k_f) \quad (44)$$

the coolant fluid mass may be expressed as

$$M_f^* = \frac{M_f}{\phi_1 M_o} = \phi_2 N_{Nu} \left(\frac{V}{\lambda} \right)^2 U \quad (45)$$

Consequently, the "volume constraint" becomes

$$\varphi_1(x) = M_{tot}^* - x_1 x_2^2 N_{Nu}(x) \left\{ x_2 [1 + 2\pi/x_4] N_{Nu}/x_3 + \phi_2/x_4^2 \right\} = 0 \quad (46)$$

where $M_{tot}^* = M^* + M_f^*$. Equation 46 reveals that while $\phi_2 > 1$ the fluid mass contributes to the total mass only when x_4 becomes small. For the expected cases of $x_4 \approx 10$ Eq. 46 reduces to a volume constraint as the influence of the density ratio ρ/ρ_f vanishes.

4. Sufficiency Requirements

An optimum radiator is found at \tilde{x}_m when $\theta_e(\tilde{x}_m)$ is a minimum, that is, when in the vicinity of \tilde{x}_m

$$\theta_e(\tilde{x}_m + \delta) > \theta_e(\tilde{x}_m) \quad (47)$$

where δ is a small vector, with components $\{\Delta x_1, \dots, \Delta x_4\}$, and with its endpoint on the hypersurface defined by Eqs. 34.

There exist analytical expressions for the sufficiency conditions in terms of second-order derivatives $\partial^2 \theta_e / \partial x_i \partial x_j$ which are applicable when either all constraints can be solved explicitly as implied by Eqs. 33 and 34 or the number of constraints is at least two. Since, however, θ_e is obtained through numerical integration of Eqs. 24 and 29 and the sufficiency test is to be performed only once the potential optimum is found, it appears economical to evaluate Eq. 47 directly. Further developments concerning the sufficiency criteria are necessary at this time.

C. Solution

1. The Optimum

The remaining task is to solve the system of Eqs. 33 as they are obtained after substitution of Eqs. 34. The solution is obtained through an iterative process based on the Newton-Raphson procedure. Starting with an estimated set of parameters \tilde{x}_1 the iteration is carried on according to

$$\tilde{x}_{k+1} = \tilde{x}_k + \Delta \tilde{x}_k, \quad k = 1, 2, \dots \quad (48)$$

where \tilde{x}_k represents the current, \tilde{x}_{k+1} the future parameter set and the increments $\Delta \tilde{x}_k$ are the solution to the system of linear algebraic equations

$$\tilde{y}_k = (\tilde{A})_k (\Delta \tilde{x})_k. \quad (49)$$

The current components $(y_i)_k$ of \tilde{y}_k are the current values of the derivatives

$$y_i = -\frac{\partial \theta}{\partial x_i}, \quad i = 1, \dots, (4 - r). \quad (50)$$

The current elements $\{A_{ij}\}_k$ of the square matrix $(A)_k$ are the second-order derivatives

$$A_{ij} = \frac{\partial^2 \theta}{\partial x_i \partial x_j}; \quad i, j = 1, \dots, (4 - r). \quad (51)$$

It is obvious that the matrix A_{ij} is symmetric and one needs to compute only $(5 - r)(4 - r)/2$ independent, second-order derivatives.

The derivatives in Eq. 50 and 51 are obtained from Eqs. 24 and 25 by first differentiating with respect to x_i , $i = 1, \dots, (4 - r)$ and then interchanging the order of differentiation. This leads first to $2(4 - r)$ first-order, ordinary, non-linear differential equations for

$$-\frac{dy_i}{d\zeta} = \frac{d}{d\zeta} \left(\frac{\partial \theta_f}{\partial x_i} \right), i = 1, \dots, (4 - r) \quad (52)$$

$$-\frac{dy_i}{d\zeta} = \frac{d}{d\zeta} \left(\frac{\partial \theta_b}{\partial x_i} \right), i = (5 - r), \dots, (8 - 2r)$$

and then to $(5 - r)(4 - r)$ first-order, ordinary non-linear differential equations for

$$\left. \begin{aligned} \frac{dA_{ij}}{d\zeta} &= \frac{d}{d\zeta} \left(\frac{\partial^2 \theta_f}{\partial x_i \partial x_j} \right) \\ \frac{dB_{ij}}{d\zeta} &= \frac{d}{d\zeta} \left(\frac{\partial^2 \theta_b}{\partial x_i \partial x_j} \right). \end{aligned} \right\} \quad (53)$$

The second sets of equations in Eqs. 52 and 53 are necessary because of the dependence of θ_e on θ_b . All initial conditions, at $\zeta = 0$, for Eqs. 52 and 53 can be derived from Eqs. 26 and 30

$$y_i(0) = (y_o)_i, A_{ij}(0) = (A_o)_{ij}, B_{ij}(0) = (B_o)_{ij}. \quad (54)$$

In summary, one needs to integrate, together with Eqs. 24 and 29, the Eqs. 52 and 53, subject to the initial conditions given by Eqs. 26, 30 and 54. The integration is carried out from $\zeta = 0$ to $\zeta = 1$ where it yields not only θ_e and $\theta_b(1)$ but also all derivatives in Eqs. 49. This system is solved for the components of $\Delta \underline{x}$, then a new set of parameters \underline{x} is computed from Eqs. 48 and the iterative cycle repeated. The repetitions are continued until either the first $(4 - r)$ y_i 's are small or one of the inequalities in Eqs. 36 is violated. Should that happen then an additional constraint is introduced, r is incremented by one, and the cycle is continued until either all limits in Eqs. 36 are reached or the remaining y_i 's are sufficiently small. The result may or may not be an optimum for the initially chosen A^* or M^* . Finally, the potential optimum is tested in accordance with Eq. 47.

2. Parameter Transformation and Physical Dimension of Optimum Radiator System.

Once the optimum set $\{x_1, \dots, x_4\}_m$ is found it is necessary to compute from this the physical dimensions L, H, t and d which define the geometry of the radiator system. To accomplish this task the set $\{x_1, \dots, x_4\}_m$ is first transformed into the previously introduced set of normalized dimensions $\{L^*, H^*, t^*, d^*\}$. This transformation is, in general, not possible in explicit form. However, when the simplified Nusselt number relation of the form given by Eq. 35 is substituted for the more general expressions in Eqs. 8 and 9 then L^* , H^* , t^* and d^* can be expressed explicitly in terms of the parameters $\{x_1, \dots, x_4\}$.

Define first the starred quantities.

$$N_{Gz}^* = \frac{c \dot{m}}{k_f L_o} \quad (55)$$

$$N_{Re}^* = \frac{4 \dot{m}}{\pi \mu L_o} \quad (56)$$

$$N_{Nu}^* = c (N_{Re}^*)^m (N_{Pr})^n \quad (57)$$

$$N_c^* = \frac{2 \epsilon \sigma T_o^3 L_o}{k} \quad (58)$$

which are essentially the unstarred quantities evaluated with the reference length instead of any other dimension and which are all known from system objectives and environmental conditions.

Next one needs to distinguish between laminar and turbulent coolant flow as the constants c, m, n and p are different for the two regimes.

For laminar flow, $c = 1.86$, $m = n = p = 1/3$.

$$L^* = \frac{N_{Gz}^*}{2 \pi \sqrt{c^3}} \quad \sqrt{x_1^3} \quad (59)$$

$$H^* = \pi \sqrt{c^3 / N_{Gz}^*} \frac{x_2}{\sqrt{x_1}} \quad (60)$$

$$t^* = \pi^2 c N_c^* / (N_{Gz}^*)^2 \frac{x_2^2}{x_1 x_3} \quad (61)$$

and

$$d^* = 4\pi \sqrt{c^3} / N_{Gz}^* \frac{x_2}{x_4 \sqrt{x_1}} \quad (62)$$

For turbulent flow, $c = 0.023$, $m = 4/5$, $n = 1/3$, $p = 0$.

With

$$\phi_3 = \pi N_{Nu}^* / N_{Gz}^* \quad (63)$$

one obtains

$$L^* = 1 / [2^5 \phi_3^{14}]^{1/9} x_1 \left[\frac{x_2}{x_4} \right]^{4/9} \quad (64)$$

$$H^* = 1/2 [2^5 \phi_3^{14}]^{1/9} (x_2^5 x_4^4)^{1/9} \quad (65)$$

$$t^* = N_c^* / 4 [2^5 \phi_3^{14}]^{2/9} \frac{(x_2^5 x_4^4)^{2/9}}{x_3} \quad (66)$$

$$d^* = \left[2 \phi_3 \frac{x_2}{x_4} \right]^{5/9} \quad (67)$$

Finally, multiplication of the starred quantities L^* , H^* , t^* and d^* by the reference length L_o gives the dimension L , H , t and d of the fin radiator system with optimum performance.

D. Results

The ultimate presentation of the results from the radiator system optimization is the plot of the optimum non-dimensional geometric parameters L^* , H^* , t^* , and d^* versus the non-dimensional enthalpy rejection $(1 - \theta_e)$. These graphs would include three or more parameters, namely the sink temperature θ_s and the parameters occurring in the constraint equations. However, the optimum geometry is not expected to depend strongly on all parameters because of physical considerations, and convenient graphical presentation should be possible.

As indicated in the Introduction, the systematic optimization based on analytical extrema search techniques was developed in addition to the original program objectives but could not be completed within the contract period. The graphical presentation of the optimum geometry in terms of intended enthalpy rejection is therefore not included in this report.

However, computer codes were written on the basis of the solution discussed in Section C. These codes produce the optimum radiator parameters L^* , H^* , t^* and d^* based on the Nusselt number relationship in Eq. 35, for any particular set of input parameters computed from mission requirements and environmental conditions. These results are described in detail in Chapter IV, Sections C. 4 and D. 4.

IV. COMPUTER CODES

A. Introduction

Three separate F \ddot{O} RTRAN codes were developed, one for the simplified radiator system simulation, one for the minimum area optimization and one for the minimum mass system optimization.

The three codes have several subprograms in common and could be united into a single code to avoid duplication. The simulation program, however, is more efficient as a single program and will remain a tool by itself. The optimization programs, on the other hand, are means to develop a tool, namely suitable working charts from which to read optimum system parameters. Once these diagrams are obtained, the codes are no longer needed.

The three F \ddot{O} RTRAN codes are discussed separately in the following three sections but reference is made in the description of subprograms which have previously been discussed.

B. Radiator System Simulation

1. Objective

The purpose of the Simplified Radiator System Simulation (SRSS) is to evaluate the analysis developed in Chapter II for determining the coolant exit temperature

$$\theta_e(U, V, \bar{N}_c, \lambda; \theta_s)$$

in terms of the five governing groups U , V , \bar{N}_c , λ and θ_s defined by Eqs. 13, 19 through 22.

The coolant exit temperature and also the fin base temperature are obtained by integrating simultaneously Eqs. 24 and 29, subject to the initial conditions given by Eqs. 27 and 30. The integration is performed by the Runge Kutta integration procedure described in Reference [1], under variable step size mode.

The individual program units are discussed in the subsequent sections to the extent deemed necessary for the proper utilization of the code. Following the program description are presented the input and output specifications.

2. Deck Assembly

The Simplified Radiator System Simulation (SRSS) code consists of:

one	main program	MAIN
three SUBROUTINE	subprograms	RKS SDRV SCNTL
three FUNCTION	subprograms	ETA PØLY

A block diagram is shown in Figure 7 below.

a. The MAIN Program accepts data input and lists the accepted input data. Following the input data management, the initial conditions for integration are set, an initial step size is computed and control variables are set to control the integration procedure. Then the Runge Kutta procedure RKS is called which performs the integration and indirectly the listing of results. After return from the integration, control is transferred to the start of the program for arbitrarily many repetitions of the program execution. When all input data are exhausted then control is transferred to a normal exit.

The input data preparation is discussed in Section 3 below.

The initial conditions are given through Eqs. 27 and 30. The dependent variables θ_f and θ_b are, during integration, placed in the array Y; $Y(1) = \theta_f$ and $Y(2) = \theta_b$. Equation 27 leads to the statement $Y(1) = 1.0$ and Eq. 30 is solved for θ_b by the Newton-Raphson iteration which follows the listing of accepted input data. The iteration process leads to the statement $Y(2) = THETAB (= \theta_b)$.

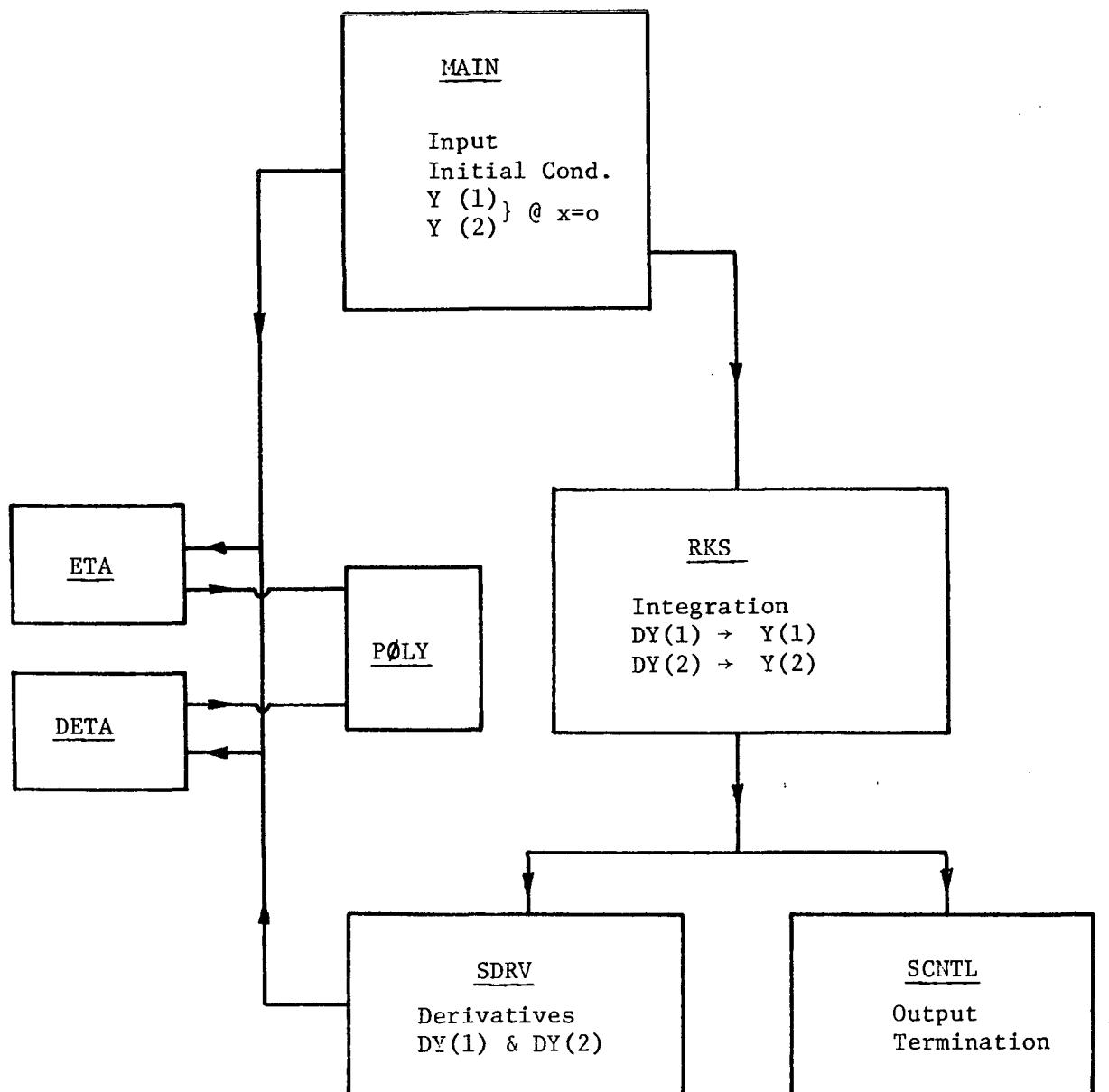


Figure 10. Block Diagram For Simplified Radiator System Simulation Code

Control variables which direct the Runge Kutta Integration
RKS are:

ZZZ = 0.0	initial value for independent variable
DX = 1/(U(1 - θ _b))	initial step size
IFVD = 0	variable step size selection
N = 2	two equations to be integrated
IBKP = 1	cut interval as required
NTRY = 1	normal integration mode
IERR = 0	normal error condition (DX ≠ 0)
A(I) = 5 x 10 ⁻⁵ ; I = 1,2	absolute error per step
R(I) = 5 x 10 ⁻⁵	relative error per step

Control variables which direct output during the integration
are:

DLMT = DXWRT/500	error limit for output interval
XWRT = 0.0	first value of independent variable at first output listing
LSTEP = 0	controls change to fixed step, LSTEP = 1 once integration step exceeds write interval DXWRT
LCNT = 0	senses cut-back (LCNT = 1) of step size prior to listing of results; used to save uncut time step
ICNT = 0	integration step counter

The CALL statement for the Runge-Kutta SUB-Routine is explained
in Reference [1] together with the specification of necessary DIMENSION and
EXTERNAL declarations. SDRV and SCNTL must be declared EXTERNAL. The
necessary array allocations can be read from the listing of the RKS code:
all arrays with variable dimension (N) must be declared in MAIN for N = 2
elements. Only the elements of Y, A and R must be specified prior to the
CALL RKS statement.

b. The Runge-Kutta SUBROUTINE RKS is described in detail in Reference [1]. The user is not expected to alter this code in any way and needs to know only the control features discussed in paragraph a above and the fact that RKS calls two subroutines SDRV and SCNTL.

c. The SUBROUTINE SDRV serves to evaluate the derivatives $d\theta_f/d\xi = dY(1)$ and $d\theta_b/d\xi = dY(2)$ in accordance to Eqs. 24 and 29. The fin effectiveness $\eta(N_c)$ and its derivative $d\eta/dN_c$ are evaluated externally by the FUNCTION subprograms ETA and DETA.

SDRV is called from RKS and supplies the derivatives, via argument list, as functions of the independent variable X and dependent variables $Y(1)$ and $Y(2)$, to the integrating procedure RKS. SDRV is called four times per integration step.

d. The SUBROUTINE SCNTL serves to provide

- (i) output listing at prescribed intervals DXWRT,
- (ii) transfer to fixed-step integration mode once the automatically selected (by RKS) step size DX exceeds the print-out interval DXWRT,
- (iii) termination of the integration procedure and RETURN to the MAIN program (via RKS). The same program, with different WRITE commands is used in the Minimum Area and Minimum Mass Optimization codes.

In the argument list are available

- (i) the dependent variables $Y(1)$ and $Y(2)$
- (ii) their derivatives $DY(1)$ and $DY(2)$
- (iii) the dependent variable X
- (iv) the step size DX which may be altered for repeat of last step
- (v) NTRY = 1 normal continuation of RKS
2 return from RKS to MAIN

```

            3  repeat with new DX
            4  restart
(vi) IFVD = 0  variable integration step
            1  fixed integration step

```

e. The FUNCTION ETA Subprogram computes the fin effectiveness $\eta(N_c)$ for the unobstructed fin in accordance to Eqs. 32a and b. The power polynomial is evaluated by calling the FUNCTION PØLY subprogram [1].

FUNCTION ETA (X) receives the independent variable $X = N_c$ and returns the fin effectiveness ETA. The two functions represented by Eqs. 32 a and b apply strictly to zero sink temperature, but the effectiveness is insensitive to the sink temperature and the equations hold sufficiently well for $\theta_s < 0.8 \theta_b$.

ETA (X) is called from MAIN and SDRV.

f. The FUNCTION DETA Subprogram computes the derivative $d\eta/dN_c$ of the fin effectiveness $\eta(N_c)$ for the unobstructed fin. The derivative is derived from Eqs. 32 a and b, and evaluated by calling the FUNCTION PØLY subprogram [1].

FUNCTION DETA (X) receives the independent variable $X = N_c$ and returns DETA = $d\eta/dN_c$. DETA (X) is called from MAIN and SDRV.

g. The FUNCTION PØLY Subprogram [1] serves to evaluate power polynomials $f(x)$ of any degree ($N - 1$).

$$f(x) = \sum_{i=1}^N A_i x^i$$

by computing the recurrence expression

$$f_i = A_N$$

$$f_{k+1} = f_k X + A_{N-k}, k = 1, \dots, (N-1)$$

(N-1) times. The argument list of FUNCTION PØLY (N, A, X) transfers to the subprogram the number N of coefficients A_i , the one-dimensional array A(N) and the independent variable X; it returns PØLY = $f(x)$. PØLY is called from ETA and DETA.

3. Input Data Preparation

The non-dimensional groups

$$\text{THETAS} = \theta_s = T_s / T_o \quad (19)$$

$$U = \pi N_{Nu} / N_{Gz} \quad (22)$$

$$V = (i/\pi)(t/H)(k/k_f)(\bar{N}_c / N_{Nu}) \quad (21)$$

$$\text{FNCBR} = \bar{N}_c = 2\varepsilon\sigma T_o^3 H^2 / (kt) \quad (20)$$

$$RH\phi D = \lambda = 4H/d \quad (13)$$

DXWRT = $\Delta z/L$, output intervals

are computed and punched, in the above sequence, on two cards in

FORMAT (5F16.8)

There may be arbitrarily many pairs of cards as specified above, one pair for each desired simulation. They will be executed in succession. The End-of-Job card will cause normal exit from the program.

The expected run time on the UNIVAC 1108 is 0.24 seconds per simulation plus necessary compiling and collecting times. There were 32 runs executed in 14.8 seconds.

4. Output Presentation

For each simulation are printed, on a separate page, first the governing parameters as read in:

THETAS = θ_s , defined by Eqs. 4 & 19

U , " Eq. 22

V , " Eq. 21

FNCBAR = \bar{N}_c , " Eq. 20

LAMBDA = λ , " Eq. 13

and then a table consisting of seven columns. In the first two columns are listed, as functions of axial distance ZETA = ζ at the selected intervals

$\Delta\zeta = DXWRT$, the coolant fluid temperature $\text{THETA}_F = \theta_f$ and the fin base temperature $\text{THETA}_B = \theta_b$. The positions $ZETA = \zeta$ are listed in the sixth column.

The conduction parameter $NC = N_c$, the combined fin-plus-tube effectiveness $ETABAR = \bar{\eta}$, defined by Eq. 11, and the fin effectiveness (unobstructed fin, Eqs. 32 a and b) $ETA = \eta$, are listed, respectively, in the third, fourth and fifth columns. The last columns indicate the integration steps required to reach the respective axial position ζ . The desired coolant fluid exit temperature $\theta_e (U, V, \bar{N}_c, \lambda; \theta_s)$ is found in the last entry of the first column.

Figure 11 shows a typical output listing

C. Minimum Area Optimization

1. Objective

The Minimum Area Optimization (MAO) code serves to find the minimum coolant fluid exit temperature for a given projected fin panel area, on the basis of the optimization analysis developed in Chapter III and the constraints as discussed in Section III-2. From the results, evaluated for a number of selected areas, one can determine the minimum area required for a chosen heat rejection rate. The optimum parameter set X is sought which satisfies Eqs. 33, 36, 40 and 41 by performing the iterations specified in Eqs. 48 through 53 until Eq. 33 is satisfied.

From the optimum parameter set X one computes the normalized system dimensions L^* , H^* , t^* and d^* in accordance to Eqs. 59 through 62 or Eqs. 64 through 67, depending on the flow regime in the coolant channels.

The necessary derivatives occurring in Eqs. 50 and 51 are obtained by Runge-Kutta Integration of the first-order, ordinary, non-linear differential equations given by Eqs. 52 and 53.

The individual program units are discussed in the following sections. Reference is made to program description in Section 3 of this Chapter and to Reference [1].

$\Theta_{AS} =$	*200000					
$U =$	*100000+01					
$V =$	*100000+01					
$FRICTION =$	*200000+00					
$LAMBDA =$	*250000+02					
TIME/F	TIME/TB	NC	ETABAR	ETA	ZETA	STEP NO
1.000000	.724992	.078213	1.001229	.9919403	.00	1
.973292	.713938	.072700	1.000161	.9922109	.10	2
.940092	.711261	.069563	1.007515	.9923832	.20	3
.921291	.692644	.066346	1.014601	.9928185	.30	4
.901791	.682975	.063375	1.013130	.9931576	.40	5
.880499	.673334	.061056	1.015711	.9935216	.50	6
.860351	.664019	.058556	1.018158	.9938714	.60	7
.841212	.655507	.056204	1.020465	.9939079	.70	8
.823160	.647288	.053949	1.022855	.9941319	.80	9
.805835	.639851	.051902	1.025729	.9943441	.90	10
.788452	.629884	.049934	1.028696	.9945453	1.00	11
59127						12

FIGURE 11. SAMPLE RESULTS OF SIMPLIFIED RADIATOR SYSTEM SIMULATION

2. Deck Assembly

In its current state the Minimum Area Optimization (MAO) code consists of

1		main program	MAIN	
14	SUBROUTINE	subprograms	RKS SDRV SCNTL BNDCND RESBND REST NDERV MDER NCDERV MIXDER DERV INITIAL INTMIX FMINV	} integration } restraints } partial derivatives } initial conditions matrix inversion
5	FUNCTION	subprograms	ETA DETA DDETA DDDETA PØLY	} η and its derivatives

The basic concept of the program is as described in Chapter B before and the block diagram in Figure 7 applies in principle. The exceptions are

- (i) there are 20 simultaneous differential equations to be solved:

2 for θ_f and θ_b

6 for the derivatives of θ_f and θ_b with respect to U , V and \bar{N}_c

12 for the second derivatives of θ_f and θ_b with respect to U , V , and \bar{N}_c ,

- (ii) the initial conditions on the last 18 differential equations are obtained in subroutines,

- (iii) partial derivatives occurring in the differential equations for the last 18 of the above derivatives are computed by subroutines,
- (iv) at the end of each integration, the system of Eq. 49 is solved by FMINV and the integration repeated until the optimum is reached.

a. The MAIN Program performs the same functions as described in Chapter IV, Section B.2.a. and, in addition, calls INITIAL and INTMIX which compute the remaining 18 initial conditions for the partial derivatives as defined through Eq. 54. Moreover, instead of returning to the next input data set after completion of an integration, new system parameters \bar{X} are computed by solving, via FMINV, the system of Eq. 49. The results are tested, through SUBROUTINE BNDCND, to satisfy the Inequalities 36. If necessary, the newly computed parameters are adjusted to fall within the above limits, and the integration is repeated.

b. The SUBROUTINES RKS, SDRV and SCNTL perform the integration as explained in Sections B.2.b, c and d. There are, however, 18 additional dependent variables $Y(3), \dots, Y(20)$ to be integrated by RKS and, consequently, 18 additional derivatives to be evaluated in accordance with Eqs. 52 and 53. These derivatives are evaluated by calling DERV for $\partial\theta_f/\partial\bar{X}_i$, $\partial\theta_b/\partial\bar{X}_i$, $\partial^2\theta_f/\partial\bar{X}_i^2$ and $\partial^2\theta_b/\partial\bar{X}_i^2$ and by calling MIXDER for $\partial^2\theta_f/\partial\bar{X}_i\partial\bar{X}_j$ and $\partial^2\theta_b/\partial\bar{X}_i\partial\bar{X}_j$, $i \neq j$. SCNTL contains a slightly altered output specification.

c. The Restraint SUBROUTINES BNDCND, RESBND and REST serve to, respectively,

- (i) test newly computed components \bar{X} for compliance with Inequalities 36.
- (ii) solve Eqs. 40 and 41 for x_3 and x_4 .

When newly computed components \bar{X} do not comply with Inequalities 36 then they are set to meet the minimum and maximum conditions and the system of Eq. 49 is solved again, all from within BNDCND.

SUBROUTINE REST is the only particular program which differentiates the two optimization modes, minimum area and minimum mass. It may be replaced to accommodate other constraints. BNDCND and REST are called from MAIN.

d. The SUBROUTINES NDERV, MDER, NCDER, MIXDER and DERV are used to compute, respectively,

- (i) N and its derivatives $dN/d\lambda$, $d^2N/d\lambda^2$ from Eq. 17,
- (ii) M and its derivatives, up to third order, with respect to its arguments λ and N_c , in accordance to Eqs. 12, 15 and 16,
- (iii) N_c and its derivatives $\partial N_c / \partial \theta_b$, $\partial^2 N_c / \partial \theta_b^2$ and $\partial^2 N_c / \partial T \partial \bar{N}_c$,
- (iv) the mixed derivatives defined by Eq. 53 for $i \neq j$,
- (v) the derivatives defined by Eqs. 52 and 53.

e. The SUBROUTINES INITIAL and INTMIX serve to compute the initial conditions for the dependent variable $Y(3), \dots, Y(20)$, at the channel inlet $\zeta = 0$ which represent simple and mixed derivatives $\partial^2 \theta_f / \partial X_i \partial X_j$ and $\partial^2 \theta_b / \partial X_i \partial X_j$ in Eq. 53.

f. The SUBROUTINE FMINV is capable of performing two related tasks:

- (i) to invert a square, invertible matrix \tilde{A}
- (ii) to solve a non-trivial system of equations $\tilde{A}\tilde{Z} = \tilde{X}$.

The solutions are obtained through a sequence of elementary row operations which lead from the properly augmented coefficient matrix to the row-reduced echelon matrix, a standard procedure described in most elementary introductions to linear algebra [1].

SUBROUTINE FMINV (A , X , N , M) accepts, through its argument list, the square, invertible matrix \tilde{A} of rank N , and if task (i) above is intended, M is set equal to $M = 2N$. Then, upon return from FMINV there will be the inverted matrix \tilde{A}^{-1} placed in XMAT(I,J) with $I = 1, \dots, N$, $J = N + 1, N + 2, \dots, 2N$. The two-dimensional array XMAT is transferred to the calling program via a COMMON declaration. When task (ii) above is intended, M is set equal to $M = N + 1$ and, upon return from FMINV, the unknown vector \tilde{Z} is placed in the one-dimensional array \tilde{X} .

FMINV is used to solve Eq. 49 and is called from MAIN and from BNDCND.

g. The FUNCTION subprograms ETA, DETA and PØLY are described in Sections B.2.e, f, and g of this chapter.

h. The FUNCTION subprograms DDETA and DDDETA are used to compute the second and third-order derivatives d^2n/dN_c^2 and d^3n/dN_c^3 as derived from Eqs. 32 a and b. The derivatives are evaluated via FUNCTION PØLY subprogram.

3. Input Data Preparation

Each optimization run is carried out for a selected $ASTAR = A^*$ (Eq. 38) and $TSTAR = t^*$ (Eq. 41) as the independent variables. The necessity of specifying t^* is not yet completely established at this time but included in the program for additional flexibility and to prevent the search from reading excessively large values of t^* .

The optimization produces

- (i) the optimum coolant exit temperature
- (ii) the optimum parameters $X = \{x_1, \dots, x_4\}$ from which to compute L^* , H^* , d^* and λ (Eqs. 59-67).

For each optimization one computes

THETAS = θ_s	, defined by Eqs. 19 & 4
U, starting value	, " " Eq. 22
V, starting value	, " " Eq. 21
FNCBR = \bar{N}_c	
starting value	, " " Eq. 20
ASTAR = A^*	, " " Eq. 40

and selects

$DXWRT = \Delta\zeta$ the axial interval for which results are to be printed.

The first five values are punched on one card in

FORMAT (5F16.8).

The last value is punched on a second card in

'FORMAT(F16.8)

There may be arbitrarily many pairs of cards as specified above, one pair for each optimization run. They will be carried out in succession. The End-of-Job card will cause normal exit from the program.

The expected run time per optimization is approximately 15 seconds plus necessary compilation and collection times.

4. Presentation of Results

Each iteration produces one page of output, first the three parameters THETAS, ASTAR and TSTAR as read in. Next the current values of the system parameters U, V, FNCBAR = \bar{N}_c , LAMBDA = λ and the identification of the flow regime, followed by the iteration count for establishing initial conditions

The table lists, as functions of $\zeta = Z/L$, in this order

THETAf = $\theta_f(\zeta)$ coolant temperature

THETAB = $\theta_b(\zeta)$ fin base temperature

NC = $N_c(\zeta) = \bar{N}_c \theta_b^3$, Eq. 14

ETABAR = \bar{n} , defined by Eq. 11

ETA = n , defined by Eq. 32

M defined by Eq. 12

N defined by Eq. 17

X = ζ , the non-dimensional distance along the channel.

Following the table is a list of the three system parameters U, V, \bar{N}_c and the first and second derivatives of θ_f with respect to these parameters. Finally are listed the newly computed changes of the above parameters.

A typical listing of the results is shown in Figure 9.

158700

02	THETAS =	• 70300000					
	ASTAR =	.675000					
	U =	250.020000					
	V =	.010050					
	ENCBR =	.020100					
	LAMBDA =	.037736					
	NUMBER OF ITERATIONS = 14						
THETA F	THETA R	IC	ETARR	ETA	W	N	ZETA
1.000000	.979813	.0060094	53.0009905	.9998844	.1801294	53.8198819	.0000000
.92.1307	.9182655	.0060776	53.0009919	.9999098	.1801264	53.8198819	.2000000
.8677819	.8609164	.0000652	53.0009928	.9999242	.1801247	53.8198819	.4000000
.8309971	.8303729	.0000573	53.0009933	.9999334	.1801236	53.8198819	.6000000
.8039970	.8035309	.0000519	53.0009938	.9999397	.1801229	53.8198819	.8000000
.7835871	.7832165	.0000480	53.0009938	.9999441	.1801224	53.8198819	1.0000000

PARAMETERS AT END OF TUBE

	THETAF =	.783587
U =	.250000+03	V = .500000-04
D.FDU =	-•247174-05	D.FDV = .117912+00
D2TF.D2U =	*197315-07	D2TF.D2V = .979100+01
D2TF.DUV =	*530499-05	D2TF.DUD.CBAR = .105256-05
DETA.U =	.126478+03	DETA.V = -.363925-04
		DELTA.NCBAR = -•224943-01

OPTIMUM REACHED

FIGURE 12. RESULTS LISTING OF MINIMUM AREA OPTIMIZATION

D. Minimum Mass Optimization

1. Objective

The objective of the Minimum Mass Optimization (MMO) code is identical to that discussed in Section C above, except that the constraints are replaced by the constraints developed in Section III-3 of this report; the minimum mass is sought. Equation 46 replaces Eqs. 40 and 41.

2. Deck Assembly

The MMO code is assembled identically to the MAO code described in Section C.2 above except the SUBROUTINE REST is replaced by the SUBROUTINE CONST which serves to compute $x_4 = \lambda$ from Eq. 46, together with all the necessary derivatives of λ with respect to $x_1 = U$, $x_2 = V$ and $x_3 = \bar{N}_c$. CONST is called from MAIN. RESBND is not required.

3. Input Data Preparation

Each optimization is carried out for a selected M_{tot}^* as the independent variable and for the two parameters N_{Nu}^* and ϕ_2 , defined by Eqs. 46, 42 and 57, respectively. The optimization produces

- (u) the optimum (minimum) coolant exit temperature
- (ii) the optimum system parameters \bar{X} from which to compute $\{L^*, H^*, t^*, d^*\}$ through Eqs. 59-67.

For each optimization are computed

$$\text{THETAS} = \theta_s \quad \text{defined by Eqs. 4 & 19}$$

$$\left. \begin{matrix} U \\ V \end{matrix} \right\} \text{starting values} \quad \begin{matrix} 22 \\ 21 \end{matrix}$$

$$\text{FNCBAR} = \bar{N}_c \quad 20$$

$$\text{TOTMAS} = M_{tot}^*, \text{selected} \quad 46$$

$$\text{PHI2} = \phi_2 \quad 44$$

$$\text{ALPHA} = \alpha = N_{Nu}^* \sqrt[3]{c} \sqrt[3]{2\pi/N^* G_z}$$

and selected

DXWRT = $\Delta\zeta$ the axial interval for which results are to
be printed.

DA, DR absolute and relative integration step errors.

The data values are punched on the data card in NAMELIST format.

The NAMELIST is called INPUT.

There may be arbitrarily many additional input data cards as specified above, or with only one datum, one NAMELIST for each optimization run. They will be carried out in succession until an End-of-Job card causes normal exit from the program.

The expected run time per optimization is approximately 20 seconds plus necessary machine preparation times.

4. Representation of Results

Results are presented in the format identical to that described in section C.4 above, except that instead of the single TSTAR1 are listed MSTAR = M*, PHI2 = ϕ_2 and FNUSTR = N^*_{Nu} , as read in. The representative output example is shown in Figure 10.

THETA-S =	.6000000					
U =	13.363189					
V =	2.792685					
FNCBR =	5.731686					
TOTMAS =	95.000000					
PHI2 =	2000.000000					
ALPHA =	5.000000					
LAMBDA =	31297273.250000					
NUMBER OF ITERATIONS = 8						
THETAF	THETAB	NC	ETABAR	ETA	N	X
1.0000000	.7686288	2.6027493	.3775592	1.0000000	.0000001	.0000000
.7136382	.6486320	1.0316816	.5284999	.5284998	.0000001	.2000000
.6322974	.6138584	1.1674339	.5047780	.5047780	.0000001	.4000000
.60888749	.6038113	1.2169663	.4969006	.4969006	.0000001	.6000000
.6020210	.6010400	1.2322024	.4945601	.4945600	.0000001	.8000000
.6006592	.6002832	1.2364472	.4939149	.4939148	.0000001	1.0000000

PARAMETERS AT END OF TUBE

THETAF =	*600659
U =	*133635*02
V =	*279267*01
NCBAR =	*573169*01
DTFDU =	-.496030=04
DTFDV =	*.131301=03
DTFNCBAR =	-.384840=04
D2TFD2U =	*105462=03
D2TFD2V =	*455954+04
D2TFD2NCBAR =	*120270+03
D2TFD2VONCBAR =	*294970=03
D2TFD2VONCBAR =	-.740525*03
INCR. SOUGHT	DELTA U = .100314+00
INCR. USED	DELTA U = *100314*00
DELTA V =	-.807482=01
DELTA NCBAR =	-.497181+00
DELTA V = *832025=01	
DELTA NCBAR = *497181*00	

INSIGNIFICANT IMPROVEMENT OVER LAST STEP

FIGURE 13. RESULTS LISTING OF MINIMUM MASS OPTIMIZATION

V. CONCLUSIONS

The work presented herein resulted in a simplified radiator system analysis and a systematic optimization procedure.

Comparison of the simplified with the rigorous [1] system analyses indicated that the agreement between the two analyses can be expected to be within approximately 5%.

The optimization procedures carried out lead frequently to an optimum on the boundaries of the parameter domain. Mass optimization tends toward widely spaced tubes between thin fins.

Optimization was originally intended to be achieved through the parametric study of trends rather than through analytical procedures. Within the resources provided by this contract two analytical iterative optimization procedures were developed beyond the original goal of work. These procedures lead to the maximum heat rejection for given system area or system mass. Future work should be aimed toward the development of

- (1) a parameter domain within which relative extrema exist,
- (2) suitable working diagrams, through repeated applications of the developed codes, which depict the optimum geometric system parameters and produce either the least area or the least weight requirements for a given heat rejection rate.

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APPENDIX A**COMPUTER CODE FOR SIMPLIFIED
RADIATOR SYSTEM SIMULATION**

QFOR IS MAIN
FOR S9A-07/25/72-22:39:39 (0)

MAIN PROGRAM

STORAGE USED: CODE(1) 000464; DATA(0) 000355; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	SDR	000014
0004	MCT	00C006

EXTERNAL REFERENCES (BLOCK, NAME)

0005	SDRV
0006	SCNTL
0007	ETA
0010	DETA
0011	RKS
0012	NINRS
0013	NRDUS
0014	NIO2S
0015	NRDUS
0016	SQRT
0017	ASIN
0020	NSTOPS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000150	100	0001	000327 105L	0001	000345 110L	0000	000265 120F	0001	000405 2326
0001	000007	45L	0000	000233 5F	0000	000234 50F	0000	000236 55F	0001	00131 65L
0001	000145	90L	0000	000304 900F	0000	000311 905F	0001	000452 920L	0000	000313 925F
0001	000147	95L	0001	000476 950L	0000	000350 A	0000	000213 AY	0000	000205 A1
0000	R 000214	BYY	0010	R 000000 DETA	0000	R 000220 DETZ	0003	R 000007 DFM	0003	000010 DFMX
0003	R 000011	DFN	0004	R 000000 DLMT	0000	R 000060 DLY	0003	000012 DROU	0003	00013 DROV
0000	R 000224	DX	0004	R 000003 DXWRT	0000	R 00014 DY	0000	R 000140 DYST	0000	R 000221 DYY
0007	R 000000	ETA	0000	R 000216 ETY	0000	R 000215 ETYY	0003	R 000006 FM	0003	R 000005 FN
0000	R 000212	FNC	0003	R 000002 FNCRR	0000	I 000232 I	0000	I 000227 LBKP	0004	I 000001 ICNT
0000	I 000231	TER?	0000	I 000225 IFVD	0004	I 000005 LCNT	0004	I 000004 LSTEP	0000	I 000226 N
0000	I 000207	NCT?	0000	I 000230 NTRY	0000	R 000074 PD	0000	R 000044 R	0003	R 000004 RHOD
0006	R 000000	SCNTL	0000	R 000110 SD	0005	R 000000 SDRV	0000	R 000206 THETAB	0003	R 000004 THETAS
0003	R 000003	TH4	0000	R 000210 T2	0000	R 000211 T3	0003	R 000000 U	0003	R 000001 V
0004	R 000002	XWRT	0000	R 000000 Y	0000	R 000124 YS	0000	R 000170 YSIMP	0000	R 000154 YST
0000	R 000217	YY	0000	R 000222 ZZ	0000	R 000223 ZZZ				

00100	1*	C	SIMPLIFIED RADIATOR SYSTEM SIMULATION
00100	2*	C	*****
00100	3*	C	*****
00100	4*	C	*****
00100	5*	C	THETAS,UV,FNCBR, AND RHOD ARE SYSTEM PARAMETERS
00100	6*	C	DXWRT IS THE INCREMENT OF AXIAL DISTANCE FOR OUTPUT LISTING

```

00100   7*   C   FORMAT (5F16.8)
00100   8*   C
00101   9*   C   EXTERNAL SDRV,SCNTL
00101          DIMENSION Y(12),DY(12),A(12),R(12),DLY(12),SD(12),YS(12),
00103   10*          1           DIST(12),ST(12),YSMP(12),
00103          11*          1           COMMON /SDR/ U,V,FNCBR,THY,RHOD,FM,DFMX,DFNX,DROU,DROV,MCT/
00103          12*          1           DLMT,ICNL,XWRT,DXRT,LSTEP,LCNT
00104   13*          1
00104   14*          C
00104   15*          C
00105   16*          C   FNN(X) = (X+3.570796*SQRT(X*(X+2.0))-ASIN(1.0/(1.0+X)))/X
00105          17*          C   FFS(X) = (SQRT(X*(X+2.0))+ASIN(1.0/(X+1.0))-1.570796)/X
00106   18*          C   FFN(X,Y) = 1.0-Y*(0.1460*Y-0.02866)/X
00107   19*          C   DFFN(X,Y) = (-0.2920*Y+0.02866)/X
00110   20*          C   DFN(X,Y) = Y*(0.1460*Y-0.02866)/(X*X)
00111   21*          C   DFFS(X) = -SQRT((X+2.0)/X)/(X*X+1.)+(1.5708-ASIN(1.0/(X*X+1.0)))/
00112   22*          1   (X*X)
00112   23*          C
00113   24*          C   WRITE(6*5)
00113   25*          C   5 FORMAT(1H1)
00115   26*          C   45 READ(5,50,END=950) THETAS,U,V,FNCBR,RHOD,DXWRT
00116   27*          C   50 FORMAT(5E16.8)
00126   29*          C   WRITE(6*55) THETAS,U,V,FNCBR,RHOD
00127   30*          C   55 FORMAT(1H0,10X,10H) THETA-S = ,FJ9.6//,
00136   31*          C   1   11X,10H U = ,E20.6//,
00136   32*          C   2   11X,10H V = ,E20.6//,
00136   33*          C   3   11X,10H FNCBAR = ,E20.6//,
00136   34*          C   4   11X,10H LAMDDA = ,E20.6//,
00136   35*          C
00137   36*          C   46 IF(THETAS.GE.1.0) GO TO 920
00141   37*          C   FN = FNN(RHOD)
00142   38*          C   DFNX = (-FN+1.0-SQRT(RHOD)*(RHOD+2.0))/RHOD
00142   39*          C
00143   40*          C   TH4 = THETAS*4
00144   41*          C   47 IF(V.GT.0.2) GO TO 90
00146   42*          C   A1 = 2.0+1.0/(V*ETA(FNCBR))
00147   43*          C   48 IF(A1.GE.2.45) GO TO .85
00151   44*          C   THETAB = 1.0-1.0/(2.0*A1)
00152   45*          C   49 60 TO 95
00153   46*          C   50 THETAB = 1.0-(A1-SQRT(A1**2-6.0))/6.0
00154   47*          C   51 60 TO 95
00155   48*          C   52 90 THETAB = 0.9
00156   49*          C   53 NCT = 0
00157   50*          C   54 100 T2 = THETAB**2
00150   51*          C   55 T3 = T2*THETAB
00161   52*          C   56 FNC = FNCBR*T3
00162   53*          C   57 FM = FNN(RHOD,FNC)*FFS(RHOD)
00163   54*          C   58 DFN = OFFN(RHOD,FNC)*FFS(RHOD)
00164   55*          C   59 AYY = 1.3*THETAB-T4
00165   56*          C   60 BYY = 1.0*THETAB
00166   57*          C   61 ETYY = ETA(FNC)
00167   58*          C   62 ETY = ETYY*FM+FV
00170   59*          C   63 YY = 1.0/V-ETY*AYY/BYY
00171   60*          C   64 DETZ = (DFM*ETYY+FV*DETA(FNC))*3.0*T2*FNCBR
00172   61*          C   65 DYY = -AYY/BYY*(DETZ+ETY/BYY)-4.0*ET1*T3/BYY
00173   62*          C   66 22 = THETAB-YY*DY
00174   63*          C   67 23 = (NCT*GT,20) WRITE(6,900)

```

```

00177   64*      IF(ZZ.LT.1.0) GO TO 105
00201   65*      THETAB = (THETAB+1.0)/2.0
00202   66*      NCT = NCT+1
00203   67*      GO TO 100
00204   68*      105 IF(ABS(ZZ-THTAB)/ZZ.LT.1.0E-06) GO TO 110
00206   69*      NCT = NCT+1
00207   70*      THETAB = ZZ
00210   71*      GO TO 100
00210   72*      C
00211   73*      110 Y(1) = 1.0
00212   74*      Y(2) = THETAB
00213   75*      ZZZ = 0.0
00214   76*      DX = 1.0/(U*(1.0-THTAB))
00215   77*      IFVO = 0
00216   78*      IF(DX.GT.DXWRT) DX = DXWRT
00220   79*      N = 2
00221   80*      IBKP = 1
00222   81*      NTRY = 1
00223   82*      IERR = 0
00223   83*      C
00224   84*      DLMT = DXWRT/500.0
00225   85*      XWRT = 0.0
00226   86*      LSTEP = 0
00227   87*      LCNT = 0
00230   88*      ICNT = 0
00231   89*      00 115 111 12
00234   90*      A(I) = 5.0E-05
00235   91*      115 R(I) = 5.0E-05
00235   92*      C
00237   93*      WRITE(6,120)
00241   94*      120 FORMAT(1H0,13X,6HTHETAB,1UX,6HTHETAB,16X,2HNc,17X,6HETABAR,15X,
00241   95*      1      JHTA.,8X4HZETA.,6X,7HSTEP NO /)
00241   96*      C
00242   97*      CALL RK5ISDRV,SCNRL,Y,DY,A,R,ZZZ,DX,N,IFVD,IBKP,NTRY,IERR,
00242   98*      1      DLY,PD,SD,YS,YST,DIST,YSIMP)
00243   99*      WRITE(6,905)
00245  100*      905 FORMAT(1H0,20HNWTON-RAPHSON FAILS)
00246  101*      900 FORMAT(1H0,37HRADIATIVE HEATING CANNOT BE SIMULATED)
00247  102*      920 FORMAT(1H0,'//')
00250  103*      920 WRITE(6,925)
00252  104*      925 FORMAT(1H0,37HRADIATIVE HEATING CANNOT BE SIMULATED)
00253  105*      950 STOP
00254  106*      END
00255  107*      END

```

END OF COMPIRATION: NO DIAGNOSTICS.

5.2
GFOR,IS SUB1
FOR T9A=07/25/72-23:00:14 (1,0)

SUBROUTINE SDRV ENTRY POINT 000150

STORAGE USED: CODE (17) 0001551 DATA(07) 00000371 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003	SDR	000004
0004	SOC	000003

EXTERNAL REFERENCES (BLOCK, NAME)

0005	ETA
0006	DETA
0007	ASIN
0010	SORT
0011	NERRJS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000136	10L	0001	000103	SL	00000 R 000005	A0	0000 R 000006	A1	0000 R 000007	A2			
0000	R	000010	A3	0000	R	000011	A4	0000	R	000012	A5	0003 R 00000	DETA	
0003	000010	DFMX	0003	000011	DFNX	0003	000012	DROU	0003	000013	DROV	0005 R 00000	EIA	
0004	R	000001	ETY	0004	R	000002	ETZ	0000	R	000003	FFN	0003 R 00000	FMM	
0003	R	000005	FN	0003	R	000002	FNCBR	0000	000024	INJPS	0003 R 000004	RHOD		
0003	R	000000	U	0003	000001	V	0000	R	000000	Y2	0000 R 000001	Y3	0000 R 000002	Y4
0004	R	000000	Z											

00101	1*	C	SUBROUTINE SDRV(Y,DY,X)		
00101	2*	C	COMPUTES DERIVATIVES		
00101	3*	C			
00101	4*	C			
00103	5*		DIMENSION Y(12),DY(12)		
00104	6*		COMMON /SDR/U,V,FNCBR,TH4,RHOD,DFMX,DFNM,DETA,DROU,DROV,SOC/		
00104	7*		1		
00104	8*	C			
00105	9*				
00106	10*				
00107	11*				
00110	12*				
00111	13*				
00112	14*				
00113	15*				
00114	16*				
00115	17*				
00116	18*				
00117	19*				
00120	20*				

00101	1*	C	SUBROUTINE SDRV(Y,DY,X)		
00101	2*	C	COMPUTES DERIVATIVES		
00101	3*	C			
00101	4*	C			
00103	5*		DIMENSION Y(12),DY(12)		
00104	6*		COMMON /SDR/U,V,FNCBR,TH4,RHOD,DFMX,DFNM,DETA,DROU,DROV,SOC/		
00104	7*		1		
00104	8*	C			
00105	9*				
00106	10*				
00107	11*				
00110	12*				
00111	13*				
00112	14*				
00113	15*				
00114	16*				
00115	17*				
00116	18*				
00117	19*				
00120	20*				

```
00121    21*      IF(A0.6T.1.0E-08) GO TO 5
00122    22*      DY(2) = 0.0
00123    23*      GO TO 10
00124    24*      5 A1      = Y(1)-Y(2)
00125    25*      A2      = (ET1*DFM+DETA(2)*FM)
00126    26*      A3      = 3.*A2*Y2*FNCR/ET2
00127    27*      A4      = 4.0*Y3/A0
00128    28*      A5      = 1.0*A1*(A3+A4)
00129    29*      DY(2) = DY(1)/A5
00130    30*      C
00131    31*      10 CONTINUE
00132    32*      RETURN
00133    33*      END
END OF COMPILED: NO DIAGNOSTICS.
```

3FOR,IS SUB2
FOR S9A-07/25/72-23:01:21 (0,0)

SUBROUTINE SCNTL ENTRY POINT 000146

STORAGE USED: CODE(1) 0001731 DATA(0) 0000161 BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	SDC	003003
0004	MCT	000005

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NWDJS

0006 NI02\$

0007 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000054	SL	0001	000061	50L	0000	000002	55F	0001	000134	60L	0004 R 000000 DLM1
0000	R	000000 DASR	0004	R	000003 DXWRT	0003	R	000001 ETY	0003	R	000002 ETZ	0004 I 000001 ICNT
0000	000010	I-JPS	0000	I	000001 LCNT	0004	I	000004 LSTEP	0004	R	000002 XWRT	0003 R 000000 Z

00101 1* SUBROUTINE SCNTL(Y,DY,DX,NTRY,IFVD)
00101 2* C
00101 3* C CONTROLS INTEGRATION
00101 4* C
00103 5* DIMENSION Y(112),DY(112)
00104 6* COMMON /SDC/Z,ETY,ETZ,MCT,ICNT,XWRT,DXWRT,LSTEP
00105 7* ICNT = ICNT+1
00106 8* IF(DX .GE. DXWRT .AND. ICNT .GT. 1) LSTEP = 1
00110 9* IF(ABS(X-XWRT) .LT. DLMT) GO TO 50
00112 10* IF(XNRT .GT. X) GO TO 5
00112 11* C
00114 12* DXSTR = DX
00115 13* DX = DX+XWRT-X
00116 14* LCNT = 1
00117 15* NTRY = 3
00120 16* RETURN
00120 17* C
00121 18* 5 NTRY = 1
00122 19* RETURN
00122 20* C
00123 21* SO WRITE(6,55) Y(1),Y(2),Z,ETZ,ETY,X,ICNT
00134 22* 55 FORMAT(1H,5F20.6,F10.2,I10)
00135 23* IF(LCNT.EQ.1) DX = DXSTR
00137 24* LCNT = 0
00140 25* IF(ABS(X-XWRT) .LE. DLMT) GO TO 60
00142 26* XWRT = XWRT+DXRT

00143 27* NTRY = 1
00144 28* IF(LSTEP.EQ.0) RETURN
02 00146 29* OX = DXWRT
00147 30* IFVO = 1
00150 31* RETURN
00150 32* C
00151 33* 60 NTRY = 2
00152 34* RETURN
00153 35* END

END OF COMPILATION: NO DIAGNOSTICS.

02 SUB3
FOR S9A-07/25/72-23:01:26 (.0)

FUNCTION ETA ENTRY POINT 000036

STORAGE USED: COJET(1) 0000441 DATA(0) 0000221 BLANK COMMONT(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 POLY
0004 EXP
0005 NERRIS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000016 1L 0000 R 000001 A 0000 R 000010 B 0000 R 000000 ETA 0000 000014 INJP\$
0003 R 000000 POLY

00101 1* FUNCTION ETA(X)
00101 2* C COMPUTES FIN EFFECTIVENESS ETA
00101 4* C
00103 5* DIMENSION A(7), B(2)
00104 6* DATA A(1),A(2),A(3),A(4),A(5),A(6),A(7)/0.10E+01, -0.1163143E+01,
00104 7* 1 0.147883E+01, -0.1267550E+01, 0.6325223E+00, -0.1627067E+00,
00104 8* 2 0.1654225E-01 / 0(1),B(2)/0.6666095E+00, -0.229718E+00/
00116 9* IF(X.GT.2.5) GO TO 1
00120 10* ETA = POLY(7,A,X)
00121 11* RETURN
00122 12* 1
00123 13* ETA = B(1)*EXP(B(2)*X)
00124 14* RETURN
END

END OF COMPILEATION: NO DIAGNOSTICS.

GFOR,IS SUB4
FOR S9A=07725772-23501:35 (10)

FUNCTION DETA ENTRY POINT 0000036

STORAGE USED: CODE(1) 0000041 DATA(0) 00000211 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK# NAME)

0003 POLY
0004 EXP
0005 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000016 1L 0000 R 000001 A 0000 R 000007 B 0000 R 000000 DETA 0000 000013 INJPS
0003 R 000000 POLY

00101 1* FUNCTION DETA(X)
00101 2* C COMPUTES FIRST DERIVATIVE DETA/DNC
00101 3* C
00101 4* C
00103 5* DIMENSION A(6), B(2)
00104 6* DATA A(1),A(2),A(3),A(4),A(5),A(6)/-0.1163143E+01, 0.2957672E+01,
00104 7* 1 -0.3802650E+01, 0.25300069E+01, -0.8135335E+00, 0.9925338E-01/
00104 8* 2 B(1),B(2)/-0.1577635E-00, -0.2297718E+00/
00115 9* IF(X.GT.2.5) GO TO 1
00117 10* DETA = POLY(6,A,X)
00120 11* RETURN
00121 12* 1 DETA = B(1)*EXP(B(2)*X)
00122 13* RETURN
00123 14* END

END OF COMPILE: NO DIAGNOSTICS.

QFOR,IS SUBS
FOR S9A-07/25/72-23:01:39 (.0)

FUNCTION POLY ENTRY POINT 000036

STORAGE USED: CODE(1) 000044! DATA(0) 000015! BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000012 107\$ 0000 000003 INJPS 0000 T 000002 K 0000 I 000001 L 0000 R 000000 POLY

```
00101 1* FUNCTION POLY(N,A,X)
00101 2* C
00101 3* C EVALUATES POLYNOMIALS
00101 4* C
00103 5* C DIMENSION A(N)
00104 6* C POLY = 0.
00105 7* C L = N
00106 8* C DO 1 K=1,N
00111 9* C POLY = POLY*X+A(L)
00112 10* C 1 L = L+1
00114 11* C RETURN
00115 12* C END
```

END OF COMPIILATION: NO DIAGNOSTICS.

QFOR,IS SUBB
FOR SSA-0725772-23:01:48 (.0)

SUBROUTINE RKS ENTRY POINT 000643

STORAGE USED: CODE(1) 0010401 DATA(0) 0000641 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	NERR2\$
0004	NEXPSS
0005	NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	0000010	10L	0001	000313	110L	0001	000333	120L	0001	000445	126L	0001	000343	130L	
0001	0000071	140G	0001	000355	140L	0001	000105	146L	0001	000130	156L	0001	000447	160L	
0001	0000150	1646	0001	00177	1746	0001	000500	185L	0001	000510	190L	0001	000013	20L	
0001	0000232	2056	0001	000270	2176	0001	000524	220L	0001	000530	230L	0001	000543	240L	
0001	0000374	2436	0001	00032	25L	0001	000552	250L	0001	000554	251L	0001	000572	257L	
0001	0000604	259L	0001	000623	270L	0001	000456	300L	0001	000615	316L	0001	000054	40L	
0001	000060	45L	0001	00006	5L	0001	000076	50L	0001	000123	70L	0001	00035	80L	
0000	R	000014	AM	0000	R	000007	AMAX	0000	R	000001	C	0000	R	000001	D
0000	R	000003	DELT	0000	R	000012	E	0000	R	000002	FR10	0000	I	000004	I
0000	R	000030	INJP\$	0000	I	000002	ISYMP	0000	I	000003	J	0000	R	000006	S

00101	1*														
00101	2*														
00101	3*	C													
00101	4*	C	INTEGRATION												
00101	5*	C													
00103	6*	C	DIMENSION Y(N),DY(N),A(N),R(N),DELY(N), IPD(N),SD(N),YS(N),DYT(N),YST(N),YSIMP(N)												
00103	7*	C	EXTERNAL DERIV. CNTRL.												
00104	8*	C	FR10 IS FIFTH ROOT OF TEN												
00104	9*	C	FR10=1.584932												
00105	10*	C	TER=0												
00106	11*	C	YS CONTAINS Y VALUES AT LEFT END POINT OF INTEGRATION INTERVAL												
00106	12*	C	DG00090												
00106	13*	C													
00106	14*	C	YSIMP CONTAINS Y FOR SIMPSONS RULE CHECK. CHECK NOT MADE FOR												
00106	15*	C	FIXED STEP MODE. ISYMP IS CONTROL PARAMETER =1.FIXED. 2.VARD00120												
00106	16*	C	DG000700												
00106	17*	C	IF FIXED STEP SIZE GO ONE INTERVAL OF LENGTH DELT AND RETURN TO CNTRL, IF VAR GO TWO INTERVALS BEFORE RETURN TO CNTRL												
00106	18*	C	DG00140												
00106	19*	C													
00106	20*	C	IFVD = 0 VARIABLE INTERVAL												
00106	21*	C	DG00150												
00106	22*	C	FIXED												
00106	23*	C	CUT INTERVAL ONCE BEFORE REPEAT (UNDER IFVD=0)												
00106	24*	C	DG00160												
00106			CUT AS REQUIRED												
00106			DG00170												
00106			DG001800												
00106			DG00190												
00106			DG00200												
00106			DG002100												

```

00106 25* C 2 RETURN FROM RKS
00106 26* C 3 STEP REPEATED WITH NEW DELT
02 00106 27* C 4 RESTART
00106 28* C IERR = 0 NORMAL
00106 29* C -1 DELT=0. RETURN FROM RKS
00106 30* C 1 A(I)+R(I)*ABS(Y(I)) = 0. • RETURN FROM RKS
00107 31* C 5 IF(DEL) 20 TO 20
00112 32* 10 IERR=-1
00113 33* GO TO 270
00114 34* 20 CALL DERIV(Y,DY,T)
00115 35* NTRY=1
00116 36* CALL CNTRL(Y,DY,DELT,NTRY,IFVD)
00117 37* 25 DOT=DEL
00120 38* IF(IFVD) 40 TO 40
00123 39* 30 ISYMP=2
00124 40* DELT=DEL/2.
00125 41* DO 31 I=1,N
00130 42* 31 SD(I)=0.0
00132 43* IFLAG=1
00133 44* S=1.
00134 45* 60 TO 45
00135 46* 40 ISYMP=1
00136 47* 45 DELT=DEL
00137 48* 45 DO 46 I=1,N
00142 49* Y(I)=Y(I)
00143 50* 46 DST(I)=DY(I)
00145 51* 50 DO 60 I=1,N
00150 52* DELT(Y(I)-DELT*D(Y(I))
00151 53* PD(I)-DEL(Y(I))
00152 54* 60 CONTINUE
00154 55* 60 TO (80/70),ISYMP
00155 56* 70 DO 71 I=1,N
00160 57* 71 SD(I)=SQ(I*S*D(Y(I))
00162 58* 80 T=T+DEL/2.
00163 59* DO 85 I=1,N
00166 60* Y(I)=Y(I)
00167 61* Y(I)=YS(I)+DELY(I)/2,
00170 62* 85 CONTINUE
00172 63* 90 CAL DERIV(Y,DY,T)
00173 64* DO 90 I=1,N
00176 65* DELT(I)=DELT*D(Y(I))
00177 66* PD(I)=PD(I)*2.*DELY(I)
00220 67* Y(I)=YS(I)+DELY(I)/2,
00221 68* 90 CONTINUE
00222 69* CAL DERIV(Y,DY,T)
00223 70* DO 95 I=1,N
00227 71* DELT(I)=DELT*D(Y(I))
00228 72* PD(I)=PD(I)*2.*DELY(I)
00229 73* Y(I)=YS(I)+DELY(I)
00230 74* 95 CONTINUE
00231 75* T=T+DEL/2.
00232 76* CALL DERIV(Y,DY,T)
00233 77* DO 100 I=1,N
00221 78* DELT(I)=DELT*D(Y(I))
00222 79* PD(I)=PD(I)+DELY(I)
00223 80* Y(I)=YS(I)+PD(I)/6.
00224 81* 100 CONTINUE

```

00226 82* GO TO (110,120),ISYMP
 00227 83* 110 NTRY=1 D6007900
 00230 84* CALL DERIV(Y,DY,T) D6008000
 00231 85* CALL CNTRL(Y,DY,DEL,T,NTRY,IFVD) D6008100
 00232 86* GO TO 300 D6008200
 00233 87* 120 GO TO (130,140),IFLAG D6008300
 00234 88* 130 S=4. D6008400
 00235 89* IFLAG=2 D6008500
 00236 90* CALL DERIV(Y,DY,T) D6008600
 00237 91* GO TO 50 D6008700
 00240 92* 140 CALL DERIV(Y,DY,T) D7008800
 00241 93* AWAX =0.0 D6008900
 00242 94* DO 180 1=1,N D6009000
 00245 95* SD(I)-SD(I)+DY(I) D6009100
 00246 96* YSIMP(I)=YSI(I)+DEL*I*SD(I)/3. D6009200
 00247 97* D=ABS(Y(I))-YSIMP(I) D6009300
 00250 98* C=AI(I)+R((1),ABS(Y(I))) D600940
 00251 99* IF(C , 160,150,160) D6009500
 00254 100* 150 JERR=1 D600960
 00255 101* GO TO 270 D6009700
 00256 102* E=FBS(D /C) D6009800
 00257 103* AWAX=MAX1(AWAX,E) D6009900
 00260 104* 180 CONTINUE D601000
 00262 105* IF(AWAX<1.) 215,215,230 D601020
 00265 106* 215 NTRY=1 D6010300
 00266 107* CALL CNTRL(Y,DY,DEL,T,NTRY,IFVD) D6010400
 00267 108* 302 IF(NTRY=1) 185,85,310 D601050
 00272 109* 310 IF(NTRY=2) 270,270,330 D601060
 00275 110* 330 IF(NTRY=3) 340,340,5 D601070
 00300 111* 343 T=T-DDT D601080
 00301 112* IF(DEL) 259,10,259 D6010900
 00304 113* 165 GO TO (40,190),ISYMP D601100
 00305 114* 191 IF(AWAX>.75) 200,25,220 D601100
 00310 115* 203 IF(AWAX<.075) 210,25,25 D601120
 00313 116* 211 DEL=DEL*FR10 D6011300
 00314 117* GO TO 25 D6011400
 00315 118* 221 DEL=DEL/FR10 D6011500
 00316 119* GO TO 25 D6011600
 00317 120* 233 I=1+ IBKP D6011700
 00320 121* GO TO (240,250),I D6011800
 00321 122* 243 T=T-DEL D6011900
 00322 123* DEL=DEL/FR10 D6012000
 00323 124* GO TO 259 D601210
 00324 125* 253 J=1 D6012200
 00325 126* 251 AW=AWMAX/10.**,J D6012300
 00326 127* 253 I=DEL/(FR10**J) D601240
 00331 128* 255 J=J+1 D6012500
 00332 129* 267 T=T-DEL D601260
 00333 130* 267 T=T-DEL D601270
 00334 131* DEL=DEL/(FR10**J) D601280
 00335 132* 259 DO 245 I=1,N D601290
 00330 133* DY(I)=YSI(I) D6013000
 00341 134* 245 Y(I)=YSI(I) D6013100
 00343 135* 263 GO TO 25 D6013200
 00344 136* 270 RETURN D6013300
 00345 137* END D6013400

END OF COMPIRATION! NO DIAGNOSTICS.

Q XGT
MAP 0023-0772523:02

ADDRESS LIMITS 001000 013206 040000 044714
STARTING ADDRESS 012523

WORDS DECIMAL 5255 YBANK 2509 OBANK

SEGMENT	MAIN	001000 013206	040000 044714
NSWTCS/FOR	1	001000 001021	
NRBLKS/FOR	1	001022 001044	
NRWINDS/FOR	1	001045 001124	2 040000 040011
NWEFS/FOR	1	001125 001326	2 040012 040031
NETCHS/FOR	1	001327 001617	2 040032 040067
NBDCVS/FOR	1	001620 001752	2 040070 04125
NFTVS/FOR	1	001753 001775	
NCNVT\$/FOR	1	001776 002222	2 040126 040215
NCLOSS\$/FOR	1	002223 002371	2 040216 040247
NWLKS/FOR	1	002372 002513	
NBSBL\$/FOR	1	002514 002550	
NUPDAS\$/FOR	1	002551 002603	
NBF00\$/FOR	1	002604 003014	2 040250 042451
NININS\$/FOR	1	003015 003657	2 042452 042463
NINOTS\$/FOR	1	003660 004173	2 042464 042503
NOTINS\$/FOR	1	004174 005162	2 042504 042507
NOOUT\$/FOR	1	005163 006041	2 042510 042534
NFQT\$/FOR	1	006042 006214	2 042535 042611
NI0ERS\$/FOR	1	006215 007076	2 042612 042716
NFCHKS\$/FOR	1		2 042717 043055
NTAB\$7/FOR			4 043056 043127
ERUS/MISC			2 043130 043166
NIBJFS\$/FOR	1	007077 007141	2 043167 043167
TIRS/TECH	1	007142 007626	0 043170 043220
SORTS/FOR	1	007627 007667	2 043221 043500
ASINCOS\$/FOR	1	007670 010104	2 043501 043512
NIE\$S\$/FOR	1	010105 010166	0 043513 043540
NOBUFS\$/FOR	1	010167 010233	2 043541 043674
EXPS/FOR	1	010234 010323	2 043675 043715
NEXPSS\$/FOR	1	010324 010411	2 043716 043725
NRERS\$/FOR	1	010412 010736	2 043726 044071
SDR (COMMON BLOCK)			044072 044105
MCT (COMMON BLOCK)			044106 044113
SDC (COMMON BLOCK)			044114 044116
BLANKSCOMMON (COMMON BLOCK)			
SUB6	1	010737 011776	0 044117 044202
			2 BLANKSCOMMON

SUB5		1	011777	012042	0	044203	044217
02	SUB4	1	012043	012106	2	BLANKS COMMON	
SUB3		1	012107	012152	0	044220	044240
SUB2		1	012153	012345	2	BLANKS COMMON	
		3	SDC		0	044241	044262
SUB1		1	012346	012522	2	BLANKS COMMON	
		3	SDR		0	044263	044300
MAIN		1	012523	013206	4	MCT	
		3	SDR		0	044301	044337
					4	SDC	
					2	BLANKS COMMON	
					4	MCT	

SYSS*RLIBS* LEVEL 63
END OF COLLECTION - TIME 1.677 SECONDS

APPENDIX B

COMPUTER CODE FOR MINIMUM

AREA OPTIMIZATION

2 FOR IS MAIN
FOR S9A-07/27/72-17:43:15 (,0)

MAIN PROGRAM:

STORAGE USED: CODE(1) 0010451 DATA(0) 0006771 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003	BLK1	000004
0004	BLK2	00002
0005	CT	00005
0006	BLKR	00002
0007	BLK3	00002

EXTERNAL REFERENCES (BLOCK, NAME)

0010	S:2Y
0011	SCJTL
0012	SIST
0013	TERV
0014	ETIA
0015	DETA
0016	ACERY
0017	TER
0020	ITLNL
0021	TRFLX
0022	FS
0023	FVLV
0024	LDCN3
0025	PESND
0026	NMTKA
0027	MRJUF
0030	N1025
0031	N4715
0032	4511
0033	SART
0034	N1015
0035	STOP5

Report available at <http://www.cs.vu.nl/~wouter/>

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	UD01021L	C001	000153100L	0000	000421100F	0001	000133105L	0001	0001511nRL
0004	010354109L	0001	000361110L	0010	0004232000F	0000	0004542010F	0000	0001672000F
0009	010525205E	0000	0006222050F	0010	0006162000F	0001	001033200AL	0000	0001312005E
0009	010514210F	0000	000521215F	0010	000602220F	0000	000533230F	0001	000162336
0000	010547240F	0000	000564250F	0011	001024300L	0001	001041300L	0001	000125340G
0001	11002450L	0001	00016000L	0010	000462000F	0000	000050A	0000	00037AV
0000	R 000353 ASIA	0000	R 000352 YY	0004	00003 A1	0004	000034 A2	0004	00005 A3
0004	000100A4	0004	0000715	0014	00001176	0000	000363 BYY	0015	000000DETA
0006	R 000367 DET2	0003	000023 DEIDL	0013	000021 DF4	0003	000013 DF4	0003	00012 DEMX
0003	R 00010 CFNX	0006	R 00006 DLDNCB	0016	R 00001 DLDU	0006	R 000002 DLDV	0005	R 00000 QLT
0000	R 000120 QLY	0007	000000 DNCBDU	0017	000001 DMCBDV	0003	R 000007 DMCRI	0000	R 00005 QX
0005	R 00003 DXWR	0000	R 00024 DY	0000	R 000240 DYST	0000	R 000370 DY	0000	R 000373 DC02T

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      0000 R 000374 D2CTIB 0000 R 000402 N2E4LN 0000 R 000376 N2E4LV 0000 R 000401 N2F4LN
      0000 R 000375 D2E4LU 0000 R 000377 N2E4TV 0003 R 000403 D2E4LL 0006 R 000403 D2D4LV
      0005 R 000005 D2L4LV 0006 R 000007 D2LNCB 0006 R 000011 D2LNUA 0006 R 000011 D2LNUB
      0003 R 000014 D2ML4C 0003 R 000011 D2JDL 0004 R 00001 D3M2LN 0004 R 000002 D4M2NL
      0014 R 000000 ETA 0000 R 000365 FTY 0003 R 000022 E3 0003 R 000015 D2NC
      0003 R 000003 FNC 0000 R 000000 FNC 0003 R 000004 FNCBR 0000 I 000003 I 0000 R 000004 FNC
      0005 I 000001 ICNT 0000 I 000412 TERR 0000 I 000406 IFVD 0000 I 000413 LCNT 0005 I 000004 LSIEP
      0000 I 000407 N 0000 I 000357 NCT 0000 I 000354 NIT 0000 I 000414 NTMAX 0000 I 000011 NTRY
      0000 R 000144 PC 0000 R 000074 R 0000 R 000355 RHOD 0006 R 00000 RLAV 0011 R 000001 SCNTL
      0000 R 000170 S2 0010 R 000000 SORV 0023 R 000001 THETAB 0000 R 000372 THETAF 003 R 000001 THETAS
      0000 R 000336 T44 0000 R 000360 T2 0000 R 000361 T3 0004 R 000000 U 0003 R 000005 V
      0000 R 000334 X' 0005 R 000002 XMRT 0000 R 000000 Y 0000 R 000214 YS 0000 R 000010 YTEMP
      0000 R 000264 YST 0000 R 000366 YY 0013 R 000017 Y1 0003 R 000020 Y2 0000 R 000371 Y7
      0000 R 000404 Z22 0000 R 000415 Z1 0010 R 000416 Z2 0000 R 000417 Z3 0000 R 000420 Z5

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00100 1* C RADIATOR SYSTEMS OPTIMIZATION FOR MINIMUM AREA
00100 2* C
00100 3* C EXTERNAL SURV,SCNTL

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00103 4* DIMENSION Y(20),DY(20),A(20),P(20),PU(20),SD(20),
00103 5* 1 Y(20),DY(20),YST(0),YS1(0),YS1P(20),X(3,4),
00103 6* 1 COMMON /BLKI/THETAS,FNU,FNCBR,FNC,V,DNC0T1,DFNU,D2NDLL,
00104 7* 1 DFNU,FM,D2WLNCD,M,DNC,D2FLN,YN2,DE4DTB,E3,DE1DL/
00104 8* 2 ALKDX,DF342LN,D342LN,D342LN,A,A2,A3,A4,A5,AG,EB
00104 9* 3 /MCT/JLT,ICUT,XRT,DX,RT,LS,STEP
00104 10* 4 /BLKP/RCLM,PLDU,PLDV,PLU,PLUV,PLDUV,PLDNCR,
00104 11* 5 /PLLNCP,PL2LNUB,PL2LNUV,PL2LDUV,PL2LDVV,PLDNCR,
00104 12* 6 /BLK/R3NCBDR,PLNCBDR,PLNCBDR
00105 13* FFX(X) = (SDT((Y*(Y+2.0))+ASI*(1.0/(X+1.0))-1.570796)/X
00105 14* FFX(Y) = 1.0-Y*(0.1660*Y-0.02*(E6))/X
00106 15* 0FF*(X,Y)=C(-2.9204*Y-0.028661)
00107 16* 1 R-A(T5,10000'E'IN=3000) THETAS,U,V,FNCBR,ASTAR,DXRT
00110 17* 1 R-A(T5,10000'E'IN=3000) THETAS,U,V,FNCBR,ASTAR,DXRT
00120 18* 100 FORAT(T5F16,A)
00121 19* 100 FORAT(T5F16,A)
00122 20* 100 IF (U,L,T4,0.07-0.07*U,GT.250.) GO TO 1
00124 21* 100 IF (V,L,T4,0.07-0.07*V,GT.50.) GO TO 1
00126 22* 100 IF(FNCBR,LT,0.0000,OR,FNCBR,LT,4.01) GO TO 1
00130 23* 100 CALL REST(U,V,ASTAR,RLAV,DLDU,LDV,DLUV,DLVN)
00131 24* 100 CALL NDERV(RLAV,FM,DFNU,D2NDLL)
00132 25* 100 R102 = RLAV
00133 26* 200 WRITE(6,200) THETAS,ASTAR,U,V,FNCBR,RLAV
00143 27* 200 FORMAT(1H1,10HTHETA-S = F20.8/
00143 28* 4 11X,10H ASTAR = F20.6/
00143 29* 1 11X,10H U = F20.6/
00143 30* 2 11X,10H V = F20.6/
00143 31* 3 11X,10H FNCBR = F20.6/
00143 32* 5 11X,10H LAMBDA = F20.6//)
00144 33* 500 WRITE(6,201) NIT
00147 34* 201 FORAT(5X,NIT,ITERATIONS = 'T2)
00150 35* T14 = THEtas**4
00151 36* IF (V,GT.0.2) GO TO 90
00153 37* .IF (VAL,E.1.0E-10) GO TO 108
00155 38* 91 THEtas = 0.9

```

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*2 00156 40*   95 NCT   = 0
  00157 41*   .00 T2   = THE TAB *#?
  00160 42*   T3   = TC *THE TAB
  00161 43*   FNC   = ENCR TAB
  00162 44*   FM   = FFN(RHD),FNC)*FFS(7H0D)
  00163 45*   DFY   = DEFN(RHD),FNC)*FFS(RHD)
  00164 46*   AYY   = T *THE TAB - TH4
  00165 47*   JYY   = 1.0 - IDE *#?
  00166 48*   ETYY   = ETA(FNC)
  00167 49*   ETY   = ETA(FNC)
  00170 50*   YY   = 1.0/V - ETY + AYY / RYY
  00171 51*   DET2   = 1.0*V*ETY + FM*DETA(FNC) * 3.0 *T2*FNCBR
  00172 52*   DYY   = - AYY / 3YY + (DET2+ETY/BYY) - 4.0 *ETY*T3/BYY
  00173 53*   Z2   = THE TAB3 - XY / DYY
  00174 54*   IF (CT.GT.20) GO TO 109
  00176 55*   IF (Z2.LT.1.0) GO TO 105
  00200 56*   THE TAB3 = (THE TAB3+1.0)/2.0
  00201 57*   NCT   = NCT+1
  00202 58*   GO TO 100
  00203 59*   05 IF (.35122-THE TAB3)/72,L1.0E-06) GO TO 110
  00205 60*   NCT   = NCT+1
  00206 61*   THE TAB3 = .77
  00207 62*   GO TO 100
  00210 63*   VB THE TAB3 = 1.0
  00211 64*   GO TO 110
  00212 65*   09 WRITE(6,900)
  00214 66*   C   = 1.0
  00215 68*   Y(2)   = THE TAB
  00216 69*   ON FOR A11H,20HIE:NON-RAPHSO FAILS
  00217 70*   THE TABF = Y(1)
  00220 71*   Y1   = Y(1)
  00221 72*   Y2   = Y(2)
  00222 73*   CALL NCERB(FNC),THE TAB,FNC,*INCOT1,2,C2T,D2CTN#,
  00223 74*   CALL MDERURLM,FM,DFUX,D1,Y,D2FML,D2NDIC,D312LN,D3M?NL
  00224 75*   CALL INITIAL(DLDR,22LN),Y(3),Y(4),Y(5),Y(6),0,1,DL2E4TU,D2E4LU)
  00225 76*   CALL INITIAL(DLDV,22LDV),Y(7),Y(8),Y(9),Y(10),0,0,0,DL2E4TV,D2E4LV)
  00226 77*   CALL INITIAL(2LDNC,22LNCR),Y(11),Y(12),Y(13),Y(14),1,1,DL2E4TN,
  00226 78*   D2E4LN)
  00227 79*   1 CALL INTMIX(02E4TV,Y(4),DLDR,22E4LN,D21DNB,Y(16),Y(15))
  00230 80*   CALL INTMIX(02E4TU,Y(4),DLDR,22E4LN,D21UNB,Y(18),Y(17))
  00231 81*   CALL INTMIX(02E4TM,Y(8),DLDR,22E4LN,D21LN,D21VN,B,Y(20),Y(19))
  00232 82*   DO 115 I=1,?0
  00235 83*   A(I)   = 1.0E-05
  00236 84*   15 R(I) = 1.0E-05
  00236 85*   L
  00240 86*   WRITE(6,2040)
  00242 87*   2.40 FOR A11JX,6HTHE TAB,9X,6HTHE TAB,9X,2HNC,13X,6HETABR,
  00242 88*   1 9X,3HETA,13X,1HM,14X,1HN,14X,4HETAB
  00242 99*   C
  00243 90*   ZZZ   = 0.0
  00244 91*   DX   = 1.0/(U*1.0-THE TAB)
  00245 92*   IF VJ = 0
  00246 93*   IF (JX,6LDXERT) DX = DXRT
  00250 94*   N   = 20
  00251 95*   13KP = 1
  00252 96*   NTRY = 1

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62      97*     TERR   = 0
00253    98*     C
00254    99*     CLNT   = DXWRIT/500.0
00255   100*     XWRT   = 0.0
00256   101*     LSTEP   = 0
00257   102*     LCNT   = 0
00260   103*     ICNT   = 0
00261   104*     CALL RKS(SDPU,SCNL,Y,DX,A,R,ZZZ,DX,N,IFVD,IAKP,NTRY,JERR,
00261          105*           "DLY,P,D,SD,YS,YS,T,DYST,YSIMP)
00262   105*           XMU()  = -Y(1)
00263   107*           XM(2)  = -Y(7)
00264   108*           XM(3)  = -Y(11)
00265   109*           AM(1*1) = Y(5)
00266   110*           AM(1*2) = Y(15)
00267   111*           AM(1*3) = Y(17)
00270   112*           AM(2,1) = Y(15)
00271   113*           AM(2*2) = Y(7)
00272   114*           AM(2,3) = Y(19)
00273   115*           AM(3,1) = Y(17)
00274   116*           AM(3,2) = Y(19)
00275   117*           AM(3*3) = Y(13)
00276   118*           CALL FVN(Y,XM,XM,3,4)
00277   119*           WRITE(6*205)
00301   120*           205 FORMAT(//45X,27H PARAMETERS AT END OF TURE //)
00302   121*           WRITE(6*210) Y(1)
00305   122*           210 FORMAT(1X,51.0DHETAE,ZF10.6,/)
00306   123*           215 FORMAT(1X,23.3H0 =,E14.6,15X,3HV =,E14.6,12X,7HNCBAR =,E14.6,/)
00313   124*           WRITE(6*230) Y(3)*Y(7)*Y(11)
00314   125*           230 FORMAT(1X,19.7H0F20.13,19.7H0F20.13,E14.6,12X,7HJFDV =,E14.6,9X,
00321   127*           10HDTFCBR =,E14.6,/)
00322   128*           WRITE(6*240) Y(5),Y(9),Y(13)
00327   129*           240 FORMAT(1X,17.9H02TFD2V =,E14.6,10X,9HD02TFD2V =,E14.6,6X,
L0327   130*           15H02TFD2NCBAR =,E14.6,/)
00330   131*           WRITE(6*250) Y(15)*Y(17)*Y(19)
00335   132*           250 FORMAT(1X,16X,10D2TFQDV =,E14.6,5X,14HD2TFQDNCBAR =,E14.6,6,
00335   133*           15X,14.1D2TFDVCNCBAR =,E14.6,7)
00335   134*           WRITE(6*220) (XM(1),I=1,3)
00344   135*           220 FORMAT(19X9,DELTU =,E14.6,10X,9HDELTA V =,E14.6,6X,
L0344   136*           13H2ELTN CGBAR,E,E4.6,/)
00345   137*           NIWAX = 20
00346   138*           200 IF(NIT,SL,NITMAX) GO TO 300
00350   139*           NIT = NIT+1
00351   140*           21   = U
00352   141*           22   = V
00353   142*           23   = FMCIR
00354   143*           WRITE(6*220) (XM(1),I=1,3)
00355   144*           NIWAX = 20
00356   145*           25   = Y(1)-THEIAS
00357   146*           IF(25.0,0.0001) GO TO 2080
00361   147*           IF((AB5(XM(1))/Z1.GT.0.0001) GO TO 50
00363   148*           IF((AB5(XM(2))/Z2.GT.0.0001) GO TO 50
00365   149*           IF((AB5(XM(3))/Z3.GT.0.0001) GO TO 50
00367   150*           WRITE(6*2070)
00371   151*           207 FORMAT(1H0,15HOPTIMUM REACHED)
00372   152*           GO TO 1
00373   153*           300 WRITE(6,2050) NITMAX

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62    00376 154*   20500 FORMAT (1X,30H NUMBER OF ITERATIONS EXCEEDS ,12)
      00377 155*   60 TO 1
      00400 156*   20800 WRITE(6,2085)
      00402 157*   2085 FORMAT(1H0,24HVANISHING HEAT REJECTION)
      00403 158*   60 TO 1
      00404 159*   3000 STOP
      00405 160*   END
```

END OF COMPIRATION - NO DIAGNOSTICS.

02 2FOR,IS,RKS
FOR 59n-07/27/72-1743:28 (C)

SUBROUTINE RKS ENTRY POINT 000643

STORAGE USED: CODE(1) 001C401 DATA(0) 000641 BLANK COMMON(2) 000000

EXTERNAL REFERENCE: (ALOCK, NAME)

	0003	NPR25
0004	NEXPSS	
0005	NERRSS	

STORAGE ASSIGNMENT (ELOCK, TYPE, RELATIVE LOCATION', NAME)

	0001	000010 10L	0001	000313 110L	0'91	000333 120L	0001	000045 126L	0001	000047 130L
0001	000071 14C	0001	000355 140L	0'91	0001C5 146G	0001	000130 156G	0001	000017 160L	
0001	000150 164	0001	000277 174G	0'91	000500 185L	0001	000510 190L	0001	000017 200L	
0001	000232 205	0001	000270 217G	0'91	000524 220L	0001	000530 230L	0001	000054 240L	
0001	000374 243	0001	000032 25L	0'91	000552 250L	0001	000554 251L	0001	000057 257L	
0001	000604 259.	0001	000623 270L	0'91	000456 300L	0001	000615 336G	0001	000054 40L	
0001	000060 45L	0001	000006 5L	0'91	000076 50L	0001	000123 70L	0001	000135 80L	
0000 R	000014 1W	6000 R	000007 MAX	0'90 R	000011 0	0000 R	000010 0	0000 P	000001 DOT	
0000 R	000003 CEL	6000 R	000012 F	0'90 R	000000 FR10	0000 I	000004 I	0000 I	000005 IELG	
0000	000030 INJ1 \$	6000 I	000002 TSYMP	0'90 I	000013 J	0000 R	000006 S			

) 00101 1* SUBROUTINE RKS(DERIV,CNTPL,Y,Y'A,R,T,DEL,N,IFVD,IAKP,NTRY,

) 00101 2* TERR,DEL,Y,PS,YS,YST,Y-TMP) D600020

) 00103 3* DIMENSION(Y(1),DY(1),A(N),R(N),DEL(Y(N)), C60 3

) 00103 4* IP(JN),SD(N),YS(N),YST(N),YSIMP(N) D600000

) 00104 5* EXTERNAL DERIV, CTRL D600050

) 00104 6* C FR10 IS FIFTH ROOT OF TEN D600 60

) 00105 7* FRIC=1.5848932 D6000700

) 00106 6* TERR=0 D600000

) 00106 9* C YS CONTAINS Y VALUES AT LEFT END POINT OF INTEGRATION INTERVAL D600000

) 00106 10* C YSIMP CONTAINS Y FOR SIMPSON'S RULE CHECK. CHECK NOT MADE FOR D600100

) 00106 11* C FIXED STEP MODE. ISY4R IS CONTROL PARAMETER =1.FIXED•2 VARD=00120

) 00106 12* C D6001300

) 00106 13* C D6000700

) 00106 14* C IF FIXED STEP SIZE GO ONE INTERVAL OF LENGTH DELT AND RETURN TO D600140

) 00106 15* C CTRL, IF VAR GO TWO INTERVALS BEFORE RETURN TO CONTROL D600150

) 00106 16* C D6001600

) 00106 17* C IFVD = 0 VARIABLE INTERVAL D600170

) 00106 18* C FIXFD D6001800

) 00106 19* C IAkp = 1 CUT INTERVAL ONCE BEFORE REPEAT (UNDER IFVD=0) D600190

) 00106 20* C E 1 CUT AS REQUIRED D600 200

) 00106 21* C NTRY = 1 CONTINUE INTEGRATING D6002100

) 00106 22* C 2 RETURN FROM RKS D60 220

) 00106 23* C 3 STEP REPEATED WITH NEW DELT D600230

) 00106 24* C 4 RESTART D600240

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>2 00106 25* C TERR = 0 NORMAL
00106 26* C -1 DELTED, RETURN FROM RKS
00106 27* C 1 A(I)+R(I)*ABS(Y(I))=0., RETURN FROM RKS
00107 28* C 5 J(EELI)20,10,23
00112 29* 1 IERR--1
00113 30* 20 TO 270
00114 31* 2 CALL DERIV(Y,DY,T)
00115 32* NTRY=1
00116 33* CALL CNTRL(Y,DY,DEL,T,NTRY,IFV)
00117 34* 2, DLTDEL
00120 35* IF(IFV<0) 40,30,40
00123 36* 3 ISYMP=2
00124 37* DLTDEL/2.
00125 38* DJ_31,I=1,N
00130 39* 3 SJ(I)=0.0
00132 40* 4 IMAGE=1
00133 41* S=1.
00134 42* 50,10,45
00135 43* 4, ISYMP=1
00136 44* 5 DLTDEL
00137 45* 4, DJ_46,I=1,N
00142 46* YST(I)=Y(I)
00143 47* 4, NYST(I)=DY(I)
00145 48* 5, DJ_66,I=1,N
00150 49* D-LY(I)=DELTY(I)
00151 50* P(I)=DELY(I)
00152 51* 6, CONTINUE
00154 52* 30 TO 10,00,70,ISYMP
00155 53* 7, DJ_71,I=1,N
00160 54* 7, SJ(I)=S(I)+S*D(I)
00162 55* 8 TEST+DEL/I/2.
00153 56* 20,95,I=1,N
00166 57* Y(I)=Y(I)
00167 58* Y(I)=YS(I)+DELY(I)/2.
00170 59* 8, CONTINUE
00172 60* CALL DERIV(Y,DY,T)
00173 61* 10,90,I=1,N
00176 62* -5,Y(I)=DELTI*Y(I)
00177 63* P(I)=P(I)*2,*DELY(I)
00200 64* Y(I)=YS(I)+DELY(I)/2.
00201 65* 9, CONTINUE
00203 66* CALL DERIV(Y,DY,T)
00204 67* 10,95,I=1,N
00207 68* DELI(I)=DELTI*Y(I)
00210 69* P(I)=P(I)*2,*DELY(I)
00211 70* Y(I)=YS(I)+DELY(I)
00212 71* 9, CONTINUE
00214 72* -5,DELTI/2.
00215 73* CALL DERIV(Y,DY,T)
00216 74* 20,100,I=1,N
00221 75* DELY(I)=DELTI*Y(I)
00222 76* P(I)=P(I)*2,*DELY(I)
00223 77* Y(I)=YS(I)+P(I)/6.
00224 78* 10, CONTINUE
00226 79* 30 TO (110,120),ISYMP
00227 80* 11,NTRY=1
00230 81* CALL DERIV(Y,DY,T)

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)2 00231 82* CALL CNTRL(Y,DY,DEL,T,NTRY,IFV)
      60 TO 300
00232 83* 121 GO TO (130,140),IFLAG
      131 S=4
00233 84* 131 IFLAG=2
      132 CALL DERIV(Y,YY,I)
00234 85* 87* 86* 87* 88* 89* 141 CALL DERIV(Y,YY,I)
      121 GO TO 50
00235 86* 121 S=4
      122 IFLAG=2
00236 87* 123 CALL DERIV(Y,YY,I)
00237 88* 124 CALL DERIV(Y,YY,I)
      125 GO TO 50
00238 89* 142 CALL DERIV(Y,YY,I)
      143 AMAX =Q_0
00239 90* 144 AMAX =Q_0
      145 DO 146 I=1,J
00240 91* 146 SJ(I)=SD(I)+CY(I)
      147 YSIMP(L)EYSI(L)+DEL I+SD(I)/3,
00241 92* 148 SJ(I)=SD(I)+CY(I)
      149 YSIMP(L)EYSI(L)+DEL I+SD(I)/3,
      150 C=AM(I)+R(I)*ABS(Y(I))
00242 93* 151 IF(C ) 160,150,160
      152 IERR=1
00243 94* 153 GO TO 270
      154 E=ABS(D /C )
00244 95* 155 AMAX=MAX(AMAX,E)
      156 CJNT1:UE
00245 96* 157 IF (AMAX-1.) 215,215,230
      158 MTRY=1
00246 97* 215 CALL CNTRL(Y,YY,DEL,T,NTRY,IFV)
      159 IF((MTRY-1) 185,185,310
      160 I=(MTRY-2) 270,270,330
      161 I=(MTRY-3) 340,340,5
      162 I=T-2)T
      163 T=DEL
      164 IF(DEL) 259,10,259
00247 98* 165 GO TO (40,190),ISW/P
      166 191 IF(AMAX-.75) 200,25,220
      167 201 IF(AMAX-.075) 210,25,25
      168 211 DEL=DEL*FR10
      169 221 DEL=DEL/FR10
      170 231 DEL=DEL/FR10
      171 241 DEL=DEL/FR10
      172 251 DEL=DEL/FR10
      173 261 J=1
      174 271 I=1+19KP
      175 281 GO TO (240,250),I
      176 291 T=DEL
      177 301 AMAX/10.**J
      178 311 IF(1.0-AM) 251,257,257
      179 321 252 J=1
      180 331 253 GO TO 251
      181 341 254 T=DEL
      182 351 255 DEL=DEL/(FR10**J)
      183 361 256 257 258
      184 371 259 260
      185 381 261 262
      186 391 263 264
      187 401 265 266
      188 411 267 268
      189 421 269 270
      190 431 271 272
      191 441 273 274
      192 451 275 276
      193 461 277 278
      194 471 279 280
      195 481 281 282
      196 491 283 284
      197 501 285 286
      198 511 287 288
      199 521 289 290
      200 531 291 292
      201 541 293 294
      202 551 295 296
      203 561 297 298
      204 571 299 300
      205 581 301 302
      206 591 303 304
      207 601 305 306
      208 611 307 308
      209 621 309 310
      210 631 311 312
      211 641 313 314
      212 651 315 316
      213 661 317 318
      214 671 319 320
      215 681 321 322
      216 691 323 324
      217 701 325 326
      218 711 327 328
      219 721 329 330
      220 731 331 332
      221 741 333 334
      222 751 335 336
      223 761 337 338
      224 771 339 340
      225 781 341 342
      226 791 343 344
      227 801 345 346
      228 811 347 348
      229 821 349 350
      230 831 351 352
      231 841 353 354
      232 851 355 356
      233 861 357 358
      234 871 359 360
      235 881 361 362
      236 891 363 364
      237 901 365 366
      238 911 367 368
      239 921 369 370
      240 931 371 372
      241 941 373 374
      242 951 375 376
      243 961 377 378
      244 971 379 380
      245 981 381 382
      246 991 383 384
      247 1001 385 386
      248 1011 387 388
      249 1021 389 390
      250 1031 391 392
      251 1041 393 394
      252 1051 395 396
      253 1061 397 398
      254 1071 399 400
      255 1081 401 402
      256 1091 403 404
      257 1101 405 406
      258 1111 407 408
      259 1121 409 410
      260 1131 411 412
      261 1141 413 414
      262 1151 415 416
      263 1161 417 418
      264 1171 419 420
      265 1181 421 422
      266 1191 423 424
      267 1201 425 426
      268 1211 427 428
      269 1221 429 430
      270 1231 431 432
      271 1241 433 434
      272 1251 435 436
      273 1261 437 438
      274 1271 439 440
      275 1281 441 442
      276 1291 443 444
      277 1301 445 446
      278 1311 447 448
      279 1321 449 450
      280 1331 451 452
      281 1341 453 454
      282 1351 455 456
      283 1361 457 458
      284 1371 459 460
      285 1381 461 462
      286 1391 463 464
      287 1401 465 466
      288 1411 467 468
      289 1421 469 470
      290 1431 471 472
      291 1441 473 474
      292 1451 475 476
      293 1461 477 478
      294 1471 479 480
      295 1481 481 482
      296 1491 483 484
      297 1501 485 486
      298 1511 487 488
      299 1521 489 490
      300 1531 491 492
      301 1541 493 494
      302 1551 495 496
      303 1561 497 498
      304 1571 499 500
      305 1581 501 502
      306 1591 503 504
      307 1601 505 506
      308 1611 507 508
      309 1621 509 510
      310 1631 511 512
      311 1641 513 514
      312 1651 515 516
      313 1661 517 518
      314 1671 519 520
      315 1681 521 522
      316 1691 523 524
      317 1701 525 526
      318 1711 527 528
      319 1721 529 530
      320 1731 531 532
      321 1741 533 534
      322 1751 535 536
      323 1761 537 538
      324 1771 539 540
      325 1781 541 542
      326 1791 543 544
      327 1801 545 546
      328 1811 547 548
      329 1821 549 550
      330 1831 551 552
      331 1841 553 554
      332 1851 555 556
      333 1861 557 558
      334 1871 559 560
      335 1881 561 562
      336 1891 563 564
      337 1901 565 566
      338 1911 567 568
      339 1921 569 570
      340 1931 571 572
      341 1941 573 574
      342 1951 575 576
      343 1961 577 578
      344 1971 579 580
      345 1981 581 582
      346 1991 583 584
      347 2001 585 586
      348 2011 587 588
      349 2021 589 590
      350 2031 591 592
      351 2041 593 594
      352 2051 595 596
      353 2061 597 598
      354 2071 599 600
      355 2081 601 602
      356 2091 603 604
      357 2101 605 606
      358 2111 607 608
      359 2121 609 610
      360 2131 611 612
      361 2141 613 614
      362 2151 615 616
      363 2161 617 618
      364 2171 619 620
      365 2181 621 622
      366 2191 623 624
      367 2201 625 626
      368 2211 627 628
      369 2221 629 630
      370 2231 631 632
      371 2241 633 634
      372 2251 635 636
      373 2261 637 638
      374 2271 639 640
      375 2281 641 642
      376 2291 643 644
      377 2301 645 646
      378 2311 647 648
      379 2321 649 650
      380 2331 651 652
      381 2341 653 654
      382 2351 655 656
      383 2361 657 658
      384 2371 659 660
      385 2381 661 662
      386 2391 663 664
      387 2401 665 666
      388 2411 667 668
      389 2421 669 670
      390 2431 671 672
      391 2441 673 674
      392 2451 675 676
      393 2461 677 678
      394 2471 679 680
      395 2481 681 682
      396 2491 683 684
      397 2501 685 686
      398 2511 687 688
      399 2521 689 690
      400 2531 691 692
      401 2541 693 694
      402 2551 695 696
      403 2561 697 698
      404 2571 699 700
      405 2581 701 702
      406 2591 703 704
      407 2601 705 706
      408 2611 707 708
      409 2621 709 710
      410 2631 711 712
      411 2641 713 714
      412 2651 715 716
      413 2661 717 718
      414 2671 719 720
      415 2681 721 722
      416 2691 723 724
      417 2701 725 726
      418 2711 727 728
      419 2721 729 730
      420 2731 731 732
      421 2741 733 734
      422 2751 735 736
      423 2761 737 738
      424 2771 739 740
      425 2781 741 742
      426 2791 743 744
      427 2801 745 746
      428 2811 747 748
      429 2821 749 750
      430 2831 751 752
      431 2841 753 754
      432 2851 755 756
      433 2861 757 758
      434 2871 759 760
      435 2881 761 762
      436 2891 763 764
      437 2901 765 766
      438 2911 767 768
      439 2921 769 770
      440 2931 771 772
      441 2941 773 774
      442 2951 775 776
      443 2961 777 778
      444 2971 779 780
      445 2981 781 782
      446 2991 783 784
      447 3001 785 786
      448 3011 787 788
      449 3021 789 790
      450 3031 791 792
      451 3041 793 794
      452 3051 795 796
      453 3061 797 798
      454 3071 799 800
      455 3081 801 802
      456 3091 803 804
      457 3101 805 806
      458 3111 807 808
      459 3121 809 810
      460 3131 811 812
      461 3141 813 814
      462 3151 815 816
      463 3161 817 818
      464 3171 819 820
      465 3181 821 822
      466 3191 823 824
      467 3201 825 826
      468 3211 827 828
      469 3221 829 830
      470 3231 831 832
      471 3241 833 834
      472 3251 835 836
      473 3261 837 838
      474 3271 839 840
      475 3281 841 842
      476 3291 843 844
      477 3301 845 846
      478 3311 847 848
      479 3321 849 850
      480 3331 851 852
      481 3341 853 854
      482 3351 855 856
      483 3361 857 858
      484 3371 859 860
      485 3381 861 862
      486 3391 863 864
      487 3401 865 866
      488 3411 867 868
      489 3421 869 870
      490 3431 871 872
      491 3441 873 874
      492 3451 875 876
      493 3461 877 878
      494 3471 879 880
      495 3481 881 882
      496 3491 883 884
      497 3501 885 886
      498 3511 887 888
      499 3521 889 890
      500 3531 891 892
      501 3541 893 894
      502 3551 895 896
      503 3561 897 898
      504 3571 899 900
      505 3581 901 902
      506 3591 903 904
      507 3601 905 906
      508 3611 907 908
      509 3621 909 910
      510 3631 911 912
      511 3641 913 914
      512 3651 915 916
      513 3661 917 918
      514 3671 919 920
      515 3681 921 922
      516 3691 923 924
      517 3701 925 926
      518 3711 927 928
      519 3721 929 930
      520 3731 931 932
      521 3741 933 934
      522 3751 935 936
      523 3761 937 938
      524 3771 939 940
      525 3781 941 942
      526 3791 943 944
      527 3801 945 946
      528 3811 947 948
      529 3821 949 950
      530 3831 951 952
      531 3841 953 954
      532 3851 955 956
      533 3861 957 958
      534 3871 959 960
      535 3881 961 962
      536 3891 963 964
      537 3901 965 966
      538 3911 967 968
      539 3921 969 970
      540 3931 971 972
      541 3941 973 974
      542 3951 975 976
      543 3961 977 978
      544 3971 979 980
      545 3981 981 982
      546 3991 983 984
      547 4001 985 986
      548 4011 987 988
      549 4021 989 990
      550 4031 991 992
      551 4041 993 994
      552 4051 995 996
      553 4061 997 998
      554 4071 999 1000
      555 4081 1001 1002
      556 4091 1003 1004
      557 4101 1005 1006
      558 4111 1007 1008
      559 4121 1009 1010
      560 4131 1011 1012
      561 4141 1013 1014
      562 4151 1015 1016
      563 4161 1017 1018
      564 4171 1019 1020
      565 4181 1021 1022
      566 4191 1023 1024
      567 4201 1025 1026
      568 4211 1027 1028
      569 4221 1029 1029
      570 4231 1030 1030
      571 4241 1031 1031
      572 4251 1032 1032
      573 4261 1033 1033
      574 4271 1034 1034
      575 4281 1035 1035
      576 4291 1036 1036
      577 4301 1037 1037
      578 4311 1038 1038
      579 4321 1039 1039
      580 4331 1040 1040
      581 4341 1041 1041
      582 4351 1042 1042
      583 4361 1043 1043
      584 4371 1044 1044
      585 4381 1045 1045
      586 4391 1046 1046
      587 4401 1047 1047
      588 4411 1048 1048
      589 4421 1049 1049
      590 4431 1050 1050
      591 4441 1051 1051
      592 4451 1052 1052
      593 4461 1053 1053
      594 4471 1054 1054
      595 4481 1055 1055
      596 4491 1056 1056
      597 4501 1057 1057
      598 4511 1058 1058
      599 4521 1059 1059
      600 4531 1060 1060
      601 4541 1061 1061
      602 4551 1062 1062
      603 4561 1063 1063
      604 4571 1064 1064
      605 4581 1065 1065
      606 4591 1066 1066
      607 4601 1067 1067
      608 4611 1068 1068
      609 4621 1069 1069
      610 4631 1070 1070
      611 4641 1071 1071
      612 4651 1072 1072
      613 4661 1073 1073
      614 4671 1074 1074
      615 4681 1075 1075
      616 4691 1076 1076
      617 4701 1077 1077
      618 4711 1078 1078
      619 4721 1079 1079
      620 4731 1080 1080
      621 4741 1081 1081
      622 4751 1082 1082
      623 4761 1083 1083
      624 4771 1084 1084
      625 4781 1085 1085
      626 4791 1086 1086
      627 4801 1087 1087
      628 4811 1088 1088
      629 4821 1089 1089
      630 4831 1090 1090
      631 4841 1091 1091
      632 4851 1092 1092
      633 4861 1093 1093
      634 4871 1094 1094
      635 4881 1095 1095
      636 4891 1096 1096
      637 4901 1097 1097
      638 4911 1098 1098
      639 4921 1099 1099
      640 4931 1100 1100
      641 4941 1101 1101
      642 4951 1102 1102
      643 4961 1103 1103
      644 4971 1104 1104
      645 4981 1105 1105
      646 4991 1106 1106
      647 5001 1107 1107
      648 5011 1108 1108
      649 5021 1109 1109
      650 5031 1110 1110
      651 5041 1111 1111
      652 5051 1112 1112
      653 5061 1113 1113
      654 5071 1114 1114
      655 5081 1115 1115
      656 5091 1116 1116
      657 5101 1117 1117
      658 5111 1118 1118
      659 5121 1119 1119
      660 5131 1120 1120
      661 5141 1121 1121
      662 5151 1122 1122
      663 5161 1123 1123
      664 5171 1124 1124
      665 5181 1125 1125
      666 5191 1126 1126
      667 5201 1127 1127
      668 5211 1128 1128
      669 5221 1129 1129
      670 5231 1130 1130
      671 5241 1131 1131
      672 5251 1132 1132
      673 5261 1133 1133
      674 5271 1134 1134
      675 5281 1135 1135
      676 5291 1136 1136
      677 5301 1137 1137
      678 5311 1138 1138
      679 5321 1139 1139
      680 5331 1140 1140
      681 5341 1141 1141
      682 5351 1142 1142
      683 5361 1143 1143
      684 5371 1144 1144
      685 5381 1145 1145
      686 5391 1146 1146
      687 5401 1147 1147
      688 5411 1148 1148
      689 5421 1149 1149
      690 5431 1150 1150
      691 5441 1151 1151
      692 5451 1152 1152
      693 5461 1153 1153
      694 5471 1154 1154
      695 5481 1155 1155
      696 5491 1156 1156
      697 5501 1157 1157
      698 5511 1158 1158
      699 5521 1159 1159
      700 5531 1160 1160
      701 5541 1161 1161
      702 5551 1162 1162
      703 5561 1163 1163
      704 5571 1164 1164
      705 5581 1165 1165
      706 5591 1166 1166
      707 5601
```

D: FORTRAN SDRV
FOR S94-7/27/72-17:43:59 (.0)

SUBROUTINE SDRV ENTRY POINT 000601

STORAGE USED: CODE(1) 000605; DATA(0) 0000661 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003	BLKI	000022
0004	BLK0	000011
0005	BLKR	000011
0006	V43	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0007	ETA	
0010	MCDRV	
0011	WERR	
0012	DETA	
0013	DE2V	
0014	MIXER	
0015	NERR35	

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000003 AA;	C004	000003 A1	0000 R 000004 A2	0004 R 000005 A3	0004 R 000006 A4
0004 C0007 AS	C004	000010 A6	0000 R 000005 AB	0000 R 000037 A12N	0000 R 000047 A10H
0009 R 000023 D1DV	0000 R 000040 D1DV	0000 R 000010 D12DU	0000 R 000024 D2DV	0000 R 000041 D3DH	0000 R 000026 D4DN
0000 R 000011 D2DU	0000 R 000025 D2DV	0000 R 000012 D14DU	0000 R 000012 D14DU	0000 R 000028 D4DN	0000 R 000014 D4DN
0000 R 000013 D4DN	0000 R 000013 D45DU	0000 R 000027 D15DV	0000 P 000044 D16DN	0000 R 000044 D16DN	0000 R 000016 D4DN
0000 R 000030 D46DV	0000 R 000045 D8DH	0000 R 000004 DEB0TB	0000 R 000015 DEBDU	0000 R 000031 DEADV	
0000 R 000046 DEJ	0000 R 000047 DEPN	0000 R 000013 DEPV	0000 R 000013 DEPV	0012 R 000041 DETA	
0000 R 000032 DEV	0000 R 000032 DEV	0003 R 000021 DF17L	0003 R 000021 DF47R	0003 R 000013 DFW	
0003 R 000012 DF4X	0003 R 000010 DFUX	0005 R 000006 DL0ICB	0005 R 000001 DLDU	0005 R 000022 DLNU	
0000 R 000050 DHCN	0000 R 000020 D12Y	0006 R 000034 D2DV	0000 R 000036 D4CN	0003 R 000007 DLICOT1	
0000 R 000006 DHCNU	0000 R 000022 D1CDV	0000 R 000001 D2CD2T	0000 R 000002 D2CT4R	0003 R 000010 D2FLCR	0005 R 000010 D2LNU
0005 R 000003 D2CDW	0005 R 000024 D2DGV	0001 R 000007 D2LNU	0005 R 000007 D2LNU	0005 R 000010 D2LNU	0005 R 000010 D2LNU
0005 R 000011 D2LVN	0003 R 000015 D2MNC	0003 R 000014 D2MLNC	0000 R 000051 D2WCN	0000 R 000021 D2WNCU	
0000 R 000035 D2:NCL	0003 R 000011 D2IDL	0004 R 000001 D3M2LN	0004 R 000002 D342LN	0004 R 000011 ER	
0006 R 000002 ET	0007 R 000001 ETA	0007 R 000022 F3	0003 R 000002 F4	0003 R 000013 F1	
0003 C0005 FC	C003 R 000004 FC2P	0000 R 000055 INUPS	0005 R 000000 RLAM	0003 R 000000 THEIAS	
0000 R 000000 THETAF	0003 R 000001 THETAS	0004 R 000000 U	0003 000006 V	0003 R 000017 Y1	
0003 R 000020 Y2	0006 R 000000 Z1	0006 R 000001 22			

00101 1* SUBROUTINE SDRV(Y,DY,X)

00101 2* C CALCULATION OF DERIVATIVES FOR THE INTEGRATION SUBROUTINE

00101 3* C DIMENSION Y(20),DY(20)

END OF COMPIRATION: NO DIAGNOSTICS.

02 SUBROUTINE SCNTL ENTRY POINT 000147
FOR S9A-07/27/72-17:42:50 1,0)

SUBROUTINE SCNTL ENTRY POINT 000147

STORAGE USED: CODE(1) 000174, DATA(0) 000014, BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	VCT	000015
0004	VAB	000013
0005	ZALKI	000124

EXTERNAL REFERENCES: (BLOCK, NAME)

0005	VWJUS
0007	AJ025
0010	NERR35

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	0.000002	2001=	C001	000054	FL	0001	000061	50L	0001	000135	60L
0000	2	000000	DXSI?	0003	R	000003	DXWRT	0004	R	000002	ET
0000	1	000001	LC41	0003	I	000004	LSTEP	0005	R	000000	VAL
0004	R	000001	22								

00101	1*	SUBROUTINE SCNTL(Y,DY,DX,X,NTRY,IFVD)										
00101	2*	C	INTEGRATION CONTROL PROGRAM									
00101	3*	C										
00101	4*	C										
00103	5*	DIMENSION Y(20),DY(20)										
00104	6*	COMMON /VCT/LVLT,LCNT,XWRT,DYRT,LSTEP										
00104	7*	1/VAB/21,72,ET										
00104	8*	2/LALKI/VNL(2n)										
00105	9*	LCNT = LCNT+1										
00106	10*	IF((X>DXWRT)AND(LCNT>1)) LSTEP = 1										
00110	11*	IF(ABS(X-XWRT)>LT.DLYT) GO TO 50										
00112	12*	I=XWRT,GT.X) GO TO 5										
00112	13*	C										
00114	14*	DXSTR = DX										
00115	15*	DA = DX+XWRT-X										
00116	16*	LCNT = 1										
00117	17*	NTRY = 3										
00120	18*	RETUR1										
00120	19*	C										
00121	20*	5 NTRY = 1										
00122	21*	RETUR1										
00122	22*	C										
00123	23*	5: WRITE(6,2000) Y(1),Y(2),Z1,Z2,ET,VAL(3),VAL(4),X										
00135	24*	2000 FORWAT (8F15.7)										

02 00136 25* IF(LCNT.EQ.1) DX = DXSTR
00140 26* LCNT = 0
00141 27* IF(ABS(1.0-XWRT).LE.DLMIT) GO TO 60
00143 28* XWRT = XWRIT+XWRT
00144 29* NTRY = 1
00145 30* IF(LSTEP.EQ.0) RETURN
00147 31* DX = DXWRT
00156 32* IF(Y) = 1
00151 33* RETURN
00151 34* C
00152 35* DO NTRY = 2
00153 36* RETURN
00154 37* END

END OF COMPILED: NO DIAGNOSTICS.

62 2FOR,IS BNDCND
FOR S9A-07/27/72-17:43:54 (,0)

SUBROUTINE BNDCND ENTRY POINT 000350

STORAGE USED: CODE(1) 0004111 DATA(0) 0000651 BLANK COMMON(2) 000000

COMMON BLOCKS:

0003 BLK3 000001

EXTERNAL REFERENCES (BLOCK, NAME)

0004 FMINV
0005 AERR3\$

STORAGE ASSIGNMENT BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000115	601L	0001	000134	602L	0001	000137	603L	0001	000167	610L
0001	000202	611L	0001	000206	612L	0001	000211	613L	0001	000241	620L
0001	000260	622L	0001	000263	623L	0001	000313	630L	0001	000404	700L
0003	000000	DNCBD	0003	000001	DNCADV	0001	000017	I	0000	000044	IINP\$,
0000	1	000021	K	0000	R	000014	XN	0000	R	000022	Z1
											0000 R 000023 Z2

00101 1* SUBROUTINE ANDCND(Y(1),V,FNCR,X")

00101 2* C ANDCND JNSURES V,V, AND NCBAR ARE WITHIN THEIR BOUNDARY CONDITIONS

00101 3* C DIMENSION AN(13,4),XN(3),XM(3),Y(20)

00104 4* C COMMON /BNK2/DNCADV,DNCBDV

00105 5* C J = 0

00106 6* C J = 0

00107 7* C E = 0

00110 8* C J = 0

00111 9* C J = 0

00112 10* C J = 0

00113 11* C J = 0

00114 12* C J = 0

00115 13* C J = 0

00116 14* C J = 0

00117 15* C J = 0

00120 16* C J = 0

00121 17* C J = 0

00122 18* C J = 0

00123 19* C J = 0

00124 20* C J = 0

00125 21* C J = 0

00126 22* C J = 0

00127 23* C J = 0

00131 24* C J = 0

00127 25* C J = 0

00131 26* C J = 0

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2 00133 27* IF (FNCBR.LT.0.00009.OR.FNCBR.GT.4.01) GO TO 620
    00135 28* RETURN
    00136 29* 60: IF (U.LE.5.0E-06) GO TO 601
    . 00140 30* 60: IF (U.GE.250.) GO TO 602
    . 00142 31* 60: TO 610
    . 00143 32* 60: XN(1) = 5.0E-06-71
    . 00144 33* 60: XN(1) = 250.-Z1
    . 00145 34* 60: AH(1,1) = 1.
    . 00146 35* 60: AH(1,2) = 0.
    . 00147 36* 60: AH(1,3) = 0.
    . 00150 37* 61: TO 603
    . 00151 38* 61: I = 1
    . 00152 39* 61: IF (I.EQ.0) YN(1) = -Y(3)
    . 00154 40* 61: IF (J.EQ.0) YN(2) = -Y(7)
    . 00156 41* 61: IF (K.EQ.0) YN(3) = -Y(11)
    . 00160 42* CALL FMINV(AN,XN,3,4)
    . 00161 43* 61: IF (V.LE.5.0E-05) GO TO 611
    . 00163 44* 61: IF (V.GE.50.) GO TO 612
    . 00165 45* 61: XH(1,2) = 5.0E-05-Z2
    . 00166 46* 61: XH(1,2) = 50.-Z2
    . 00167 47* 61: XH(1,2) = 50.-Z2
    . 00170 48* 61: AH(1,1) = 0.
    . 00171 49* 61: AH(1,2) = 1.
    . 00172 50* 61: AH(1,3) = 0.
    . 00173 51* 61: J = 1
    . 00174 52* 61: IF (J.EQ.0) XN(1) = -Y(3)
    . 00175 53* 61: IF (J.EQ.0) YN(1) = -Y(7)
    . 00177 54* 61: IF (K.EQ.0) YN(3) = -Y(11)
    . 00201 55* CALL FMINV(AN,XN,3,4)
    . 00203 56* 62: IF (FNCBR.LE.1.0E-04) GO TO 622
    . 00204 57* 62: IF (FNCBR.GE.4.00) GO TO 622
    . 00206 58* 62: AN(3,2) = 0.
    . 00210 59* 62: AN(3,3) = 1.
    . 00211 60* 62: Y(3) = 1.0E-04-Z3
    . 00212 61* 62: XH(1,3) = 4.0E-23
    . 00213 62* 62: XH(1,3) = 0.
    . 00214 63* 62: AN(3,1) = 0.
    . 00215 64* 62: AN(3,2) = 0.
    . 00216 65* 62: AN(3,3) = 1.
    . 00217 66* 65: K = 1
    . 00220 67* 65: IF (I.EQ.0) XN(1) = -Y(3)
    . 00222 68* 65: IF (J.EQ.0) YN(2) = -Y(7)
    . 00224 69* 65: IF (K.EQ.0) XN(3) = -Y(11)
    . 00226 70* CALL FMINV(AN,XN,3,4)
    . 00227 71* 63: XN(1) = XN(1)
    . 00230 72* 63: XN(2) = XN(2)
    . 00231 73* 63: XN(3) = XN(3)
    . 00232 74* 64: U = Z1+XN(1)
    . 00233 75* 64: V = Z2+XN(2)
    . 00234 76* 64: FNCBR = Z3+XN(3)
    . 00235 77* 66: GO TO 700
    . 00236 78* END

```

END OF COMPIILATION: NO DIAGNOSTICS.

2)FOR, IS RESERVE
FOR SSA-07/27/72-17:44:04 (,0)

SUBROUTINE RESBND ENTRY POINT 000203

STORAGE USED: CODE(), 000232: DATA(0) 0000531 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

STORAGE ASSIGNMENT	BLOCK, TYPE, RELATIVE LOCATION, NAME
0001 000026 1L	0001 000126 2L
0000 R 000003 A	0000 R 000004 3
0000 R 000000 U2	0000 R 000001 V2
0001 1*	SUBROUTINE RESBND(U,V,XM,ASTAR)
00101 2* C	RES AND CHECKS THE BOUNDARY OF LAMBDA AND KEEPS ASTAR
00101 3* C	GREATER THAN U+V
00101 4* C	
00101 5* C	
00103 6* C	DIMENSION XM(1)
00104 7* C	U2 = U-X(1,1)
00105 8* C	V2 = V-Y(1,2)
00106 9* C	Z = ASTAR-U*V
00107 10* C	IF(Z>LT.2.*1.*V1*0.F-06) GO TO 1
00111 11* C	RETURN
00112 12* C	A = XM(1,1)*XM(2)
00113 13* C	B = (P*XM(2)+V2*XM(1))
00114 14* C	C = U2*(Z-0.09*ASTAR)
00115 15* C	IF(ABS(C)*LE.1.OE-05.AND.XM(2).LT.0.) GO TO 2
00117 17* C	IF(L55(C),LE.1.OE-05.AND.XM(1).LT.0.) GO TO 3
00121 19* C	EPS = (-1)*SQR((3**2-4.*A**2)/2./A)
00122 20* C	X1(1) = EPS*X(1,1)
00123 21* C	X1(2) = EPS*X(1,2)
00124 22* C	U = U2+XM(1,1)
00125 23* C	V = V2+XM(1,2)
00126 24* C	GO TO 4
00127 25* C	EPS = (0.99*ASTAR-U2*V)/(V*XM(1))
00130 26* C	X1(1) = EPS*X(1,1)
00131 27* C	U = U2+XM(1,1)
00132 28* C	GO TO 4
00133 29* C	EPS = (0.99*ASTAR-U2*V)/(U*XM(2))
00134 30* C	X1(2) = EPS*X(1,2)

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01 00135 31*      V      = V2+X^1(2)
    00135 32*      C
00136 33*      4   "RITE(6*2000) XW(11)*XW(12)*EPS
00136 34*      FOR RAT (//5X) EPSILON CALCULATED   DELTA V = 'E14.6/
00143 35*      1   2000 FOR RAT (//5X) EPSILON = 'E14.6/
00143 36*      C
00143 37*      RETURN
00144 38*      END
00145 38*      END

END OF COMPLATC1:      NO DIAGNOSTICS.
```

©2 3FOR.IIS REST
FOR S9A-07/27/72-17:44:10 (0)

SUBROUTINE REST

ENTRY POINT 000066

STORAGE USED: CODE(1) 0001201 DATA(0) 0000231 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000000 A1 0000 000003 INPS

00101	1*	SUBROUTINE REST(U,V,ASTAR,RLNM,DLDU,DLDV,D2LNUU,D2LDUV,D2LNVV,
00101	2*	1DLDIC3,D2LNCB,D2LNUB,D2LNVB)
00101	3*	C
00101	4*	C CONSTANT AREA RESTRAINT
00101	5*	C
00103	6*	A1 E ASTAR!!*V
00104	7*	RLAV E 2*U*/V/A1
00105	8*	DLDJ E 2.*ASTAR*V/A1**2.
00106	9*	DLDV E 2.*ASTAR*U/A1**2.
00107	10*	D2LNUU E 4.*ASTAR*V**2./A1**3.
00110	11*	D2LDUV E 2.*ASTAR*(ASTAR+U*V)/A1**3.
00111	12*	D2LNUV E 4.*ASTAR*U**2./A1**3.
00112	13*	DLDIC3 E 0.
00113	14*	D2LIC3 E 0.
00114	15*	D2LNUA E 0.
00115	16*	D2LN3 E 0.
00116	17*	RETURN
00117	18*	END

END OF COMPIILATION: NO DIAGNOSTICS.

② 3FOR. IS N2ERV
FOR S9A-07/27/72-17:44:13 (4.0)

SUBROUTINE N2ERV ENTRY POINT 000056

STORAGE USED: CODE(1) 0000701 DATA(0) 0000151 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	SORT
0004	ASIN
0005	NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000000 C4	0000 R 000001 C5	0000 R 000002 C6	0000 000006 INJP\$
------------------	------------------	------------------	--------------------

00101 1* SUBROUTINE N2ERV(RLAM,FN,DFNX,D2NDLL)
00101 2* C
00101 3* C
00101 4* C
00103 5* C4 E RLAM+1.0
00104 6* C5 E RLAM+2.0
00105 7* C6 E SORT(RLAM+C5)
00106 8* FN E (1.5707963+C5-C6-ASIN(1.0/C4))/RLAM
00107 9* DFNX E -(FN+C6/C4-1.0)/RLAM
00110 10* D2NDLL E -(2.0*DFNX+1.0/(C4*C4*C6))/RLAM
00111 11* RETURN
00112 12* END

END OF COMPIILATION: NO DIAGNOSTICS.

62 2FOR,IS MDER
FOR 59A-07/27/72-17:44116 (1,0)

C SUBROUTINE MDER ENTRY POINT 000251

C STORAGE USED: CODE(1) 0003041 DATA(0) 0000661 BLANK COMMON(12) 0000000

C EXTERNAL REFERENCES (LOCK, NAME)

C 0003 SQR7				
C 0004 AS1'				
C 0005 NERRJS				
C				
C STORAGE ASSIGNMENT (LOCK, TYPE, RELATIVE LOCATION, NAME)				
C 0000 R 000011 CFN	0000 R 000000 C1	0000 R 0000017 C10	0000 R 000020 C11	0000 R 000022 C12
C 0000 R 000001 C2	0000 R 000003 C3	0000 R 000002 C4	0000 R 000014 C5	0000 R 000005 C6
C 0000 R 000006 C7	0000 R 000007 C8	0000 R 000010 C9	0000 R 000015 DCFDNC	0000 R 000013 DCFNAL
C 0000 R 000014 DFFS0L	0000 R 000016 D2CFLL	0000 R 000025 D2CFNC	0000 R 000026 D2CLNC	0000 R 000023 D2C2LL
C 0000 R 000021 D2CS0L	0000 R 000024 D2FS0L	0000 R 000027 D3C2LN	0000 R 000030 D3C2NL	0000 R 000012 FFS
C 0000 000040 INJP\$				

C 00101 1* JROUTINE MDER (RLAM,FNC,FM,DFMX,DFM,D2FMLL,D2MDNC,D2MLNC,D3M2LN,	
C 00101 2* 1 3M2NL	
C 00101 3* C AND ITS DERIVATIVES	
C 00101 4* C	
C 00103 5* C	
C 00104 6* C	= 0.1460*FC-0.02866
C 00104 7* C	= SQR7(RLAM*(2.+RLAM))
C 00105 8* C	= 1.0/(RLA+1.0)
C 00106 9* C	= ASIN(C4)
C 00107 10* C	= 1/(C4+C2)
C 00110 11* C	= (C1**2)/SQR7(1-C4+C2)
C 00111 12* C	= 1/(RLA**2)
C 00112 13* C	= FNC/BLAM
C 00113 14* C	= ? * C7 * CB
C 00114 15* C	= 1.0-C1*CB
C 00115 16* FFS	= (C2+C3-1.57*79635)/RLAM
C 00116 17* FM	= FFS*DCFONC
C 00117 18* CFIDL	= C1*C7*FNC
C 00120 19* FES0L	= C5-C6-FFS/RLAM
C 00121 20* FMX	= CFN*DFFSDI+FFS*DCFNDL
C 00122 21* CFJNC	= (0.1460*FC+C1)/RLAM
C 00123 22* FM	= FFS*DCFONC
C 00124 23* 2CELL	= SC1*G2
C 00125 24* C10	= 1-C4**2
C 00126 25* C11	= 1.0+.5/C10*C4**2
C 00127 26* D2C3LL	= 2*(C4**3)*C11/SQRT(C10)
C 00130 27* C12	= 1/C2-C2*(C4**2)
C 00131 28* D2C2LL	= -C12/(C4**2)**2

```

2 00132   29*    D2F5LL = (D2C2LL*D2C3LL-2.*DFF5L)/RLAM
00133   30*    D2F4LL = CFN*D2F5LL+2.*DFF5DL*DFF5S*D2CFLL
00134   31*    K = -0.*2920*RLAM
00135   32*    D2C4NC = FFS*D2CFAC
00136   33*    D2CLNC = (0.*146*FNC+C1)*C7
00137   34*    D2M4NC = DCEDNC*DFF4DL+D2CLNC*FFS
00140   35*    D3C2LN = -2.*D2CLNC/RLAM
00141   36*    D3M2L1 = DCEDNC*D2F5LL+2.*DFF5L*D2CLNC+FFS*D3C2LN
00142   37*    D3C2NL = 0.*2920*C7
00143   38*    D3C2NL = FFS*D3C2NL+DEF5DL*D2C4NC
00144   39*    RETURN
00145   40*    END

```

END OF COMPILATION: NO DIAGNOSTICS.

02 3FOR,IS NCDERV
FOR 59A-07/27/72-17:44:19 (0)

SUBROUTINE NCDERV ENTRY POINT 000031

STORAGE USED: CODE(1) 000444! DATA(0) 000013! BLANK COMMON(2) 000000

EXTERNAL REFERENCE (BLOCK, NAME)

0003 LERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION!, NAME)

0000 00004 IN, S 0000 R 000000 T2 0"00 R 000001 T3

00101	1*	C	SUBROUTINE NCDERV(FNCBR,THETA1,FNC,DNCDT1,D2CDT1,D2CTNR)
00101	2*	C	IC AND ITS DERIVATIVES
00101	4*	C	
00103	5*	C	T2 = THETAB**2
00104	6*	C	T3 = T2*THETAB
00105	7*	FNC	FNCBR*T3
00106	8*	DNCDT1	DNCDT1 = 3.*FNCHAR*T2
00107	9*	D2CDT1	D2CDT1 = 6.*FNCHAR*THETAB
00110	10*	D2CT1	D2CT1 = 3.*T2
00111	11*	RETURN	
00112	12*	END	

END OF COMPILE: NO DIAGNOSTICS.

6.2 FOR IS MIXER
FOR S9A-0727/72-1744:19 (0)

SUBROUTINE MIXER ENTRY POINT 000347

STORAGE USED: CODE(L) 0004541 DATA(0) 0001041 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003 BLKI 000021
0004 BLKC 000012

EXTERNAL REFERENCES (BLOCK, NAME)

0005 DDETA

0006 DETA

0007 DDDETA

0010 ETA

0011 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0004 R 00003 A1	0004 R 000004 A2	0001 R 000005 A3	0004 R 000006 A4	0004 R 000007 A5
0004 R 000016 F6	0007 R 000000 DDETA	0005 R 000000 DDETA	0006 R 000000 DDETA	0003 R 000023 D101
0003 000021 DE4DT	0003 R 000013 DF4	0003 R 000012 DFMX	0003 R 000010 DFNX	0003 R 000007 D10T1
0000 R 000006 DNCDX	0000 R 000003 D2A1XY	0001 R 000020 D2A2XY	0000 R 000021 D2A3XY	0000 R 000022 D2A4Y
0000 R 000015 D215Y	0000 R 000004 D2A6XY	0001 R 000017 D2E0XY	0000 R 000012 D2EPXY	0001 R 000011 D2EXY
0003 R 000016 D2E4M	0000 R 000013 D2M0LY	0001 R 000015 D2M0NC	0000 R 000014 D2M1NC	
0003 R 000011 D2D1L	0000 R 000016 D2D0XY	0001 R 000007 D3M0LY	0000 R 000010 D3M0XY	0004 R 000001 D342LN
0004 R 000002 D342L	0000 R 000005 D3W2NY	0001 R 000011 EN	0010 R 000000 ETA	0003 R 000022 F3
0003 R 000002 FM	0003 00003 FN	0003 R 000005 FNC	0003 R 000004 FNCSR	0000 R 000006 V
0003 000002 THE1	0003 00001 THETAS	0001 R 000000 U	0003 000006 V	
0003 000017 Y1	0003 R 000020 Y2	0007 R 000002 Z		

(0101 1* SUBROUTINE MIXER(DTRDY,DTRDY,D2TXY,D2TXY,DNCDY,DNCDY,
C0101 2* D2TXY,D10X,D10Y,D2DY,D2DY,D3DX,D3DX,DA3DY,
C0101 3* DA5DX,D15Y,D46Y,D46Y,D2DX,D2DY,
C0101 4* D2DXY,DENDY,DENDY,D2DX,D2DX,D2DX,
C0101 5* D2WXY,D2MNXY,D2WNCY,R,C,D3TXY,D3TXY)

(0101 6* C FOR MIXED DERIVATIVES OF U AND V SET BE1. AND CE 0.

00101 7* C FOR MIXED DERIVATIVES OF U AND FNCR SET BE1. AND CE 1.

00101 8* C FOR MIXED DERIVATIVES OF V AND FNCR SET BE0. AND CE 1.

00101 11* C DIMENSION Y(2)

00104 12* COMMON /BLKI/THETAS,FM,F1,FNCBR,FNC,V,DNCDT1,DFNX,D2NDLL,
C0104 13* DF4X,DF4,DF4NLC,D2NLC,D2M2NL,A1,A2,A3,A4,A5,A6,EB
00104 14* 2 BLKDU,D3M2LN,Y1,Y2,DE4DTB,E3,DE1DL,
00105 15* Y(2) = Y2
00106 16* 2 = FNC

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3FUR,IS D7V
FOR S9A-07/27/72-17:44:54 (1,0)

SUBROUTINE D7V ENTRY POINT 000604

STORAGE USED: CODE(11) 200721; DATA(0) 000130; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	SLKI	000024
0004	BLKD	000012

EXTERNAL REFERENCES (P-OC<, NAME)

0005	ETA
0006	DETA
0007	DDETA
0010	DDDETA
0011	NERRJS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0004 R 000003 A1	0004 R 000004 A2	0004 I 000005 A3	0004 R 000006 A4	0004 R 000007 A5
0004 I 000010 I6	0004 R 000051 A7	0004 I 000063 DATOU	0010 R 000000 D7DETA	0007 R 000000 D7DETA
0006 R 000000 DETA	0003 R 000023 DEOL	0003 R 000021 DE4DTA	0003 R 000013 DFW	0003 R 000012 DFVX
0003 R 000010 F'X	0003 R 000017 DNC0T1	0000 R 000052 MNDO	0000 R 000024 DY	0000 R 000053 MNALW
0000 R 000006 D2A2U	0000 R 02A3NU	0000 R 000070 D2A4UU	0000 R 000061 D2ASUU	0000 R 000062 MNALW
0000 R 000005 D2E8LU	0000 R 000055 D2EPNU	0000 R 000060 D2EUU	0003 R 000016 D2FMLL	0003 R 000015 D2MONC
0003 R 000014 D2LN	0000 R 000056 D2MNU	0000 R 000054 D2RCUU	0003 R 000011 D2NLL	0000 R 000064 D2NUL
0000 R 000057 L3-NLU	0004 R 000011 D342LN	0004 R 000002 D3M2NL	0004 R 000011 EA	0005 R 000000 ETA
0003 R 000022 E3	0003 R 000002 FW	0003 R 000003 FN	0003 R 000005 FMC	0003 R 000004 FNCAR
0000 R 000077 INJPS	0003 R 000001 THETAB	0003 R 000001 THETAS	0004 R 000000 U	0003 R 000006 V
0000 R 000000 Y	0003 R 000017 Y1	0003 R 000020 Y2	0000 R 000050 Z	

00101 1* S,ROUTINE DERIV(Y3,Y4,Y5,Y6,DLDU,D2LDU,DY3,DY4,DY5,DY6,B,C,
00101 2* 1 DNDU,DADU,DA2D1,D3DU,DADU,D4DU,DADU,
00101 3* 2 DEPDUEU,DEPU,DEJU,D2MNCU)

00101 4* C DERIVATIVES

00101 5* C DERIVATIVES
00101 6* C FOR FIRST AND SECOND DERIVATIVES OF U SET C=1 AND B=0
00101 7* C FOR FIRST AND SECOND DERIVATIVES OF V SET C=0 AND B=0
00101 8* C FOR FIRST AND SECOND DERIVATIVES OF FNCOR SET C=U AND B=1

00101 9* C DIMENSION Y(20),Y(20)

00103 11* COMMON /BLKI/THETAB,THETAS,FM,FNFNCBR,FNC,V,DNC0T1,DFNX,D2NDLL,
00104 12* DFNY,DFM,D2MLNC,D2MDNC,D2M2LN,Y1,Y2,DE40FB,E3,DE1DL,
00104 13* 1 BLKD/U,D3M2LN,A1,A2,A3,A4,A5,A6,EB
00105 14* 2 Y(1) = Y1
00105 15* Y(2) = Y2

62 3FOR.IS INITIAL
FOR S9A-07/27/72-17:44:39 (.0)

SUBROUTINE INITIAL ENTRY POINT 000470

STORAGE USED: CODE(1, 000522) DATA(0) 0001231 BLANK COMMON(2) 0000000

COMMON BLOCKS:

0003 BLKI 0002

EXTERNAL REFERENCES (BLOCK, NAME)

0004	ETA
0005	DETA
0006	DDETA
0007	MERR3

STORAGE ASSIGNMENT BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000037 A1	0000 R 000040 A2	0000 R 000041 A3	0000 R 000053 A1	0000 R 000054 A2
0006 R 000000 DDETA	0000 R 000051 DDETA	0000 R 000046 DETA	0000 R 000046 DETAU	0003 R 000023 DE10L
0000 R 000032 DE10N	0000 R 000027 DE10T	0000 R 000047 DE10U	0000 R 000030 DE20T	0000 R 000024 DE20U
0000 R 000031 DE20T	0000 R 000035 DE30U	0000 R 000021 DE4DTA	0000 R 000033 DE4D	0000 R 000021 DECNH
0003 R 000013 DF ₁	0000 R 000045 DFMOU	0000 R 000012 DFMX	0000 R 000043 DENDU	0003 R 000010 DEPIX
0003 R 000007 DNCDT	0000 R 000061 D1	0000 R 000062 D2	0000 R 000065 DE1CR	0000 R 000060 DE51U
0000 R 000055 DE1T	0000 R 000036 DE2TU	0000 R 000042 DE3TU	0000 R 000066 DE24CR	0000 R 000071 DE47U
0003 R 000016 D2EMI	0000 R 000035 D2MDU	0000 R 000015 D2MNC	0003 R 000014 D2MLNC	0000 R 000052 D2MRU
0000 R 000067 D2ICN	0000 R 000050 D2VCTU	0003 R 000011 D2NDLL	0000 R 000057 D2NDLU	0000 R 000063 F3
0000 R 000064 D4	0004 R 000000 ETA	0000 R 000025 F1	0000 R 000026 F2	0003 R 000022 F3
0003 R 000002 F4	0003 R 000003 FN	0000 R 000005 FNC	0003 R 000004 FNCBR	0000 R 000010 TNJPF
0000 R 000070 TERM1	0003 R 000000 THETAB	0003 R 000001 THETAS	0003 R 000006 V	0000 R 000000 Y
0003 R 000017 Y1	0003 R 000020 Y2	0000 R 000024 Z		

00101 1* SUEROOTIVE INITIAL.(OLDU,D2LDUU,Y1,Y2,Y3,Y4,Y5,Y6,B,C,D2E4TU,D2E4LU)

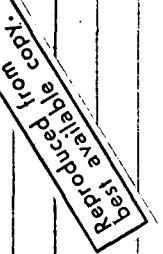
00101 2* C INITIAL CONDITIONS

00101 3*	C FOR FIRST AND SECOND DERIVATIVES OF U SET C=1 AND B=0
00101 4*	C FOR FIRST AND SECOND DERIVATIVES OF V SET C=0 AND B=0
00101 5*	C FOR FIRST AND SECOND DERIVATIVES OF FNCBR SET C=1 AND B=1
00101 6*	C FOR FIRST AND SECOND DERIVATIVES OF FNCBR SET C=1 AND B=1
00101 7*	C DIMENSION Y(20)
00103 8*	COMMON /BLKI/THETAB,THETAS,FM,FN,FNCBR,FNC,V,DNCDT1,DENX,D2NDLU, DF4X,DF1,D2MLNC,D2NDNC,Y1,Y2,DE4DTB,E3,DE1DL
00104 9*	
00105 10*	Y(1) = Y1
00105 11*	Y(2) = Y2
00106 12*	
00106 13*	= FNC
00107 14*	= FMC
00110 15*	= FM*ETA(Z)+FN
00111 16*	= THETAB**4-THETAS**4

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S : 00112 17*      E3      = E2/1-THEΤΑ(3)
    00113 16*      Y(3)     = 0.
    00114 19*      DE15T8 = DΝCΟT1A(DFV*EΤΑ(Z)+FV*DEΤΑ(Z))
    00115 20*      DE22I3 = 0.*THEΤΑP**3)
    00116 21*      DE35T8 = E3*(DE2D1A+E3)*Ε2
    00117 22*      DE41T9 = E1*F3D1T3+E3*DE12T8
    00118 23*      DE15L = ΕΤΑ(Z)*DFVK+DFN
    00121 24*      DE12NC = ΕΤΑ(Z)*DFM+DEΤΑ(Z)*FV
    00122 25*      DE15U = E1*F1NL*DLDU+R*E3*DE10IC*THEΤΑB**3
    00123 26*      Y(4)     = -(1-C)/V**2+DE42U)/D*4Dta
    00124 27*      Y(5)     = 0.
    00125 29*      DE22U = DΕ2D1B*Y(4)
    00126 29*      DE22U = E3*E3*Y(4)*DE2C(U)/Ε2
    00127 30*      DE22IU = 12.*Y(4)*(THEΤΑ3**2)
    00130 31*      A1      = E3*(D2E2TU+DE3DU)/Ε2
    00131 32*      A2      = DE2D3-E3
    00132 33*      A3      = -E3*DE2D1U/(ΕΡ**2)+DE3*ΙV/E?
    00133 34*      D2E3TU = ALΛΑ2*A3
    00134 35*      DFNCDU = DFNCJU
    00135 36*      DFCJLU = DΝCJ1A(Y("))+B*Y(2)**3
    00136 37*      DFNCDU = DFw+COLDII+DFw+DFNCNDU
    00137 38*      DE15U = DE15(Z)*DFCNDU
    00140 39*      DE15U = DE15(Z)*DFM+DEΤΑ(Z)*DFNDU
    00141 40*      DE15U = DE15(Z)*DFM+DEΤΑ(Z)*DFNDU
    00142 41*      DE15U = DE15(Z)*DFCNDU
    00143 42*      D2E3TU = D2E3C(DL1+D2MNC*DF*NDU
    C0144 43*      D2E3TU = DE4TAU+ΕΤΑ(Z)*D2V1CU+FM*DDETDU+DEΤΑ(Z)*DFNDU
    00145 44*      D2E3TU = DE15(Z)*D2C(U)/DNC0T1
    00146 45*      D2E3TU = DΝCΤ1*31+32
    00147 46*      D2E3LU = D2E3L*D11+Q2MLNC*DF*NDU
    00150 47*      D2E3LU = D2V1LU
    00151 48*      D2E3LU = ΕΤΑ(Z)*DFCNDU
    C0152 49*      D2E4LU = E3*D2E1LU+ΣΕ10L*ΣΕ30U
    00153 50*      D2E4LU = DE1(Z)*DFCNDU+DFN
    00154 51*      D2   = ΕΤΑ(Z)*DFCNDU
    00155 52*      D3   = DΕΤΑ(Z)*F4*DFCNDU
    00156 53*      D4   = DΕΤΑ(Z)*F4*DFCNDU
    00157 54*      D2E4C3 = D1*Δ2+Δ3+Δ4
    00160 55*      D2E4C3 = DΕ3D0*DE1DNC+Ε3*D2E1C
    00161 56*      D2E4C9 = 3*Y(4)*Y(2)**2
    00162 57*      TERM13 = 9*(Ε3*DE1CNC+D2NCNB+Y(2)**3*D2E4CB)
    00163 58*      D2E4UU = E3*ΙV1L*ΙV2L+ΙV3L+ΙLDU+Ι2E4U+TERMNR
    00164 59*      D2E4TU = E1*D2E3TU+DE3D0B*DE10U+D2E1TU+D10TB*DE3DU
    00165 60*      Y(6)     = -(Y(4)*D2E4TU+D2E4UU+2*(ΙC-1))/V**3)/DE4DTB
    00166 61*      Y3      = Y(3)
    A0167 62*      Y4      = Y(4)
    00170 63*      Y5      = Y(5)
    C0171 64*      Y6      = Y(6)
    00172 65*      RETURN
    00173 65*      ENJ

```



ΕΡΓΑΣΙΑ ΔΙΑΤΗΓΑ ΤΗΣ ΕΠΙΧΕΙΡΗΣΗΣ
ΠΟΛΥΤΕΧΝΕΙΟΥ ΑΘΗΝΩΝ

END OF COMPILATION: NO DIAGNOSTICS.

02 FOR S9A-07/27/72-17:45:03 110

SUBROUTINE INTMIX ENTRY POINT 000024

STORAGE USED: CODE(1) 0000321 DATA(0) 0000071 BLANK CONVON(2) 0000000

COMMON BLOCKS:

0003 BLKI 000024

EXTERNAL REFERENCES (BLOCK, NAME)

0004 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0003 R 000023 DE1DL	0000 R 000000 DE4DL	0003 R 000021 DE4DTB	0000 R 000001 DE4DXY	0003 R 000013 DEM
0003 000012 DFMAX	0003 000010 DFNX	0003 000007 DNCDT1	0003 000016 D2FMLL	0003 000015 D2MDNC
0003 000014 D2MLNC	0003 000011 D2NDLL	0003 000012 E3	0003 000012 FM	0003 000013 FN
0003 000005 FNC	0003 000001 FNCRR	0000 000002 TNJPS	0003 000000 THETAB	0003 000001 THETAS
0003 000006 Y	0003 000017 Y1	0003 000020 Y2		

00101 1* SL 3ROUTINE INTMIX(D2E4TY,D2ADX,D2DX,D2E4LY,D2LDXY,D2TBXY,D2TDXY)

00101 2* C INITIAL MIXED DERIVATIVES

00101 3* C COMMON /BLKI/ THE T,S,FN,FNCBR,FNC,V,DNCDT1,DFX,D2NDLL,

00103 4* 1 DFW,DFM,D2MLNC,D2MDNC,D2FMLL,Y1,Y2,DE4DT1,E3,DE1DL

00103 5* 7* D2TDXY = 0.

00104 6* DE4DL = E3*DE1DL

00105 6* DE4DXY = D2E4LY*D2DX+DE4DL*D2LDXY

00106 9* D2TAXY = -(DE4DT1+D2BX*D2E4LY)/DE4DTB

00107 10* RETURN

00110 11* E11

00111 12* E11

END OF COMPILATION: NO DIAGNOSTICS.

2 FOR IS FMINV
FOR 59A-07/27/72-17:45:07 (1.0)

SUBROUTINE FMINV ENTRY POINT 000254

STORAGE USED: CODE(1) 0003061 DATA(0) 0012601 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR35

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000046 105*	0001	000151 11L	0011	000051 111G	0001	000071 1173	0001	000104 1236
0001	000125 133C	0001	000130 137G	0011	000172 150G	0001	000175 154G	0001	000227 154G
0001	000212 20L	0000 R	0001214 AA	0010 R	001217 B	0000 I	001212 I	0000	001224 TNJPS
0000 I	0001215 11	0000 I	0001220 12	0010 I	001213 J	0000 I	001216 K	0000 R	000000 XMAT

00101 1* SUBROUTINE FMINV (I,X,N,M) 1
00101 2* C MATRIX INVERSION AND SOLUTION OF SIMULTANEOUS EQUATIONS
00101 3* C
00101 4* C
00103 5* C DIMENSION A(I,N),X(N),XMAT(25,26)
00104 6* DO 1 I=1*N
00107 7* XMAT(I,N)=X(I)
00110 8* DO 1 J=1*N
00113 9* XMAT(I,J)=A(I,J)
00116 10* DO 20 I=1*N
00121 11* A4 = XMAT(I,I)
00122 12* DO 5 J=1*M
00125 13* XMAT(I,J)=XMAT(I,J)/A4
00127 14* IF ((I.EQ.1) GO TO 11
00131 15* I=I+1
00132 16* DO 15 K=1*I1
00135 17* B = XMAT(K,I)
00136 18* DO 15 J=1*M
00139 19* XMAT(K,J)=XMAT(K,J)-XMAT(I,J)*B
00144 20* IF ((I.EQ.N) GO TO 20
00146 21* I=I+1
00147 22* DO 15 K=I2,N
00152 23* B = XMAT(K,I)
00153 24* DO 15 J=1*M
00156 25* XMAT(K,J)=XMAT(K,J)-XMAT(I,J)*B
00161 26* 2, CONTINUE
00163 27* 2, X(I)=XMAT(I,M)
00166 28* 2, RETURN
00170 29* END
00171 30*
END OF COMPILATION: NO DIAGNOSTICS.

2 JFOR,IS ETA
FOR S9A-07/27/72-17:45:11 (,0)

FUNCTION ETA ENTRY POINT 000036

STORAGE USED: CODE(1) 0000441 DATA(0) 0000221 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	POLY
0004	EXP
0005	NERNS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000016 1L	0000 R 000001 A	0000 R 000019 A	0000 R 000000 ETA	0000 R 000014 TNUP+
0003	R 000000 POLY,				

00101 1* FUNCTION ETA(X)

00101 2* C FIN EFFECTIVENESS OF THE UNSTRUCTURED FIN

00101	3*	C	DIMENSION A(7), R(2)
00103	4*	C	DATA A(1),A(2),A(3),A(4),A(5),A(6),A(7)/0.10E+01, -0.1163143E+01,
00104	5*	C	0.148636E+01, -0.126750E+01, 0.6325223E+00, -0.162067E+00,
00104	6*	C	0.148636E+01, -0.126750E+01, 0.6325223E+00, -0.162067E+00,
00104	7*	C	0.148636E+01, -0.126750E+01, 0.6325223E+00, -0.162067E+00,
00104	8*	C	0.1654223E-01, B(1),R(2)/n.68666035E+00, -0.2297718E+00,
00116	9*	C	IF(X>R1,2.5) 30 TO 1
00120	10*	C	ETA = POLY(7,A,X)
00121	11*	C	RETURN
00122	12*	C	ETA = B(1)*EXP(B(2)*X)
00123	13*	C	RETURN
00124	14*	C	END

END OF COMPIRATION: AND DIAGNOSTICS.

02 2FOR IS DETA
FOR S9A-07/27/2-17:45 :15 (,0)

FUNCTION DETA ENTRY POINT 000036

STORAGE USED: CODE(1) 0000441 DATA(0) 0000211 BLANK COMMON(2) 000000

EXTERNAL REFERENCE: (BLOCK, NAME)

0003 POLY
0004 EXP
0005 SER3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000016 1L 0000 R 000001 A 0000 R 0000007 B 0000 R 0000000 DETA 0000 0000013 INJP\$
0003 R 000000 POL

00101 1* FUNCTION DETA(X)
00101 2* C DETA/DNC
00101 3* C
00103 4* C DIMENSION A(6),B(2)
00104 5* C DATA A(1),A(2),A(3),A(4),A(5),A(6)/-0.116343C+01, 0.2957672E+01,
00104 6* C -0.382550E+01, 0.253008E-01, -0.8135335E+00, 0.9925338E-01/
00104 7* C 2 A(1)*B(2)/-0.1577635E+00, -0.2297718E+00/
00115 8* C IF(X.GT.2.5) GO TO 1
00117 9* C DETA = POLY(5,A,X)
00120 10* C RETURN
00121 11* C DETA = B(1)*EXP(B(2)*X)
00122 12* C RETURN
00123 13* C EID
00123 14* C

END OF COMPIILATION: NO DIAGNOSTICS.

2 IFOR IS DDETA
FOR S9A-07/27/72-17:45:23 (,0)

FUNCTION DDETA ENTRY POINT 000036

STORAGE USED: CODE(1) 0000441 DATA(0) 00000201 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 POLY
0004 EXP
0005 FERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 0000016 1L 0000 R 0000001 A 00r0 R 0000006 B 0000 R 0000000 DDETA 0000 000012 INJP\$
0003 R 0000000 POLY

00101 1* FUNCTION DDETA(X)
00101 2* C DDETA/22NC
00101 3* C
00101 4* C
00103 5* DIMENSION A(15), B(?)
00104 6* DATA A(1), A(2), A(3), A(4), A(5)/0.29576725+01, -0.7605300E+01,
00104 7* 1 0.7590267E+01, -0.325413E+01, 0.4962669E+00/, B(1), B(2),/
00104 8* 2 IF (X>2.5) 30 TO 1
00104 9* DDETA = POLY(5,A,X)
00116 10* RETURN
00117 11*
00120 12* 1 DDETA = B(1)*EXP(B(2)*X)
00121 13* RETURN
00122 14* END

END OF COMPIRATION: NO DIAGNOSTICS.

2 FOR IS DDETA
FOR S9A-07/27/72-17:45:35 (,0)

FUNCTION DDETA ENTRY POINT n00036

STORAGE USED: CODE(1) 0000441 DATA(0) 0000171 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

n003 POLY
n004 EXP
n005 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 0000161L 0000 R 000001 A 0000 R 000005 R
0003 R 000000 POLY

20101 1* FUNCTION DDETA(X)
00101 2* C. DDETA/D3NC
00101 3* C.
00101 4* C
00103 5* C DIMENSION A(4), 3(2)
00104 6* C4/A A(1), A(2)*A(3), A(4)/-0.740930E+01, 0.1518053E+02,
00104 7* 1-0.2762402E+01, 0.10A5048E+01/
00104 8* 2 A(1), B(2)/-0.8329136E-02,-0.297718E+00/
00113 9* IFLX*GT, 2, 51, 50, T, 0
00115 10* DDETA = POLY(4,A,X)
00116 11* RETURN
00117 12* DDETA = B(1)*EXP(A(2)*X)
00120 13* RETURN
00121 14* E10

END OF COMPIRATION: NO DIAGNOSTICS.

c2 2FOR IS POLY
FOR S2A=07/27/72-17:45:42 (1,0)

FUNCTION POLY ENTRY POINT 000036

STORAGE USED: CODE(1) 000046! DATA(0) 000015! BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000012 1076 0000. 000003 INJP\$ 0000 I 000002 K 0000 I 000001 L 0000 R 000000 POLY

```

00101 1* FUNCTION POLY(N,A,X)
00101 2* C POLYNOMIAL EVALUATION Y = A(N)*X+N-1)+X**2*A(N-2)+...
00101 3* C
00101 4* C DIMENSION A(N)
00103 5* C
00104 6* C POLY = 0.
00105 7* C L = N
00106 8* C DO 1 K=N
00111 9* C POLY = POLY*X+A(L)
00112 10* C 1 L = L-1
00112 11* C RETURN
00115 12* C END

```

END OF COMPILATION: NO DIAGNOSTICS.

02 2XJT MAP 023-07/27-17:45

ADDRESS LIMITS 001 00 020432 040000 047526
STARTING ADDRESS 017366

WORDS DECIMAL 7 163 IBANK 3927 DBANK

SEGMENT	1411	001000 020432	040000 047526
NSAT\$/\$FOR	1	001000 001021	
NRELKS/\$FOR	1	001021 001044	
NRN\$/\$FOR	1	001045 001124	2 040000 040011
NWF\$/\$FOR	1	001125 001326	2 040012 040031
NFTCH\$/\$FOR	1	001227 001617	2 040032 040067
NEDOL\$/\$FOR	1	001621 001752	2 040070 040125
NFTVS\$/\$FOR	1	001753 001775	
NCMT\$/\$FOR	1	001776 002222	2 040126 040215
NCLOSS\$/\$FOR	1	002223 002371	2 040216 040247
NWLKS/\$FOR	1	002372 002513	
NBSH\$/\$FOR	1	002514 002550	
NUDOL\$/\$FOR	1	002551 002603	
N3FOR\$/\$FOR			2 040250 042051
N1LN\$/\$FOR	1	002604 003014	2 042452 042463
NIMPT\$/\$FOR	1	003015 003657	2 042464 042503
NOLN\$/\$FOR	1	003660 004173	2 042504 042507
NOUT\$/\$FOR	1	004174 005162	2 042510 042534
NFNT\$/\$FOR	1	005163 006041	2 042535 042611
NIOER\$/\$FOR	1	006042 006214	2 042612 042716
NFCWK\$/\$FOR	1	006215 007076	2 042717 043055
NT_31\$/\$FOR			4 043056 043127
ER05\$/\$FOR			2 043130 043166
NLUE\$/\$FOR	1	007077 007141	2 043167 043167
TIR\$/\$TECH	1	007142 007626	0 043170 043220
NEAPES\$/\$FOR	1	007627 007714	2 043221 043500
NJERS\$/\$FOR	1	007715 007775	2 043501 043544
NOJES\$/\$FOR	1	007777 00843	
ASINCJS\$/\$FOR	1	010044 010260	0 043645 043672
SQRT\$/\$FOR	1	010261 00321	2 043673 043704
EXPSEL\$/\$FOR	1	010322 010411	2 043705 043725
NERS\$/\$FOR	1	010412 010736	2 043726 044071
BLGR (COMMON BLOCK)			044072 044103
VAB (COMMON BLOCK)			044104 044106
YCT (COMMON BLOCK)			044107 044113
BLKB (COMMON BLOCK)			044114 044115
BLKD (COMMON BLOCK)			044116 044127
BLK1 (COMMON BLOCK)			044130 044153

62	BLANK\$COMMON (COMMON BLOCK)	1	010737 011002	0	044154 044179
	POLY			2	BLANK\$COMMON
V	DDDETIA	1	011003 011046	0	044171 044207
/	DDDETIA	1	011047 011112	0	044210 044227
\	DETA.	1	011113 011156	0	044230 044250
/	EIA	1	011157 011222	0	044251 044272
C	FMINN	1	011223 011539	0	044273 045552
/	INIMIX	1	011531 011562	0	045553 045561
C	INITIAL	3	SLKI	2	BLANK\$COMMON
/	DERV	1	011563 012304	0	045562 045704
C	MIXER	3	SLKI	2	BLANK\$COMMON
/	NCDEV	1	012305 013225	0	045705 046034
C	YDER	3	BLKI	2	BLANK\$COMMON
/	NDEV	1	013226 013701	0	046035 046149
C	NCDEV	3	BLKI	2	BLANK\$COMMON
/	YDER	1	013702 013745	4	BLKD
C	NDEV	1	013746 014251	0	046141 046153
/	RESTI	1	014342 014461	2	BLANK\$COMMON
C	RESAN2	1	014462 014713	0	046154 046241
/	ENDCOND	1	014714 015324	0	046242 046256
C	SCNTL	3	BLK3	2	BLANK\$COMMON
/	SORV	1	015325 015520	0	046355 046441
C	RKS	3	MCT	2	BLANK\$COMMON
/	SORV	5	BLKI	4	WAB
C	441N	1	015521 016325	0	046456 046543
/	441N	3	BLKI	2	BLANK\$COMMON
C	RKS	5	BLKR	4	BLKD
/	RKS	7	BLKB	6	BLKR

SYSSRLIBS. LEVEL 63
END OF COLLECTION - TIME 2.084 SECONDS

APPENDIX C

COMPUTER CODE FOR MINIMUM
MASS OPTIMIZATION

B26221

BFOR, IS MAIN
EDB 29-A-1173702-209: 7 MUL 1971

WATN ERBONGBAN

STORAGE USED: CODE(1) DATA(8) COMMON(2) BILK 000000

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EXTERNAL REFERENCES (BIOCK: NAME)

0007	SDRV
0010	SCNTL
0011	CONST
0012	NDERV
0013	ETA
0014	DETA
0015	NCDEV
0016	MDER
0017	INITIAL
0020	TINVIX
0021	RKS
0022	FMTNV
0023	BNDCOND
0024	NTNTR\$
0025	NRNL\$
0026	NWDUS
0027	NI02\$
0030	SGRT
0031	ASIN
0032	NIDIS
0033	NGTOD

```

00003 R 000016 D2FLML 0006 R 000003 D2LDUU 0006 R 000004 D2LDUV 0006 R 000007 D2LNCB
0006 R 000010 D2LUNB 0006 R 000011 D2LVNB 0003 R 000015 D2MDNC 0003 R 000111 D2NDLL
0004 R 00001 D3M2LN 0004 R 00002 D3M2NL 0004 R 000011 EB 0013 R 000000 ETA 0000 R 000375 ETY
0000 R 000374 ETYY 0003 R 00022 E3 0003 R 00002 FM 0003 R 00003 FN 0003 R 00005 FNC
0003 R 00004 FNC:R 0000 I 000415 1 0000 I 000420 IBKP 0005 I 00001 ICNT 0000 I 000422 JERR
0000 I 000416 IFVD 0000 000426 INPUT 0000 I 000424 LCNT 0005 00004 LS1EP 0000 I 000423 L0TEP
0000 I 000417 N 0000 I 000367 NCT 0000 I 000360 NIT 0000 I 000421 NTRY 0000 R 000144 PD
0000 R 000354 PHI12 0000 R 000074 R 00007 R 000000 SDRV 0000 R 000365 RHOD 0006 R 000000 SCNTL
0000 R 000170 SO 0000 R 000366 THQ 0000 R 000364 TFLEXT 0003 R 000000 THETAB 0000 R 000402 THETAF
0003 R 000001 THEtas 0000 R 000353 TOTMAS 0000 R 000370 T2 0000 R 000371 T3
0004 R 000000 U 0003 R 000006 V 0000 R 000334 XM 0005 R 000002 XNRT 0000 R 000000 Y
0030 R 000214 YS 0000 R 000310 YSIMP 0000 R 000264 YST 0000 R 000376 YY 0003 R 000017 Y1
0003 R 000020 Y2 0000 R 000425 ZS 0000 R 000401 ZZ 0000 R 000413 ZZ 0000 R 000361 Z1
0000 R 000362 Z2 0000 R 000363 Z3

```

```

00100 1* C
00100 2* C
00100 3* C
00100 4* C
00100 5* C

```

RADIATOR SYSTEMS OPTIMIZATION FOR MINIMUM MASS

```

00101 6* C
00101 7* C
00101 8* C
00101 9* C
00104 10* C
00104 11* C
00104 12* C
00104 13* C
00104 14* C
00105 15* C
00105 16* C
00106 17* C
00107 18* C
00110 19* C
00111 20* C
00114 21* C
00115 22* C
00116 23* C
00117 24* C
00120 25* C
00121 26* C
00122 27* C
00123 28* C
00124 29* C

```

EXTERNAL SDRV•SCNTL

```

00103 1 COMMON /BLKI/THETAB,THETAS,FM,FN,FNCBR,FNC,V,DNCOT1,DFNX,D2NDLL,
          DFNM,DFM,D2MLNC,D2MDNC,D2MLL,Y1,Y2,DE4DTB,E37DE1DL/
          BLKD/U,D3W2LN,D3M2NL,A1,A2,A3,A4,A5,A6,EB
          2 7MCT/DLY,TCNT,XWRT/TDXWRT,LSTEP
          3 /BLKR/RLAM,DLDU,DLDV,D2LDUV,D2LNCB,
          4 D2LNCB,D2LUNB,D2LVNB
          5 NAMELIST /INPUT/ THETAS,U,V,FNCBR,TOTMAS,PHI2,ALPHA,DXWRT,DA,DR

```

```

00106 17* FFS(X) = (SQRT(X*(X+2.0))+ASIN(1.0/(X+1.0))-1.570796)/X
00107 18* FFN(X,Y) = 1.0-Y*0.1460*Y-0.78667/X
00110 19* UFFN(X,Y)=(-0.2920*Y+0.028667)/X
00111 20* I READ(S$INPUT,END=3000)
00114 21* NIT = 1
00115 22* 21
00116 23* 22
00117 24* 23
00120 25* XM(1) = 0.
00121 26* XM(2) = 0.
00122 27* XM(3) = 0.
00123 28* TFLEXT = 2.0
00124 29* 50 CALL CONST(TOTMAS,PHI2,ALPHA,U,V,FNCBR,RЛАM,DLDU,DLDV,D2LNCB),
          00124 30* 1 D2LDUV,D2LNUF,D2LUH,D2LUV,D2LVNB,D2LNCB,
          00125 31* CALL NDERV(RЛАM,FN,DFNX,D2NDLL)
          00126 32* RHOD = RЛАM
          00127 33* WRITE(6,2000) THETAS,U,V,FNCBR,TOTMAS,PHI2,ALPHA,RЛАM
          00141 34* 2000 FORMAT(THT,10X,10HTHETA'S=F20.8/
          00141 35* 1 11X10H U = F20.6/
          00141 36* 2 11X10H V = F20.6/
          00141 37* 3 11X10H FNCBR = F20.6/
          00141 38* 4 11X10H TOTMAS = F20.6/
          00141 39* 5 11X10H PHI2 = F20.6/

```

```

00141   40*      6      1IX.10H  ALPHA = F20.6/
00141   9*      9      1IX.10H LAMBDA = F20.6/777
02 00142   42*      WRITE(6,2010) NIT
00145   43*      2010 FORMAT(15X,NUMBER OF ITERATIONS = '12)
00146   44*      TH4 = THETA$**4
00147   45*      IF(V.GT.0.2) GO TO 90
00148   46*      IF(V.LE.1.0E-10) GO TO 108
00153   47*      90 THETAB = 0.9
00154   48*      95 NCT = 0
00155   49*      100 T2 = THETAB**2
00156   50*      100 T3 = T2*THETAB
00157   51*      FNC = FNGBR*T3
00160   52*      FM = FFN(RHOD,FNC)*FFS(RHOD)
00161   53*      DFN = OFFN(RHOD,FNC)*OFFS(RHOD)
00162   54*      AYY = T3*HETAB-TH4
00163   55*      BYY = 1.0*HETAB
00164   56*      ETA = ETA(FNC)
00165   57*      ETY = ETY*FM/FN
00166   58*      YY = 1.0/V-ETY*AYY/BYY
00167   59*      OETZ = (DFN*ETYY+F*DETA(FNC))*3.0*T2*FNGBR
00170   60*      DYY = -AYY/BYY*(OETZ+ETY/BYY)-4.0*ETY*T3/BYY
00171   61*      22 = THETAB-YY/DY
00172   62*      IF(INCI.GT.20) GO TO 109
00174   63*      IF((22.LT.1.0) GO TO 105
00176   64*      THETAB = (THETAB+1.0)/2.0
00177   65*      NCT = NCT+1
00200   66*      GO TO 100
00201   67*      105 IF(ABS((22-THETAB)/22.LT.1.0E-06) GO TO 110
00203   68*      NCT = NCT+1
00204   69*      THETAB = 22
00205   70*      GO TO 100
00206   71*      108 THETAB = 1.0
00207   72*      GO TO 110
00210   73*      109 WRITE(6,900)
00210   74*      C
00212   75*      110 Y11 = 1.0
00213   76*      Y(2) = THETAB
00214   77*      900 FORMAT(1H0,20HNEWTON-RAPHSON FAILS)
00215   78*      THETAF = Y(1)
00216   79*      Y1 = Y(1)
00217   80*      Y2 = Y(2)
00220   81*      CALL INTDRV(FNGBR,THETAB,D2C021,D2CTN)
00221   82*      CALL MDER(1,LM,FNC,FM,DFM,D2MNL,D2MLNC,D3M2LN,D3M2NL)
00222   83*      CALL INITIAL(DLDU,D2LDU),(13),Y(4),Y(5),Y(6),Y(7),Y(8),Y(9),Y(10),Y(11),Y(12),Y(13),Y(14),Y(15)
00223   84*      CALL INITIAL(DLDV,D2LDV),(Y(7),Y(8),Y(9),Y(10),Y(11),Y(12),Y(13),Y(14),Y(15))
00224   85*      CALL INITIAL(DLNCCB,D2LNCCB),(Y(11),Y(12),Y(13),Y(14),Y(15))
00225   87*      CALL INTMX(1,2EATN,Y(4),DLDU,D2E4LN,D2LUNB,(16),Y(17))
00226   88*      CALL INTMX(1,2EATN,Y(4),DLDU,D2E4LN,D2LUNB,(16),Y(17))
00227   89*      CALL INTMX(1,2EATN,Y(4),DLDU,D2E4LN,D2LUNB,(16),Y(17))
00230   90*      222 = 0
00231   91*      DLMT = 0
00232   92*      100 115 I=1,20
00233   93*      115 R(I) = DR
00236   94*      WRITE(6,2040)
00238   95*      C
00240   96*      WRITE(6,2040)

```

```

00242   97*    2040 FORMAT(//7X,6HTHETAF,10X,6HTHETAB,10X,2HNC,13X,6HETABR,
02      00242   98*           1           IIX*3HETAT3X,IHW,I4X,IHN,I4X,IHX)
02      00243   99*           C           ZZZ           = 0.0
02      00244  100*           C           JX           = 1.0/(U*(1.0-THETA))
02      00245  102*           FVDF           = 0
02      00246  103*           LF(DX,GT,DWXRT) DX = DXWRT
02      00250  104*           N           = 20
02      00251  105*           .           1BKP           E 1
02      00252  106*           .           VTRY           E 1
02      00253  107*           .           IERR           E 0
02      00253  108*           C           JLMJ           = DXWRT/500.0
02      00254  109*           .           XWRT           = 0.0
02      00255  110*           .           UOTEP           = 0
02      00256  111*           .           LCNT           = 0
02      00257  112*           .           LCNT           = 0
02      00260  113*           .           CALL RRSTSDRV,SCNT,Y,DYTA,R,ZZZ,DX,N,IFVD,TBKP,NTRY,ICRR,
02      00261  114*           .           OLY,PD,SD,YS,YST,DYST,YSIMP)
02      00262  116*           .           KM(1)           = Y(3)
02      00263  117*           .           KM(2)           = -Y(7)
02      00264  118*           .           XM(1)           = -Y(11)
02      00265  119*           .           AM(1,1)           = Y(5)
02      00266  120*           .           AM(1,2)           = Y(15)
02      00267  121*           .           AM(1,3)           = Y(17)
02      00270  122*           .           AM(2,1)           = Y(15)
02      00271  123*           .           AM(2,2)           = Y(9)
02      00272  124*           .           AM(2,3)           = Y(19)
02      00273  125*           .           AM(3,1)           = Y(17)
02      00274  126*           .           AM(3,2)           = Y(19)
02      00275  127*           .           AM(3,3)           = Y(13)
02      00276  128*           .           CALL FMINV(AM,XN,3,4)
02      00277  129*           205        FORMAT(//45X,27H PARAMETERS AT END OF TUBE //)
02      00300  130*           210        FORMAT(1X,51X,BATHTAF,U0.6,/)
02      00301  131*           215        FORMAT(1X,23X,3HV,E14.6,12X,7HNCBAR =,E14.6,/)
02      00302  132*           230        FORMAT(IIX,19X,7HDTFDU,E14.6,12X,7HDTFOV =,E14.6,BX,
02      00302  133*           1           11HDTFNCBAR =,E14.6,/)
02      00303  134*           240        FORMAT(IIX,17X,9HDTFDU,E14.6,10X,9HD2TDFD2V =,E14.6,BX,
02      00303  135*           1           13HD2TFD2NCBAR =,E14.6,/)
02      00304  136*           250        FORMAT(IIX,16X,10HD2TFJUDV,E14.6,5X,14HD2TFDDNCBAR =,E14.6,
02      00304  137*           1           5X,14HD2FVDNCBAR =,E14.6,/)
02      00305  138*           220        FORMAT(IIX,24HNCR, SOUGHT DELTA U =,E14.6,10X,9HDELTA V =,
02      00305  139*           1           E14.6,6X,13HDELTA NCBAR =,E14.6,/
02      00306  140*           221        FORMAT(IIX,24HNCR, USED DELTA U =,E14.6,10X,9HDELTA V =,
02      00306  141*           1           E14.6,6X,13HDELTA NCBAR =,E14.6,/
02      00307  142*           NIT           = NIT+1
02      00310  143*           .           21           = U
02      00311  144*           .           22           = V
02      00312  145*           .           23           = FNCBR
02      00313  146*           .           WRITE(6,205)
02      00315  147*           .           WRITE(6,210) Y(1)
02      00320  148*           .           WRITE(6,215) Z1722,23
02      00325  149*           .           WRITE(6,230) Y(3),Y(7),Y(11)
02      00332  150*           .           WRITE(6,240) Y(5),Y(9),Y(13)
02      00337  151*           .           WRITE(6,250) Y(15),Y(17),Y(19)
02      00344  152*           .           WRITE(6,220) YXX(17),I=1,31
02      00352  153*           .           CALL BNCDND(U,V,FNCBR,XM,TOMAS,ALPHA)

```

```

00353   154*      WRITE(6,221) (XM(I),I=1,3)
00361   155*      200 IF (INIT .GT. 2D1) GO TO 300
@2     00363   156*      ZS = Y(1)-THEtas
00364   157*      IF(ZS.LT.0.0001) GO TO 2070
00366   158*      IF (ABS(Y(1)-TFLEXT)/Y(1) .LE. 5.0E-04) GO TO 2090
00370   159*      TFLEXT = Y(1)
00371   160*      IF (ABS(XM(1))/Z1.GT.0.0001) GO TO 50
00373   161*      IF (ABS(XM(2))/Z2.GT.0.0001) GO TO 50
00375   162*      IF (ABS(XM(3))/Z3.GT.0.0001) GO TO 50
00377   163*      WRITE(6,2060)
00401   164*      2060 FORMAT(1H0,15H OPTIMUM REACHED)
00402   165*      GO TO 1
00403   166*      300 WRITE(6,2050)
00405   167*      2050 FORMAT(1X,32H NUMBER OF ITERATIONS EXCEEDS 20 )
00406   168*      GO TO 1
00407   169*      2070 WRITE(6,2075)
00411   170*      2075 FORMAT(1H0,24HVANISHING HEAT REJECTION)
00412   171*      GO TO 1
00413   172*      2090 WRITE(6,2095)
00415   173*      2095 FORMAT(1H0,40H INSIGNIFICANT IMPROVEMENT OVER LAST STEP)
00416   174*      GO TO 1
00417   175*      3000 STOP
00420   176*      END
)
END OF COMPILED:      NO DIAGNOSTICS.

```

QFOR,TIS CONST
FOR SS#=07727772=19:37:44 (r,0)

SUBROUTINE CONST

ENTRY POINT 000373

STORAGE USED: CODE(1) 0000467 DATA(0) 0000711 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 SORT
0004 NERJS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000003 A	0000 R 000002 AZ	0000 R 000004 B	0000 R 000005 C	0000 R 000006 D
0000 R 000010 DAN	0000 R 000014 DBN	0000 R 000014 DBN	0000 R 000013 DBV	0000 R 000017 DCU
0000 R 000020 DCV	0000 R 000026 DBN	0000 R 000024 DCU	0000 R 000025 DBV	0000 R 000023 DCZ
0000 R 000012 DZANN	0000 R 000031 DAVN	0000 R 000011 DZAVV	0000 R 000016 D2BNN	0000 R 000032 D2BVN
0000 R 000015 D2BVV	0000 R 000021 D2CUU	0000 R 000033 D2CUV	0000 R 000022 D2CVV	0000 R 000030 D2DNN
0000 R 000034 D2DNN	0000 R 000027 D2DVV	0000 00043 INPS	0000 R 000000 PI	0000 R 000001 Z

00101 1* SUBROUTINE CONST(TOMAS,PHI2,ALPHA,U,V,FNCBR,HOD,DLDU,DLOV,DLCNCB,
02LDDU,D2LDUV,J2LDNB,D2LDOV,D2LVNB,D2LNCB)

00101 2* C PI = 3.1415926

00103 4* Z V**3/FNCBR

00104 5* AZ = ALPHA*ALPHA

00105 6* A = TOMAS-AZ*Z

00106 7* TF(A,LT,1.0E-06) A = 1.0E-06

00107 9* C

00111 10* 50 B = PI*ALPHA*Z

00112 11* C = PHI2*ALPHA*V**2*SORT(U)

00113 12* D = SORT(B*B+A*C)

00114 13* HOD = (B+D)/A

00114 14* C

00115 15* DAV = -3.0*B*ALPHA/(PI*V)

00116 16* DAN = AZ*Z/FNCBR

00117 17* D2AVV = -6.0*A2*V/FNCBR

00120 18* D2ANN = -2.0*DAN/FNCBR

00120 19* C

00121 20* DBV = C/12.0*U

00122 21* DBN = -B/FNCBR

00123 22* D2BVV = 6.0*B/(V*V)

00124 23* D2BNN = 2.0*B/(FNCBR+FNCBR)

00124 24* C

00125 25* DCU = C/12.0*U

00126 26* DCV = -2.0*C/V

00127 27* D2CUU = -DCU/(2.0*U)

00129 28* D2CVV = DCV/V

00130 29* C

```

00131    30*      DZ      = 2.0*D
00132    31*      DDD      = A*D0/DZ
00133    32*      DDV      = (2.0*B*DBV+A*DCV+C*DAN)/DZ
00134    33*      DDN      = (-2.0*B*DBNFC*DAN)/DZ
00135    34*      D2DVW     = (-DDV*DDV+DBV*DBV+B*D2BVV+DAV*DCV+(D2CVV*A+D2AVV*C)/2.0)
00135    35*      /D
00136    36*      1        D2DNN     = (-DDN*DDN+DBN*DBN+B*D2BNN+C*D2ANN/2.0)/D
00136    37*      C        D2AVN     = -3.0*DBN*ALPHA/(PI*V)
00137    38*      D2BNV     = 3.0*DBN/V
00140    39*      D2CUV     = C/(U*V)
00141    40*      D2DVN     = (-DDN*DDV+DBV*DBN+B*D2BVN+(DCV*DAN+C*D2AVN)/2.0)/D
00142    41*      C        DLDU      = DCU/DZ
00142    42*      C        DLDV      = (-HOD*DAV+DBV+DDV)/A
00143    43*      DLDU      = (-HOD*DAN+DBN+DDN)/A
00144    44*      DLDV      = (-HOD*DAN+DBN+DDN)/A
00145    45*      DLDNCB    = (-HOD*DAN+DBN+DDN)/A
00145    46*      C        DLDNCB    = (-HOD*DAN+DBN+DDN)/A
00146    47*      D2LDU     = (D2CU-DDU*DCU/D)/DZ
00147    48*      D2LDV     = (-2.0*DLDV*DAV-HOD*D2AVV+D2BVV+D2DVV)/A
00150    49*      D2LNB     = (-2.0*DLDNCB*DAN-HOD*D2ANN+D2BNN+D2DNN)/A
00150    50*      C        D2LNB     = (-2.0*DLDNCB*DAN-HOD*D2ANN+D2BNN+D2DNN)/A
00151    51*      D2LDV     = (D2CU-2.0*DDU*DDV)/DZ
00152    52*      D2LNB     = -DLDV*DDN/D
00153    53*      D2LNB     = (-DDV*DAN-DDNCB*DAV-HOD*D2AVV+D2BVN+D2DVN)/A
00154    54*      RETURN
00155    55*      END

```

END OF COMPUTATION: NO DIAGNOSTICS.

QFOR,IS,BNDCOND
FOR S9A=07727772=19:37:47 170

SUBROUTINE BNDCOND ENTRY POINT 000154

STORAGE USED: CODE(1) 0002077 DATATO 00000277 BLANK COMMONT(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NEXP6\$
0004 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000011 500L	0000 000014 INJPS	0000 I 000000 L	0000 R 000004 X1	0000 R 000005 X2
0000 R 000001 21	0000 R 000002 22	0000 R 000003 23			

```
00101 1*      SUBROUTINE BNDCOND(U,V,FNCBR,XM,TOTMAS,ALPHA)
00101 2*      C
00101 3*      C   BNDCOND INSURES U,V, AND NCBAR ARE WITHIN THEIR BOUNDARY CONDITIONS
00101 4*      C
00102 5*      DIMENSION XM(3)
00104 6*      L      = 1
00105 7*      Z1     = U
00105 8*      Z2     = V
00106 9*      Z3     = FNCBR
00107 10*     500 U      = Z1+XM(1)
00110 11*     V      = Z2+XM(2)
00111 12*     FNCBR = Z3+XM(3)
00112 13*     IF(L.EQ.2) RETURN
00113 14*      C
00115 15*      IF(U.LT.5.0E-06) XM(1) = 5.0E-06-21
00117 16*      IF(U.GT.250.0) XM(1) = 250.0-21
00121 17*      IF(V.LT.5.0E-06) XM(2) = 5.0E-06-22
00123 18*      IF(V.GT.50.0) XM(2) = 50.0-22
00125 19*      IF(FNCBR.LT.1.0E-04) XM(3) = 1.0E-04-23
00127 20*      IF(FNCBR.GT.6.0) XM(3) = 6.0-23
00131 21*      X1     = TOTMAS+FNCBR
00132 22*      X2     = ALPHA**2
00133 23*      IF(X1-X2*V**3.LT.0.0) XM(2) = (X1/X2)**(1.0/3.0)-22
00135 24*      L      = 2
00136 25*      GO TO 500
00137 26*      END
```

END OF COMPIILATION: NO DIAGNOSTICS.

QFOR IS NDERV
FOR 59A-0772772-19:37:49 (0)

SUBROUTINE NDERV ENTRY POINT 000056

STORAGE USED: CODE(17) 0000707 DATAT(07) 0000015, BLANK COMMENT2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	SQRT
0004	ASIN
0005	NERRJS

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 0000000 C4 00000 R 000001 C5 0000 R 000002 C6 0000 000006 TNJPS

00101	1*	C	SUBROUTINE NDERV(RRAM,FN,DFNX,D2NDLL)
00101	2*	C	
00101	3*	C	N AND ITS DERIVATIVES
00101	4*	C	
00103	5*	C ₄	= RRAM+1.0
00104	6*	C ₅	= RRAM*2.0
00105	7*	C ₆	= SQRT(RRAM*C ₅)
00106	8*	FN	= (1.5707963+C ₅ -C ₆ -ASIN(C ₆ /C ₄ -1.0))/RRAM
00107	9*	DFNX	= -(FN+C ₆ /C ₄ -1.0)/RRAM
00110	10*	D2NDLL	= -(2.0*DFNX+1.0)/(C ₄ *C ₅)*RRAM
00111	11*	RETURN	
00112	12*	END	

END OF COMPILED: NO DIAGNOSTICS.

2
FOR S9A=07727772=19:37:57 (170)

SUBROUTINE MDER ENTRY POINT 000251

STORAGE USED: CODE (1) 0003047 DATA(0) 0000667 BLANK COMMENT(2) 0000000

EXTERNAL REFERENCES (BLOCK# NAME)

0003	SORT
0004	ASIN
0005	NERR3\$

STORAGE ASSIGNMENT (BLOCK# TYPE, RELATIVE LOCATION, NAME)

0000 R 000001 CFN	0000 R 000000 C1	0000 R 000017 C10	0000 R 000020 C11	0000 R 000022 C12
0000 R 000001 C2	0000 R 000003 C3	0000 R 000002 C4	0000 R 000004 C5	0000 R 000005 C6
0000 R 000006 C7	0000 R 000007 CB	0000 R 000010 C9	0000 R 000015 DCFDNC	0000 R 000013 DCFNDL
0000 R 000014 DFSSDL	0000 R 000016 D2CFLL	0000 R 000025 D2CLNC	0000 R 000026 D2CLNL	0000 R 000023 D2C2LL
0000 R 000021 D2C3LL	0000 R 000024 D2FSLL	0000 R 000027 D3C2LN	0000 R 000030 D3C2NL	0000 R 000032 FFS
0000 00040 INPS				

00101	1*	SUBROUTINE MDER(RLAM,FNC,FMX,DFNDZ,DFNDL,D2FLL,D2MNC,D2MNL,D2MLN,
00101	2*	103M2NL)
00101	3*	C
00101	4*	C AND ITS DERIVATIVES
00103	5*	C
00103	6*	C1 = 0.1460*FNC-0.02866
00104	7*	C2 = SORTRLAM*(T2+RLAM)
00105	8*	C4 = 1.0/(RLAM+1.0)
00106	9*	C3 = ASIN(C4)
00107	10*	C5 = 1/(C4*C2)
00110	11*	C6 = (C4*2)/SQRRT1=C1*(T2+2)
00111	12*	C7 = 1/(RLAM**2)
00112	13*	C8 = FNC/RLAM
00113	14*	C9 = 2.*C7*CB
00114	15*	CFN = 1.0-C1*CB
00115	16*	FFS = (C2+C3-1.57079635)/RLAM
00116	17*	FM = CFN*FFS
00117	18*	DCFNOL = C1*C7*FNC
00120	19*	DFFSDL = (C5-C6-FFS)*RLAM
00121	20*	DFMX = CFN*DFFSDL+FFS*DCFNOL
00122	21*	DCFNDNC = -(0.1460*FNC+C1)*RLAM
00123	22*	DFM = FFS*DCFNDNC
00124	23*	D2CFLL = -C1*C9
00125	24*	C10 = 1-C4**2
00126	25*	C11 = +1.*0.5*C10*C4**2
00127	26*	D2C3LL = 2*(C4**3)*C11/SQR(C10)
00130	27*	C12 = 17C2-C2*(C4**2)
00131	28*	D2C2LL = -C12/(C4*C2)**2

```

00132   29*      D2FSLL = (02C2LL*D2C3LL-2*DFFSDL)/RLAM
          30*      D2FNL  = CFN*DFFSLL+2*DFFSDL*DCFNL+FFS*D2CFLL
          31*      D2CFNC = -0.2920/RLAM
          32*      D2M0NC = FFS*D2CFNC
          33*      D2CLNC = (0.146-FNC+C1)*C7
          34*      D2MLNC = DCFDNC*DFFSDE*D2CLNC*FFS
          35*      D3C2LN = -2.*D2CLNC/RLAM
          36*      D3M2LN = DCFDNC*D2FSLL+2.*DFFSDL*D2CLNC+FFS*D3C2LN
          37*      D3C2NL = 0.2920*C7
          38*      D3M2NL = FFS*D3C2NL*DFFSDL*D2CFNC
          39*      RETURN
          40*      END

END OF COMPIRATION:    NO DIAGNOSTICS.

```

9FOR,IS INITIAL
FOR S9A=07727772=19:38:01 (P0)

SUBROUTINE INITIAL ENTRY POINT 000470

STORAGE USED: CODE(11) 0005221 DATA(0) 0001231 BLANK COMMON(2) 000000

COMMON BLOCKS:

0003 BLKI 0000::4

EXTERNAL REFERENCES (BLOCK, NAME)

0004	ETA
0005	DETA
0006	DDETA
0007	NERR36

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000037 A1	0000 R 000040 A2	0000 R 000041 A3	0000 R 000053 B1	0000 R 000054 B2
0006 R 000000 DDET,	0000 R 000051 DDETDU	0005 R 000000 DETA	0000 R 000046 DETAU	0003 R 000023 DEIDL
0000 R 000032 DE101C	0000 R 000027 DE101B	0000 R 000047 DE1DU	0000 R 000030 DE201B	0000 R 000034 DE2DU
0000 R 000031 DE3D19	0000 R 000035 DE3DU	0003 R 000021 DE4DTB	0000 R 000033 DE4DU	0000 R 000044 DFCDNU
0001 R 000013 DF4	0000 R 000045 DF4DU	0003 R 000012 DFMX	0000 R 000043 DFNDU	0003 R 000010 DFNX
0003 R 000007 DNC011	0000 R 000061 D1	0000 R 000062 D2	0000 R 000065 D2ETCB	0000 R 000060 D2EILU
0000 R 000055 D2E11U	0000 R 000036 D2E2TU	0000 R 000042 D2E3TU	0000 R 000066 D2E4CB	0000 R 000071 D2E4UU
0003 R 000016 D2FMLL	0000 R 000056 D2MDLU	0003 R 000014 D2MNC	0003 R 000014 D2MLNC	0000 R 000052 D2MNCU
0000 R 000067 D2NC1B	0000 R 000050 D2NCTU	0003 R 000011 D2NDLU	0000 R 000057 D2NDLU	0000 R 000063 D3
0000 R 000064 D4	0004 R 000007 ETA	0010 R 000025 E1	0000 R 000026 E2	0003 R 000022 E3
0003 R 000002 FM	0003 R 00003 FN	0003 R 000005 FNC	0003 R 000004 FNCBR	0000 00100 INJPS
0000 R 000070 TERMIB	0003 R 000000 THETAB	0013 R 000001 THETAS	0003 R 000006 V	0000 R 000000 Y
0003 R 000017 Y1	0003 R 000020 Y2	0000 R 000024 Z		

00101 1* SUBROUTINE INITALTDUD, D2CDUD, D2E4U, D2E4LU, D2E4UL

00101 2* C INITIAL CONDITIONS

00101 3* C

00101 4* C FOR FIRST AND SECOND DERIVATIVES OF U SET C=1 AND B=0

00101 5* C FOR FIRST AND SECOND DERIVATIVES OF V SET C=0 AND B=0

00101 6* C FOR FIRST AND SECOND DERIVATIVES OF FNCBR SET C=1 AND B=1

00101 7* C

00101 8* C

00103 9* C DIMENSION Y120

00104 10* C COMMON /BLK1/ THETAB, THETAS, FM, FN, FNCBR, FNC, V, DNC01, DFNX, D2NDLU,

00104 11* C DFMX, DFMD2MNC, D2DNC, D2FMLL, Y1, Y2, D2DTB, E1, DEIDL

00105 12* C

00106 13* C Y1(Y1) = Y1

00107 14* C Y2(Z) = Y2

00107 15* C FNC(E1) = FM*ETATZ*FN

00111 16* C E2 = THETAB**4 - THETAS**4

```

00112    17*      E3      = E2/(1-THETAB)
00113    18*      Y(3)    = 0.
02 00114    19*      DE1DTB = DNC0T1*(DFM*ETA(Z)+FM*DETA(Z))
00115    20*      DE2DTB = Y.*(THETAB**3)
00116    21*      DE3DTB = E3*(DE20TB+E3)/E2
00117    22*      DE4DTB = E1*DE3DTB*E3*DE1DTB
00118    23*      DE5DTB = ETA(Z)*DFMX*DFNX
00120    24*      DE1DNC = ETA(Z)*DFM*DETA(Z)*FN
00121    25*      DE2DNC = E3*DE1DL*OLDL+B*E3*DE1NC*THETAB**3
00122    26*      Y(4)    = -(1+C17V**2*DE4DU77DE4DTB
00123    27*      Y(5)    = 0.
00124    28*      DE2DU = DE2DTB*Y(4)
00125    29*      DE3DU = E3*E3*Y(4)*DE2DU/E2
00126    30*      DE2E2TU = 12.*Y(4)*(THETAB**2)
00127    31*      A1     = E3*02E2TU+DE3DU)/E2
00128    32*      A2     = DE2DTB*E3
00129    33*      A3     = -E3*DE2DU/(E2**2)+DE3DU/E2
00130    34*      DE2E3TU = A1*A2*A3
00131    35*      DE4DU = DFNX*OLDU
00132    36*      DEFCNDU = DNC0T1*Y(4)*Y(2)**3
00133    37*      DE5MDU = DFMAX*DLDU+DEV*DFCNDU
00134    38*      DE1ADU = DETA(Z)*DFCNDU
00135    39*      DE1DU = FM*DETA(DAU+ETA(Z))*DFMDU+DFNU
00136    40*      D2VCTU = 6*ENCR*Y(2)*Y(4)+B*3*(1/2)**2
00137    41*      DDETDU = DETA(Z)*DFCNDU
00138    42*      D2VNCU = D2MNC*DLDU*D2WNC*DFCNDU
00139    43*      B1     = DFMDETADU+ETA(Z)*D2MNCU+FM*DDETDU+DETA(Z)*DFMDU
00140    44*      B2     = DE1DTB*D2NCNT*DFCNDU
00141    45*      D2E1TU = DNC0T1*B1+B2
00142    46*      D2F4LL*DLDU = D2MNC*DFCNDU
00143    47*      D2NDLU = D2NDLL*DLDU
00144    48*      D2E1LU = ETA(Z)*D2MOLU*DETA(DU+JFPMX*D2NDLU
00145    49*      D2E4LU = E3*DE21LU+DE1DL*DE3DU
00146    50*      D1     = DETA(Z)*DFCNDU*DFH
00147    51*      D2     = ETA(Z)*D2VNCU
00148    52*      D3     = DDETA(Z)*FM*DFCNDU
00149    53*      D4     = DETA(Z)*DFMDU
00150    54*      D2E1CB = D1+02*03+04
00151    55*      D2E4CB = DE3DU*DE1DNC+E1*D2E1C3
00152    56*      D2NCNB = 3*Y(4)*Y(2)**2
00153    57*      TERMNB = B*(E3*DE1DNC*D2NCNB+Y(2)**3*D2E4CB)
00154    58*      D2E4DU = E3*DE2DL*D2CD0FD0DD*J2ECD0*TERMNB
00155    59*      D2E4TU = E1*D2E3TU*DE3D0B*DE1DU*E3*D2E1TU*DE1DTB*DE3DU
00156    60*      Y(6)   = -(Y(4)*D2E4TU*D2E4DU*2*TC-177V**37*DE4DTB
00157    61*      Y3     = Y(3)
00158    62*      Y4     = Y(4)
00159    63*      Y5     = Y(5)
00160    64*      Y6     = Y(6)
00161    65*      RETURN
00162    66*      END

```

END-OF-COMPIILATION: NO DIAGNOSTICS.

© 2 FORTRAN IS DERR
FOR S9A=07727772=19:38:07 (10)

SUBROUTINE DERV ENTRY POINT 000604

STORAGE USED: CODE(17) 000721; DATA(0) 000130; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	BLKI	000024
0004	BLKD	000012

EXTERNAL REFERENCES (BLOCK, NAME)

0005	ETA
0006	DETA
0007	DDETA
0010	DDDETA
0011	NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0004 R 000003 A1	0004 R 000004 A2	0004 R 000005 A3	0004 R 000006 A4	0004 R 000007 A5
0004 R 000010 A6	0004 R 000051 A7	0003 R 0000023 DE1DL	0010 R 0000021 DE4DTB	0007 R 0000000 DDETA
0006 R 000000 DETA	0003 R 000023 DE1DL	0003 Q 000021 DE4DTB	0003 R 000013 DFMX	0003 R 000012 DFMX
0005 R 000010 DFNX	0003 Q 000007 DNC0T1	0000 R 000052 DN0U	0000 R 000024 DY	0000 R 000053 D2A1U0
0000 R 000066 D242UJU	0000 R 000067 D2A3UJU	0000 R 000070 D2A4UJU	0000 R 000061 D2A5UJU	0000 R 000062 D2A6U
0003 R 000065 D22EJU	0000 R 000056 D2EPUU	0000 R 000060 D2EUU	0003 R 000016 D2FILL	0003 R 000015 D2MDNC
0003 R 000014 D2MLNC	0000 R 000056 D2MUU	0000 R 000054 D2NCUU	0003 R 000011 D2NDLL	0000 R 000064 D2NUU
0000 R 000057 D3MRJU	0004 R 000001 D3M2LN	0004 R 000002 D3M2NL	0004 R 000011 EB	0005 R 000000 ETA
0003 000022 E3	0003 R 000002 FM	0003 R 000003 FN	0003 R 000005 FNC	0003 R 000004 FNCBR
0000 000077 INDF\$	0003 000000 THETAB	0003 R 000001 THETAS	0004 R 000000 U	0003 000006 V
0000 R 000000 Y	0003 R 000017 Y1	0003 R 000020 Y2	0000 R 000050 Z	

00101 1* SUBROUTINE DERRV3,T4,T5,T6,D0U,D2CD000,DY3,DY4,DY5,DY6,B'C,
00101 2* 1 DNC0U,D10U,D20U,D30U,D4DU,D5DU,D6DU,
00101 3* 2 DEBDU,DEU,DEPU,DMDU,DEHNCU,

C DERIVATIVES

00101 4*	C	FOR FIRST AND SECOND DERIVATIVES OF U SET C=1 AND B=0
00101 5*	C	FOR FIRST AND SECOND DERIVATIVES OF V SET C=0 AND B=1
00101 6*	C	FOR FIRST AND SECOND DERIVATIVES OF FNCBR SET C=0 AND B=1
00101 7*	C	DIMENSION T(20),DY(20)
00101 8*	C	COMMON /BLKI,THETAB,THETAS,FM,FN,FNCBR,FNC,V,DNC01,DFNX,DMNDL,
00101 9*	C	DFMX,DFM,D2MLNC,D24DNC,D2FHLC,D3M2LN,A1,A2,A3,A4,A5,A6,EB
00101 10*	C	BLKD/U,D3M2LN,D3M2NL,A1,A2,A3,A4,A5,A6,EB
00103 11*		
00104 12*		
00104 13*	1	
00104 14*	2	
00105 15*	Y(1)	= Y1
00106 16*	Y(2)	= Y2

```

00107    17*      Y(3)      = Y3
00110    18*      Y(t)      = Y4
@2   00111    19*      Y(5)      = Y5
00112    20*      Y(t6)     = Y6
00113    21*      Z         = FNC
00114    22*      EB       = FM*ETA(Z)+FN
00115    23*      A1       = 1./Y(1)-Y(2)
00116    24*      A5       = FM*DETA(Z)+ETA(Z)*DFM
00117    25*      A6       = 3*Y(2)**2*FNCBR
00118    26*      A7       = A6*AS5*EB
00119    27*      A3       = 4*Y(2)**3/(Y(2)**4-THETAS**4)
00120    28*      A4       = A1+A2+A3
00121    29*      A1DU     = -A1**2*(Y(3)-Y(4))
00122    30*      DNUDU   = A6*Y(4)+B*Y(2)**3
00123    31*      DEPU     = DETA(Z)*DNCU
00124    32*      DMDU     = DFMX*DLDU+DFW*DNCU
00125    33*      D2NUCU  = D2MLNC*DLOU+D2MDIC*DNCU
00126    34*      D1DU     = DETA(Z)*DNCU
00127    35*      DASDU   = FM*DEP+DETA(Z)*DMDU+ETA(Z)*D2MNCU+DFM*DEU
00128    36*      DA6DU   = 6*Y(2)*FNCBR*Y(4)+B**3*Y(2)**2
00129    37*      A7       = A6*DASDU+A5*DA6DU
00130    38*      DNDU     = DFNX*DLDU
00131    39*      DEBDU   = FM*DEU+ETA(Z)*DN3U+DN DU
00132    40*      DA2DU   = (A7-A2*DEBDU)/E3
00133    41*      DA3DU   = A3*Y(4)*(12-^3)
00134    42*      DA4DU   = DA1DU*DA2DU+DA3DU
00135    43*      DY(4)   = -C/A4+U/A4**2*DA1DU
00136    44*      DA1DU   = -A1**2*(Y(5)-Y(6))-2*A1*DADU*(Y(3)-Y(4))
00137    45*      D2NUCU  = A6*Y(6)+DAGDU*Y(4)+B*3*Y(4)*Y(2)**2
00138    46*      D2EPDU  = DETA(Z)*D2NUCU+TRCDU**2*DEDETA(Z)
00139    47*      D2MUU   = DFMX*D2LDUU+OLDU*(D2FMLL*DLDU+D2MLNC*DNCU)+DFM*D2NCU
00140    48*      1       = DNCU*D02MLNC*DLDU+D2MDIC*DNCU
00141    49*      03MNUU = D2MLNC*D2LNU+DL3DU*(D3MNL*DLDU+D3M2NL*DNCU)
00142    50*      1       = D2MDNC*D2NCU+DLCU*D3M2NU*DLDU
00143    51*      D2EUU   = DETA(Z)*D2NCU+DETA(Z)*DNCU**2
00144    52*      D2A5DU = FM*D2EPDU**2*DEPD*DNDU*DETA(Z)*D3MNUU
00145    53*      1       = 2*DEU*D2NCU+DF*Y*02EUU
00146    54*      D2A6U   = 6*Y(2)*FNCBR*Y(6)**2*B**2*Y(2)*Y(4)
00147    55*      D2DUU   = D2NUU*D2LDUU+D2NDU*DLDU**2
00148    56*      D2E6U   = D2A5DU+DASDU+JACDU+A5*D26U+DA6DU*DASDU
00149    57*      D2E5DU = FM*D2E5DU+D2E6U+D2A5DU
00150    58*      D2A2DU = DATDU-RZ*D2EBDU-D2DEBDU*DATD077EB
00151    59*      D2A3DU = A3*(3/Y(2)-A3)*Y(6)+Y(4)*(-3/Y(2)*2*Y(4)-DASDU)
00152    60*      1       = ((1/A3*D3DU)**2)
00153    61*      D2A4UU = D2A1UU+D2A3DU
00154    62*      DY(6)   = D2/A4*DT(Y)*DADU/F(A4**2*D2A4UU
00155    63*      DY(3)   = U((Y(4)-Y(3))+(Y(2)-Y(1))*C
00156    64*      DT(5)   = U*((Y(6)-Y(5))**2*(Y(4)-DASDU)
00157    65*      DY(3)   = DY(3)
00158    66*      DY(4)   = DT(Y)
00159    67*      DY(5)   = DY(5)
00160    68*      DY(6)   = DT(6)
00161    69*      RETURN
00162    70*      END

```

END-OF-COMPILEATION: NO DIAGNOSTICS.

©2 FOR 59A-07727772-19738:11 (r.0)

SUBROUTINE INTMIX ENTRY POINT 0000024

COMMON BLOCKS:

00003 BLK1 000124

EXTERNAL REFERENCES (BLOCK, NAME)

0004 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0003 R 000025 DE11L	0000 R 0000000 DE4DL	0003 R 0000021 DE9DTB	0003 R 0000001 DE4DXY	0003 R 000013 DFM
0003 000012 DFM	0003 00010 DFNX	0003 00007 DNCDT1	0003 00016 D2FMLL	0003 00015 D2MDNC
0003 000014 D2M1NC	0003 00011 D2NDLL	0003 R 000022 E3	0003 00002 F4	0003 00003 FN
0003 000005 FNC	0003 00004 FNCBR	0000 00002 INUPS	0003 000000 THETAB	0003 000001 THETAS
0003 000006 V	0003 00017 Y1	0003 00020 Y2		

00101 1* SUBROUTINE INTMIX(D2E4TY,DTBOX,QLDX,D2E4LY,D2TBXY,D2TDXY)
00103 2* COMMON /BLK1/THETAB,THETAS,FN,FNCNCB,FNCV,DNCDT1,DE4DXY,D2NDLL
00103 3* 1 D2TDXY = 0.
00104 4* DE4DL = E3*DE1DL
00105 5* DE4DXY = D2E4LY*D2LDXY
00106 6* D2TBXY = -D2E4DXY+DTBOX*D2E4TY/DE4DTB
00107 7* RETURN
00110 8* END
00111 9*
END OF COMPIRATION: NO DIAGNOSTICS.

FOR S9A=07727772-1938:IB (7U)

SUBROUTINE MIXDER ENTRY POINT 000347

STORAGE USED: CODE(1)-00045H DATA(0) 0001048 BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	BLKI	00004
0004	BLKO	000012

EXTERNAL REFERENCES (BLOCK, NAME)

0005	UDETA
0006	DETA
0007	DODETA
0010	ETA
0011	MERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0004 R 000003 A1	0004 R 000004 A2	0004 R 000005 A3	0004 R 000006 A4	0004 R 000007 A5
0004 R 000010 A6	0007 R 000000 DDETA	0005 R 000000 DDETA	0006 R 000000 DETA	0003 R 000023 DEIDL
0005 R 000021 DE4D13	0003 R 000013 DFM	0003 R 000012 DFMX	0003 R 000010 DFNX	0003 R 000007 DNCDT1
0000 R 000006 DNCDY	0000 R 000005 D2A1XY	0000 R 000020 D2A2XY	0000 R 000021 D2A3XY	0000 R 000022 D2ARYY
0000 R 000004 D2A5AY	0000 R 000004 D2A6XY	0000 R 000017 D2EBAY	0000 R 000012 D2EPXY	0000 R 000011 D2EXY
0003 R 000016 D2FMLL	0000 R 000015 D2MOLY	0003 R 000015 D2MDNC	0000 R 000014 D2MDXY	0003 R 000014 D2MNC
0003 R 000011 D2NDLL	0000 R 000016 D2NDXY	0000 R 000007 D3MNL	0000 R 000010 D3MNLX	0004 R 000001 D3M2LN
0004 R 000002 D3M2LN	0000 R 000005 D3M2NY	0004 R 000011 EB	0010 R 000000 ETA	0003 R 000022 E3
0003 R 000002 FM	0003 R 000003 FN	0003 R 000005 FNC	0003 R 000004 FNCBR	0000 R 000026 TNIPS
0003 000000 TETTAB	0003 000001 TETAS	0004 R 000000 U	0003 000006 V	0000 R 000000 Y
0003 000017 Y1	0003 R 000020 Y2	0000 R 000002 Z		

00101 1* SUBROUTINE MIXDER(D2BX,D2BY,D2CX,D2DY,
00101 2* 1 D2TBX,D2DY,D1DY,D2DX,D2DY,D3DX,D3DY,
00101 3* 2 D4DY,D5DY,D4DY,D5DY,D6DY,D6DY,
00101 4* 3 D2DXY,DEBOY,DEBOX,DEX,DEY,DEPXD,DEPY,DMDX,
00101 5* 4 DMDY,D2MNCX,D2MNCY,B,C,D3TXYE,D3FDXY),
00101 6* C
00101 7* C FOR MIXED DERIVATIVES OF U AND V SET B=1. AND C= 0.
00101 8* C FOR MIXED DERIVATIVES OF U AND FNCBR SET B=1. AND C= 1.
00101 9* C FOR MIXED DERIVATIVES OF V AND FNCBR SET B=0. AND C= 1.
00101 10* C
00103 11* DIMENSION T(2)
00104 12* COMMON /BLKI/THETAB,THETAS,FM,FN,FNCBR,FNC,V,DNCDT1,DFNX,D2NDLL,
00104 13* 1 DFMX,D2MNC,D2MNC,D2FMLL,Y1,Y2,Y3,Y4,Y5,Y6,
00104 14* 2 BLKD/U,D3M2LN,D3M2LN,A1,A2,A3,A4,A5,A6,E8
00105 15* 1(2) = Y2
00106 16* 2 = FNC

```

00107   17*      DTFDXY = U*(D2TBXY-D2TDXY)+B*(DTBDY-DTFFDY)
00110   18*      D2A1XY = 2*DA1DXDA1DY/A1-A1**2*(D2TDXY-D2TBXY)
00111   19*      D2A6XY = 6*FNCBR*D1BDX*D1B0Y*6*Y(2)*FNCBR*D2TBXY+C*6**Y(2)*DTBDX
00112   20*      D3W2NY = DLDY*D3M2NL
00113   21*      DNCDXY = 6*FNCBR*Y(2)*DT9DX*DT3DY+3*FNCBR*(Y(2)**2)*D2TBXY+
00113   22*      C*3*(Y(2)**2)*DTBDX
00114   23*      D3MNLY = DL0Y*D34PLN+ONCDY*D3M2NL
00115   24*      D3WNY = D3WILY*D1DX+D2MLNC*D2L0XY+D3H2NY*DNCDX*D2MDCN*DNCDXY
00116   25*      D2EXY = DDETA(2)*JNCJX*JNCY+JETA(2)*DNCDXY
00117   26*      D2EPXY = DDETA(2)*DNCDX*ONCDY+DDETA(2)*DNCDXY
00120   27*      D2MDLY = DLJY*02MLL+ONCDY*D2MLNC
00121   28*      D2MDXY = DL0X*D2W0LY+DFMX*D2L0XY*D2MUNCY*DNCDX*DFM*DNCDXY
00122   29*      D2A5XY = FM*D2EPXY+DEP*X*DUD+C5PY*DMDA*DETA(2)*D2M0XY+DEY*D2MNCX+
00122   30*      I = ETA(2)*D2WNY+D2X0WNCY+DFMD2EXY
00123   31*      D2NDXY = DFNX*D2L0XY+DL0Y*D2NDXY
00124   32*      D2EBXY = FM*D2EY*DMDY*DEY+DETA(2)*D2NDXY*D2NDXY
00125   33*      D2A2XY = -(DEBDY*D2DX+DEBDX*D2DY+A2*D2EBXY-(A6*D2A5XY+
00125   34*      I = DA60Y*D05DX+D450Y*D46JX+A5*D2A6XY)/7EB
00126   35*      D2A3XY = DA3DX*D3JCY/A3+D2BXY*DA3DX*DTBDX+
00126   36*      I = A3*DTB0X*(-3*D1B0Y/Y(2)**2-D3DY)
00127   37*      D2A4XY = D2A1XY*D2A2XY+D2A3XY
00130   38*      D3TXYE = U*D2A4XY*7A4**2-D4DY*(2*A4*D2TBXY+B)/7A4**2
00131   39*      RETURN
00132   40*      END

```

END OF COMPIRATION: NO DIAGNOSTICS.

QFOR IS ETA
FOR \$9A**0772772=19:38:27 (r0)

FUNCTION ETA ENTRY POINT 000036

STORAGE USED: CODE (1) 0000444 DATA(0) 0000221 BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 POLY

0004 EXP

0005 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000016 1L 0000 R 000001 A 0000 R 000010 B 0000 R 000000 ETA 0000 000014 INJPS

0003 R 000000 POLY

```
00101 1* FUNCTION ETA(X)
00103 2* DIMENSION A(7), B(2)
00104 3* DATA T1,T2,A(3),A(7),A(5),A(6),A(7770-10E+01, -0.1163143E+01,
00104 4* 1 0.1478836E+01, -0.1267550E+01, 0.632223E+00, -0.1627067E+00,
00104 5* 2 0.1654223E-01/ B1,778127/0.68866095E+00, -0.2297718E+007
00116 6* IF (X .GT. 2.5) GO TO 1
00120 7* ETA = POLY(T1,A,X)
00121 8* RETURN
00122 9* ETA = 8(1)*EXP(B(2)*X)
00123 10* RETURN
00124 11* END
```

END OF COMPIRATION: NO DIAGNOSTICS.

QFOR,IS DETA
FOR S9A=07727772-19738744 (00)

FUNCTION DETA ENTRY POINT 0000036

STORAGE USED: CODE(1) 0000441 DATA(0) 0000217 BLANK COMMENT(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	POLY
0004	EXP
0005	NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000016 IC	0000 R 000001 A	0000 R 0000007 B	0000 R 0000000 DETA	0000 000013 INJPS
0003	R 000000 POLY				

```
00101      1*      FUNCTION DETA(X)
00103      2*      DIMENSION A(6); B(2)
00104      3*      DATA A(1),A(2),A(3),A(4),A(5),A(6)/-0.1163143E+01, 0.2957672E+01,
00104      4*                  1 -0.3802650E+01, 0.2530089E+01, -0.8135335E+00, 0.9925338E-01/
00104      5*                  2 B(1),B(2)/-0.1577635E+00, -0.2297718E+00
00115      6*      IF(X.GT.2.5) GO TO 1
00117      7*      DETA = POLY(6,A,X)
00120      8*      RETURN
00121      9*      T DETA = B(1)*EXP(B(2)*X)
00122      10*     RETURN
00123      11*     END
```

END OF COMPIRATION: NO DIAGNOSTICS.

2FOR,IS DDETA
FOR S9A=077277/72-19:59:00 1701

FUNCTION DDETA ENTRY POINT 0000036

STORAGE USED: CODE(17) 00000447 DATA(07) 0000201 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, "NAME")

0003 POLY
0004 EXP
0005 NERR3\$

STORAGE ASSIGNMENT - BLOCK TYPE RELATIVE LOCATION, NAME)

0001 000016 1L 0000 R 000001 A 0000 R 000006 B 0000 R 0000000 DDETA 0000 000012 INJPYS
0003 R 000000 POLY

```
00101 1* FUNCTION DDETA(X)
00103 2* DIMENSION A(5), B(2)
00104 3* DATA A1/A(2),A(3)/A(4),A(5)/0.2957672E+01, -0.7605300E+01,
00104 4* 1 0.7590267E+01, -0.325434E+01, 0.4962669E+00, B(1),B(2)/
00104 5* 2 0.3524960E-01, -0.2297718E+00
00114 6* IF(X.GT.2.5) GO TO 1
00116 7* DDETA = POLY(S,A7X)
00117 8* RETURN
00120 9* 1 DDETA = B(1)*EXP(B(2)*X)
00121 10* RETURN
00122 11* END
```

END OF COMPILED: NO DIAGNOSTICS.

QFOR IS DODETA
FOR S9A=07727772-19:39:17 (r0)

FUNCTION DODETA ENTRY POINT 000036

STORAGE USED: CODE(11) DATA(0) 0000177, BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 POLY
0004 EXP
0005 NERR3S

STORAGE ASSIGNMENT TBLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000016 TL 0000 R 000001 R 0000 R 0000005 B 0000 R 0000000 DODETA 0000 000011 INPS
0003 R 000000 POLY

00101 1* FUNCTION DODETA(X)
00103 2* DIMENSION A(4), B(2)
00104 3* DATA A11,A12,A13,A14)/-0.7605300E+01,0.1518053E+02,
00104 4* 1-0.9762402E+01,0.1985068E+01/
00104 5* 2 B11,B12)/-0.8329136E-02,-0.2297718E+00/
00113 6* IF(X.GT.2.5) GO TO 1
00115 7* DDDETA = POLY(4,A,X)
00116 8* RETURN
00117 9* 1 DDDETA = B11*EXP(B12*X)
00120 10* RETURN
00121 11* END

END OF COMPIILATION: NO DIAGNOSTICS.

QFOR,IS POLY
FOR S9A=07727772=19:39:21 (7.0)

FUNCTION POLY ENTRY POINT 000036

STORAGE USED: CODE(1) 0000441 DATA(0) 0000131 BLANK COMMON(2) 0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000012 1076 0000 000003 INPS 0000 I 000002 K 0000 Y 000001 L 0000 R 0000000 POLY

```
00101 1* FUNCTION POLY(N,A,X)
00103 2* DIMENSION A(N)
00104 3* POLY = 0.
00105 4* L = N
00106 5* DO 1 K=1,N
00111 6* POLY = POLY*X+A(L)
00112 7* 1 L = L-1
00114 8* RETURN
00115 9* END
```

END OF COMPILED: NO DIAGNOSTICS.

02 AFOR,IS SDRV
FOR SYR=07727772=1939:24 (70)

SUBROUTINE SDRV ENTRY POINT 000601

STORAGE USED: TCODE(1)=000605, DATA(0)=000667 BLANK COMMON(2)=000000

COMMON BLOCKS:

0003	BLKI	000024
0004	BLKD	000012
0005	BLKR	000002
0006	VAB	000003

EXTERNAL REFERENCES (BLOCK, NAME)

0007	ETA	
0010	NCDERV	
0011	MJER	
0012	DETA	
0013	DERV	
0014	MIXJR	
0015	NERR35	

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 R 000003 /AA	0004	000003 A1	0004	000004 A2	0004	000005 A3	0004	000006 A4
0004 R 000007 /5	0004	000010 A6	0000 R 000005 BBR	0000 R 000037 DAJDN	0000 R 000007 DAIDU	0000 R 000041 DA3DN	0000 R 000026 DA4DV	
0000 R 000023 LA1DV	0000 R 000040 DA2DN	0000 R 000010 DA2DU	0000 R 000024 DA2DV	0000 R 000012 DA4DU	0000 R 000014 DA6DU			
0000 R 000011 LA3DQJ	0000 R 000025 DA3DV	0000 R 000042 DA4DN	0000 R 000044 DA6DN	0000 R 000015 DEBDU	0000 R 000031 DEGDU	0000 R 000006 DEPV	0012 R 000000 DETA	
0000 R 000043 LA5DN	0000 R 000013 DA5DU	0000 R 000027 DA5DV	0000 R 000046 DEPU	0000 R 000017 DEPU	0003 R 000013 DFW	0003 R 000002 DLDV		
0000 R 000030 LA6DV	0000 R 000045 DERBY	0000 R 000047 DEPN	0000 R 000018 DEQDU	0000 R 000018 DEQDU	0000 R 000001 DLDU	0003 R 000007 DNCDT1		
0000 R 000046 CEN	0000 R 000047 DEPN	0000 R 000019 DEPU	0000 R 000033 DEPV	0000 R 000019 DEQDU	0005 R 000006 DLDNCB	0000 R 000002 DLDV		
0000 R 000016 LEU	0000 R 000032 DEV	0003 R 000023 DE1DL	0003 R 000021 DE4DTB	0003 R 000021 DE4DTB	0005 R 000001 DNDN	0003 R 000007 DNCDT1		
0003 R 000012 LFMX	0003 R 000010 DFNX	0005 R 000006 DMDU	0000 R 000034 DMDV	0000 R 000002 DNDU	0000 R 000002 D2CDT2	0000 R 000002 D2CTNB		
0000 R 000050 CNDN	0000 R 000020 DMDV	0000 R 000022 DNCDV	0005 R 000005 D2LDUV	0005 R 000007 D2LNUB	0000 R 000051 D2MNCN	0000 R 000021 D2MNCU		
0005 R 000003 L2LDDU	0005 R 000004 D2LDDU	0003 R 000015 D2M0NC	0003 R 000014 D2MLNC	0004 R 000001 D3M2LN	0004 R 000011 E8			
0005 R 000011 L2LVNB	0003 R 000015 D2M0NC	0003 R 000011 D2NDLL	0003 R 000011 D2NDLL	0003 R 000002 FM	0003 R 000003 FN			
0000 R 000035 L2MNCV	0003 R 000002 ET	0007 R 000000 ETA	0003 R 000022 E3	0005 R 000006 INJP3	0005 R 000000 RLAM	0003 R 000000 THETAB		
0006 R 000002 ET	0003 R 000004 FNCBR	0000 R 000004 FNCBR	0000 R 000005 INJP3	0005 R 000000 RLAM	0003 R 000006 V	0003 R 000017 Y1		
0003 R 000005 FNC	0003 R 000001 THETAS	0006 R 000000 Z1	0004 R 000000 U	0006 R 000001 Z1	0006 R 000001 Z2			

00101 1* SUBROUTINE SDRV(Y,DY,X)

00103 2* DIMENSTON Y(120),DT207

00104 3* COMMON /BLK1/THETAB,THETAS,FM,FN,FNCBR,FNC,V,DNCOT1,DFNX,02NDLL,

00104 4* 1 DFNX,DFM,D2MLNC,D2M0NC,D2NDLL,Y1,Y2,DE4DTB,E3,DE1DL

00104 5* 2 BLKO/U,D3M2LN,D3M2LN,A1,A2,A3,A4/A5,A6,E8

ESBLL

END OF COMPILED WORKS

137

3FOR 15 SCNTL
FOR S9A=07727772=19:40:52 1107

SUBROUTINE SCNTL ENTRY POINT 000147

STORAGE USED: CODE(17) 00001741 DATA(1) 0000147 BLANK COMMON(2) 000000

COMMON BLOCKS:

00003	NCT	000009
00004	VAB	000003
00005	BLKI	000024

EXTERNAL REFERENCES (BLOCK, NAME)

00006	NWDUS
00007	NIC2S
00010	NEAR3S

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

00000	000002	2000	0001	000054	5L	0001	000061	50L	0003 R 00000000	DLMT	
00000	R	00000000	DXSTR	0003	R	00000003	DXWRT	0004	R	00000002	ET
00000	I	000001	LCNT	0003	I	000004	LSTEP	0005	R	00000000	VAL
00001	R	000001	Z2								Z1

```
00101   1*          SUBROUTINE SCNTL(Y,DY,DX,X,NTRY,ITV0)
00103   2*          DIMENSION Y(20),DY(20)
00104   3*          COMMON/YC17/DLWT,ICNT,XWRT,DX,WRT,LSTEP
00104   4*          1          /VAB/ 21,22,ET
00104   5*          2          /BLKI/VAL(20)
00105   6*          ICNT = ICNT+1
00105   7*          IF(DX.GE.DXWRT.AND.ICNT.GT.1) LSTEP = 1
00110   8*          IF(ABS(X-XWRT).LT.DLWT) GO TO 50
00112   9*          ITWXWRIT.GT.X) GO TO 5
00112  10*          C
00114  11*          DXSTR = DX
00115  12*          DX = DX+XWRT-X
00116  13*          LCNT = 1
00117  14*          NTRY = 3
00120  15*          RETURN
00120  16*          C
00121  17*          5 NTRY = 1
00122  18*          RETURN
00122  19*          C
00123  20*          50 WRITE(6,20001) Y(1)*Y(2),Z1,Z2,ET,VAL(3),VAL(4),X
00135  21*          2000 FORMAT(1BF15.7)
00136  22*          1FLCNT.EQ.1) DX = DXSTR
00140  23*          LCNT = 0
00141  24*          IF(ABS(1.0-XWRT).LE.DLWT) GO TO 60
```

00143	25*	XWRT	= XWRT+DXWRT
00144	26*	NRY	= 1
00145	27*	IF(LSTEP.EQ.0) RETURN	
00147	28*	DX	= DXWRT
00150	29*	IFVD	= 1
00151	30*	RETURN	
00151	31*	C	
00152	32*	60 NRY	= 2
00153	33*	RETURN	
00154	34*	END	

END OF COMPILED: NO DIAGNOSTICS.

2000.1 IS RKS
FOR 59A=07/27/72=19:41:32 (7.0)

SUBROUTINE RKS ENTRY POINT 000643

STORAGE USED: CODE (1) DATA(0) DATA(1) DATA(2) BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK > NAME)

0003	NERR2\$
0004	NEXP5\$
0005	NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	00010 10C	0001	000313 110L	0001	000333 120L	0001	000045 1266	0001	000343 130L
0001	000071 140\$	0001	000355 140L	0001	000105 1466	0001	000130 1566	0001	000417 160L
0001	000150 164\$	0001	000177 1746	0001	000505 1851	0001	000510 1901	0001	000413 201
0001	000232 205\$	0001	000270 2176	0001	000524 220L	0001	000530 230L	0001	000543 240L
0001	000374 243\$	0001	000332 251L	0001	000552 250L	0001	000554 251L	0001	000572 257L
0001	000604 259L	0001	000623 270L	0001	000456 300L	0001	000615 3366	0001	000054 40L
0001	000060 45L	0001	000006 5L	0001	000076 50L	0001	000123 70L	0001	000135 80L
0000	R 00014 AM	0000	R 00007 AMAX	0000	R 000011 C	0000	R 000010 D	0000	R 000001 DOT
0000	R 00003 DEL	0000	R 000012 E	0000	R 000000 FR10	0000	I 000004 I	0000	I 000005 IFLAG
0000	00030 INJS	0000	I 00002 ISYMP	0000	I 000013 J	0000	R 000006 S		

00101 1* SUBROUTINE RKS(DERIV,CNTRL,T,DYTA,R,T,DELT,N,IFVD,IBKP,NTRY)

00101 2* 1IERR,DELY,PD,SD,YST,DYST,YSIMP)

00103 3* DIMENSION Y(N),DY(N),ATN,RTN,DELY(N),

1PD(N),SD(N),DIST(N),YST(N),YSIMP(N)

00104 4* EXTERNAL DERIV, CNTRL

00104 5* FR10 IS FIFTH ROOT OF TEN

00105 6* C FR10=1.5848932

00105 7* IERR=0

00106 8* DS000000

00106 9* C DS00090

00106 10* C DS001000

00106 11* C H6001100

00106 12* C VARD600120

00106 13* C DS001300

00106 14* C IF FIXED STEP SIZE GO ONE INTERVAL OF LENGTH DELT AND RETURN TO CNTRL

00106 15* C IF VAR GO TWO INTERVALS BEFORE RETURN TO CNTRL

00106 16* C DS00150

00106 17* C DS001600

00106 18* C DS00170

00106 19* C DS001800

00106 20* C DS00190

00106 21* C DS00200

00106 22* C DS00220

00106 23* C DS002300

00106 24* C DS00240

25621

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00106 25* C IERR = 0 NORMAL
00106 26* C =1 DELT=0. RETURN FROM RKS
00106 27* C 1 A(I)+R(I)*ABS(Y(I)) = 0. RETURN FROM RKS
00107 28* S IF(DEL<20,T0,20)
00112 29* 10 IERR=-1
00113 30* GO TO 270
00114 31* 20 CALL DERIV(Y,DY,T)
00115 32* NTRY=1
00116 33* CALL CNTRL(Y,DY,DELT,NTRY,IFVUD)
00117 34* 25 DDTDELT
00120 35* IF(IFVUD) 40,30,40
00123 36* 30 ISYMP=2
00124 37* DELT=DELT/2.
00125 38* DO 31 I=1,N
00130 39* 31 SD(I)=0.0
00132 40* 42 FLAG=1
00133 41* S=1.
00134 42* 60 TO 45
00135 43* 40 ISYMP=1
00136 44* DELT=DELT
00137 45* 45 DO 46 I=1,N
00142 46* Y(I)=EY(I)
00143 47* 46 DST(I)=DY(I)
00145 48* 50 DO 60 I=1,N
00150 49* 50 DELY(I)=DELT*D(Y(I))
00151 50* PD(I)=DEL(Y(I))
00152 51* 60 CONTINUE
00154 52* 60 TO (80,70)ISYMP
00155 53* 70 DO 71 I=1,N
00160 54* 71 SD(I)=SD(I)+S*D(Y(I))
00162 55* 80 I=I+DELT/2.
00163 56* 80 DO 85 I=1,N
00166 57* Y(I)=Y(I)
00167 58* Y(I)=YS(I)+DELY(I)/2.
00170 59* 85 CONTINUE
00172 60* 86 CALL DERIV(Y,DY,T)
00173 61* 87 DO 90 I=1,N
00176 62* 87 DELY(I)=DELT*D(Y(I))
00177 63* PD(I)=PD(I)+2.*DELY(I)
00200 64* Y(I)=YS(I)+DELY(I)/2.
00201 65* 90 CONTINUE
00212 66* 91 CALL DERIV(Y,DY,T)
00214 67* 92 DO 95 I=1,N
00204 68* 92 DELY(I)=DELT*D(Y(I))
00216 69* PD(I)=PD(I)+2.*DELY(I)
00221 70* Y(I)=YS(I)+DELY(I)
00212 71* 95 CONTINUE
00223 72* 96 T=T+DELT/2.
00215 73* 97 CALL DERIV(Y,DY,T)
00207 74* 98 DO 100 I=1,N
00210 69* 98 DELY(I)=DELT*D(Y(I))
00222 70* PD(I)=PD(I)+DELY(I)
00223 71* 99 Y(I)=YS(I)+PO(I)/6.
00224 78* 100 YOU CONTINUE
00226 79* 60 TO (110,120),ISYMP
00227 80* 110 NTRY=1
00230 81* CALL DERIV(Y,DY,T)

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```

00231    82*   CALL CNTRL(Y,DY,DEL,T,NTRY,IFND)      D600820
          00232    83*   GO TO 300                         D6008300
02  00233    84*   120 60 TO (130,140),IFLAG      D6008400
          00234    85*   130  SEq.                         D6008500
          00235    86*   IFLAG=2
          00236    87*   CALL DERIVY,DY,T)      D6008600
          00237    88*   GO TO 50                         D6008700
          00240    89*   140 CALL DERIVY,DY,T)
          00241    90*   AMAX =0.0                         D6008800
          00242    91*   DO 180,177N
          00245    92*   SD(I)=SD(I)+DY(I)                  D6008900
          00246    93*   YSIMPLY=YST(TT)*DEL*T(I)*T5.      D6009000
          00247    94*   D - EAS(Y(I))-YS4P(I)
          00250    95*   C - EA(I)*R(I)*ABS(Y(I))
          00251    96*   IF(C > 160,150,160
          00254    97*   150 TERRI
          00255    98*   GO TO 270                         D6009100
          00256    99*   160 E =AUSD /C
          00257   100*   MAXEAMAX(AMAX,E)
          00260   101*   180 CONTINUE
          00262   102*   IF(AMAX>1.) 215:215:230
          00265   103*   215 NTRY=1
          00266   104*   CALL CNTRL(Y,DY,DEL,T,NTRY,IFND)  D6009200
          00267   105*   301 IF(NTRY=1) 185:185:310
          00272   106*   310 IF(NTRY=2) 270:270:330
          00275   107*   330 IF(NTRY=3) 340:340:5
          00282   108*   340 T=T-DDT
          00301   109*   IF(DEL) 259:10:259
          00304   110*   180 GO TO (40,190),ISYMP
          00305   111*   190 IF(TAMAX>75) 200:25:220
          00310   112*   200 IF(AMAX>0.75) 210:25,25
          00313   113*   210 DEL=DEL+FR10
          00314   114*   20 TO 25
          00315   115*   220 DEL=DEL-FR10
          00316   116*   20 TO 25
          00317   117*   230 T =1+ ISKP
          00320   118*   60 TO (240,250),1
          00321   119*   240 T=T-DEL
          00322   120*   DEL=DEL-FR10
          00323   121*   GO TO 259
          00324   122*   250 J=1
          00325   123*   25 AWEAMAX(10,**J)
          00326   124*   IF((1.-AM) 255,257,257
          00331   125*   250 J=J+1
          00332   126*   60 TO 251
          00333   127*   257 T=T-DEL
          00334   128*   DEL=DEL/(FR10**J)
          00335   129*   259 DO 245,251,N
          00340   130*   DY(I)=DST(I)
          00341   131*   245 Y(I)=YST(I)
          00343   132*   60 TO 25
          00344   133*   270 RETURN
          00345   134*   END

```

END OF COMPILATION: NO DIAGNOSTICS.

6.2
OFOR,IS FMINV
FOR S9A=07727772-19:47:58 (70)

SUBROUTINE FMINV ENTRY POINT 000254

STORAGE USED: CODE(17)=0003061 DATA(0)=0012601 BLANK COMMON(2)=0000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR35

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

00101	1*	000046 105,	0001 000151 111L	0001 000051 111G	0001 000071 117G	0001 000014 123G
00103	2*	DIMENSION A(N,N),X(N),XMAT(25,26)				
00104	3*	DO 1 I=1,N				
00107	4*	XMAT(I,4) = X(I)				
00110	5*	DO 1 J=1,N				
00113	6*	1 XMAT(I,J) = A(I,J)				
00116	7*	DO 20 I=1,N				
00121	8*	AA = XMAT(I,I)				
00122	9*	DO 5 J=1,M				
00125	10*	5 XMAT(I,J) = XMAT(I,J)/AA				
00127	11*	IF (I.EQ.1) GO TO 11				
00131	12*	I1 = I-1				
00132	13*	DO 10 K=I,II				
00135	14*	B = XMAT(K,I)				
00136	15*	DO 10 J=1,M				
00141	16*	10 XMAT(K,J) = XMAT(I,J) * B				
00144	17*	IF (I.EQ.N) GO TO 20				
00146	18*	I1 I2 = I+1				
00147	19*	DO 15 K=I2,N				
00152	20*	B = XMAT(K,I)				
00153	21*	DO 15 J=1,M				
00156	22*	15 XMAT(K,J) = XMAT(K,J) - XMAT(I,J) * B				
00161	23*	20 CONTINUE				
00163	24*	DO 25 I=1,N				
00166	25*	25 XIIJ = XMAT(I,M)				
00170	26*	RETURN				
00171	27*	END				

~

1 SUBROUTINE FMINV(A,X,N,M)
2
3 DO 1 I=1,N
4 XMAT(I,4) = X(I)
5
6 DO 1 J=1,N
7 1 XMAT(I,J) = A(I,J)
8
9 DO 20 I=1,N
10 AA = XMAT(I,I)
11 DO 5 J=1,M
12 5 XMAT(I,J) = XMAT(I,J)/AA
13 IF (I.EQ.1) GO TO 11
14 I1 = I-1
15 DO 10 K=I,II
16 B = XMAT(K,I)
17 DO 10 J=1,M
18 10 XMAT(K,J) = XMAT(I,J) * B
19 IF (I.EQ.N) GO TO 20
20 CONTINUE
21 DO 15 K=I2,N
22 B = XMAT(K,I)
23 DO 15 J=1,M
24 15 XMAT(K,J) = XMAT(K,J) - XMAT(I,J) * B
25 XIIJ = XMAT(I,M)
26 RETURN
27 END

END OF COMPIRATION: NO DIAGNOSTICS.

GFOR,IS NCDERV
FOR S9A-07/27/72-19:42:07 (7.0)

S2 SUBROUTINE NCDERV ENTRY POINT 000031

STORAGE USED: COJET1-0000447 DATATT0 0000137 BLANK COMMON(27) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 000004 T JPS 0000 R 000000 T2 0000 R 000001 T3

001D1	1*	SUBROUTINE NCDERV(FNCBR,THETAB,FNC,DNCDT1,D2CDT1,D2CTNB)	
001D1	2*	C	
001D1	3*	C	NC AND ITS DERIVATIVES
001D1	4*	C	
001D3	5*	T2	= THETAB**2
001D4	6*	T3	= T2*THETAB
001C3	7*	FNC	= FNCBR*T3
001D6	8*	DNCDT1	= 3.*FNCBR*T2
001D7	9*	D2CDT1	= 6.*FNCBR*THETAB
001D10	10*	D2CTNB	= 3.*T2
00111	11*	RETURN	
00112	12*	END	

END OF COMPILED: NO DIAGNOSTICS.

QXOT
MAP 0023-07727-19:42

177961

ADDRESS LIMITS 001000 021317 040000 047773

STARTING ADDRESS 020263

WORDS DECIMAL 8400 TBANK 4092 DBANK

SEGMENT MAIN	001000 021317	040000 047773
NSWCS\$/FOR	1 001000 001021	
NZBLKS\$/FOR	1 001022 001041	
NRVDS\$/FOR	1 001045 001124	2 040000 040011
NWES\$/FOR	1 001125 001326	2 040012 040031
NFTCH\$/FOR	1 001327 001617	2 040032 040067
NBJCWE\$/FOR	1 001620 001752	2 040070 040125
NFTVS\$/FOR	1 001753 001775	
NCLOSS\$/FOR	1 001776 002144	2 040126 040157
NWBLS\$/FOR	1 002145 002266	
NB3S3L\$/FOR	1 002267 002323	
NUPDAY\$/FOR	1 002324 002356	
NBTU\$7\$/FOR	1 002357 002603	2 040160 042361
NCVTS\$/FOR	1 002604 003014	2 042362 042451
NIIN\$/FOR	1 003015 003330	2 042452 042463
NOTIN\$/FOR	1 003331 004317	2 042464 042467
NOOUT\$/FOR	1 004320 005176	2 042470 042514
NFVTS\$/FOR	1 005177 005351	2 042515 042571
NTOERS\$/FOR	1 005352 006233	2 042572 042676
NFCHS\$/FOR	1 006233 007747	2 042677 043035
NT43\$5\$/FOR	1 006234 007747	2 043036 043107
ERUSUM\$/FOR	1 006234 007747	2 043110 043146
NLINS\$/FOR	1 007750 010934	2 043147 043330
TTT\$TECH	1 007750 010934	0 043331 043361
NEXP6\$5\$/FOR	1 010435 010631	2 043362 043641
ASINCO\$3\$/FOR	1 010632 011046	0 043364 043713
SQRT\$/FOR	1 011047 011107	2 043714 043741
EXP\$/FOR	1 011110 011177	2 043742 043753
INTER\$/FOR	1 011200 011261	2 043754 043774
NO3JFS\$/FOR	1 011262 011326	
NEXP5\$5\$/FOR	1 011327 011414	2 044131 044140
NERRS\$/FOR	1 011415 011741	2 044141 044304
BLKR TCOMMON BLOCK		044305 044316
BLKD (COMMON BLOCK)		044317 044330
BLKT TCOMMON BLOCK		044331 044354
VAB (COMMON BLOCK)		044355 044357
MCT TCOMMON BLOCK		044360 044364
BLANKS COMMON (COMMON BLOCK)		

NCDEV	1	011742 012005	0	044365 044377
❷2 FM1AV	1	012006 012313	2	BLANK\$COMMON 044400 045657
RKS	1	012314 013353	0	BLANK\$COMMON 045660 045743
SCNTL	1	013354 013547	2	BLANK\$COMMON 045744 045757
SURV	5	BLKI	2	BLANK\$COMMON
POLY	1	013550 014354	4	VAB
DODETA	3	BLKI	0	045760 046005
DDETA	5	BLKR	2	BLANK\$COMMON
DETA	1	014355 014420	6	VAB
DETA	1	014421 014464	0	046046 046062
DDETA	1	014465 014530	0	BLANK\$COMMON 046102 046121
DETA	1	014531 014574	2	BLANK\$COMMON 046122 046142
EIA	1	014575 014640	0	BLANK\$COMMON 046143 046164
MIXGER	1	014641 015314	2	BLANK\$COMMON 046165 046270
INTWIX	3	BLKI	2	BLANK\$COMMON
DERV	1	015315 015346	4	BLKD
INTIAL	3	BLKI	0	046271 046277
MDER	1	015347 016267	2	BLANK\$COMMON 046300 046427
NDERV	3	BLKI	2	BLANK\$COMMON BLKD
BNDND	1	016270 017011	0	046430 046552
CONST	1	017012 017315	2	BLANK\$COMMON 046553 046640
MAIN	1	017316 017405	2	BLANK\$COMMON 046641 046655
	3	BLKI	2	BLANK\$COMMON 046656 046704
	5	WC†	0	BLANK\$COMMON 046705 046775
			2	BLANK\$COMMON
			4	BLKD
			6	BLKR

STSPRIBS, LEVEL 63
END OF COLLECTION - TIME 1.955 SECONDS