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APPENDIX A

DEFINED PARAMETERS AND PROPERTIES OF STIFFENERS

1. New Parameters.

New parameters for extensional, flexural, twisting and torsional stiffnesses of skin, stringer, and ring of the stiffened cylindrical shell are as follows:

$$E_{xxp} = E_{yyp} = \frac{Eh}{1-\nu^2}$$

$$E_{xxst} = \frac{E_x A_x}{l_x}, \qquad E_{yyr} = \frac{E_y A_y}{l_y}$$

$$G_{xy} = \frac{Eh}{2(1+\nu)}$$

$$E_{xx} = E_{xxp} + E_{xxst}, E_{yy} = E_{yyp} + E_{yyr}$$

$$D_{xxp} = D_{yyp} = D = \frac{Eh^3}{12(1-\nu^2)}$$

$$D_{xxst} = \frac{E_x I_{xc}}{l_x}, \qquad D_{yyr} = \frac{E_y I_{yc}}{l_y}$$

$$D_{xy} = (1-\nu)D_{xxp}$$

$$D_{xx} = D_{xxp}+D_{xxst}, D_{yy} = D_{yyp}+D_{yyr}$$

2. Nondimensional Parameters.

Nondimensional groups of parameters to be used in Phase 1 and Phase 2 are as follows :

$$\bar{\lambda}_{xx} = \frac{E_{xxst}}{E_{xxp}} = \frac{E_x A_x(1-\nu^2)}{Ehl_x}, \bar{\lambda}_{yy} = \frac{E_{yyr}}{E_{yyp}} = \frac{E_y A_y(1-\nu^2)}{Ehl_y}$$

$$\bar{\rho}_{xx} = \frac{D_{xxst}}{D} = \frac{E_x I_{xc}}{Dl_x}\,, \quad \bar{\rho}_{yy} = \frac{D_{yyr}}{D} = \frac{E_x I_{xc}}{Dl_y}$$

$$\bar{e}_x = \frac{\pi^2 Re_x}{L^2}\,, \qquad \bar{e}_y = \frac{\pi^2 Re_y}{L^2}$$

$$Z = \frac{L^2(1-\nu^2)^{1/2}}{Rh}$$

$$\bar{K}_{xx} = \frac{\bar{N}L^2}{\pi^2 D}\,, \quad \bar{K}_{yy} = \frac{qRL^2}{\pi^2 D}\,, \quad \bar{K}_s = \frac{N^o_{xy} L^2}{\pi^2 D}$$

3. Properties of Stiffener Cross-Sections.

3.1 Rectangular stiffener. The radius of gyration of a rectangular cross-section is

$$\alpha = \frac{d}{\sqrt{12}}$$

Through nondimensionalization with respect to the radius of gyration of the skin per unit width, one obtains

$$\bar{\alpha} = \frac{d}{h}$$

The nondimensionalized stiffener flexural stiffness and eccentricity parameters are

$$\bar{\rho} = \frac{E_{st} I_{st_c}}{lD}\,, \quad \bar{e} = \frac{\pi^2 Re}{L^2}$$

where $D = \dfrac{Eh^3}{12(1-\nu^2)}$, and $I_{st_c} = \dfrac{td^3}{12} = \dfrac{Ad^2}{12}$

These two quantities can be expressed as

$$\bar{\rho} = \bar{\alpha}^2 \bar{\lambda} \qquad \text{(A1)}$$

$$\bar{e} = \frac{\pi^2(1-\nu^2)^{1/2}}{2Z}(1+\bar{\alpha})$$

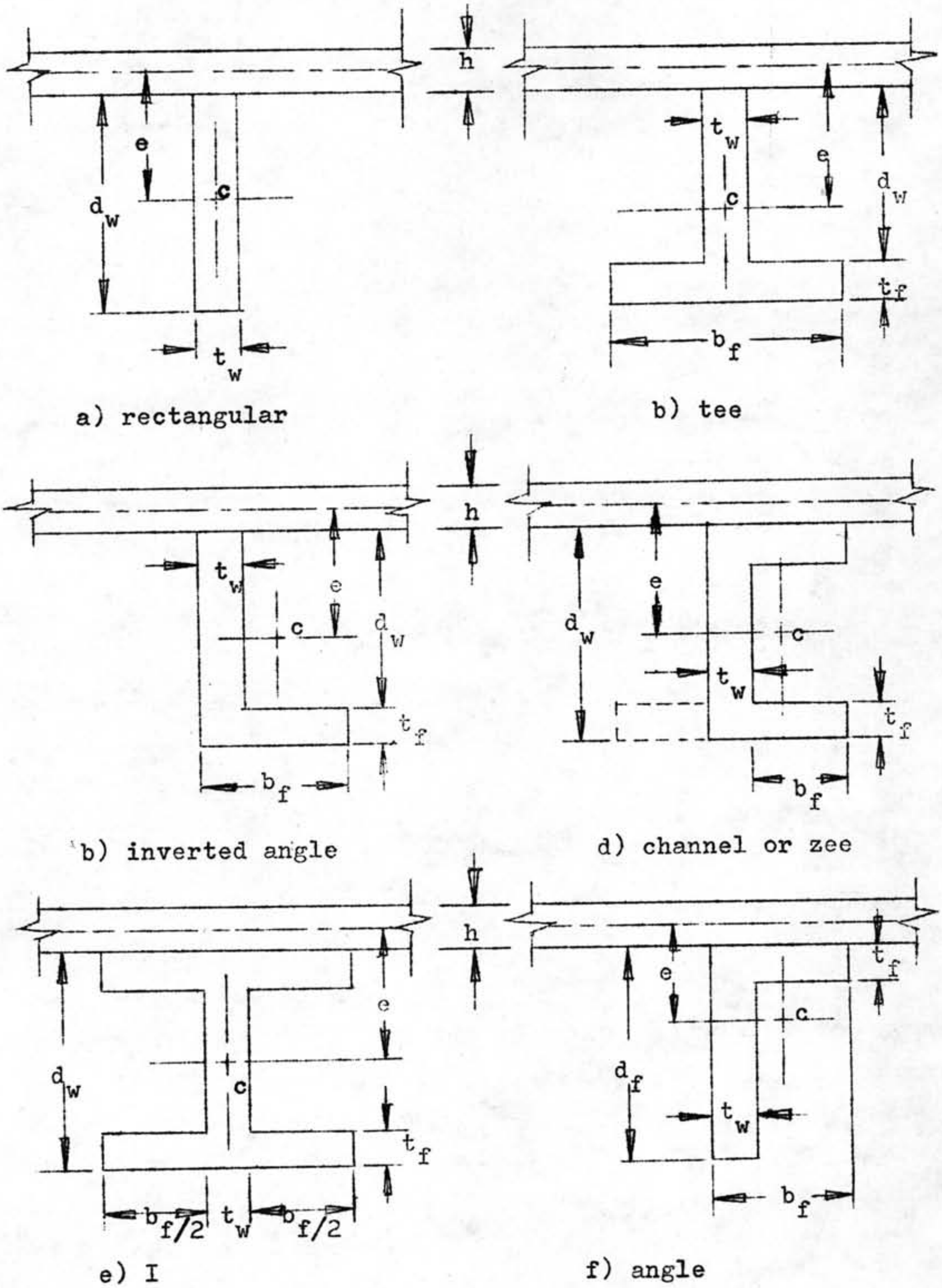
3.2 Other types of stiffeners. With the assumption that t_w, $t_f \ll d_w$, $\bar{\rho}$ and $\bar{e}$ of the tee, angle, channel, zee, I, and inverted angle cross-sections can be expressed as

$$\begin{aligned} \bar{\rho}_{xx} &= \bar{\alpha}_x^{\,2}\,\bar{\lambda}_{xx} \\ \bar{\rho}_{yy} &= \bar{\alpha}_y^{\,2}\,\bar{\lambda}_{yy} \\ \bar{e}_x &= \frac{\pi^2(1-\nu^2)^{1/2}}{2Z}(1+C_x\bar{\alpha}_x) \\ \bar{e}_y &= \frac{\pi^2(1-\nu^2)^{1/2}}{2Z}(1+C_y\bar{\alpha}_y) \end{aligned} \qquad \text{(A2)}$$

The expressions for $\bar{\alpha}$ and C, for each type of stiffener cross-section, are given in Table A1

Table A1. Properties of Stiffener Cross-Sections.

Section	Area, A	$\bar{\alpha}$	C
Rectangular	td	$\frac{d}{h}$	1.0
Tee or Inverted Angle	$d_w t_w(1+c_f k)$	$(\frac{d_w}{h})\frac{(1+4c_f k)^{1/2}}{1+c_f k}$	$\frac{1+2c_f k}{(1+4c_f k)^{1/2}}$
Channel, I, or or Z	$d_w t_w(1+2c_f k)$	$(\frac{d_w}{h})(\frac{1+6c_f k}{1+2c_f k})^{1/2}$	$(\frac{1+2c_f k}{1+6c_f k})^{1/2}$
Angle	$d_w t_w(1+c_f k)$	$(\frac{d_w}{h})\frac{(1+4c_f k)^{1/2}}{1+c_f k}$	$\frac{1}{(1+4c_f k)^{1/2}}$



$$b_f = kd_w \quad ; \qquad t_f = c_f t_w$$

Fig. A1 Geometry of Stiffener Cross-Section.

APPENDIX B

EXAMPLE OF DESIGN TABLE.

Table B1. Design Table for TSRR. c_{fx}= 1., c_{fy}= 0.

ν	C_x	C_y	k_s	k_r	$\bar{N}^*$	Z
.33	1.097	1.0	0.35	0.0	1.6389×10^{-8}	39000
$\bar{\alpha}_x$	$\bar{\alpha}_y$	$\bar{W}$	$\bar{\lambda}_{xx}$	$\bar{\lambda}_{yy}$	m	β
20.0	60.0	4.76431	1.40358	1.9508	15	8.005
20.0	70.0	4.16409	1.31625	1.50327	15	7.862
20.0	80.0	3.61362	1.63669	0.69231	14	7.902
20.0	90.0	3.32791	1.44953	0.62487	15	7.862
23.0	145.0	2.21722	0.73076	0.35391	17	6.939
23.0	150.0	2.20375	0.70901	0.36365	17	6.777
23.0	155.0	2.15442	0.72046	0.30824	17	6.777
23.0	160.0	2.17441	0.67414	0.37237	17	6.516
23.0	162.0	2.15479	0.67769	0.35134	17	6.516
24.0	140.0	2.12869	0.69355	0.31223	16	7.023
24.0	145.0	2.09040	0.70319	0.26847	16	7.175
24.0	150.0	2.05978	0.74202	0.20235	16	7.421
24.0	155.0	2.07573	0.64172	0.31686	17	6.777
25.0	70.0	3.00701	0.89952	0.88893	14	8.035
25.0	80.0	2.74696	0.81658	0.74014	14	7.902
25.0	87.0	2.53115	0.92017	0.44423	14	8.035
25.0	89.0	2.50098	0.94759	0.38993	14	8.250
25.0	90.0	2.48693	0.94906	0.37594	14	8.250
25.0	91.0	2.46914	0.89288	0.41627	14	8.035
25.0	93.0	2.43929	0.86890	0.41364	14	8.035
25.0	95.0	2.41339	0.89862	0.36086	14	8.035
25.0	100.0	2.34538	0.80111	0.39776	15	7.862
25.0	120.0	2.15414	0.72013	0.30833	15	7.489

$\bar{\alpha}_x$	$\bar{\alpha}_y$	$\bar{W}$	$\bar{\lambda}_{xx}$	$\bar{\lambda}_{yy}$	m	β
25.0	125.0	2.11621	0.70532	0.28934	15	7.489
25.0	127.0	2.11236	0.67726	0.31396	16	7.421
25.0	130.0	2.09212	0.67103	0.30216	16	7.421
25.0	132.0	2.08769	0.65534	0.31390	16	7.268
25.0	134.0	2.11675	0.61089	0.38425	16	7.023
25.0	136.0	2.05831	0.65409	0.28897	16	7.268
25.0	138.0	2.06663	0.62365	0.32682	16	7.023
25.0	140.0	2.06174	0.61325	0.33287	16	7.023
25.0	145.0	2.01855	0.62067	0.28696	16	7.023
25.0	150.0	1.98851	0.61889	0.26197	16	7.023
25.0	155.0	2.03231	0.56427	0.35562	17	6.616
25.0	160.0	1.95972	0.58867	0.26654	17	6.777
26.0	86.0	2.50612	0.71985	0.62225	15	7.862
26.0	88.0	2.42301	0.77343	0.49461	14	7.902
26.0	90.0	2.42099	0.71806	0.54819	15	7.862
26.0	92.0	2.34813	0.80362	0.39770	14	8.035
26.0	94.0	2.32113	0.79496	0.38229	14	8.035
26.0	100.0	2.24801	0.74502	0.36708	14	7.902
26.0	110.0	2.15957	0.67487	0.35843	15	7.632
26.0	120.0	2.08286	0.63124	0.33369	15	7.489
27.0	84.0	2.37070	0.78697	0.43446	13	8.184
27.0	86.0	2.34899	0.73785	0.46424	14	8.035
27.0	88.0	2.32503	0.71804	0.46270	14	8.035
27.0	90.0	2.27868	0.75382	0.38562	14	8.250
27.0	92.0	2.25099	0.76607	0.34869	14	8.250
27.0	100.0	2.16023	0.72519	0.30869	14	8.035
27.0	110.0	2.06773	0.64457	0.30689	15	7.862
27.0	120.0	1.99452	0.61373	0.27249	15	7.632
27.0	140.0	1.91243	0.52638	0.28669	16	7.175
27.0	145.0	1.86483	0.54608	0.22457	16	7.268
27.0	150.0	1.84464	0.53857	0.21408	16	7.268
28.0	82.0	2.31969	0.71892	0.45706	13	8.184

α_x	α_y	$\bar{W}$	$\bar{\lambda}_{xx}$	$\bar{\lambda}_{yy}$	m	β
28.0	84.0	2.28442	0.71541	0.42914	13	8.184
28.0	86.0	2.27257	0.66560	0.46839	14	8.035
28.0	88.0	2.23026	0.67655	0.41973	14	8.250
28.0	90.0	2.21417	0.65212	0.42982	14	8.035
28.0	100.0	2.08339	0.65647	0.30895	14	8.035
28.0	110.0	1.99479	0.62664	0.25982	14	8.035
28.0	120.0	1.92335	0.60124	0.22155	14	7.902
29.0	80.0	2.26707	0.70465	0.42444	13	8.307
29.0	82.0	2.23641	0.68280	0.41897	13	8.307
29.0	84.0	2.20923	0.65331	0.42424	13	8.184
29.0	86.0	2.18160	0.63440	0.41852	14	8.250
29.0	88.0	2.19121	0.58504	0.47645	14	8.035
29.0	90.0	2.14267	0.60062	0.41762	14	8.035
29.0	92.0	2.10968	0.60502	0.38378	14	8.035
29.0	94.0	2.07540	0.65711	0.30118	13	8.184
29.0	95.0	2.06586	0.66075	0.28904	13	8.184
30.0	70.0	2.41711	0.65364	0.60915	13	8.307
30.0	78.0	2.21937	0.68402	0.40256	13	8.507
30.0	80.0	2.18649	0.68929	0.36799	13	8.507
30.0	82.0	2.16169	0.64488	0.39031	13	8.037
30.0	84.0	2.13431	0.62938	0.38140	13	8.037
30.0	86.0	2.15094	0.55112	0.47448	14	8.035
30.0	88.0	2.08503	0.68003	0.28684	13	8.507
30.0	90.0	2.05812	0.65323	0.28966	13	8.507
30.0	100.0	1.95610	0.60330	0.24869	13	8.307
30.0	110.0	1.90534	0.48150	0.32525	15	7.862
30.0	120.0	1.85033	0.45242	0.30532	15	7.489
33.0	95.0	1.88365	0.59822	0.18920	12	8.634
33.0	97.0	1.90094	0.64012	0.16271	11	8.716
33.0	100.0	1.80772	0.50240	0.21736	13	8.507

APPENDIX C

DESIGN EXAMPLE

The following design example illustrate the design result to determine minimum weight of the stiffened cylindrical shell under uniform axial compression of 1100 lb/in. The given quantities are:

$$R = 95.5 \text{ in.}, \quad L = 291 \text{ in.},$$

$$E = E_x = E_y = 10.5\text{x}10^6 \text{ psi.},$$

$$\rho_{sk} = \rho_x = \rho_y = .101 \text{ lbs/in}^3.,$$

$$\nu = .33 \ , \sigma_o = 50{,}000 \text{ psi.},$$

$$\bar{N} = 1100 \text{ lbs/in.},$$

$$\bar{N}^* = \frac{12R^3\bar{N}}{\pi^2 EL^4(1-\nu^2)^{1/2}} = 1.6389\text{x}10^{-8}$$

The stiffeners are tee stringers and rectangular rings (TSRR).

$$c_{fy} = 0 \ , \quad k_r = 0 \ , \quad C_x = 1.097 \ ,$$

$$c_{fx} = 1 \ , \quad k_s = .35 \ , \quad C_y = 1 \ ,$$

MG (minimum gage) = 0.02 in.

All design steps are listed in Chapter III.

$$Z = 39000$$

$$h = \frac{L^2(1-\nu^2)^{1/2}}{RZ} = 0.02146$$

$$\bar{\alpha}_x = 24.0 \ , \quad \bar{\alpha}_y = 145.0$$

For Table B1, one has

$$\bar{\lambda}_{xx} = 0.70\ \ 9 \ , \quad \bar{\lambda}_{yy} = 0.26847 \ ,$$

$$\bar{W} = 2.0904 \ , \quad m = 16 \ , \quad \beta = 7.175$$

Calculate the stresses in the skin, stringers, and rings by using equations (8)

$$\sigma_{xxsk} = -28969.50 \text{ psi.}, \qquad \sigma_{yysk} = -2213.37 \text{ psi.},$$
$$\sigma_{xxst} = -28239.09 \text{ psi.}, \qquad \sigma_{yyr} = 7346.57 \text{ psi.}$$

From Steps 3 and 4,

$$d_{wx} = \frac{(1+c_{fx}k_s)}{(1+4c_{fx}k_s)^{1/2}} h\bar{\alpha}_x = 0.4488586 \text{ in.}$$

$$d_{wy} = h\bar{\alpha}_y = 3.11199 \text{ in.}$$

$$\frac{t_{wx}}{l_x} = \frac{E\bar{\lambda}_{xx}h}{E_x(1-\nu^2)(1+c_{fx}k_s)d_{wx}} = 0.027949$$

$$\frac{t_{wy}}{l_y} = \frac{E\bar{\lambda}_{yy}h}{E_y(1-\nu^2)d_{wy}} = 0.0020777$$

Then

$$l_x < h\sqrt{\frac{\pi^2 E}{3(1-\nu^2)\,|\sigma_{xxsk}|}} \qquad \text{or } l_x < 0.78509$$

Select the stringer spacing such that one has a whole number of stringers and yet stays away from skin buckling.

Choose $l_x = 0.7500553$ in.

Therefore

$t_{wx} = 0.020963$ in.,

$t_{fx} = 0.020963$ in.,

$b_{fx} = 0.1571005$ in.,

$t_{fy} = b_{fy} = 0$

From Step 7, one finds that any ring spacing, l_y, will satisfy the constraint

$$|\sigma_{xxsf_{cr}}| > |\sigma_{xxst}|$$

Thus, the determination of l_y must be based on panel instability only. Using the computer program in Appendix E, one has

$$l_y = 10.03448 \text{ in.}$$

$$\bar{N}_{xxp_{cr}} = 1227.273 \text{ lbs/in.}$$

$$m_p = 1 \quad , \quad n_p = 31.7$$

Thus,

$$t_{wy} = 0.020848 \text{ in.}$$

Next, calculate the local buckling stresses using appropriate equations in Table 1.

$$\sigma_{xxsk_{cr}} = \frac{\pi^2 E}{3(1-\nu^2)}\left(\frac{h}{l_x}\right)^2 = 31739.14 \text{ psi.}$$

$$\sigma_{xxsw_{cr}} = \frac{\pi^2 E}{3(1-\nu^2)}\left(\frac{t_{wx}}{d_{wx}}\right)^2 = 84553 \text{ psi.}$$

$$\sigma_{xxsf_{cr}} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{2t_{fx}}{b_{fx}-t_{wx}}\right)^2\left[\left(\frac{b_{fx}-t_{wx}}{2l_y}\right)^2 + 0.425\right]$$

$$= 396367.1 \text{ psi.}$$

Finally, compute the ratios of actual load to failure load, which clearly demonstrate the desired separation of failure modes.

$$PB = \bar{N}/N_{xxp_{cr}} = 0.8963$$

$$SB = \sigma_{xxsk}/\sigma_{xxsk_{cr}} = 0.9127$$

$$STWB = \sigma_{xxst}/\sigma_{xxsw_{cr}} = 0.3339$$

$$STFB = \sigma_{xxst}/\sigma_{xxsf_{cr}} = 0.0712$$

$$SY = \sigma_{xxsk}/\sigma_o = 0.5794$$

$$STYC = \sigma_{xxst}/\sigma_o = 0.5648$$

$$RYT = \sigma_{yyr}/\sigma_o = 0.1469$$

$$W = 2\pi RLh\rho_{sk}\bar{W} = 791.22 \text{ lbs.}$$

Other design, with the same weight, which satisfy all constraints (including geometric constraints) is

$$l_y = 9.7 \text{ in.}$$

$$t_{wy} = 0.02015 \text{ in.}$$

$$N_{xxp_{cr}} = 1313.14 \text{ lbs/in.}$$

$$m_p = 1 \;,\; n_p = 32.1$$

$$PB = 0.8377$$

APPENDIX D

GUIDELINE FOR DATA GENERATION[1]

In several design cases the approximate value of the skin thickness can be estimated, therefore the interval of Z,

$$Z = \frac{L^2(1-\nu^2)^{1/2}}{Rh}$$

for which the data must be generated, is greatly reduced. But with priori knowledge of the skin thickness the following procedure to establish the range of Z values is recommened.

It is well-known that the skin thickness of an unstiffened cylindrical shell subject to a given axial compressive load is given by

$$h_u = \sqrt{\frac{\overline{N}R}{.61E}}$$

Since the weight of the unstiffened geometry is greater than that of a stringer- and ring-stiffened geometry, h_u will provide a lower bound for the value of Z. It may also be anticipated that the optimum stiffened geometry has a skin thickness not less than 15 % of h_u. This may be considered as a lower bound for h or an upper bound for the value of Z. Thus, if one defines Z_u by

$$Z_u = \frac{L^2(1-\nu^2)^{1/2}}{Rh_u}$$

then the range of Z values, in which the optimum configuration will lie, is

$$Z_u \leq Z \leq 6Z_u$$

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[1]Ungbhakorn, V., op. cit., pp. 106-108.

In the case of uniform axial compression, from designing experience, one generally expects the optimum configuration to have both rings and stringers with rings being deeper than stringers to strengthen the local stringer buckling. Furthermore, when stringers are deeper than rings and in the region $\bar{\alpha}_x > \bar{\alpha}_y$, the design dimensions (stringer and ring thickness, ring spacing, etc.) become too small to accept. Also from thin ring theory one must have approximately

$$\bar{\alpha}_y \leq \frac{R}{20h}.$$

Hence, the region for which the data must be generated, for each Z, is where

$$\bar{\alpha}_x \leq \bar{\alpha}_y \quad \text{and} \quad \bar{\alpha}_y < \frac{R}{20h}.$$

The following procedure is recommended.

1. Divide Z into 6 intervals: Z_u, $2Z_u$,......, $6Z_u$.

2. Obtain data at $Z = 4Z_u$ and design the stiffened shell according to the design procedure outlined in Chapter III, such that the resulting configuration has the lowest weight with all constraints being satisfied. Call this weight W_4.

3. Repeat Step 2 with $Z = 5Z_u$ and obtain the cylinder weight W_5.

4. If $W_4 < W_5$, one repeats Step 2 with $Z = 3Z_u$. If $W_4 > W_5$, one repeat Step 2 with $Z = 6Z_u$. If $W_4 \simeq W_5$ then the minimum weight configuration is between $4Z_u$ and $5Z_u$.

5. Plot W vs. h. If necessary, Step 2 is repeated with $Z = 2Z_u$.

APPENDIX E

COMPUTER PROGRAMS

1. Program for the Development of Design Charts and Tables.

The structure of this program consists of a main program and five subprograms. The purpose of each program is as follows:

Main program is the search method of Nelder and Mead.

SUBROUTINE START sets up an initial simplex from a given starting point.

SUBROUTINE SUMR contains nondimensional composite weight function, $\overline{W}^*$.

SUBROUTINE KXX is the search method of Golden Section.

FUNCTION F(Z) is the $\overline{K}_{xx}$ expression with m as a continuous variable.

FUNCTION G(Z) is the $\overline{K}_{xx}$ expression with m as an integer.

1.1 Descriptions of inputs and outputs.

The symbols of the computer listings, with thier corresponding representations, necessary to operate the Optimization Program are:

ALP = $\overline{N}^*$, ALX = $\bar{\alpha}_x$, ALY = $\bar{\alpha}_y$,

BET = β , CX = C_x , C_y = C_y ,

CFX = c_{fx} , CFY = c_{fy} ,

DIFER = Standard deviation of the $\overline{W}$ of the simplex to determine convergence.

FCX = k_s , FCY = k_r

GZ = $\overline{K}_{xx_{cr}}$

II = Number of iterations.

M = m

PO = ν

SUM(IN) = $\overline{W}^*$

SUML = $\overline{W}^*$ for minimum weight

WP = $\overline{W}$

XI(KOUNT,1) = $\overline{\lambda}_{xx}$

XI(KOUNT,2) = $\overline{\lambda}_{yy}$

ZZZ = Z

To use the program, lines 9 through 17 in the main program must be modified according to the type of the stiffening member, load parameter, and curvature parameter. The data cards, to be read in, are $\overline{\alpha}_x$ and $\overline{\alpha}_y$. Each pair of $\overline{\alpha}_x$ and $\overline{\alpha}_y$ is punched on same card with the Format (2F10.5) of line 25.

```
C     MINIMIZATION OF THE WEIGHT OF THE STIFFENED SHELL BY FLEXIBLE
C     POLYHEDRON METHOD OF NELDER AND MEAD.
C     ALLOWANCE HAS BEEN MADE FOR A  6-DIMENSIONAL PROBLEM.
C     NX IS THE NUMBER OF INDEPENDENT VARIABLES.
C     STEP IS THE INITIAL STEP SIZE.
C     X%I< IS THE ARRAY OF INITIAL GUESSES.
C     X(1) = LAMBDA XX BAR.
C     X%2< # LAMBDA YY BAR
C     10**X%3< # LAGRANGE MULTIPLIER.
C     ZZZ # CURVATURE PARAMETER.
C     Z # BETA BAR, ARGUMENT IN THE KXX EXPRESSION.
C     M OR AM # NUMBER OF AXIAL WAVES.
C     ALP # APPLIED LOAD PARAMETER.
C     SUM%IN< = COMPOSITE WEIGHT FUNCTION.
C     GZ = KXXCR.
C     WP = WEIGHT PARAMETER.
C     PO # POISSON RATIO.
C     CFX = STRINGER THICKNESS RATIO.
C     CFY # RING THICKNESS RATIO.
C     FCX = KS = STRINGER FLANGE WIDTH RATIO.
C     FCY = KR = RING FLANGE WIDTH RATIO.
C     FOR PROPER PRINT OUT FORMAT STATEMENT 2002 AND 101 MUST BE
C     REVISED ACCORDINGLY.
C
      DIMENSION X1(6,6),X(4),SUM(6)
      COMMON/S/X1,NX,STEP,K1,SUM,IN
      COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
      COMMON/EE/Z,AM,GZ
      COMMON/SR/ALP
      WRITE(3,2005)
      NX = 2
      STEP = .1
      PO = .33
      ALP = 1.341E-8
      ZZZ = 40000.
      CFX = 1.0
      CFY = 0.
      FCX = .35
      FCY = 0.
      CX = (1.0+2.0*CFX*FCX)/(SQRT(1.0+4.0*CFX*FCX))
      CY = 1.0
      WRITE(3,111)
  111 FORMAT(/' NU',5X,'CX',5X,'CY',7X,'Z',6X,'CFX',4X'CFY',4X,'KS',5X,
     1'KR'/)
      WRITE(3,113) PO,CX,CY,ZZZ,CFX,CFY,FCX,FCY,ALP
 2005 FORMAT(//8X,'GENERAL INSTABILITY OPTIMIZATION-TSRR'//)
  113 FORMAT (6X,F5.3,F6.3,F7.3,3X,F8.2,4F7.4,E15.6//)
      WRITE(3,2002)
 2002 FORMAT(8X,'ALX',4X,'ALY',3X,'WP',10X,'KXXCR',5X,'X(1)',6X,'X(2)',
     15X,'M',4X,'BETA',8X,'WPSTAR',4X,'DIFER',5X,'II'/)
  100 READ(1,110) ALX,ALY
      IF (ALX.EQ.0.) GO TO 999
  110 FORMAT (2F10.5)
C     GUESS STARTING VALUES OF X(1) AND X(2)
```

```
          X(1) = 0.60
          X(2) = 0.25
          X(3) = 10.0
    C
          ALFA = 1.0
          BETA = 0.5
          GAMA = 2.0
          DIFER = 0.
          XNX = NX
          IN = 1
          CALL SUMR
          K1 = NX+1
          K2 = NX+2
          K3 = NX+3
          K4 = NX+4
          CALL START
          DO 3 I = 1,K1
          DO 4 J = 1,NX
        4 X(J) = X1(I,J)
          IN = I
          CALL SUMR
        3 CONTINUE
    C
       63 II = 0
       28 II = II+1
          IF (II.LT.25) GO TO 60
          GO TO 888
    C
    C     SELECT LARGEST VALUE OF SUM(I) IN SIMPLEX
       60 SUMH = SUM(1)
          INDEX = 1
          DO 7 I = 2,K1
          IF(SUM(I).LE.SUMH) GO TO 7
          SUMH = SUM(I)
          INDEX = I
        7 CONTINUE
    C     SELECT MINIMUM VALUE OF SUM(I) IN SIMPLEX
          SUML = SUM(I)
          KOUNT = 1
          DO 8 I = 2,K1
          IF(SUML.LE.SUM(I)) GO TO 8
          SUML = SUM(I)
          KOUNT = I
        8 CONTINUE
    C     FIND CENTROID OF POINTS WITH I DIFFERENT THAN INDEX
          DO 9 J = 1, NX
          SUM2 = 0.
          DO 10 I = 1,K1
       10 SUM2 = SUM2+X1(I,J)
          X1(K2,J) = 1./XNX*(SUM2-X1(INDEX,J))
    C     FIND REFLECTION OF HIGH POINT THROUGH CENTROID
          X1(K3,J) = (1.+ALFA)*X1(K2,J)-ALFA*X1(INDEX,J)
          IF(X1(K3,J)) 70,9,9
       70 X1(K3,J) = 0.
```

```
      9 X(J)= X1(K3,J)
        IN = K3
        CALL SUMR
        IF(SUM(K3).LT.SUML) GO TO 11
C       SELECT SECOND LARGEST VALUE IN SIMPLEX
        IF(INDEX.EQ.1) GO TO 38
        SUMS = SUM(1)
        GO TO 39
     38 SUMS = SUM(2)
     39 DO 12 I = 1,K1
        IF((INDEX-I).EQ.0) GO TO 12
        IF(SUM(I).LE.SUMS) GO TO 12
        SUMS = SUM(I)
     12 CONTINUE
        IF(SUM(K3).GT.SUMS) GO TO 13
        GO TO 14
C       FORM EXPANSION OF NEW MINIMUM IF REFLECTION HAS PRODUCED ONE MINI.
     11 DO 15 J = 1, NX
        X1(K4,J) = (1-GAMA)*X1(K2,J)+GAMA*X1(K3,J)
        IF(X1(K4,J)) 72,15,15
     72 X1(K4,J) = 0.
     15 X(J) = X1(K4,J)
        IN = K4
        CALL SUMR
        IF(SUM(K4).LT.SUML) GO TO 16
        GO TO 14
     13 IF(SUM(K3).GT.SUMH) GO TO 17
        DO 18 J = 1,NX
     18 X1(INDEX,J) = X1(K3,J)
     17 DO 19 J = 1, NX
        X1(K4,J) = BETA*X1(INDEX,J)+(1.-BETA)*X1(K2,J)
        IF(X1(K4,J)) 74,19,19
     74 X1(K4,J) = 0.
     19 X(J) = X1(K4,J)
        IN = K4
        CALL SUMR
        IF(SUMH.GT.SUM(K4)) GO TO 16
C       REDUCE SIMPLEX BY HALF IF REFLECTION HAPPENS TO PRODUCE A LARGER
C       VALUE THAN THE MAXIMUM
        DO 20 J = 1,NX
        DO 20 I = 1,K1
     20 X1(I,J) = 0.5*(X1(I,J)+X1(KOUNT,J))
        DO 29 I= 1, K1
        DO 30 J = 1,NX
     30 X(J) = X1(I,J)
        IN = I
        CALL SUMR
     29 CONTINUE
        GO TO 26
     16 DO 21 J = 1,NX
        X1(INDEX,J) = X1(K4,J)
     21 X(J) = X1(INDEX,J)
        IN = INDEX
        CALL SUMR
```

```
      GO TO 26
   14 DO 22 J = 1, NX
      X1(INDEX,J) = X1(K3,J)
   22 X(J) = X1(INDEX,J)
      IN = INDEX
      CALL SUMR
   26 DO 23 J = 1,NX
   23 X(J) = X1(K2,J)
      IN = K2
      CALL SUMR
C     TO TERMINATE THE SEARCH ,DIFFER MUST BE LESS THAN EPSILON
      DIFER = 0.
      DO 24 I = 1,K1
   24 DIFER = DIFER+(SUM(I)/SUM(K2)-1.)**2
      DIFER = SQRT(1./(XNX+1.0)*DIFER)
      IF(DIFER.GE.0.005) GO TO 28
  888 BET = Z*AM
      M = AM
      WP = 1.+(X1(KOUNT,1)+X1(KOUNT,2))/(1.-PO*PO)
      WRITE(3,101) ALX,ALY,WP,GZ,(X1(KOUNT,J),J=1,NX),M,BET,SUML,DIFER,
     1II
  101 FORMAT(1X,F8.1,F7.1,F10.5,F10.0,2F10.5,I5,F8.3,4X,F10.5,E12.5,I5)
      GO TO 100
  999 CONTINUE
      STOP
      END
```

```
C         SET UP THE INITIAL SIMPLEX FROM ONE STARTING POINT.
          SUBROUTINE START
          DIMENSION X1(6,6),X(4),SUM(6) ,A(3,3)
          COMMON/S/X1,NX,STEP,K1,SUM,IN
          COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
          VN = NX
          STEP1 = STEP/(VN*SQRT(2.))*(SQRT(VN+1.)+VN-1.)
          STEP2 = STEP/(VN*SQRT(2.))*(SQRT(VN+1.)-1.)
          DO 1 J = 1,NX
        1 A(1,J) = 0.
          DO 2 I = 2,K1
          DO 2J = 1,NX
          A(I,J) = STEP2
          L = I-1
          A(I,L) = STEP1
        2 CONTINUE
          DO 3 I = 1,K1
          DO 3 J = 1,NX
        3 X1(I,J) = X(J)+A(I,J)
          RETURN
          END
```

```
      SUBROUTINE SUMR
C     SUMR IS THE WEIGHT EXPRESSION
      DIMENSION X1(6,6),X(4),SUM(6)
      COMMON/S/X1,NX,STEP,K1,SUM,IN
      COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
      COMMON/EE/Z,AM,GZ
      COMMON/SR/ALP
      DO 10 J = 1,NX
      IF (X(J)) 9,10,10
    9 X(J) = 0.
   10 CONTINUE
      CALL KXX
      SUM(IN) = 1.0+(X(1)+X(2))/(1.-PO*PO)+10.**X(3)*ABS(GZ/(ZZZ*ZZZ)-
     1ALP*ZZZ)
      RETURN
      END
```

```
      SUBROUTINE KXX
C     CALCULATE BETA BAR AND M FOR KXXCR FOR EACH MOVEMENT OF X%I<
C     UNIDIMENSIONAL SEARCH BY GOLDEN SECTION METHOD USING FIBONACCI
C     FRACTIONS
C     FIBONACCI FRACTION # F1 # 0.382
C
      DIMENSION X1(25),X2(25),X3(25),Y1(25),Y2(25),DEL(25),X(4),M(3),
     1GG(3),Z1(3)
      COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
      COMMON/CC/P,Q,R
      COMMON/DD/M,JJ
      COMMON/EE/Z,AM,GZ
      DATA X1(1),X2(1),X3(1),F1,EPS/.00,4.00,5.00,0.381966011,0.05/
      K = 1
      L = 0
   11 IF(F(X2(K))-F(X3(K))) 10,10,20
   20 X3(K) = X3(K)+0.2*X3(K)
      IF(X3(K).LT.15) GO TO 11
      L = L+1
      IF(L.LT.10) GO TO 11
      X1(1) = 0.005
      X2(1) = 0.8
      X3(1) = 1.0
      IF(L.LT.11) GO TO 11
C     BETA BAR CURVE IS TOO FLAT, SET A TRIAL M = 1
      AM = 1.0
      GO TO 8
   10 DEL(K) = X3(K)-X1(K)
   12 Y1(K) = X1(K) + F1*DEL(K)
      Y2(K) = X3(K)-F1*DEL(K)
      IF(F(Y1(K))-F(Y2(K))) 30,31,32
   30 DEL(K+1) = Y2(K)-X1(K)
      X1(K+1) = X1(K)
      X3(K+1) = Y2(K)
      K = K+1
      IF(ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   31 DEL(K+1) = Y2(K)-X1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF(ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   32 DEL(K+1) = X3(K)-Y1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF(ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   40 Z = (X1(K)+X3(K))/2.
      FX = F(Z)
      AM = (Q/P)**0.25
      BE = Z*AM
    8 JJ = 1
```

```
      IF (AM-1.0) 41,41,42
   41 M(JJ) = 1
      GO TO 49
   42 JJ = JJ+1
      M(JJ) = AM
      GO TO 49
   43 JJ = JJ+1
      M(JJ) = M(JJ-1)+1
   49 X1(1) = 0.05
      X2(1) = 4.5
      X3(1) = 5.
      K = 1
      L = 0
   71 IF (G(X2(K))-G(X3(K))) 72,72,73
   73 X3(K) = X3(K) + 0.2*X3(K)
      IF (X3(K).LT.15.) GO TO 71
      L = L+1
      IF (L.LT.20) GO TO 71
      WRITE (3,101)
  101 FORMAT (/5X,'BETA BAR HAS BEEN LOST IN GZ')
   72 DEL(K) = X3(K)-X1(K)
   74 Y1(K) = X1(K) + F1*DEL(K)
      Y2(K) = X3(K)-F1*DEL(K)
      IF (G(Y1(K))-G(Y2(K))) 75,76,77
   75 DEL(K+1) = Y2(K)- X1(K)
      X1(K+1) = X1(K)
      X3(K+1) = Y2(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 78
      GO TO 74
   76 DEL(K+1) = Y2(K)- X1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT. EPS) GO TO 78
      GO TO 74
   77 DEL(K+1) = X3(K)-Y1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 78
      GO TO 74
   78 Z1(JJ) = (X1(K)+X3(K))/2.
      GG(JJ) = G(Z1(JJ))
      IF (JJ.EQ.1) GO TO 51
      IF (JJ.EQ. 3) GO TO 44
      GO TO 43
   44 IF (GG(JJ)-GG(JJ-1))  51,51,52
   51 GZ = GG(JJ)
      Z = Z1(JJ)
      AM = M(JJ)
      GO TO 47
   52 GZ = GG(JJ-1)
      Z = Z1(JJ-1)
```

```
      AM = M(JJ-1)
   47 CONTINUE
      RETURN
      END
```

```
C      F IS THE KXX EXPRESSION TREATED M AS CONTINUOUS VARIABLE
C
       FUNCTION F(Z)
       DIMENSION X(4)
       COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
       COMMON/CC/P,Q,R
       RHOX = ALX*ALX*X(1)
       RHOY = ALY*ALY*X(2)
       EX = 3.1416*3.1416*SQRT(1.-PO*PO)*(1.0+CX*ALX)/(2.0*ZZZ)
       EY = 3.1416*3.1416*SQRT(1.-PO*PO)*(1.0+CY*ALY)/(2.0*ZZZ)
       A = 1.+RHOX+2.*Z*Z+(1.+RHOY)*Z**4
       B = 12.*ZZZ*ZZZ/(3.1416**4*(1.-PO*PO))
       C = B*(EX*EX*X(1)+2.*EX*EX*X(1)*(1.-PO+X(2))*Z*Z/(1.-PO)+(EX*EX
      1*X(1)*(1.+X(2))+2.0*(1.0+PO)*X(1)*X(2)*EX*EY/(1.-PO)+EY*EY*X(2)
      2*(1.0+X(1)))*Z**4+2.*EY*EY*X(2)*(1.-PO+X(1))/(1.-PO)*Z**6+EY*EY*
      3X(2)*Z**8)
       D = 2.0*B*(PO*EX*X(1)-(EX*X(1)*(1.+X(2))+EY*X(2)*(1.+X(1)))*Z*Z+
      1PO*EY*X(2)*Z**4)
       E = B*((1.0+X(1))*(1.0+X(2))-PO*PO)
       FF = 1.0+X(1)+2.0/(1.-PO)*((1.+X(1))*(1.+X(2))-PO)*Z*Z+(1.+X(2))
      1*Z**4
       P = A+C/FF
       Q = E/FF
       R = D/FF
       F = 2.0*SQRT(P*Q)+R
       RETURN
       END
```

```
      FUNCTION G(Z)
C     G IS THE KXX EXPRESSION TREATED M AS INTEGER.
      DIMENSION X(4),M(3)
      COMMON/SS/ALX,ALY,CX,CY,PO,X,ZZZ
      COMMON/DD/M,JJ
      RHOX = ALX*ALX*X(1)
      RHOY = ALY*ALY*X(2)
      EX = 3.1416*3.1416*SQRT(1.-PO*PO)*(1.0+CX*ALX)/(2.0*ZZZ)
      EY = 3.1416*3.1416*SQRT(1.-PO*PO)*(1.0+CY*ALY)/(2.0*ZZZ)
      A = 1.+RHOX+2.*Z*Z+(1.+RHOY)*Z**4
      B = 12.*ZZZ*ZZZ/(3.1416**4*(1.-PO*PO))
      C = B*(EX*EX*X(1)+2.*EX*EX*X(1)*(1.-PO+X(2))*Z*Z/(1.-PO)+(EX*EX
     1*X(1)*(1.+X(2))+2.0*(1.0+PO)*X(1)*X(2)*EX*EY/(1.-PO)+EY*EY*X(2)
     2*(1.0+X(1)))*Z**4+2.*EY*EY*X(2)*(1.-PO+X(1))/(1.-PO)*Z**6+EY*EY*
     3X(2)*Z**8)
      D = 2.0*B*(PO*EX*X(1)-(EX*X(1)*(1.+X(2))+EY*X(2)*(1.+X(1)))*Z*Z+
     1PO*EY*X(2)*Z**4)
      E = B*((1.0+X(1))*(1.0+X(2))-PO*PO)
      FF = 1.0+X(1)+2.0/(1.-PO)*((1.+X(1))*(1.+X(2))-PO)*Z*Z+(1.+X(2))
     1*Z**4
      P = A+C/FF
      Q = E/FF
      R = D/FF
      G = P*M(JJ)*M(JJ)+Q/(M(JJ)*M(JJ))+R
      RETURN
      END
```

2. Panel Buckling Program.

The computer program for panel buckling analysis consists of a main program and two subprograms.

Main Program is the search method of Golden Section.

FUNCTION F(Z) is the $\vec{\bar{K}}_{xxp}$ expression with m as a continuous variable.

FUNCTION G(Z) is the $\vec{\bar{K}}_{xxp}$ expression with m as an integer.

2.1 Descriptions of Inputs and Outputs.

The symbols of the computer listings, with their corresponding representations, necessary to operate the program are:

ALX = $\bar{\alpha}_x$,	BET = β ,
CX = C_x ,	CMN = n ,
E = E ,	GZ = $\vec{\bar{K}}_{xxp_{cr}}$,
MM = m ,	PO = ν ,
PCR = $\vec{\bar{N}}_{xxp_{cr}}$,	ZZZ = Z_p ,
W1 = $\bar{\lambda}_{xx}$,	W2 = l_y ,
W3 = R ,	W4 = h .

To use the program , the value of ν in line 5 of the main program listings must be changed according to the material used in the design. The data card contains seven quantities, E, C_x, R, $\bar{\alpha}_x$, $\bar{\lambda}_{xx}$, h, l_y, punched on one card according to the Format of line 8.

```
C       PROGRAM FOR CHECKING PANEL INSTABILITY.
C       UNIDIMENSIONAL SEARCH BY GOLDEN SECTION.
C       F1 = FIBONACCI FRACTION.
C       ZZZ = CURVATURE PARATURE.
C       CMW = NO. OF CIRCUMFERENTIAL WAVES.
C       Z = BETA BAR,ARGUMENT IN THE FUNCTION.
C       PO = POISSIN RATIO.
C       M = NO. OF AXIAL WAVES.
C       ALX = ALPHA X BAR.
C       PCR = CRITICAL LOAD.
C       GZ = PANEL BUCKLING COEFFICIENT.
C       W1 = LAMBDA X BAR.
C       W2 = LY.
C       W3 = RADIUS.
C       W 4 = SKIN THICKNESS.
C
        DIMENSION X1(25),X2(25),X3(25),Y1(25),Y2(25),DEL(25),M(5),GG(5)
       1,Z1(5)
        COMMON/KXXP/ALX,CX,PO,ZZZ,W1,W2,W3,W4
        COMMON/FFF/P,O
        COMMON/GGG/M,JJ
        PO = .33
      4 READ(1,2) E,CX,W3,ALX,W1,W4,W2
        IF(E.EQ.0.) GO TO 999
      2 FORMAT (F10.0,6F10.5)
        DATA X1(1),X2(1),X3(1),F1,EPS/.01,4.00,5.00,0.381966011,0.05/
        WRITE(3,105)
    105 FORMAT (//9X,'E',4X,'CX',8X,'RADIUS',4X,'ALX',7X,'X(1)',7X,'H',
       18X,'LY')
        WRITE(3,7) E,CX,W3,ALX,W1,W4,W2
      7 FORMAT (F10.0,6F10.5)
        WRITE(3,3)
      3 FORMAT (11X,'KXXPCR',8X,'ZP',6X,'M', 4X,'BETA',4X,'N',5X,'NXXCR')
        ZZZ = W2*W2*SQRT(1.-PO*PO)/(W3*W4)
        K = 1
        L = 0
     11 IF(F(X2(K))-F(X3(K))) 10,10,20
     20 X3(K) = X3(K) + 0.2*X3(K)
        IF (X3(K).LT.15.) GO TO 11
        L = L +1
        IF (L.LT.10) GO TO 11
        X1(1) = 0.01
        X2(1) = 0.8
        X3(1) = 1.0
        IF (L.LT.11) GO TO 11
C       BETA BAR CURVE IS TOO FLAT. SET M = 1.
        AM = 1.0
        GO TO 8
     10 DEL(K) = X3(K)-X1(K)
     12 Y1(K) = X1(K) + F1*DEL(K)
        Y2(K) = X3(K) - F1*DEL(K)
        IF(F(Y1(K))-F(Y2(K))) 30,31,32
     30 DEL(K+1) = Y2(K) - X1(K)
        X1(K+1) = X1(K)
```

```
      X3(K+1) = Y2(K)
      K = K+1
      IF(ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   31 DEL(K+1) = Y2(K)-X1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   32 DEL (K+1) = X3(K)-Y1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 40
      GO TO 12
   40 Z = (X1(K)+X3(K))/2.
      FX = F(Z)
      AM = (Q/P)**0.25
      BE = Z*AM
    8 JJ = 1
      IF(AM-1.0) 41,41,42
   41 M(JJ) = 1
      GO TO 49
   42 JJ = JJ+1
      M(JJ) = AM
      GO TO 49
   43 JJ = JJ+1
      M(JJ) = M(JJ-1) +1
   49 X1(1) = 0.01
      X2(1) = 4.5
      X3(1) = 5.
      K = 1
      L = 0
   71 IF (G(X2(K))-G(X3(K))) 72,72,73
   73 X3(K) = X3(K) + 0.2*X3(K)
      IF (X3(K).LT.15.) GO TO 71
      L = L+1
      IF (L.LT.20) GO TO 71
      WRITE(3,101)
  101 FORMAT (/5 X,'BETA BAR HAS BEEN LOST IN GZ')
      GO TO 4
   72 DEL(K) = X3(K)-X1(K)
   74 Y1(K) = X1(K) + F1*DEL(K)
      Y2(K) = X3(K) - F1*DEL(K)
      IF (G(Y1(K))-G(Y2(K))) 75,76,77
   75 DEL (K+1) = Y2(K) - X1(K)
      X1(K+1) = X1(K)
      X3(K+1) = Y2(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 78
      GO TO 7 4
   76 DEL(K+1) = Y2(K)-X1(K)
      X1(K+1) = Y1(K)
```

```
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 78
      GO TO 7 4
   77 DEL(K+1) = X3(K)-Y1(K)
      X1(K+1) = Y1(K)
      X3(K+1) = X3(K)
      K = K+1
      IF (ABS((X3(K)-X1(K))/X3(K)).LT.EPS) GO TO 78
      GO TO 7 4
   78 Z1(JJ) = (X1(K)+X3(K))/2.
      GG(JJ) = G(Z1(JJ))
      IF(JJ.EQ.1) GO TO 51
      IF(JJ.EQ.3) GO TO 44
      GO TO 43
   44 IF (GG(JJ) - GG(JJ-1)) 51,51,52
   51 GZ = GG(JJ)
      Z = Z1(JJ)
      AM = M(JJ)
      GO TO 47
   52 GZ = GG(JJ-1)
      Z = Z1(JJ-1)
      AM = M(JJ-1)
   47 CONTINUE
      BET = Z*AM
      MM = AM
      CMW = 3.14159*BET*W3/W2
      PCR = 3.14159*3.14159*E*W4**3*GZ/(W2*W2*12.*(1.-PO*PO))
      WRITE(3,102) GZ,ZZZ,MM,BET,CMW,PCR
  102 FORMAT (5X,2F12.3,I5,F8.3,F7.1,E1 4.7)
      GO TO 4
  999 CONTINUE
      STOP
      END
```

```
      FUNCTION F(Z)
C
C     F IS THE KXXP EXPRESSION TREATED M AS CONTINUOUS VARIABLE.
      COMMON/KXXP/ALX,CX,PO,ZZZ,W1,W2,W3,W4
      COMMON/FFF/P,Q
      RHOX = ALX*ALX*W1
      EX = 3.14159*3.14159*SQRT(1.-PO*PO)*(1. + CX*ALX)/(2.0*ZZZ)
      A = 1. + RHOX + 2.*Z*Z + Z** 4
      B = 12.*ZZZ*ZZZ/(3.14159** 4*(1.-PO*PO))
      C = 1.+W1+2./(1.-PO)*(1.-PO+W1)*Z*Z+ Z**4
      P = A+B*EX*EX*W1*(1.+Z*Z)*(1.+Z*Z)/C
      Q = B*(1.-PO*PO+W1)/C
      R = 2.*B*EX*W1*(PO-Z*Z)/C
      F = 2.*SQRT(P*Q)+ R
      RETURN
      END
```

```
      FUNCTION G(Z)
C
C     G IS THE KXXP EXPRESSION TREATED M AS DISCRETE VARIABLE
      COMMON/KXXP/ALX,CX,PO,ZZZ,W1,W2,W3,W4
      COMMON/GGG/M,JJ
      DIMENSION M(5)
      RHOX = ALX*ALX*W1
      EX = 3.14159*3.14159*SQRT(1.-PO*PO)*(1.0+ CX*ALX)/(2.0*ZZZ)
      A = 1.+RHOX+2.*Z*Z+Z**4
      B = 12.*ZZZ*ZZZ/(3.14159**4*(1.-PO*PO))
      C = 1.+W1+2./(1.-PO)*(1.-PO+W1)*Z*Z+ Z**4
      P = A+B*EX*EX*W1*(1.+Z*Z)*(1.+Z*Z)/C
      Q = B*(1.-PO*PO+W1)/C
      R = 2.*B*EX*W1*(PO-Z*Z)/C
      G = P*M(JJ)*M(JJ)+ Q/(M(JJ)*M(JJ))+ R
      RETURN
      END
```

VITA

Mr. Jumlong Limtragool was born in Prachaup Khiri Khant, Thailand, on September 12, 1949. He received his Bachelor's Degree in Mechanical Engineering with First Class Honors from King Mongkut's Institute of Technology(KMIT), in 1973. After his graduation,he became a lecturer in the Faculty of Engineering at KMIT and he also enrolled at the Graduate School, Chulalongkorn University.

In 1976, he received the Royal Thai Government Scholarship of the Faculty of Engineering, Khon Kaen University to further his study in the United States after he completed this thesis.