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AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS RESEARCH LABORATORIES

RESULTS OF PIPE BEND ANALYSIS
PART X: STRESS DISTRIBUTIONS IN FLANGED PIPE ELBOWS FROM AN AXIAL FORCE

by

J.F. WHATHAM

June 1984

ISBN 0 642 59794 4

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ABSTRACT

Graphs of outside surface stress distributions are presented and numerical values of stresses on inside and outside surfaces tabulated for a wide range of flange-ended pipe elbows subjected to an axial force applied to one flange; calculations are based on linear thin shell theory.

National Library of Australia card number and ISBN 0 642 59794 4

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ANALYTICAL SOLUTION; FLANGES; PIPES; STRESS ANALYSIS; STRESSES

CONTENTS

1. INTRODUCTION

The objective of this report is to present the surface stress distributions for a range of flanged elbows subjected to an axial force, to assist pipework design engineers, and to provide analytic solutions for checking numerical solution methods. Wall thicknesses vary from one to ten per cent of the pipe radius with bend radii two, three and five times the pipe radius.

Stresses were calculated by the thin shell theory of Novozhilov [1970] and details of the analysis have been published [Whatham 1982, 1983]. The assumptions were that:

(i) the pipe wall is thin ($t/r < 0.3$),

(ii) normal stresses through the wall are negligible,

(iii) normals through the wall remain normal to it and unchanged in length, and

(iv) the flanges are infinitely stiff.

2. STRESS DERIVATION

The flanged pipe elbow configuration is shown in Figure 1, and a segment of a curved pipe middle surface, an imaginary surface mid-way between the inner and outer surfaces, is shown in Figure 2 with one end flanged. An element of the middle surface in Figure 3 is supposed to have forces T_θ, T_η, $T_{\theta\eta}$, $T_{\eta\theta}$, N_θ, N_η and moments M_θ, M_η, $M_{\eta\theta}$, $M_{\theta\eta}$ per unit length acting on its edges and the solution was obtained by thin shell theory in terms of these forces and moments; the stresses presented in this report were then derived as follows:

$$\begin{aligned} \text{Hoop stress: } \sigma_{\theta\theta} &= T_\theta/t + 12zM_\theta/t^3 \quad , \\ \text{Axial stress: } \sigma_{\eta\eta} &= T_\eta/t + 12zM_\eta/t^3 \quad , \\ \text{Shear stress: } \sigma_{\eta\theta} &= S/t + z(12H/t^3 - S/rt) \quad , \end{aligned} \tag{1}$$

where $S = T_{\theta\eta} - M_{\eta\theta}/r_\eta = T_{\eta\theta} - M_{\theta\eta}/r$, and $H = M_{\theta\eta} = M_{\eta\theta}$.

These stresses were close to those derived from beam theory when considering a straight pipe subjected to bending or torsion; if a moment M is

applied to a straight pipe, Novozhilov's theory [see Whatham 1981] gives

$$T_\eta = \frac{12M\cos\theta}{(12+\gamma)\pi r^2} \quad ,$$

$$M_\eta = \frac{\gamma M\cos\theta}{(12+\gamma)\pi r} \quad , \tag{2}$$

$$T_\theta = M_\theta = S = H = 0 \quad ,$$

where $\gamma = (t/r)^2$.

Substituting in Equations (1), the axial stress distribution approximates that from beam theory, which is

$$\sigma_{\eta\eta} = \frac{M(r+z)\cos\theta}{\pi r^3 t(1+\gamma/4)} \quad . \tag{3}$$

If torque T is applied to a straight pipe, Novozhilov's theory gives

$$S = \frac{3T}{2(3+\gamma)\pi r^2} \quad ,$$

$$H = \frac{\gamma T}{4(3+\gamma)\pi r} \quad , \tag{4}$$

$$T_\eta = M_\eta = T_\theta = M_\theta = 0 \quad .$$

Substituting in Equations (1), the shear stress distribution approximates that from beam theory, which is

$$\sigma_{\eta\theta} = \frac{T(r+z)}{2\pi r^3 t(1+\gamma/4)} \quad . \tag{5}$$

Equations (1) assume that the strains are linearly distributed through the pipe wall; this is not true for curved shells and the stresses $\sigma'_{\theta\theta}$, $\sigma'_{\eta\eta}$, $\sigma'_{\eta\theta}$ derived by the following equations are theoretically more accurate, even though the results do not agree with beam theory in the case of straight pipes:

$$\sigma'_{\theta\theta} = \sigma_{\theta\theta} - z(A+\nu B)/(1-\nu^2) \quad ,$$

$$\sigma'_{\eta\eta} = \sigma_{\eta\eta} - z(B+\nu A)/(1-\nu^2) \quad , \tag{6}$$

$$\sigma'_{\eta\theta} = \sigma_{\eta\theta} - \frac{z}{2r}\left[(r/(r+z)+r/(r_\eta+z))\sigma_{\eta\theta} - (r_\eta-r)\bar{\sigma}_{\eta\theta}/(r_\eta+z)\right] \quad ,$$

where

$$r_\eta = r + R/\cos\theta \ ,$$

$$A = (\sigma_{\theta\theta} - \nu\sigma_{\eta\eta})/(r+z) \ ,$$

$$B = (\sigma_{\eta\eta} - \nu\sigma_{\theta\theta})/(r_\eta+z) \ , \quad \text{and}$$

$$\bar{\sigma}_{\eta\theta} = \frac{1}{2}\sigma_{\eta\theta}(\text{inside}) + \frac{1}{2}\sigma_{\eta\theta}(\text{outside}).$$

3. ELBOW CONFIGURATION AND RESULTS

Stresses are duplicated each side of the bend in Figure 1 because of lateral symmetry, and hoop and axial stresses on the outside surface from $\theta = 0$ to $180°$ are plotted in Appendix A, together with the stresses at $\phi = 0$ and $\phi = 90°$ on theoretically unterminated or unflanged pipe bends. The latter stresses have two components, one varying as $\cos\phi$ and the other independent of ϕ, and the stress maxima and minima are given by the floating numbers; note that the shear stresses on unflanged pipe bends with this loading vary as $\sin\phi$.

The two graphs for each pipe bend are accompanied by tabulated stresses from which the graphs were constructed. In addition, since shear stresses and inside surface stresses are also given and a linear variation through the wall is assumed, the complete stress state in each pipe bend is provided.

A computer program package BENDPAC, written in FORTRAN IV and ASSEMBLER for an IBM3031 computer and designed to calculate the stresses in and the flexibility of flanged pipe elbows under in-plane or out-of-plane loading, is available from the Australian Atomic Energy Commission, the Risley Nuclear Power Development Establishment, Cheshire, UK, or the National Energy Software Center, Argonne National Laboratory, USA.

4. ACKNOWLEDGEMENT

The author acknowledges the advice and encouragement of Professor J.J. Thompson of the School of Nuclear Engineering, University of New South Wales.

5. REFERENCES

Novozhilov, V.V. [1970] - Thin Shell Theory. 2nd Augmented and Revised Edition, Wolters-Noordhoff, Gröningen, The Netherlands.

Whatham, J.F. [1981] - Thin shell equations for circular pipe bends. J. Nucl. Eng. Des., 65(1)77.

Whatham, J.F. [1982] - Analysis of circular pipe bends with flanged ends. J. Nucl. Eng. Des., 72(2)175.

Whatham, J.F. [1983] - Thin shell analysis of flanged pipe bends. Trans. Inst. Eng. Aust., CE25(1)1.

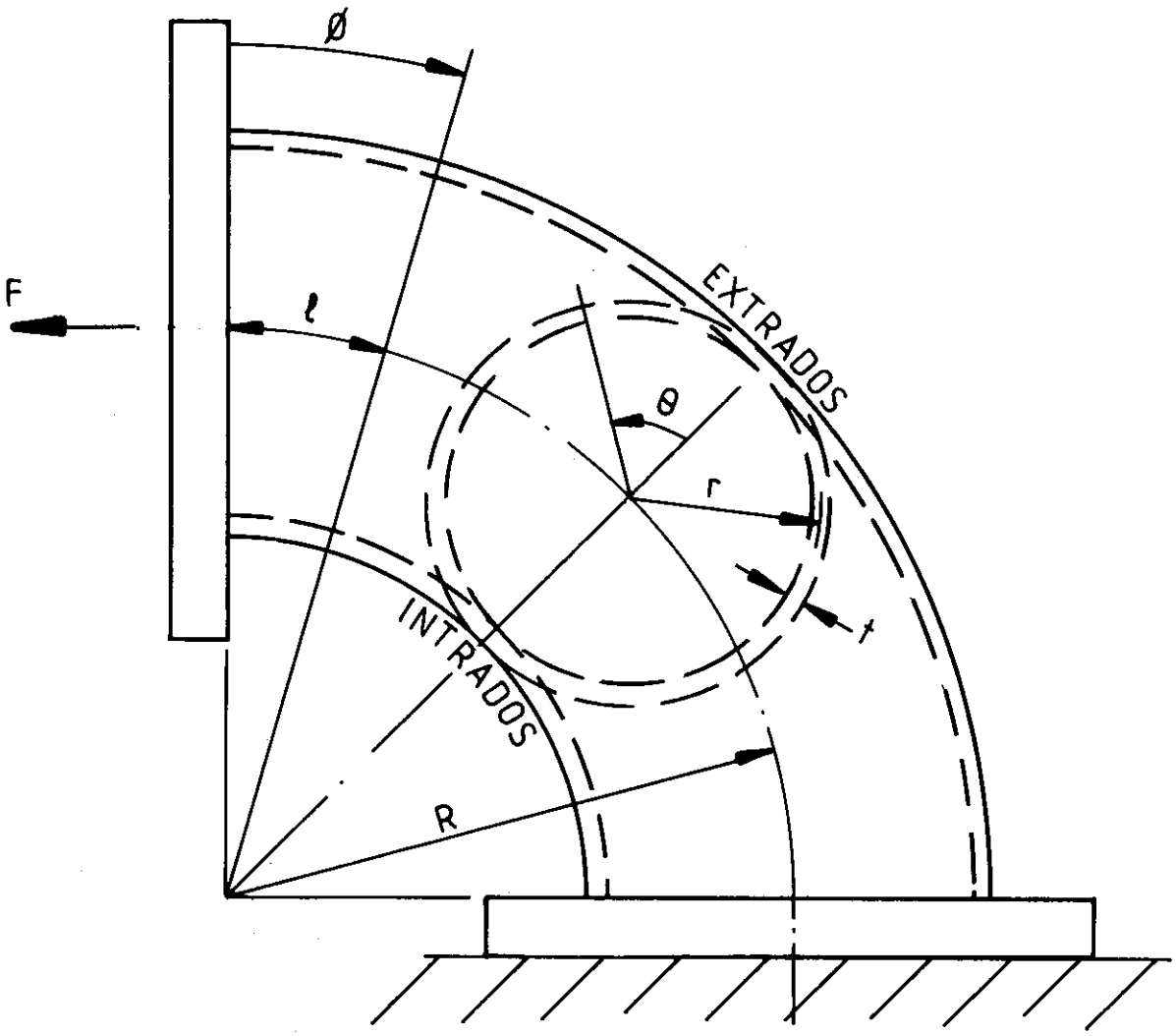


FIGURE 1. PIPE BEND CONFIGURATION

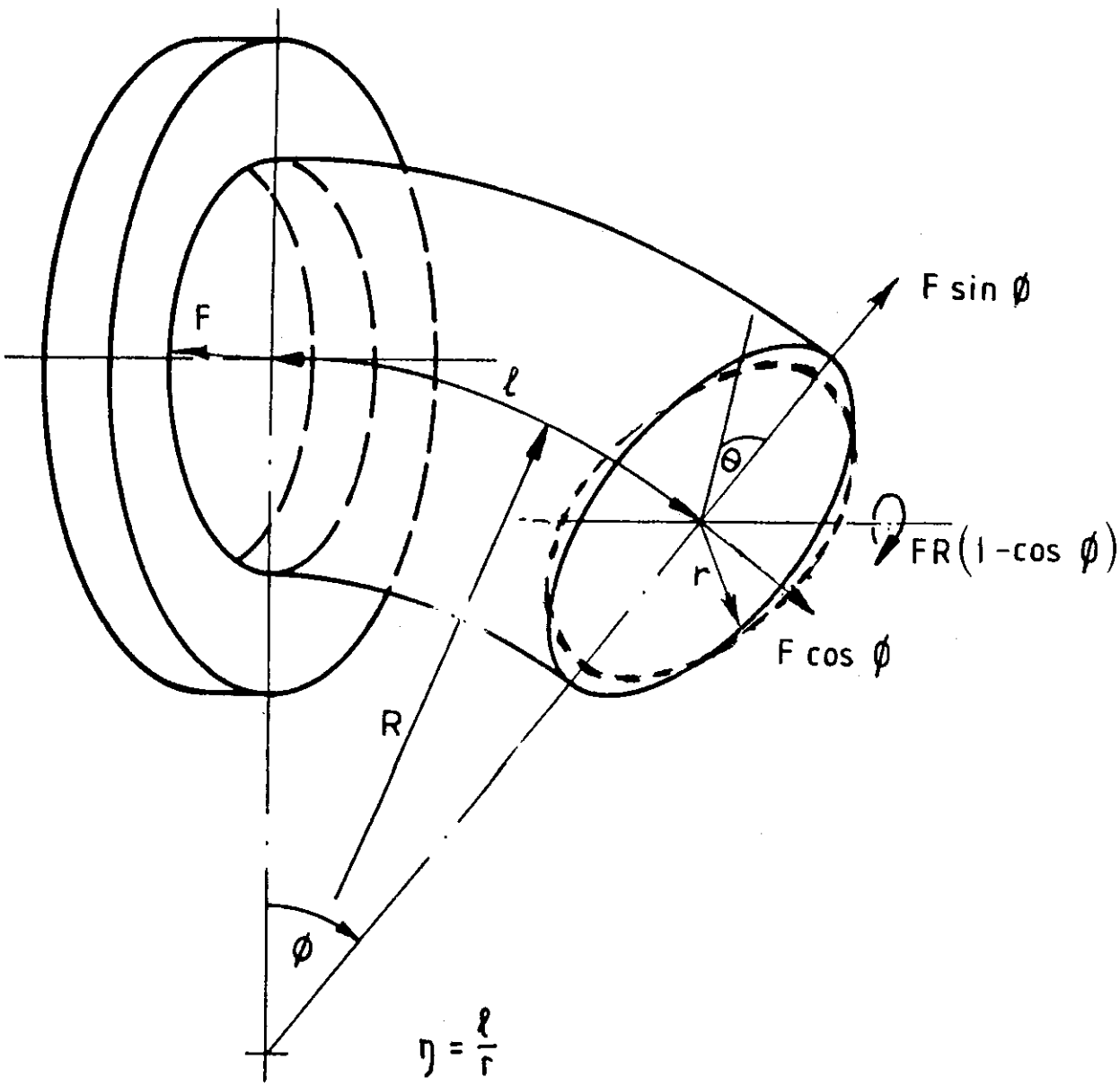


FIGURE 2. PIPE MIDDLE SURFACE

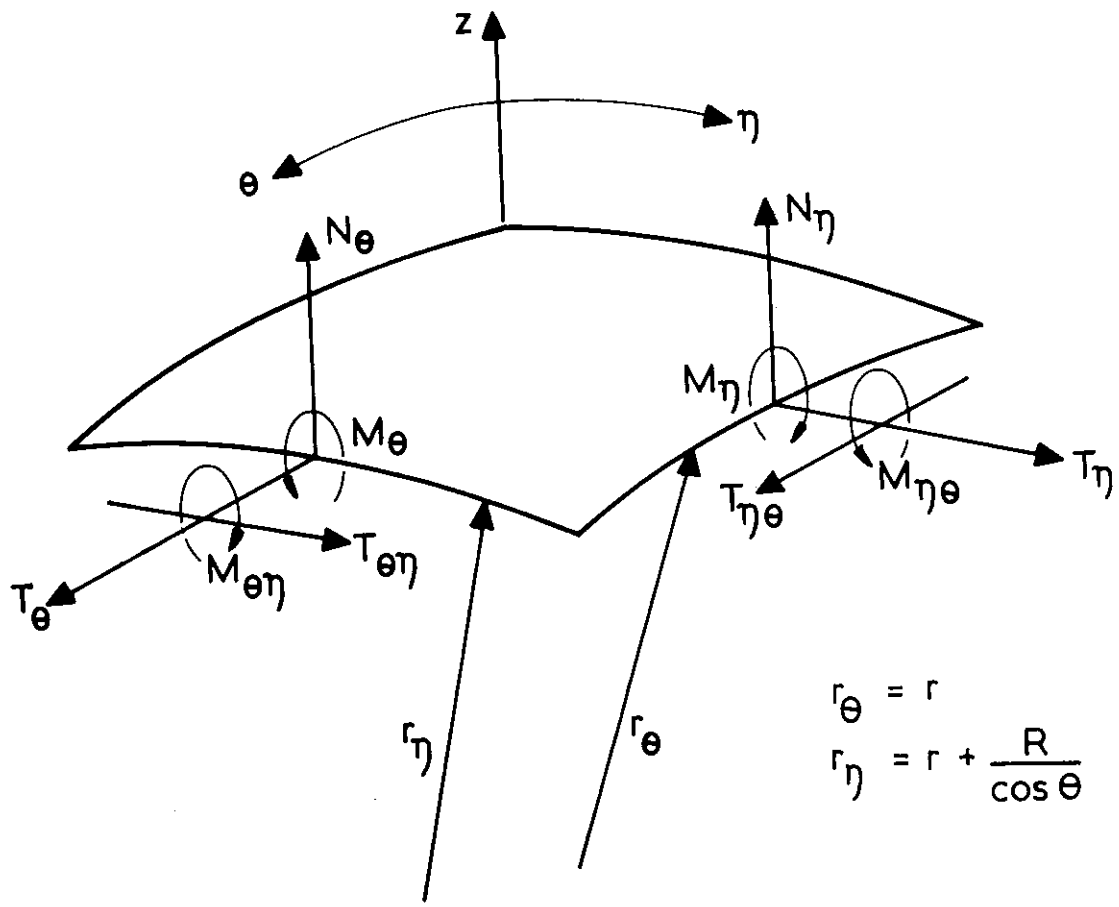


FIGURE 3. ELEMENT OF PIPE MIDDLE SURFACE

APPENDIX A

STRESSES IN FLANGED PIPE ELBOWS FROM AN AXIAL FORCE

Parameters of pipe elbows considered:

R/r = 2, 3, 5

t/r = 0.01, 0.02, 0.05, 0.1

ν = 0.3

Stress factor (S) = stress . $\pi r^2 t/FR$

For unflanged pipe bends:

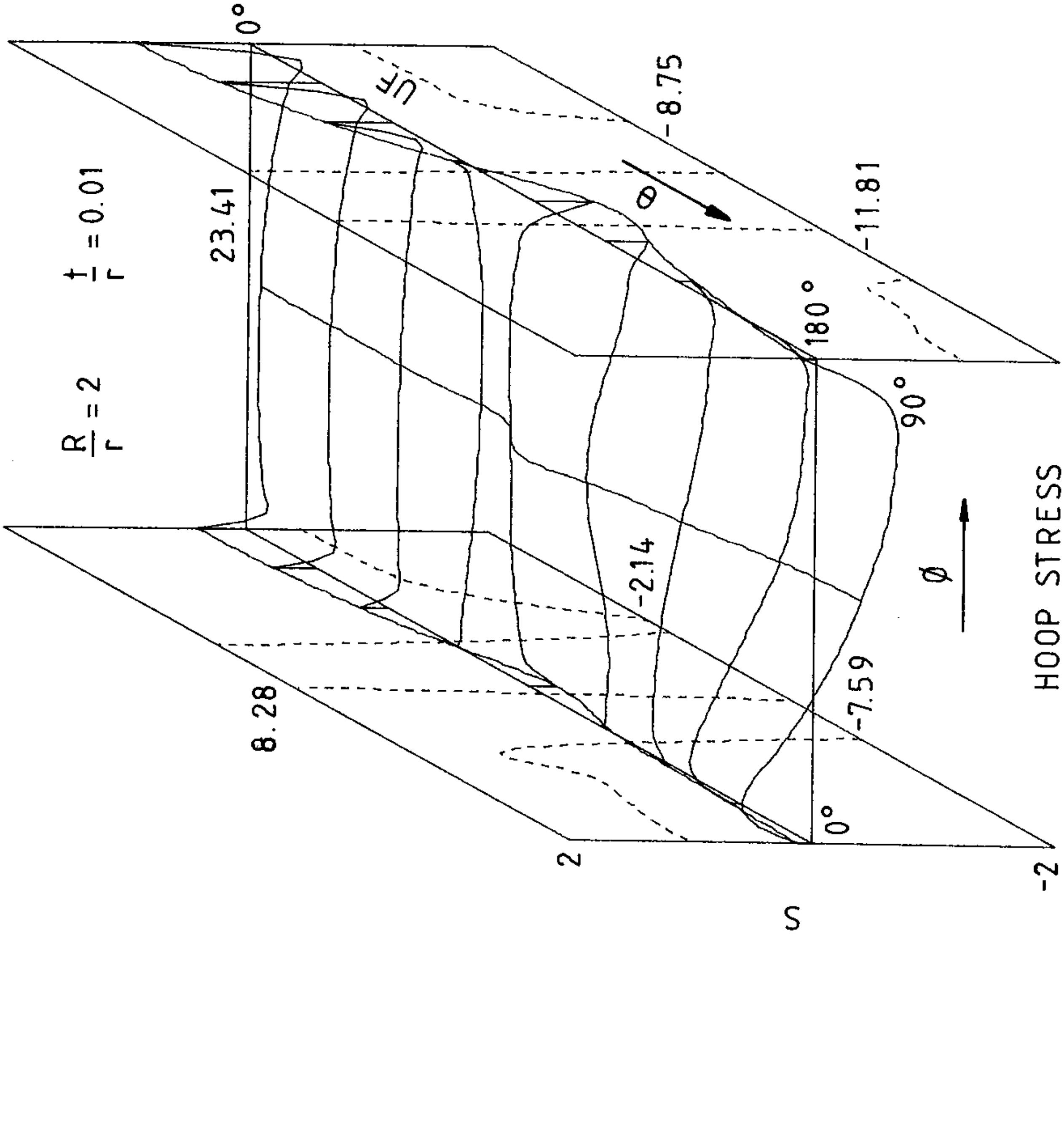
x sin } = multiply stress factors by { sin ϕ
x cos } = multiply stress factors by { cos ϕ

+ const. = add constant stress factor

UF = unflanged pipe bend.

Diameter expansion factor = diameter expansion . $\pi rEt/FR$

E = Young's modulus



HOOP STRESS

FIGURE A1

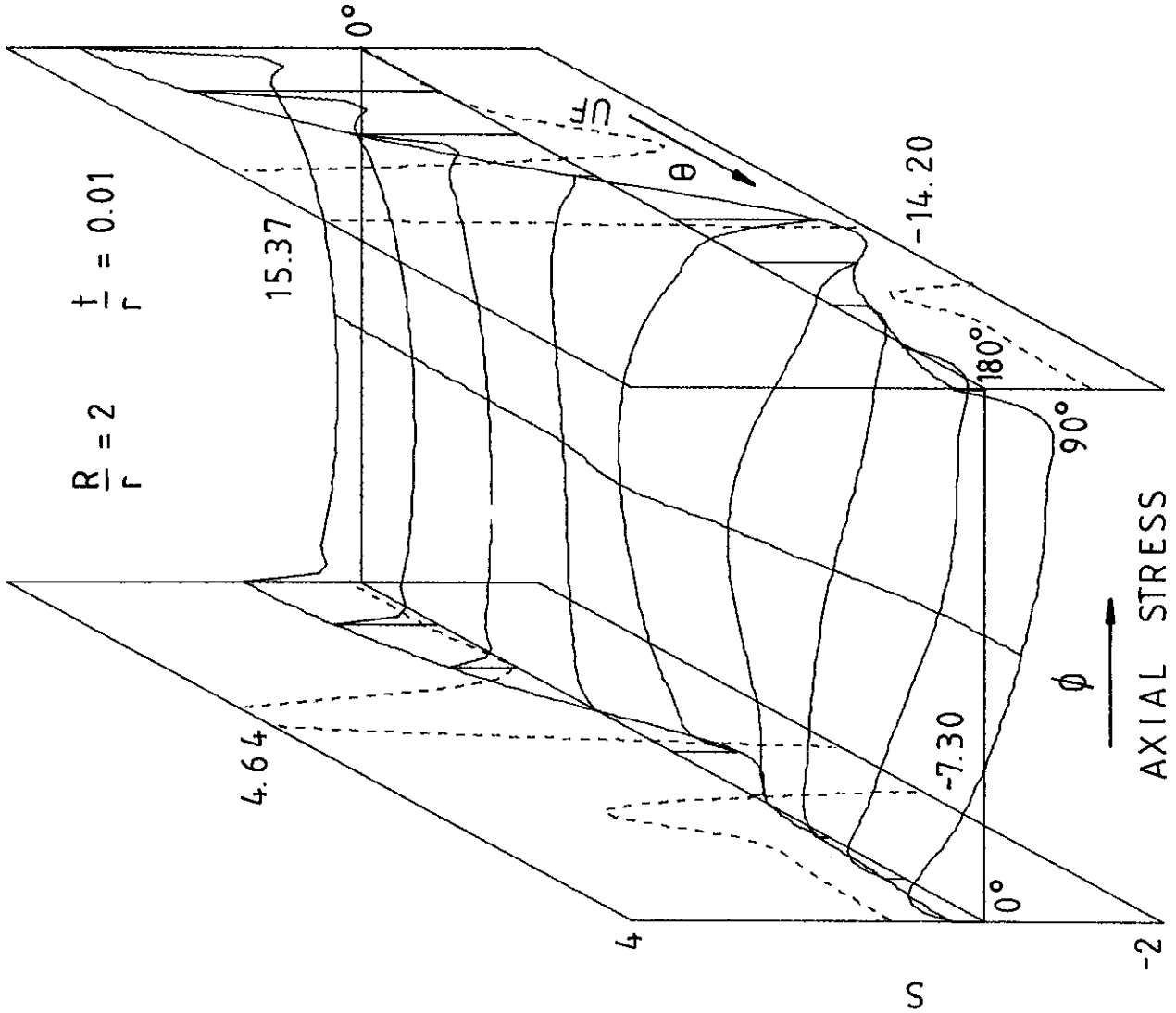


FIGURE A2

TABLE A1

R/r = 2.0 t/r = 0.01

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3936	-0.1430	-0.1150	-0.0992	-0.0925	-0.0936	-0.1021	-0.1188	-0.1455	-0.1850	-0.2426	-0.3272	0.9554	0.3670 -0.8258
22.5	0.3523	-0.1305	-0.1083	-0.0957	-0.0906	-0.0923	-0.1008	-0.1167	-0.1413	-0.1768	-0.2265	-0.2972	0.8567	0.3988 -0.8881
45.0	0.2286	-0.0941	-0.0872	-0.0829	-0.0815	-0.0840	-0.0913	-0.1038	-0.1220	-0.1458	-0.1743	-0.2084	0.5657	0.8666 -2.3000
67.5	0.0025	-0.0432	-0.0826	-0.1139	-0.1382	-0.1566	-0.1700	-0.1779	-0.1779	-0.1656	-0.1363	-0.0865	0.0735	8.7875 -7.7007
90.0	-0.2294	0.0670	0.1138	0.1461	0.1595	0.1642	0.1694	0.1791	0.1899	0.1901	0.1631	0.1154	-0.4889	-18.3855 23.3854
112.5	-0.0451	-0.0668	-0.0695	-0.0259	0.0388	0.0976	0.1263	0.1095	0.0452	-0.0521	-0.1496	-0.2027	-0.3567	5.2962-11.1507
135.0	0.0373	0.1480	0.1338	0.1035	0.0567	-0.0048	-0.0767	-0.1513	-0.2168	-0.2628	-0.2938	-0.3269	-0.1285	2.9458 -1.7647
157.5	0.0695	0.4259	0.3152	0.1628	0.0017	-0.1607	-0.3002	-0.3997	-0.4574	-0.4847	-0.5077	-0.4776	0.0193	2.2889 -1.3633
180.0	0.1085	0.5731	0.3620	0.1197	-0.0797	-0.2481	-0.3900	-0.5087	-0.5991	-0.6519	-0.6743	-0.5628	0.1064	2.2104 -1.1951

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.3119	0.4211	0.3309	0.2833	0.2630	0.2655	0.2898	0.3380	0.4151	0.5307	0.7008	0.9663	3.1848	0.1328 0.0234
22.5	1.1742	0.4032	0.3276	0.2868	0.2700	0.2744	0.2997	0.3476	0.4227	0.5323	0.6883	0.9208	2.8555	0.1215 0.0548
45.0	0.7618	0.3378	0.3066	0.2880	0.2831	0.2937	0.3214	0.3677	0.4342	0.5222	0.6310	0.7614	1.8858	1.0070 -0.9486
67.5	0.0085	0.2091	0.2667	0.2957	0.3140	0.3338	0.3615	0.3988	0.4426	0.4820	0.4942	0.4417	0.2451	-1.2892 5.2491
90.0	-0.7647	-0.0419	0.1709	0.3387	0.4588	0.5426	0.5959	0.6142	0.5805	0.4654	0.2302	-0.1335	-1.6297	-11.9149 8.0969
112.5	-0.1503	-0.1286	-0.0747	0.0388	0.1580	0.2427	0.2605	0.1904	0.0268	-0.2153	-0.4954	-0.7228	-1.1889	10.7520-11.7260
135.0	0.1242	0.2808	0.2363	0.1991	0.1424	0.0621	-0.0451	-0.1744	-0.3087	-0.4244	-0.5078	-0.6084	-0.4284	2.0467 -0.9160
157.5	0.2317	0.6039	0.3745	0.2012	0.0078	-0.1917	-0.3618	-0.4804	-0.5456	-0.5704	-0.5909	-0.6815	0.0644	2.2081 -1.2391
180.0	0.3618	0.7540	0.3587	0.1038	-0.1006	-0.2716	-0.4141	-0.5358	-0.6313	-0.6816	-0.7081	-0.7590	0.3546	2.2205 -1.1878

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1540	0.1051	0.0631	0.0325	0.0078	-0.0147	-0.0378	-0.0644	-0.0979	-0.1429	-0.2069	-0.3027	-0.4185	-0.0260
45.0	0.2617	0.1935	0.1205	0.0621	0.0115	-0.0365	-0.0867	-0.1437	-0.2131	-0.3020	-0.4202	-0.5824	-0.7430	-0.0279
67.5	0.2419	0.2073	0.1379	0.0683	-0.0033	-0.0788	-0.1609	-0.2523	-0.3558	-0.4736	-0.6064	-0.7548	-0.8321	-0.5840
90.0	-0.0128	0.0118	-0.0065	-0.0527	-0.1190	-0.2001	-0.2904	-0.3830	-0.4697	-0.5403	-0.5824	-0.5761	-0.4789	-2.1832
112.5	-0.2130	-0.2249	-0.2395	-0.2739	-0.3232	-0.3774	-0.4267	-0.4621	-0.4739	-0.4498	-0.3749	-0.2370	-0.0901	0.5127
135.0	-0.3145	-0.3999	-0.4822	-0.5313	-0.5456	-0.5333	-0.4962	-0.4317	-0.3380	-0.2209	-0.0960	0.0055	0.0623	0.3268
157.5	-0.3224	-0.3777	-0.4484	-0.4951	-0.4965	-0.4508	-0.3660	-0.2594	-0.1509	-0.0547	0.0239	0.0718	0.1175	0.1911
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	1.491	2.971	4.305	5.389	6.207	6.755	6.990	6.809	6.073	4.670	2.652	0.0	-583.979 701.057

TABLE A2

R/r = 2.0 t/r = 0.01

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0605	-0.1384	-0.1064	-0.0904	-0.0836	-0.0842	-0.0920	-0.1075	-0.1324	-0.1700	-0.2260	-0.3185	-0.1552	-0.4625	0.8259
22.5	-0.0482	-0.1257	-0.0992	-0.0860	-0.0805	-0.0817	-0.0892	-0.1037	-0.1266	-0.1604	-0.2092	-0.2882	-0.1267	-0.5072	0.8880
45.0	-0.0143	-0.0856	-0.0745	-0.0701	-0.0695	-0.0728	-0.0801	-0.0917	-0.1080	-0.1295	-0.1567	-0.1970	-0.0503	-1.0632	2.3477
67.5	0.0380	-0.0163	0.0038	0.0254	0.0425	0.0531	0.0569	0.0533	0.0407	0.0181	-0.0131	-0.0448	0.0524	-9.1739	7.4080
90.0	0.0513	-0.0731	-0.1349	-0.1693	-0.1816	-0.1841	-0.1879	-0.1985	-0.2121	-0.2156	-0.1893	-0.1191	0.0756	21.0830	-26.9049
112.5	-0.0131	0.0465	0.0875	0.0886	0.0606	0.0215	-0.0115	-0.0275	-0.0255	-0.0181	-0.0305	-0.0978	-0.1548	-3.8851	10.8953
135.0	0.1227	0.1128	0.1008	0.0952	0.1012	0.0996	0.0779	0.0278	-0.0528	-0.1547	-0.2560	-0.2989	-0.2369	-2.2479	1.7920
157.5	0.2682	0.3388	0.2947	0.1693	0.0470	-0.0723	-0.1881	-0.2955	-0.3839	-0.4448	-0.4780	-0.3965	-0.3426	-1.4835	1.3642
180.0	0.3182	0.4665	0.4076	0.2059	-0.0072	-0.2113	-0.3814	-0.4987	-0.5618	-0.5864	-0.5833	-0.4350	-0.4222	-1.3495	1.1946

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.2018	0.4120	0.3329	0.2853	0.2651	0.2677	0.2923	0.3408	0.4183	0.5342	0.7047	0.9438	-0.5174	0.1607	-0.0323
22.5	-0.1606	0.3940	0.3291	0.2887	0.2722	0.2768	0.3023	0.3505	0.4258	0.5355	0.6911	0.8982	-0.4223	0.1648	-0.0238
45.0	-0.0478	0.3295	0.3069	0.2896	0.2851	0.2958	0.3235	0.3695	0.4356	0.5226	0.6290	0.7401	-0.1676	0.8644	-0.4013
67.5	0.1266	0.1925	0.2741	0.3206	0.3528	0.3821	0.4148	0.4521	0.4890	0.5130	0.5002	0.4077	0.1746	-4.6817	7.0971
90.0	0.1709	-0.0980	0.0807	0.2129	0.3157	0.3898	0.4326	0.4364	0.3886	0.2719	0.0665	-0.2796	0.2519	2.1123	-7.0406
112.5	-0.0435	-0.0366	0.0442	0.1215	0.1797	0.2039	0.1849	0.1171	-0.0028	-0.1738	-0.3861	-0.6386	-0.5159	4.7661	-1.1067
135.0	0.4091	0.2144	0.2075	0.1828	0.1568	0.1142	0.0436	-0.0592	-0.1901	-0.3351	-0.4694	-0.5214	-0.7896	-1.5910	1.8986
157.5	0.8940	0.3351	0.3180	0.1905	0.0502	-0.0851	-0.2152	-0.3350	-0.4349	-0.5075	-0.5294	-0.4349	-1.1421	-1.2500	1.2426
180.0	1.0606	0.3546	0.3687	0.2088	0.0081	-0.1853	-0.3487	-0.4641	-0.5299	-0.5591	-0.5299	-0.4057	-1.4075	-1.3371	1.1828

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1525	0.1068	0.0638	0.0328	0.0081	-0.0143	-0.0372	-0.0636	-0.0970	-0.1423	-0.2073	-0.3054	-0.4143	0.0665
45.0	0.2591	0.1968	0.1217	0.0624	0.0117	-0.0359	-0.0855	-0.1419	-0.2110	-0.3004	-0.4211	-0.5878	-0.7356	0.1882
67.5	0.2395	0.2381	0.1606	0.0831	0.0059	-0.0729	-0.1568	-0.2504	-0.3584	-0.4850	-0.6319	-0.7967	-0.8238	0.9354
90.0	-0.0127	0.0386	0.0460	0.0089	-0.0626	-0.1593	-0.2733	-0.3956	-0.5141	-0.6117	-0.6637	-0.6415	-0.4741	-0.5143
112.5	-0.2108	-0.2791	-0.2977	-0.3196	-0.3562	-0.4063	-0.4573	-0.4896	-0.4823	-0.4206	-0.3036	-0.1433	-0.0892	-1.8987
135.0	-0.3114	-0.3980	-0.5173	-0.6007	-0.6338	-0.6083	-0.5291	-0.4132	-0.2838	-0.1637	-0.0643	0.0286	0.0616	-0.7934
157.5	-0.3192	-0.4191	-0.5042	-0.5248	-0.4986	-0.4406	-0.3617	-0.2700	-0.1711	-0.0690	0.0322	0.1201	0.1163	-0.4973
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-0.747	-1.618	-2.510	-3.228	-3.737	-4.044	-4.161	-4.071	-3.740	-3.142	-2.178	0.0	290.940	-330.349

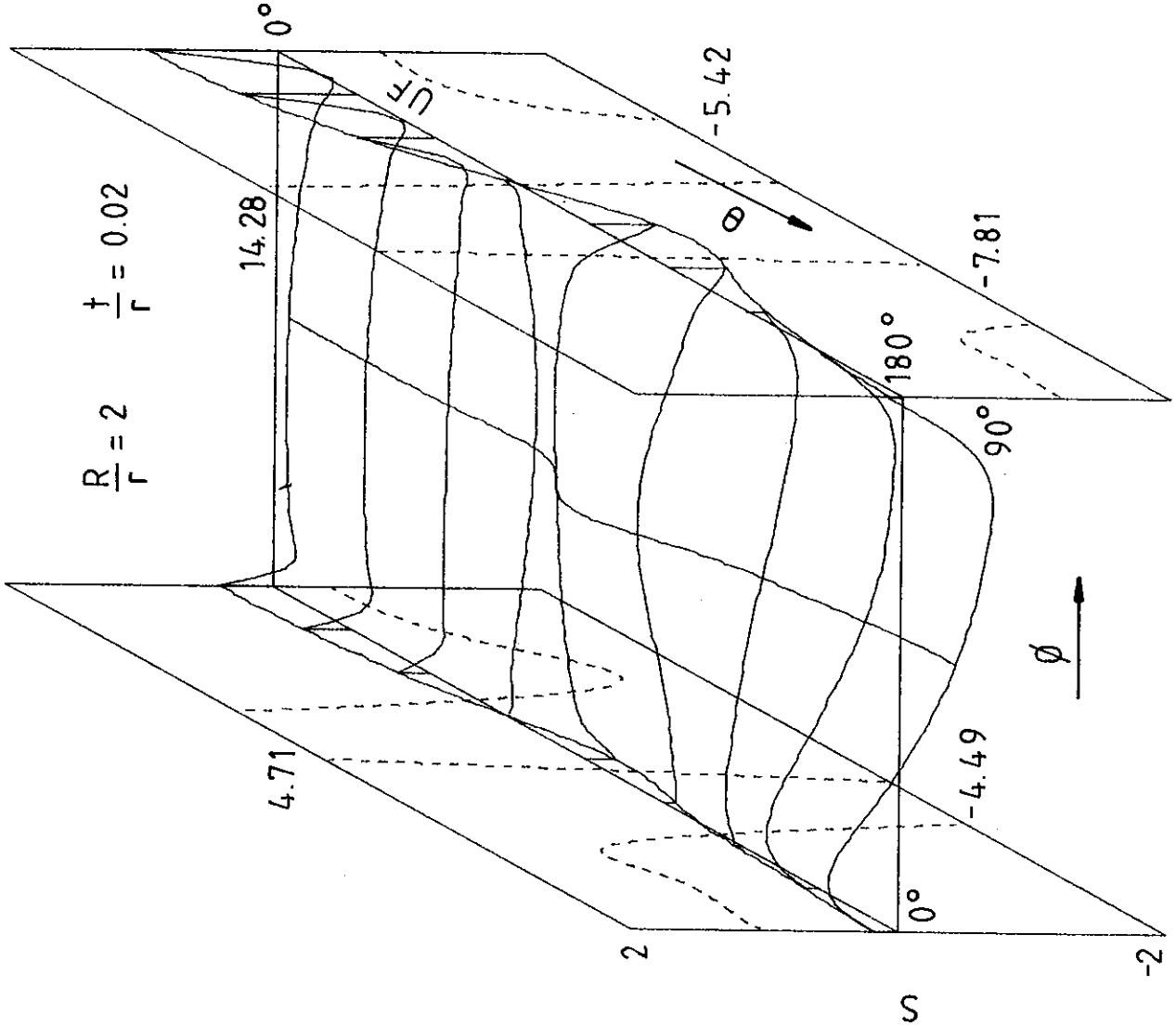
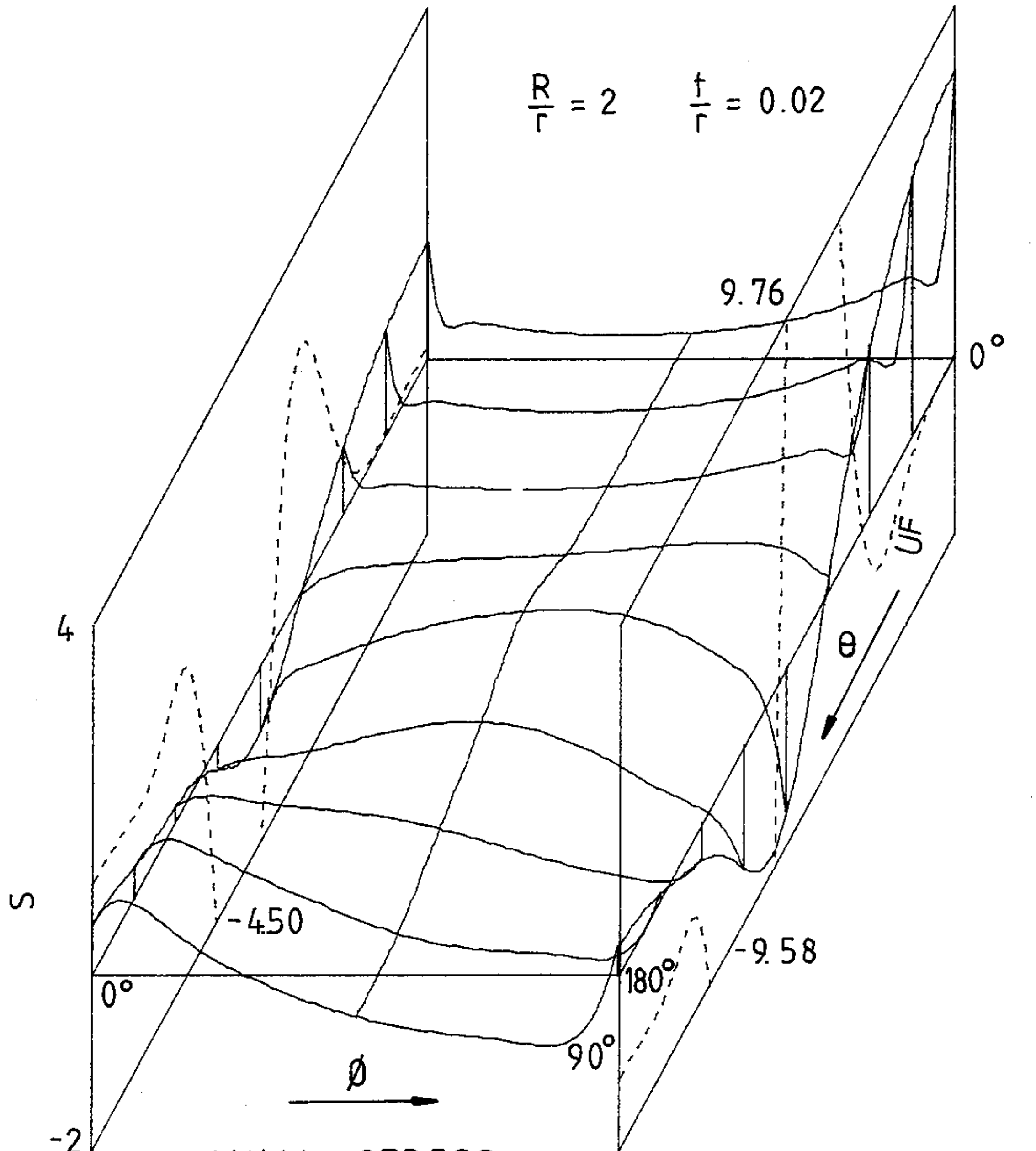


FIGURE A3



AXIAL STRESS

FIGURE A4

TABLE A3

R/r = 2.0 t/r = 0.02

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3988	-0.1617	-0.1163	-0.1013	-0.0948	-0.0962	-0.1053	-0.1226	-0.1500	-0.1904	-0.2474	-0.3766	0.9829	0.3264 -0.7469
22.5	0.3568	-0.1480	-0.1086	-0.0958	-0.0900	-0.0913	-0.0997	-0.1161	-0.1418	-0.1790	-0.2291	-0.3425	0.8808	0.2503 -0.8669
45.0	0.2272	-0.1135	-0.1067	-0.1102	-0.1136	-0.1192	-0.1286	-0.1424	-0.1605	-0.1814	-0.2014	-0.2488	0.5750	2.3966 -3.8065
67.5	-0.0108	-0.0322	-0.0690	-0.1084	-0.1439	-0.1726	-0.1920	-0.1990	-0.1907	-0.1653	-0.1219	-0.0708	0.0503	4.1416 -2.1347
90.0	-0.2252	0.0571	0.1255	0.1678	0.1967	0.2169	0.2339	0.2486	0.2557	0.2437	0.2055	0.1110	-0.4894	-11.2631 14.2537
112.5	-0.0868	-0.0634	-0.0310	0.0340	0.1149	0.1827	0.2156	0.2002	0.1338	0.0285	-0.0848	-0.2049	-0.4232	-0.2206 -4.2219
135.0	0.0533	0.1231	0.0977	0.0494	-0.0018	-0.0633	-0.1369	-0.2167	-0.2902	-0.3457	-0.3790	-0.3567	-0.1267	4.5244 -3.6569
157.5	0.1070	0.3968	0.3325	0.1638	-0.0128	-0.1799	-0.3219	-0.4245	-0.4852	-0.5186	-0.5285	-0.4030	0.0210	2.1748 -1.2206
180.0	0.1681	0.5189	0.3873	0.1418	-0.0796	-0.2638	-0.4135	-0.5284	-0.6106	-0.6655	-0.6661	-0.4509	0.1032	2.2077 -1.1844

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.3292	0.3947	0.3250	0.2781	0.2583	0.2611	0.2854	0.3334	0.4101	0.5251	0.6947	0.9119	3.2764	0.0865 0.0684
22.5	1.1893	0.3760	0.3204	0.2797	0.2633	0.2679	0.2932	0.3410	0.4157	0.5248	0.6812	0.8642	2.9360	0.2367 -0.1654
45.0	0.7572	0.3173	0.2960	0.2716	0.2620	0.2690	0.2944	0.3400	0.4080	0.5001	0.6170	0.7144	1.9166	1.2118 -0.6659
67.5	-0.0359	0.2324	0.2970	0.3344	0.3576	0.3806	0.4113	0.4519	0.4981	0.5367	0.5416	0.4765	0.1676	-3.4430 6.2809
90.0	-0.7505	-0.0005	0.1878	0.3573	0.4868	0.5819	0.6431	0.6626	0.6239	0.5012	0.2654	-0.0530	-1.6313	-7.3494 5.1399
112.5	-0.2893	-0.1503	-0.0831	0.0404	0.1622	0.2439	0.2597	0.1921	0.0353	-0.2015	-0.4826	-0.7311	-1.4106	7.2028 -9.5356
135.0	0.1777	0.2853	0.2131	0.1583	0.1052	0.0287	-0.0800	-0.2168	-0.3643	-0.4980	-0.6064	-0.6810	-0.4223	2.9315 -1.3663
157.5	0.3566	0.6572	0.4338	0.2038	-0.0111	-0.2185	-0.3963	-0.5219	-0.5883	-0.6169	-0.6639	-0.6671	0.0702	2.1526 -1.2056
180.0	0.5602	0.8053	0.4397	0.1221	-0.1169	-0.3131	-0.4716	-0.5885	-0.6650	-0.7205	-0.7902	-0.7224	0.3439	2.2187 -1.1721

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1444	0.1045	0.0622	0.0320	0.0075	-0.0150	-0.0381	-0.0647	-0.0981	-0.1430	-0.2066	-0.3040	-0.3995	-0.0138
45.0	0.2430	0.1915	0.1195	0.0626	0.0124	-0.0359	-0.0867	-0.1446	-0.2147	-0.3037	-0.4206	-0.5838	-0.7065	-0.0387
67.5	0.2125	0.1808	0.1192	0.0544	-0.0130	-0.0855	-0.1649	-0.2529	-0.3511	-0.4607	-0.5836	-0.7153	-0.7739	-0.7611
90.0	-0.0060	0.0017	-0.0264	-0.0780	-0.1430	-0.2169	-0.2952	-0.3735	-0.4468	-0.5088	-0.5504	-0.5446	-0.4747	-1.6928
112.5	-0.2102	-0.2056	-0.2302	-0.2703	-0.3206	-0.3724	-0.4184	-0.4521	-0.4661	-0.4494	-0.3857	-0.2782	-0.1199	0.0898
135.0	-0.3169	-0.3914	-0.4455	-0.4815	-0.4967	-0.4953	-0.4768	-0.4351	-0.3633	-0.2592	-0.1361	-0.0392	0.0328	0.4512
157.5	-0.3076	-0.3447	-0.4052	-0.4559	-0.4685	-0.4352	-0.3623	-0.2645	-0.1600	-0.0667	-0.0016	0.0286	0.0787	0.1885
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	1.195	2.493	3.679	4.699	5.499	6.031	6.230	6.011	5.287	4.020	2.172	0.0	-258.470 309.870

TABLE A4

R/r = 2.0 t/r = 0.02

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	-0.0724	-0.1385	-0.1004	-0.0851	-0.0784	-0.0788	-0.0862	-0.1010	-0.1250	-0.1616	-0.2155	-0.3227	-0.1900	-0.4209 0.7474
22.5	-0.0587	-0.1241	-0.0943	-0.0827	-0.0782	-0.0799	-0.0875	-0.1014	-0.1231	-0.1551	-0.2009	-0.2883	-0.1578	-0.3592 0.8725
45.0	-0.0181	-0.0725	-0.0498	-0.0380	-0.0324	-0.0325	-0.0375	-0.0476	-0.0637	-0.0880	-0.1220	-0.1763	-0.0672	-2.6453 3.8834
67.5	0.0520	-0.0409	-0.0107	0.0196	0.0498	0.0726	0.0836	0.0794	0.0582	0.0207	-0.0247	-0.0792	0.0706	-4.2005 1.5103
90.0	0.0807	-0.1005	-0.1531	-0.2034	-0.2320	-0.2507	-0.2679	-0.2856	-0.2976	-0.2899	-0.2416	-0.1955	0.1240	13.4035-17.0399
112.5	0.0110	0.0347	0.0591	0.0228	-0.0360	-0.0970	-0.1422	-0.1595	-0.1470	-0.1162	-0.0910	-0.1429	-0.1006	1.9576 3.4071
135.0	0.1124	0.1080	0.1342	0.1436	0.1527	0.1543	0.1392	0.1000	0.0298	-0.0727	-0.1859	-0.2418	-0.2463	-3.8739 3.7993
157.5	0.2307	0.2728	0.2708	0.1763	0.0740	-0.0218	-0.1211	-0.2274	-0.3333	-0.4202	-0.4417	-0.3272	-0.3446	-1.3728 1.2179
180.0	0.2427	0.3790	0.4012	0.2528	0.0495	-0.1539	-0.3274	-0.4509	-0.5216	-0.5476	-0.5053	-0.3418	-0.4279	-1.3525 1.1829

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	-0.2415	0.4249	0.3284	0.2819	0.2622	0.2653	0.2901	0.3387	0.4161	0.5319	0.7016	0.9867	-0.6334	0.1396 -0.0336
22.5	-0.1957	0.4068	0.3221	0.2820	0.2655	0.2701	0.2956	0.3438	0.4191	0.5289	0.6839	0.9411	-0.5260	0.3584 -0.2445
45.0	-0.0604	0.3411	0.3044	0.2878	0.2825	0.2921	0.3189	0.3648	0.4314	0.5188	0.6233	0.7757	-0.2240	0.2193 0.6610
67.5	0.1734	0.1827	0.2795	0.3377	0.3813	0.4198	0.4578	0.4952	0.5260	0.5370	0.5061	0.3895	0.2353	-3.9379 4.9620
90.0	0.2689	-0.0882	0.0863	0.2043	0.2970	0.3635	0.3990	0.3961	0.3445	0.2323	0.0419	-0.3118	0.4133	1.6972 -4.3042
112.5	0.0366	-0.0351	0.0408	0.0940	0.1242	0.1267	0.0961	0.0294	-0.0757	-0.2200	-0.4066	-0.6383	-0.3354	5.2371 -3.4875
135.0	0.3746	0.2091	0.2122	0.1982	0.1674	0.1221	0.0549	-0.0388	-0.1592	-0.2964	-0.4171	-0.4875	-0.8209	-1.8217 2.7142
157.5	0.7690	0.2809	0.2588	0.1922	0.0842	-0.0285	-0.1417	-0.2566	-0.3665	-0.4458	-0.4444	-0.4396	-1.1488	-1.2396 1.1833
180.0	0.8090	0.2776	0.2959	0.2253	0.0679	-0.1052	-0.2593	-0.3791	-0.4572	-0.4776	-0.4145	-0.4365	-1.4263	-1.3470 1.1888

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1415	0.1053	0.0627	0.0320	0.0076	-0.0144	-0.0370	-0.0631	-0.0961	-0.1412	-0.2065	-0.3042	-0.3916	0.0586
45.0	0.2382	0.2020	0.1238	0.0636	0.0126	-0.0351	-0.0844	-0.1406	-0.2100	-0.3007	-0.4238	-0.5980	-0.6925	0.2696
67.5	0.2083	0.2490	0.1703	0.0943	0.0166	-0.0645	-0.1522	-0.2508	-0.3644	-0.4962	-0.6461	-0.8225	-0.7586	0.7601
90.0	-0.0059	0.0418	0.0469	0.0088	-0.0631	-0.1608	-0.2760	-0.3989	-0.5167	-0.6122	-0.6640	-0.6438	-0.4653	-0.4476
112.5	-0.2060	-0.2966	-0.3080	-0.3302	-0.3683	-0.4175	-0.4649	-0.4929	-0.4835	-0.4225	-0.3031	-0.1218	-0.1175	-1.8352
135.0	-0.3106	-0.4058	-0.5354	-0.6182	-0.6436	-0.6146	-0.5380	-0.4254	-0.2936	-0.1616	-0.0426	0.0495	0.0321	-0.8402
157.5	-0.3015	-0.3993	-0.4884	-0.5258	-0.5112	-0.4543	-0.3679	-0.2665	-0.1633	-0.0648	0.0275	0.0940	0.0772	-0.4956
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
180.0	0.0	-0.768	-1.499	-2.352	-3.109	-3.683	-4.037	-4.150	-4.018	-3.641	-2.993	-2.029	0.0	144.758-165.036

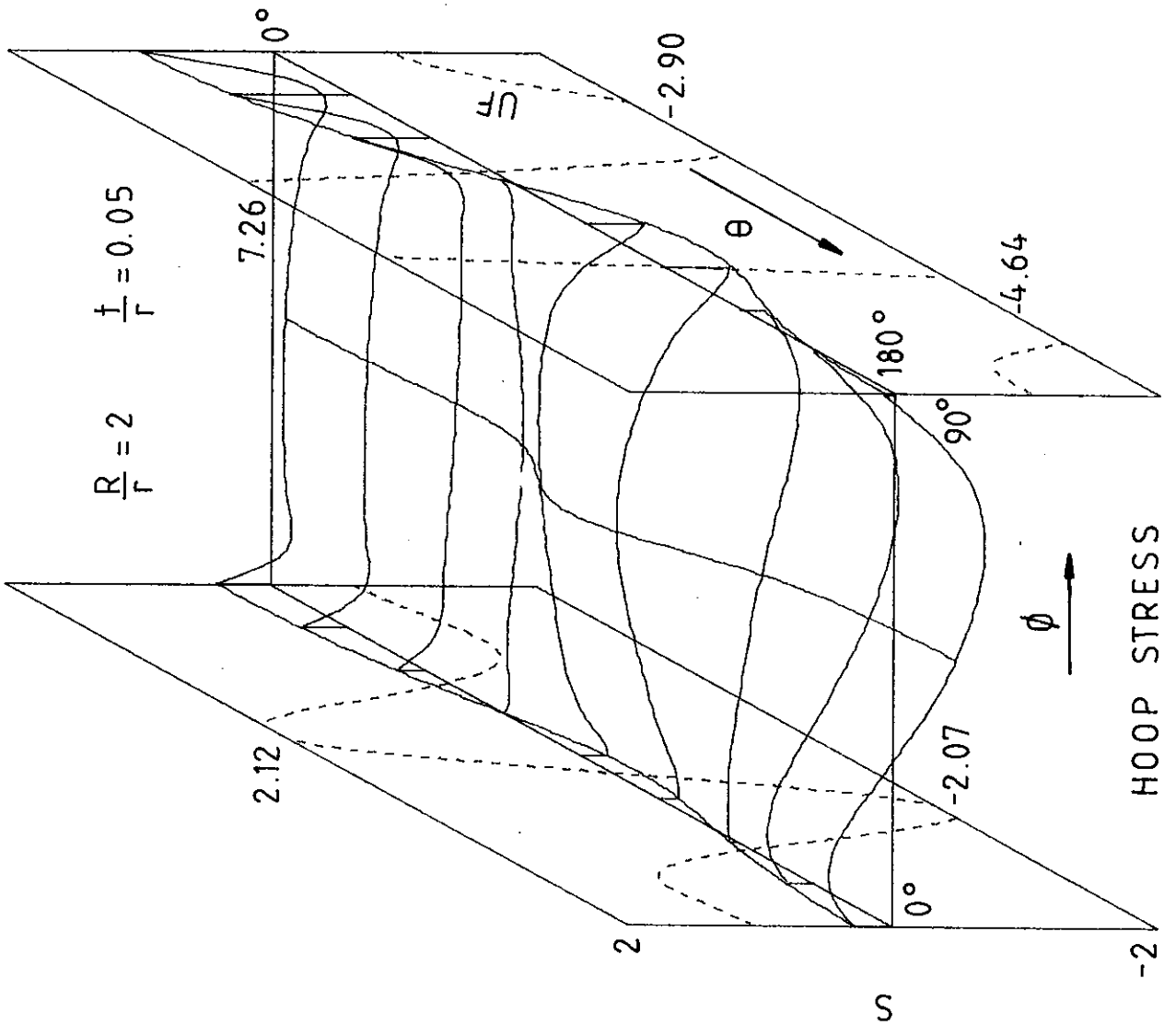
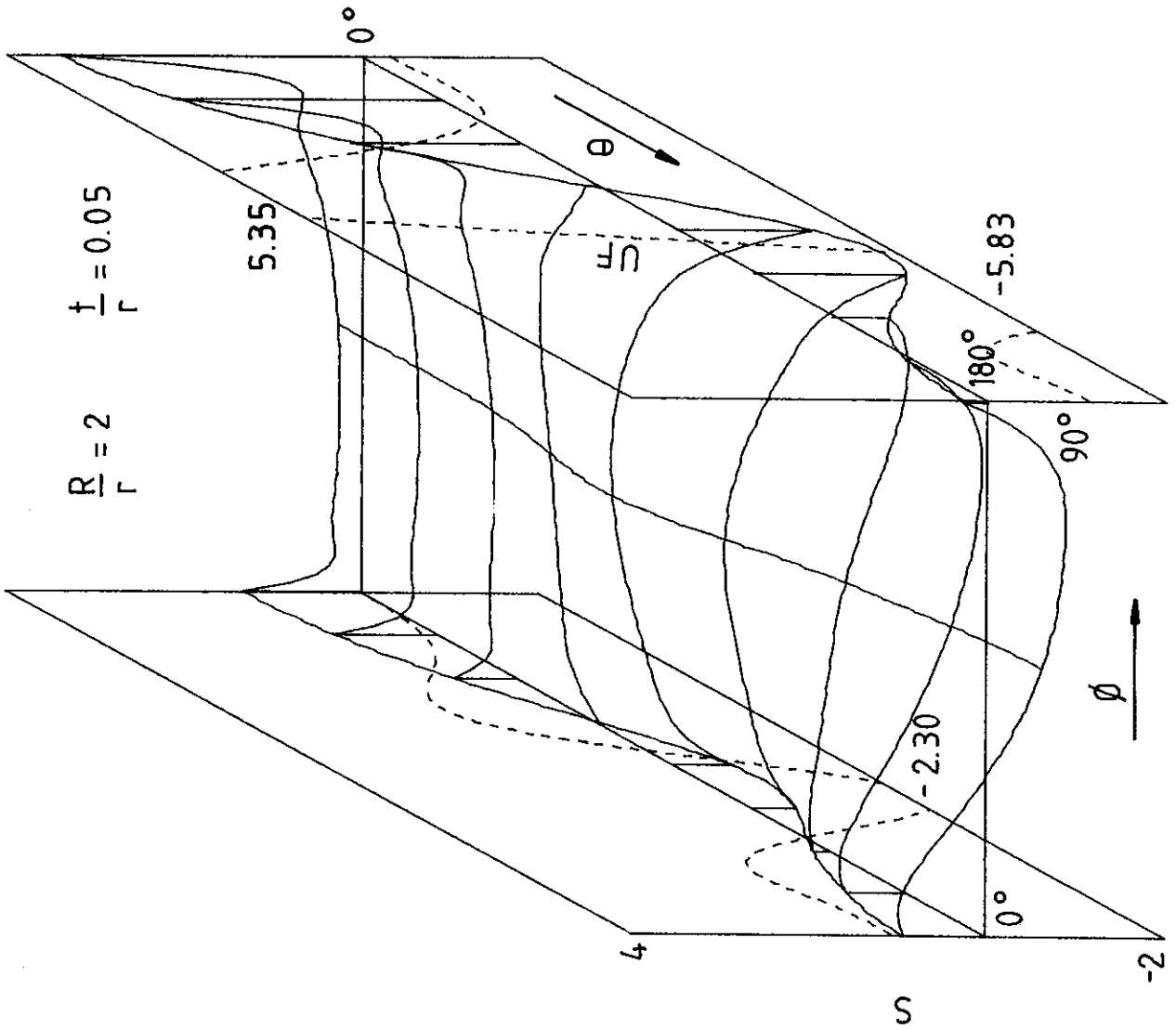

0°
UF
-2.90
7.26
θ
-4.64
180°
90°
$\frac{R}{r} = 2$
$\frac{t}{r} = 0.05$
ϕ
2.12
-2.07
0°
2
-2
S
HOOP STRESS

FIGURE A5



AXIAL STRESS

FIGURE A6

TABLE A5

R/r = 2.0 t/r = 0.05

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3954	-0.1600	-0.1245	-0.1013	-0.0932	-0.0930	-0.1020	-0.1212	-0.1526	-0.1967	-0.2753	-0.3814	1.0177	0.2459 -0.8641
22.5	0.3514	-0.1481	-0.1324	-0.1196	-0.1184	-0.1227	-0.1342	-0.1535	-0.1816	-0.2174	-0.2796	-0.3437	0.9076	0.9310 -1.7357
45.0	0.2129	-0.1070	-0.1333	-0.1551	-0.1793	-0.2013	-0.2208	-0.2368	-0.2474	-0.2495	-0.2534	-0.2260	0.5719	2.3984 -2.8812
67.5	-0.0119	-0.0324	-0.0301	-0.0606	-0.0923	-0.1168	-0.1299	-0.1287	-0.1119	-0.0792	-0.0414	-0.0447	0.0403	0.3554 1.1226
90.0	-0.2022	-0.0049	0.1297	0.1931	0.2435	0.2864	0.3189	0.3377	0.3374	0.3142	0.2475	0.0036	-0.4565	-5.7270 7.2329
112.5	-0.1517	-0.0633	0.0523	0.1459	0.2337	0.3033	0.3360	0.3206	0.2552	0.1475	-0.0047	-0.2556	-0.5097	-2.4647 0.6523
135.0	0.0562	0.0714	0.0484	0.0014	-0.0504	-0.1069	-0.1752	-0.2566	-0.3434	-0.4181	-0.4540	-0.4019	-0.1927	3.9147 -4.5341
157.5	0.2026	0.3557	0.2942	0.1280	-0.0641	-0.2445	-0.3974	-0.5154	-0.5928	-0.6164	-0.5495	-0.3316	0.0204	2.6676 -1.5186
180.0	0.2751	0.4791	0.3934	0.1769	-0.0669	-0.2880	-0.4660	-0.5944	-0.6701	-0.6790	-0.5786	-0.3103	0.0789	2.0911 -1.0336

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.3179	0.2850	0.3019	0.2543	0.2348	0.2380	0.2619	0.3085	0.3829	0.4976	0.6709	0.6690	3.3924	0.3055 -0.2856
22.5	1.1714	0.2825	0.2955	0.2497	0.2289	0.2304	0.2532	0.2996	0.3743	0.4879	0.6523	0.6572	3.0254	0.5243 -0.3464
45.0	0.7098	0.2777	0.3031	0.2757	0.2623	0.2666	0.2911	0.3388	0.4113	0.5116	0.6357	0.6234	1.9065	-0.0885 1.0458
67.5	-0.0398	0.2264	0.3419	0.3911	0.4341	0.4763	0.5215	0.5696	0.6139	0.6436	0.6418	0.4746	0.1343	-3.3980 4.8176
90.0	-0.6740	0.0104	0.2392	0.3917	0.5256	0.6299	0.6966	0.7160	0.6736	0.5562	0.3584	-0.0593	-1.5215	-3.7536 2.8162
112.5	-0.5057	-0.1562	-0.0083	0.1094	0.2221	0.2973	0.3102	0.2466	0.1005	-0.1183	-0.3843	-0.7746	-1.6991	3.1330 -5.1786
135.0	0.1874	0.2146	0.1476	0.0741	0.0128	-0.0600	-0.1654	-0.3089	-0.4813	-0.6583	-0.8013	-0.8569	-0.6423	4.2586 -3.5269
157.5	0.6752	0.7348	0.5026	0.2163	-0.0495	-0.2810	-0.4747	-0.6272	-0.7381	-0.8090	-0.8139	-0.6240	0.0679	2.1692 -0.9343
180.0	0.9171	0.9155	0.5908	0.2128	-0.1294	-0.4113	-0.6223	-0.7609	-0.8408	-0.8798	-0.8497	-0.5835	0.2631	2.1866 -1.1432

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1219	0.0978	0.0623	0.0331	0.0090	-0.0138	-0.0380	-0.0660	-0.1007	-0.1461	-0.2105	-0.2980	-0.3569	-0.0032
45.0	0.1953	0.1542	0.1048	0.0532	0.0066	-0.0401	-0.0905	-0.1476	-0.2153	-0.2989	-0.4084	-0.5262	-0.6155	-0.1841
67.5	0.1606	0.1115	0.0702	0.0119	-0.0481	-0.1106	-0.1773	-0.2497	-0.3292	-0.4183	-0.5175	-0.5855	-0.6627	-0.7725
90.0	0.0005	-0.0211	-0.0647	-0.1199	-0.1798	-0.2394	-0.2971	-0.3526	-0.4053	-0.4525	-0.4850	-0.4864	-0.4633	-1.1841
112.5	-0.1882	-0.1674	-0.2108	-0.2590	-0.3100	-0.3580	-0.3983	-0.4281	-0.4432	-0.4367	-0.4050	-0.3639	-0.1947	-0.3171
135.0	-0.3054	-0.3149	-0.3404	-0.3695	-0.3984	-0.4226	-0.4353	-0.4290	-0.3972	-0.3383	-0.2644	-0.1908	-0.0437	0.4817
157.5	-0.2780	-0.2891	-0.3183	-0.3467	-0.3615	-0.3557	-0.3268	-0.2760	-0.2098	-0.1410	-0.0851	-0.0442	0.0122	0.2453
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	0.743	1.797	2.749	3.581	4.244	4.674	4.809	4.592	3.981	2.927	1.342	0.0	-84.157 101.501

TABLE A6

R/r = 2.0 t/r = 0.05

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.0907	-0.0636	-0.0918	-0.0740	-0.0712	-0.0740	-0.0816	-0.0943	-0.1136	-0.1427	-0.2062	-0.1438	-0.2503	-0.3375	0.8654
22.5	-0.0736	-0.0503	-0.0686	-0.0467	-0.0394	-0.0384	-0.0429	-0.0534	-0.0718	-0.1014	-0.1646	-0.1151	-0.2100	-1.0634	1.7640
45.0	-0.0189	-0.0353	-0.0211	0.0190	0.0463	0.0641	0.0707	0.0638	0.0409	-0.0006	-0.0748	-0.0772	-0.0881	-2.5960	2.8487
67.5	0.0672	-0.0793	-0.0644	-0.0331	-0.0048	0.0163	0.0223	0.0088	-0.0236	-0.0693	-0.1292	-0.1545	0.0891	-0.0896	-1.9492
90.0	0.1219	-0.1233	-0.1806	-0.2453	-0.3054	-0.3542	-0.3933	-0.4201	-0.4263	-0.4003	-0.3486	-0.2868	0.1811	7.2996	-9.2749
112.5	0.0874	-0.0044	-0.0247	-0.1023	-0.2024	-0.2905	-0.3482	-0.3656	-0.3396	-0.2785	-0.2194	-0.2080	0.0178	4.2146	-1.8869
135.0	0.0875	0.1152	0.1764	0.1990	0.1916	0.1726	0.1493	0.1200	0.0778	0.0159	-0.0686	-0.1622	-0.2306	-3.0823	4.6040
157.5	0.1274	0.1903	0.2352	0.2291	0.1911	0.1333	0.0558	-0.0420	-0.1502	-0.2417	-0.2783	-0.2591	-0.3578	-1.8982	1.5491
180.0	0.1081	0.2510	0.3106	0.2640	0.1544	0.0180	-0.1248	-0.2587	-0.3629	-0.4077	-0.3688	-0.2888	-0.4122	-1.2535	1.0297

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.3024	0.4878	0.3044	0.2602	0.2405	0.2425	0.2666	0.3149	0.3931	0.5080	0.6733	1.1873	-0.8344	0.4069	-0.3164
22.5	-0.2454	0.4606	0.3053	0.2674	0.2510	0.2546	0.2795	0.3280	0.4046	0.5136	0.6659	1.1131	-0.6999	0.2489	0.0641
45.0	-0.0631	0.3690	0.3084	0.3067	0.3126	0.3297	0.3612	0.4084	0.4718	0.5475	0.6336	0.8629	-0.2936	-0.8557	1.6092
67.5	0.2240	0.1962	0.2596	0.3334	0.3888	0.4360	0.4770	0.5091	0.5268	0.5164	0.4517	0.3842	0.2971	-1.8894	2.1155
90.0	0.4062	0.0192	0.0934	0.1938	0.2598	0.3010	0.3173	0.3039	0.2536	0.1504	-0.0389	-0.2021	0.6037	1.2398	-2.2038
112.5	0.2915	0.0476	0.0414	0.0684	0.0657	0.0390	-0.0066	-0.0712	-0.1574	-0.2746	-0.4288	-0.4828	0.0595	3.5085	-3.1149
135.0	0.2916	0.1977	0.1843	0.1741	0.1353	0.0740	-0.0004	-0.0835	-0.1722	-0.2627	-0.3508	-0.4529	-0.7687	-0.3030	1.5266
157.5	0.4245	0.1833	0.1811	0.1937	0.1663	0.1041	0.0209	-0.0704	-0.1546	-0.2185	-0.2858	-0.4994	-1.1927	-1.5710	1.6202
180.0	0.3602	0.1158	0.1399	0.1727	0.1507	0.0820	-0.0121	-0.1102	-0.1891	-0.2357	-0.2952	-0.5557	-1.3740	-1.3454	1.1249

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1159	0.1130	0.0623	0.0320	0.0080	-0.0134	-0.0352	-0.0606	-0.0935	-0.1394	-0.2055	-0.3269	-0.3395	0.1073
45.0	0.1857	0.2214	0.1352	0.0751	0.0235	-0.0257	-0.0779	-0.1382	-0.2129	-0.3099	-0.4408	-0.6500	-0.5855	0.3400
67.5	0.1528	0.2484	0.1797	0.1068	0.0299	-0.0542	-0.1481	-0.2542	-0.3746	-0.5107	-0.6660	-0.8392	-0.6304	0.4283
90.0	0.0005	0.0503	0.0458	-0.0013	-0.0771	-0.1745	-0.2863	-0.4038	-0.5159	-0.6089	-0.6625	-0.6347	-0.4407	-0.3885
112.5	-0.1790	-0.2867	-0.3110	-0.3407	-0.3840	-0.4330	-0.4773	-0.5029	-0.4946	-0.4363	-0.3127	-0.1478	-0.1852	-1.4586
135.0	-0.2905	-0.4458	-0.5704	-0.6412	-0.6604	-0.6319	-0.5614	-0.4545	-0.3185	-0.1638	-0.0127	0.0699	-0.0416	-1.1150
157.5	-0.2644	-0.3717	-0.4750	-0.5344	-0.5366	-0.4841	-0.3898	-0.2724	-0.1516	-0.0457	0.0274	0.0479	0.0116	-0.4722
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
180.0	0.0	-0.705	-1.358	-2.093	-2.815	-3.408	-3.796	-3.932	-3.795	-3.379	-2.705	-1.711	0.0	57.885	-66.861

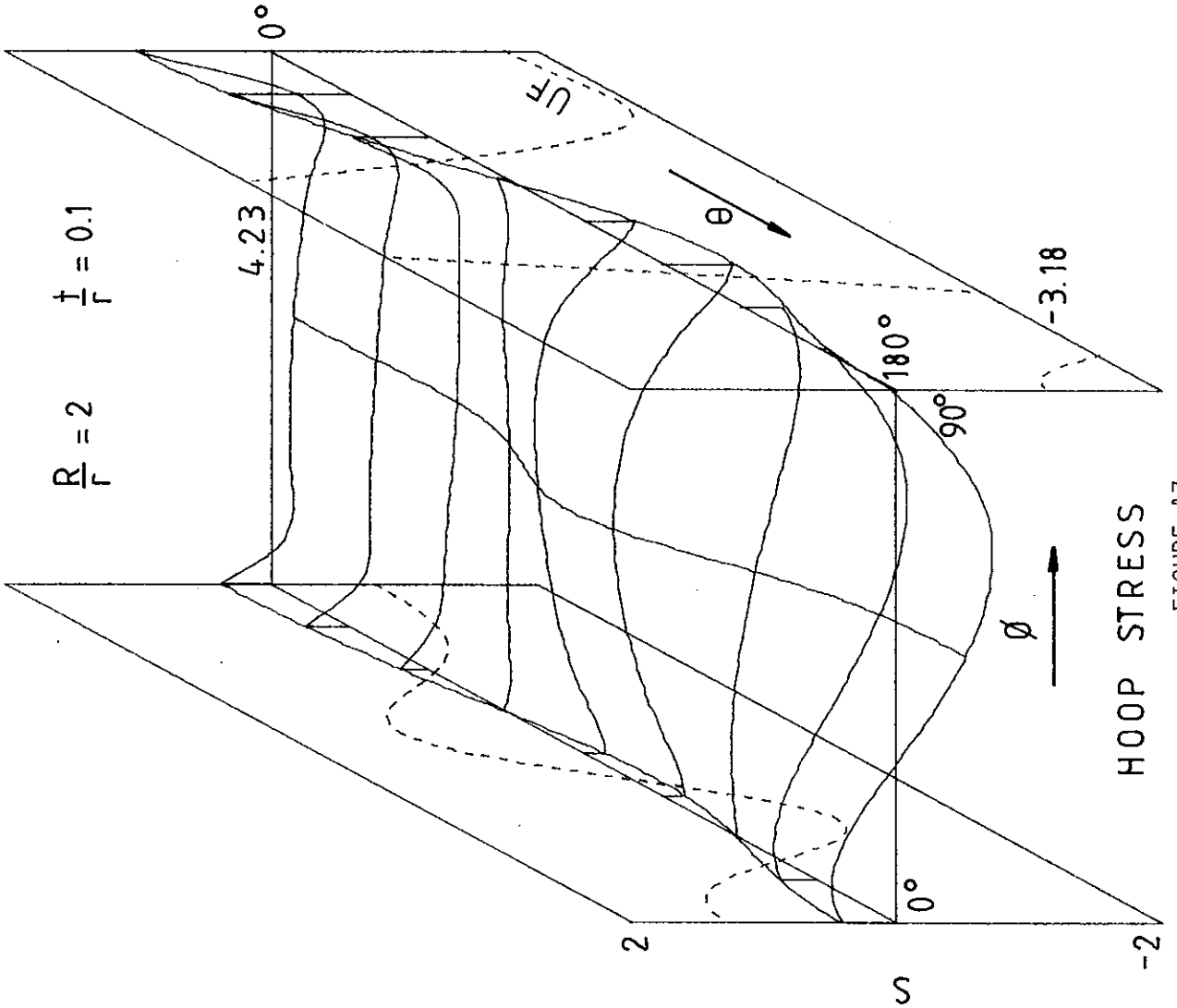


FIGURE A7

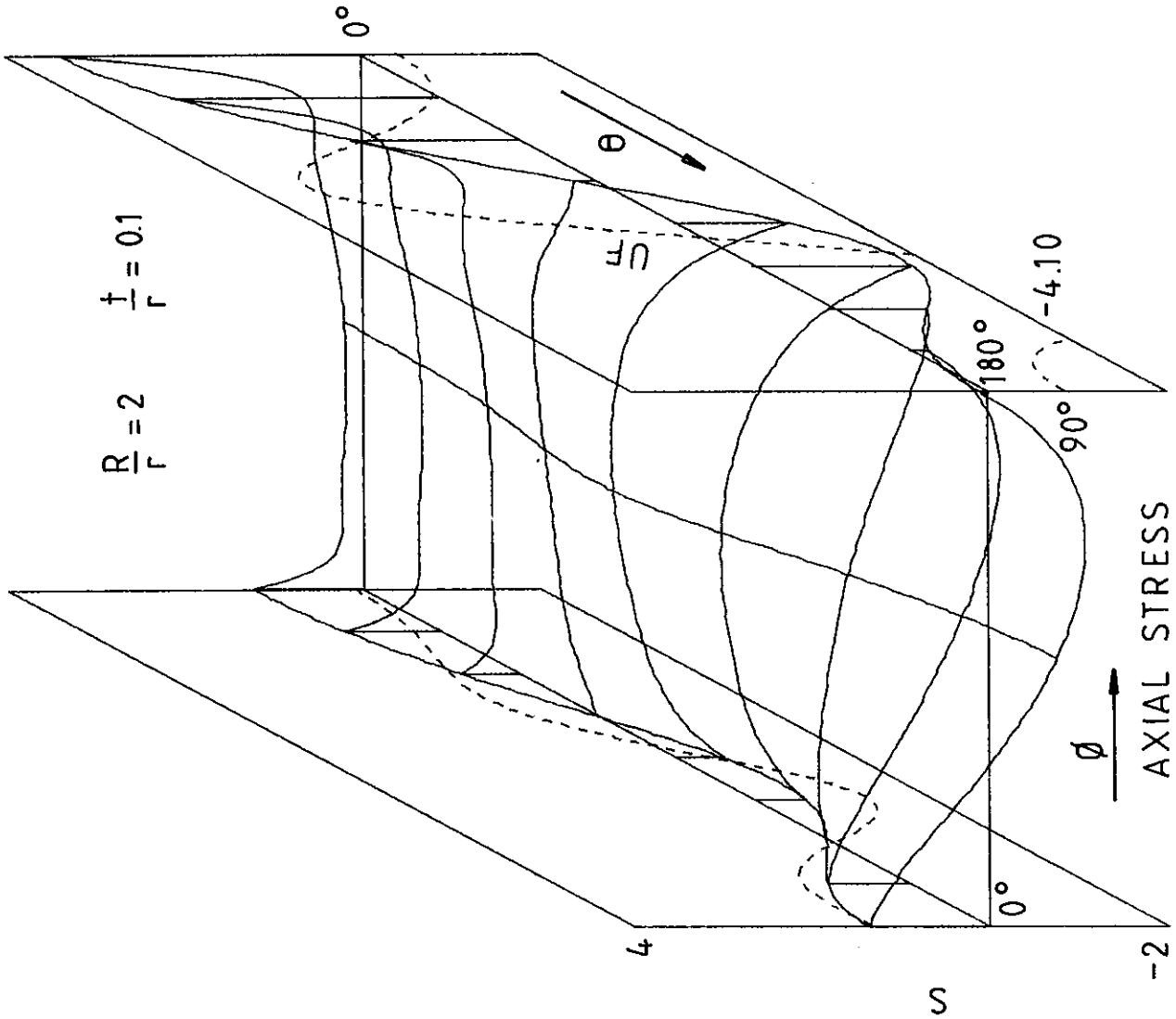


FIGURE A8

TABLE A7

R/r = 2.0 t/r = 0.1

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3689	-0.0971	-0.1681	-0.1467	-0.1448	-0.1540	-0.1710	-0.1963	-0.2300	-0.2845	-0.3848	-0.2171	1.0191	0.9720 -1.7442
22.5	0.3248	-0.0880	-0.1655	-0.1599	-0.1691	-0.1857	-0.2058	-0.2289	-0.2541	-0.2921	-0.3615	-0.1827	0.9013	1.2453 -1.9071
45.0	0.1960	-0.0624	-0.1287	-0.1485	-0.1760	-0.2026	-0.2229	-0.2345	-0.2356	-0.2343	-0.2429	-0.0924	0.5619	1.2244 -1.3245
67.5	0.0075	-0.0368	-0.0173	-0.0124	-0.0202	-0.0261	-0.0241	-0.0128	0.0068	0.0236	0.0116	-0.0146	0.0714	-0.6793 1.5405
90.0	-0.1592	-0.0478	0.0986	0.1936	0.2595	0.3111	0.3494	0.3702	0.3667	0.3218	0.1926	-0.0835	-0.3825	-3.3205 4.2128
112.5	-0.1717	-0.0677	0.0833	0.2014	0.2874	0.3446	0.3680	0.3505	0.2864	0.1669	-0.0287	-0.3108	-0.5332	-2.0743 1.5342
135.0	0.0212	0.0540	0.0662	0.0494	0.0102	-0.0453	-0.1151	-0.1973	-0.2863	-0.3718	-0.4356	-0.4391	-0.3237	2.0656 -2.8364
157.5	0.2815	0.3262	0.2329	0.0695	-0.1180	-0.3008	-0.4605	-0.5839	-0.6576	-0.6632	-0.5748	-0.3677	-0.0614	3.0251 -2.3514
180.0	0.4047	0.4753	0.3530	0.1386	-0.1028	-0.3312	-0.5216	-0.6572	-0.7230	-0.7005	-0.5673	-0.3114	0.0262	2.4286 -1.1576

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.2296	0.2544	0.2285	0.2092	0.1820	0.1775	0.1963	0.2399	0.3183	0.4393	0.5246	0.6376	3.3969	0.5232 -0.4041
22.5	1.0826	0.2605	0.2433	0.2269	0.2024	0.2000	0.2212	0.2676	0.3482	0.4677	0.5503	0.6489	3.0043	0.2682 0.0575
45.0	0.6534	0.2599	0.2926	0.3017	0.2992	0.3134	0.3471	0.4009	0.4792	0.5785	0.6277	0.6329	1.8731	-0.8392 1.6332
67.5	0.0252	0.1891	0.3405	0.4211	0.4788	0.5367	0.5947	0.6488	0.6955	0.7216	0.6605	0.4268	0.2381	-2.5234 3.3249
90.0	-0.5308	-0.0015	0.2683	0.4259	0.5453	0.6407	0.7040	0.7243	0.6928	0.5943	0.3721	-0.1357	-1.2749	-2.1508 1.7780
112.5	-0.5723	-0.1364	0.0933	0.2222	0.3102	0.3622	0.3644	0.3045	0.1777	-0.0188	-0.3154	-0.8310	-1.7773	1.5176 -2.8026
135.0	0.0705	0.1598	0.1553	0.1005	0.0268	-0.0640	-0.1815	-0.3311	-0.5072	-0.6951	-0.8796	-1.0425	-1.0790	3.7202 -3.7764
157.5	0.9383	0.7757	0.5001	0.1963	-0.0952	-0.3584	-0.5880	-0.7794	-0.9245	-1.0056	-0.9836	-0.7723	-0.2047	2.7409 -1.5238
180.0	1.3489	1.0754	0.6739	0.2486	-0.1487	-0.4906	-0.7620	-0.9546	-1.0636	-1.0779	-0.9604	-0.6213	0.0874	2.1854 -0.8583

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0905	0.0640	0.0503	0.0259	0.0036	-0.0185	-0.0423	-0.0696	-0.1024	-0.1447	-0.2010	-0.2340	-0.2955	-0.0760
45.0	0.1407	0.0867	0.0654	0.0240	-0.0170	-0.0581	-0.1018	-0.1504	-0.2067	-0.2758	-0.3584	-0.3941	-0.5043	-0.2927
67.5	0.1145	0.0436	0.0124	-0.0366	-0.0876	-0.1379	-0.1886	-0.2417	-0.2991	-0.3635	-0.4279	-0.4451	-0.5569	-0.6718
90.0	0.0018	-0.0453	-0.0943	-0.1476	-0.1993	-0.2466	-0.2893	-0.3283	-0.3647	-0.3988	-0.4262	-0.4341	-0.4475	-0.8775
112.5	-0.1535	-0.1355	-0.1807	-0.2326	-0.2823	-0.3272	-0.3654	-0.3953	-0.4157	-0.4266	-0.4306	-0.4189	-0.2715	-0.4218
135.0	-0.2674	-0.2114	-0.2215	-0.2549	-0.2968	-0.3407	-0.3800	-0.4079	-0.4193	-0.4130	-0.3901	-0.3325	-0.1424	0.2957
157.5	-0.2383	-0.1952	-0.1918	-0.2076	-0.2310	-0.2546	-0.2718	-0.2769	-0.2669	-0.2430	-0.2077	-0.1549	-0.0636	0.3511
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	0.426	1.177	1.908	2.535	3.023	3.332	3.415	3.229	2.725	1.865	0.740	0.0	-34.050 41.610

TABLE A8

R/r = 2.0 t/r = 0.1

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0990	0.0321	-0.0349	-0.0196	-0.0050	0.0001	0.0003	-0.0041	-0.0176	-0.0547	-0.0896	0.1044	-0.2969	-1.0663	1.7450
22.5	-0.0784	0.0247	-0.0238	0.0031	0.0277	0.0407	0.0455	0.0411	0.0228	-0.0231	-0.0722	0.0829	-0.2466	-1.3675	1.9088
45.0	-0.0180	-0.0085	-0.0276	0.0160	0.0552	0.0793	0.0877	0.0781	0.0460	-0.0182	-0.0906	-0.0051	-0.1051	-1.2984	1.1579
67.5	0.0703	-0.0700	-0.1082	-0.0948	-0.0830	-0.0825	-0.0945	-0.1198	-0.1584	-0.2110	-0.2533	-0.1637	0.0811	1.0690	-2.3647
90.0	0.1467	-0.0944	-0.1957	-0.2709	-0.3460	-0.4155	-0.4709	-0.5049	-0.5118	-0.4894	-0.4296	-0.2683	0.1970	4.5626	-5.8181
112.5	0.1584	-0.0090	-0.0922	-0.1892	-0.2997	-0.3978	-0.4617	-0.4790	-0.4484	-0.3827	-0.3038	-0.1981	0.1122	3.6131	-2.8123
135.0	0.1021	0.0987	0.1291	0.1341	0.1107	0.0767	0.0472	0.0274	0.0115	-0.0150	-0.0658	-0.1273	-0.1313	-1.0521	2.6379
157.5	0.0088	0.1295	0.2270	0.2870	0.3085	0.2943	0.2475	0.1719	0.0753	-0.0285	-0.1228	-0.2032	-0.3239	-2.2527	2.4216
180.0	-0.0543	0.1324	0.2462	0.2965	0.2953	0.2497	0.1658	0.0548	-0.0634	-0.1619	-0.2208	-0.2583	-0.3829	-1.6143	1.1554

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.3299	0.4573	0.3208	0.2432	0.2250	0.2282	0.2529	0.3031	0.3802	0.4955	0.7631	1.1730	-0.9896	0.1898	0.0954
22.5	-0.2615	0.4299	0.3243	0.2641	0.2554	0.2651	0.2934	0.3438	0.4161	0.5190	0.7515	1.0830	-0.8219	-0.1238	0.5047
45.0	-0.0600	0.3511	0.3169	0.3080	0.3284	0.3563	0.3924	0.4377	0.4881	0.5445	0.6675	0.8133	-0.3502	-0.7917	1.2400
67.5	0.2343	0.2440	0.2539	0.3016	0.3537	0.3957	0.4283	0.4499	0.4516	0.4252	0.3979	0.4029	0.2704	-0.7231	0.8195
90.0	0.4889	0.1744	0.1359	0.1796	0.2200	0.2386	0.2363	0.2114	0.1550	0.0584	-0.0480	-0.0013	0.6565	0.9615	-1.3134
112.5	0.5280	0.1964	0.0864	0.0639	0.0451	0.0086	-0.0439	-0.1099	-0.1921	-0.2881	-0.3529	-0.2255	0.3740	2.1495	-2.0488
135.0	0.3403	0.2016	0.1382	0.1076	0.0714	0.0190	-0.0453	-0.1150	-0.1856	-0.2517	-0.3006	-0.3278	-0.4377	0.4856	0.2982
157.5	0.0293	0.0284	0.0948	0.1558	0.1850	0.1793	0.1459	0.0939	0.0293	-0.0531	-0.1876	-0.4684	-1.0798	-1.3283	1.6537
180.0	-0.1811	-0.1211	0.0168	0.1397	0.2168	0.2451	0.2317	0.1870	0.1168	0.0113	-0.1761	-0.5517	-1.2763	-1.6252	1.4772

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0819	0.1202	0.0733	0.0413	0.0173	-0.0052	-0.0293	-0.0582	-0.0956	-0.1465	-0.2266	-0.3572	-0.2674	0.1509
45.0	0.1273	0.2151	0.1474	0.0879	0.0367	-0.0149	-0.0716	-0.1382	-0.2198	-0.3238	-0.4704	-0.6624	-0.4563	0.2849
67.5	0.1036	0.2200	0.1720	0.1015	0.0254	-0.0587	-0.1528	-0.2589	-0.3786	-0.5129	-0.6660	-0.7927	-0.5039	0.2054
90.0	0.0016	0.0559	0.0367	-0.0212	-0.1017	-0.1972	-0.3019	-0.4098	-0.5128	-0.5984	-0.6476	-0.6163	-0.4049	-0.3647
112.5	-0.1388	-0.2378	-0.2894	-0.3376	-0.3918	-0.4461	-0.4912	-0.5167	-0.5100	-0.4573	-0.3528	-0.2325	-0.2457	-1.1448
135.0	-0.2419	-0.4444	-0.5725	-0.6394	-0.6600	-0.6399	-0.5809	-0.4842	-0.3531	-0.1988	-0.0531	0.0089	-0.1289	-1.2152
157.5	-0.2156	-0.3705	-0.4868	-0.5467	-0.5493	-0.5010	-0.4116	-0.2950	-0.1689	-0.0557	0.0166	0.0186	-0.0575	-0.5886
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-0.543	-1.187	-1.810	-2.417	-2.930	-3.278	-3.412	-3.301	-2.945	-2.349	-1.284	0.0	28.858	-33.606

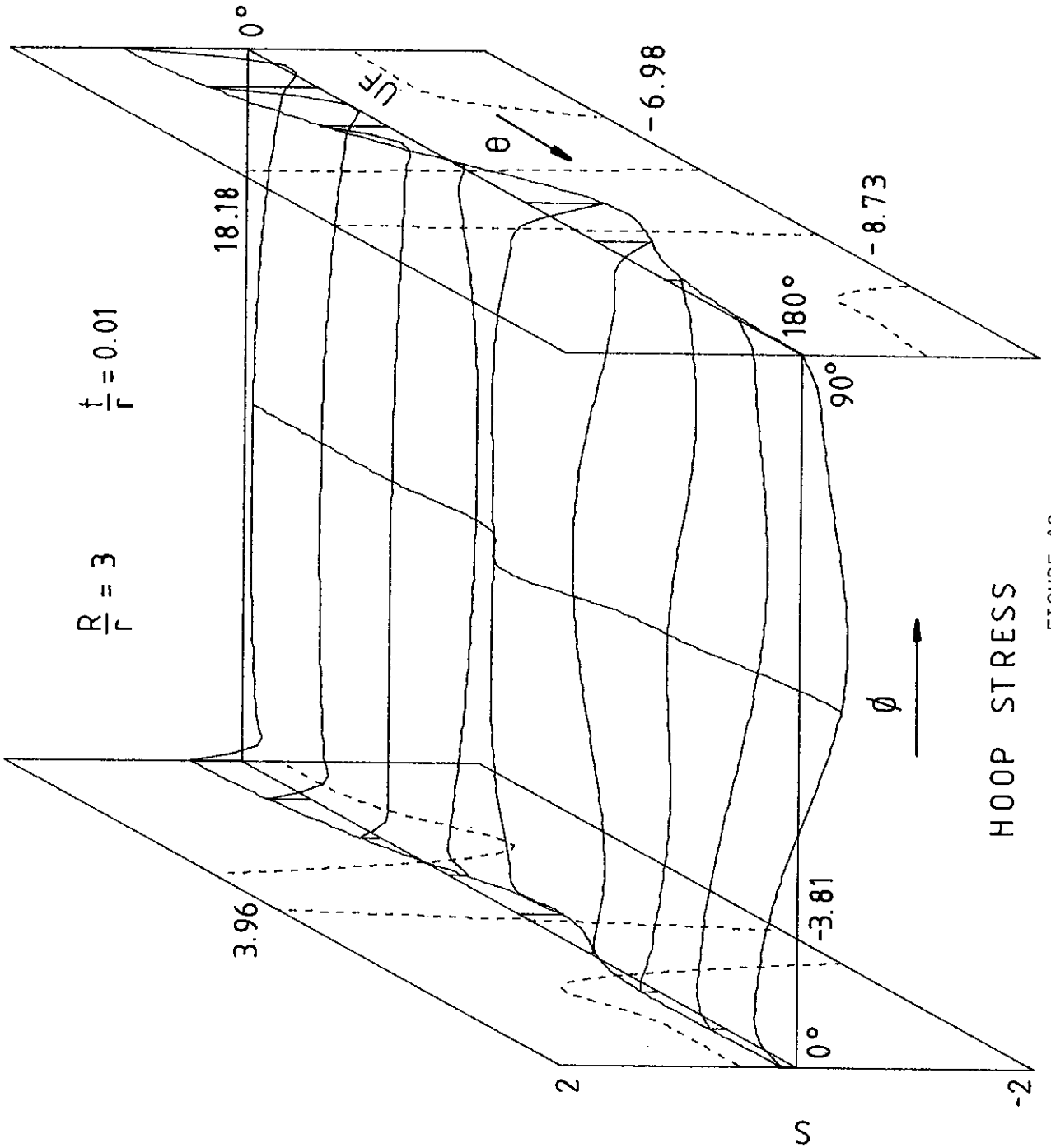

0°
18.18
-6.98
-8.73
180°
90°
θ
$\frac{R}{r} = 3$
$\frac{t}{r} = 0.01$
3.96
-3.81
0°
2
-2
S
ϕ
HOOP STRESS

FIGURE A9

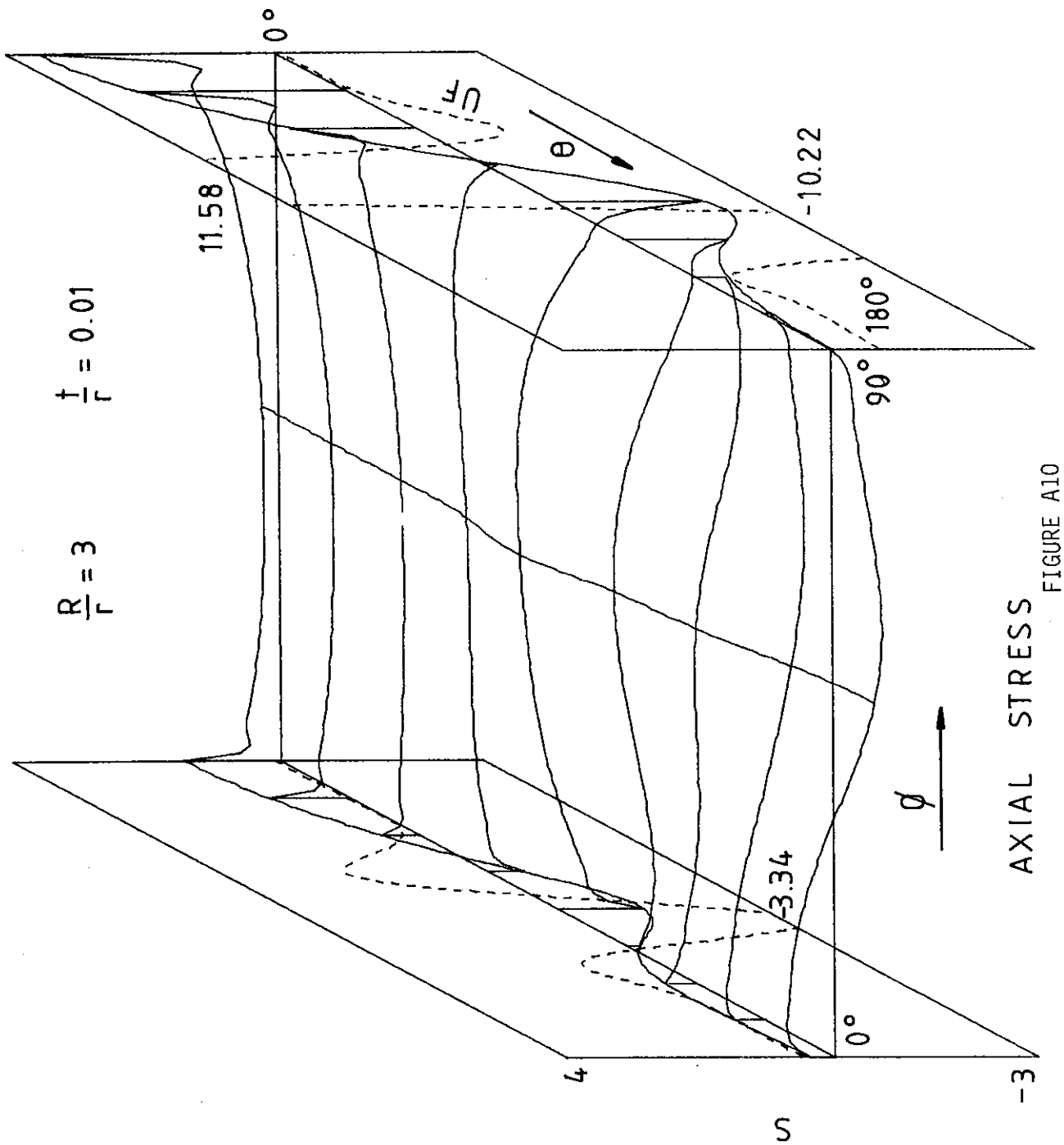

0°
U_T
θ
11.58
-10.22
180°
90°
$\frac{t}{r} = 0.01$
$\frac{R}{r} = 3$
-3.34
0°
φ
AXIAL STRESS
4
-3
S

FIGURE A10

TABLE A9

R/r = 3.0 t/r = 0.01

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.4271	-0.1141	-0.0863	-0.0704	-0.0632	-0.0630	-0.0694	-0.0831	-0.1058	-0.1409	-0.1941	-0.2735	1.0557	0.5456 -0.8527
22.5	0.3630	-0.0990	-0.0776	-0.0646	-0.0588	-0.0591	-0.0655	-0.0785	-0.0996	-0.1313	-0.1775	-0.2422	0.9284	0.4599 -0.8132
45.0	0.1732	-0.0664	-0.0691	-0.0686	-0.0682	-0.0699	-0.0750	-0.0844	-0.0988	-0.1184	-0.1416	-0.1627	0.5562	2.3238 -3.3085
67.5	-0.1550	-0.0181	-0.0736	-0.1215	-0.1570	-0.1816	-0.1978	-0.2058	-0.2024	-0.1810	-0.1354	-0.0655	-0.0633	6.1749 -4.4420
90.0	-0.3782	0.1014	0.1927	0.2411	0.2541	0.2502	0.2457	0.2494	0.2593	0.2610	0.2282	0.1387	-0.6569	-16.4706 18.1680
112.5	-0.0538	-0.1218	-0.1168	-0.0491	0.0358	0.1080	0.1534	0.1614	0.1207	0.0277	-0.0933	-0.1763	-0.4658	2.9610 -6.2355
135.0	0.1458	0.0297	-0.0451	-0.0883	-0.0824	-0.0577	-0.0578	-0.1063	-0.1900	-0.2638	-0.2811	-0.2412	-0.1447	3.6769 -2.8711
157.5	0.1418	0.2417	0.1862	0.0947	-0.0229	-0.1396	-0.2345	-0.2933	-0.3061	-0.2770	-0.2295	-0.1887	-0.0308	1.6083 -1.1496
180.0	0.1164	0.3508	0.2910	0.1664	-0.0141	-0.2062	-0.3487	-0.4011	-0.3716	-0.3000	-0.2211	-0.1584	-0.0028	1.5177 -1.0451

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.4236	0.4322	0.3116	0.2460	0.2165	0.2148	0.2385	0.2901	0.3767	0.5123	0.7220	1.0530	3.5188	0.1488 -0.0455
22.5	1.2102	0.3996	0.3008	0.2451	0.2203	0.2209	0.2458	0.2974	0.3820	0.5110	0.7035	0.9926	3.0946	0.1572 -0.0773
45.0	0.5775	0.2817	0.2451	0.2176	0.2059	0.2129	0.2406	0.2914	0.3686	0.4759	0.6147	0.7796	1.8540	1.4245 -1.1844
67.5	-0.5167	0.0772	0.1907	0.2373	0.2595	0.2794	0.3082	0.3502	0.4032	0.4543	0.4698	0.3776	-0.2110	-3.7046 5.8509
90.0	-1.2607	-0.2781	0.0372	0.2537	0.3945	0.4862	0.5475	0.5804	0.5649	0.4571	0.1909	-0.3116	-2.1896	-8.3006 6.0826
112.5	-0.1793	-0.3977	-0.3435	-0.1898	-0.0205	0.1116	0.1746	0.1442	-0.0000	-0.2646	-0.6180	-0.9636	-1.5525	9.1057 -9.7407
135.0	0.4859	0.1528	0.0083	-0.0495	-0.0277	0.0080	-0.0132	-0.1296	-0.3271	-0.5400	-0.6774	-0.6845	-0.4822	1.5531 -0.6012
157.5	0.4726	0.5321	0.4068	0.2153	-0.0078	-0.2215	-0.4027	-0.5350	-0.5977	-0.5805	-0.5052	-0.4160	-0.1027	1.2755 -0.7955
180.0	0.3879	0.6876	0.5778	0.3484	0.0181	-0.3363	-0.6079	-0.7236	-0.6888	-0.5685	-0.4277	-0.3093	-0.0094	1.2011 -0.7180

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1712	0.1115	0.0642	0.0333	0.0105	-0.0092	-0.0291	-0.0526	-0.0833	-0.1271	-0.1936	-0.3003	-0.4407	-0.0306
45.0	0.2645	0.1924	0.1175	0.0624	0.0180	-0.0226	-0.0647	-0.1138	-0.1764	-0.2612	-0.3810	-0.5555	-0.7420	-0.0525
67.5	0.1656	0.1578	0.1100	0.0599	0.0071	-0.0500	-0.1140	-0.1884	-0.2767	-0.3818	-0.5053	-0.6457	-0.7160	-0.6435
90.0	-0.1552	-0.0726	-0.0440	-0.0494	-0.0804	-0.1317	-0.1975	-0.2700	-0.3395	-0.3936	-0.4162	-0.3834	-0.2267	-1.2668
112.5	-0.2504	-0.2413	-0.2135	-0.2094	-0.2252	-0.2531	-0.2840	-0.3067	-0.3082	-0.2732	-0.1830	-0.0180	0.1787	0.3668
135.0	-0.1012	-0.2298	-0.3195	-0.3621	-0.3719	-0.3565	-0.3169	-0.2519	-0.1602	-0.0439	0.0823	0.1851	0.2106	0.2867
157.5	0.0029	-0.0962	-0.2154	-0.3078	-0.3453	-0.3185	-0.2363	-0.1202	-0.0006	0.0911	0.1355	0.1383	0.1198	0.1182
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	2.720	5.613	8.134	10.018	11.296	12.067	12.342	11.971	10.667	8.152	4.482	0.0	-609.657 656.591

TABLE A10

R/r = 3.0 t/r = 0.01

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0430	-0.1007	-0.0699	-0.0532	-0.0458	-0.0452	-0.0507	-0.0629	-0.0836	-0.1164	-0.1680	-0.2500	-0.1068	-0.6044	0.8530
22.5	-0.0296	-0.0876	-0.0641	-0.0509	-0.0451	-0.0451	-0.0505	-0.0618	-0.0806	-0.1098	-0.1541	-0.2216	-0.0787	-0.5254	0.8137
45.0	0.0039	-0.0408	-0.0277	-0.0198	-0.0169	-0.0185	-0.0243	-0.0342	-0.0489	-0.0691	-0.0966	-0.1324	-0.0077	-2.4724	3.3623
67.5	0.0461	0.0079	0.0415	0.0800	0.1102	0.1294	0.1384	0.1368	0.1221	0.0904	0.0415	-0.0093	0.0757	-6.1819	4.0990
90.0	0.0065	-0.1130	-0.2175	-0.2689	-0.2808	-0.2749	-0.2687	-0.2719	-0.2830	-0.2867	-0.2540	-0.1505	0.0391	18.3146	-20.2240
112.5	-0.0875	0.0421	0.0570	0.0227	-0.0269	-0.0722	-0.1076	-0.1286	-0.1268	-0.0980	-0.0605	-0.0616	-0.1882	-2.1115	5.8506
135.0	0.0412	0.0620	0.0711	0.0933	0.0942	0.0756	0.0548	0.0410	0.0243	-0.0182	-0.0959	-0.1697	-0.2097	-3.4790	2.9345
157.5	0.1967	0.2149	0.1521	0.0867	0.0336	-0.0125	-0.0610	-0.1157	-0.1726	-0.2145	-0.2176	-0.1845	-0.1608	-1.3713	1.1489
180.0	0.2714	0.2945	0.2408	0.1570	0.0496	-0.0614	-0.1599	-0.2318	-0.2617	-0.2476	-0.2090	-0.1645	-0.1318	-1.2820	1.0445

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.1434	0.4320	0.3137	0.2485	0.2192	0.2177	0.241[illegible]	0.2937	0.3808	0.5168	0.7265	1.0533	-0.3561	0.0797	0.0532
22.5	-0.0988	0.3972	0.3011	0.2460	0.2215	0.2223	0.2476	0.2996	0.3846	0.5137	0.7057	0.9889	-0.2623	0.1686	-0.0414
45.0	0.0130	0.2788	0.2510	0.2273	0.2172	0.2246	0.2522	0.3026	0.3790	0.4844	0.6185	0.7695	-0.0258	0.4362	0.1606
67.5	0.1535	0.0638	0.1999	0.2722	0.3146	0.3481	0.3847	0.4281	0.4740	0.5057	0.4878	0.3557	0.2523	-5.7464	6.5881
90.0	0.0217	-0.3216	-0.1014	0.0685	0.1942	0.2849	0.3450	0.3696	0.3411	0.2295	-0.0057	-0.4058	0.1302	3.0436	-5.4593
112.5	-0.2915	-0.2645	-0.2125	-0.1145	-0.0142	0.0590	0.0822	0.0382	-0.0831	-0.2826	-0.5468	-0.8323	-0.6273	5.4392	-3.6899
135.0	0.1373	0.1705	0.0861	0.0620	0.0637	0.0565	0.0137	-0.0794	-0.2221	-0.3938	-0.5502	-0.6266	-0.6989	-1.8034	2.1455
157.5	0.6558	0.4808	0.3589	0.2003	0.0347	-0.1240	-0.2688	-0.3918	-0.4804	-0.5175	-0.4923	-0.4123	-0.5360	-0.7266	0.7554
180.0	0.9046	0.5904	0.4917	0.3014	0.0533	-0.2035	-0.4161	-0.5454	-0.5763	-0.5251	-0.4312	-0.3233	-0.4392	-0.7425	0.7349

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1695	0.1144	0.0652	0.0336	0.0107	-0.0089	-0.0286	-0.0518	-0.0825	-0.1267	-0.1945	-0.3048	-0.4363	0.0544
45.0	0.2619	0.1993	0.1197	0.0628	0.0179	-0.0225	-0.0641	-0.1126	-0.1747	-0.2599	-0.3826	-0.5654	-0.7346	0.1927
67.5	0.1639	0.2045	0.1467	0.0837	0.0209	-0.0428	-0.1110	-0.1894	-0.2842	-0.4013	-0.5434	-0.7044	-0.7088	0.6154
90.0	-0.1537	-0.0545	0.0103	0.0139	-0.0249	-0.0919	-0.1783	-0.2767	-0.3773	-0.4621	-0.4995	-0.4417	-0.2245	-0.5771
112.5	-0.2479	-0.3293	-0.2855	-0.2384	-0.2224	-0.2441	-0.2893	-0.3301	-0.3329	-0.2670	-0.1192	0.0884	0.1769	-1.2277
135.0	-0.1002	-0.2251	-0.3585	-0.4360	-0.4522	-0.4201	-0.3500	-0.2443	-0.1089	0.0345	0.1494	0.2103	0.2085	-0.3831
157.5	0.0029	-0.0862	-0.2289	-0.3539	-0.4142	-0.3777	-0.2537	-0.0903	0.0522	0.1348	0.1574	0.1456	0.1186	-0.2086
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-0.870	-2.024	-3.680	-5.620	-7.399	-8.499	-8.595	-7.724	-6.204	-4.402	-2.587	0.0	313.478	-330.412

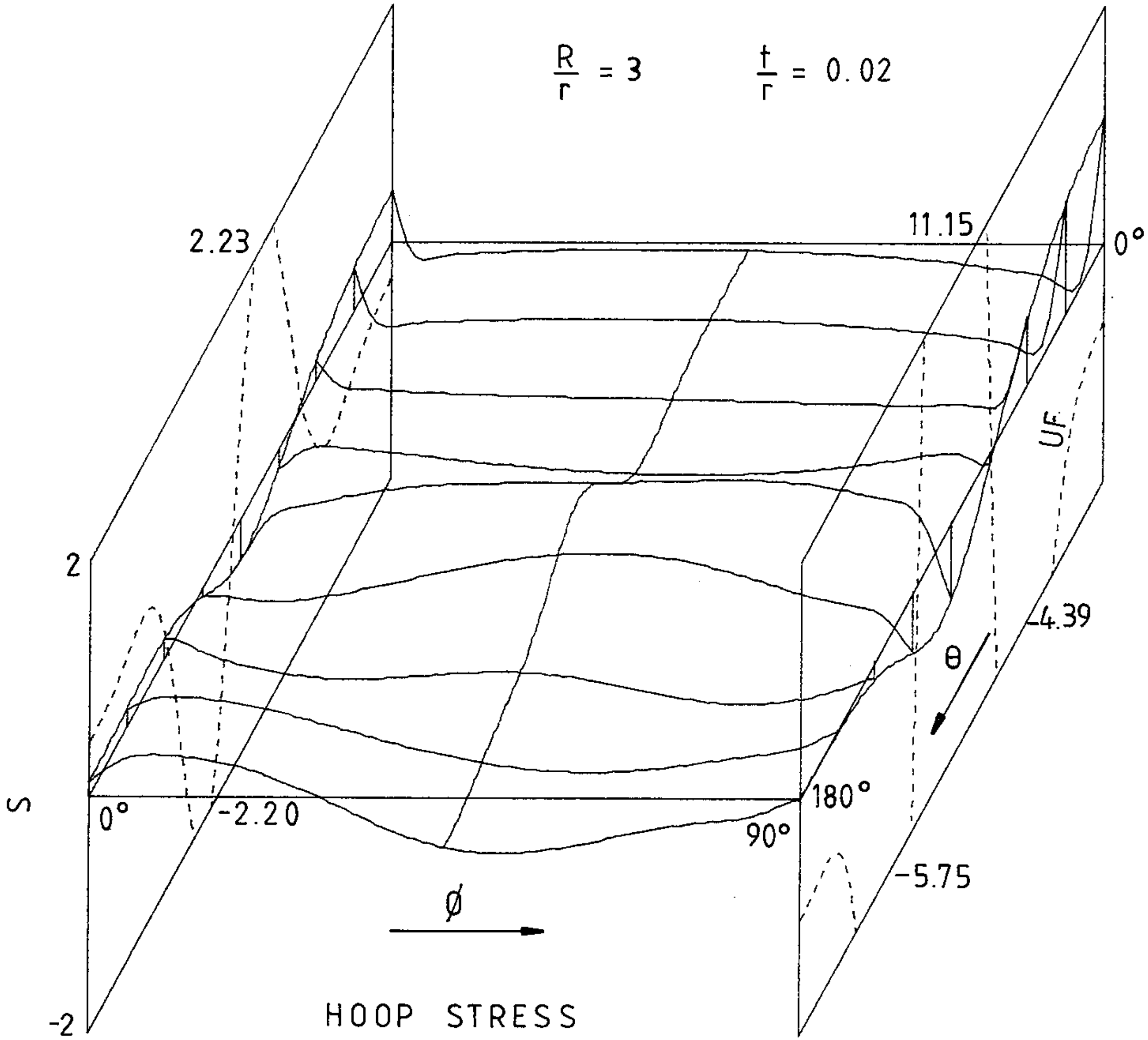
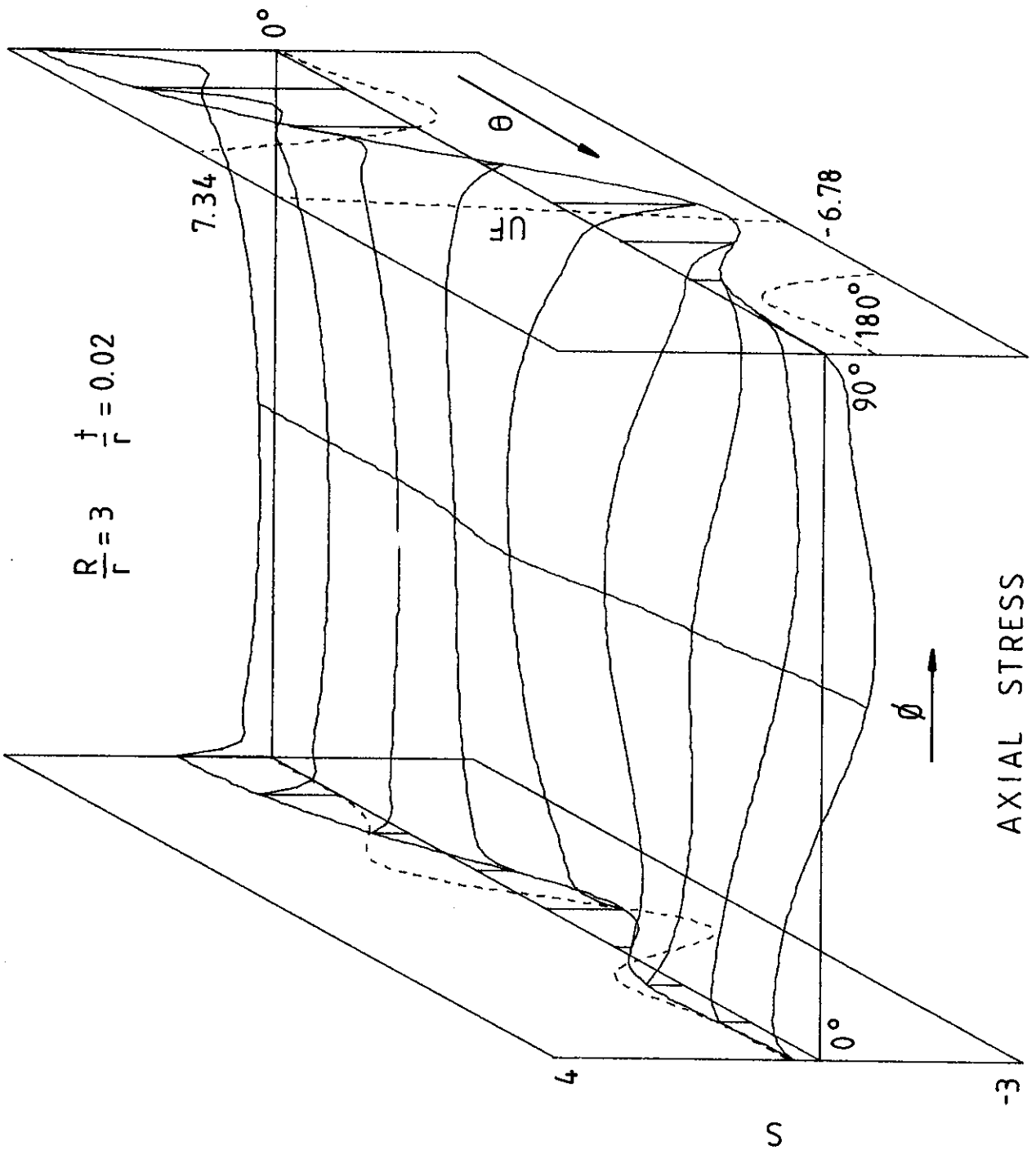


FIGURE A11



AXIAL STRESS

FIGURE A12

TABLE A11

R/r = 3.0 t/r = 0.02

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.4249	-0.1171	-0.0866	-0.0703	-0.0629	-0.0628	-0.0697	-0.0841	-0.1079	-0.1443	-0.1990	-0.2859	1.0768	0.3517 -0.6520
22.5	0.3611	-0.1060	-0.0836	-0.0705	-0.0639	-0.0635	-0.0694	-0.0825	-0.1046	-0.1379	-0.1857	-0.2580	0.9469	0.6758 -1.1850
45.0	0.1614	-0.0843	-0.1089	-0.1262	-0.1374	-0.1459	-0.1549	-0.1657	-0.1781	-0.1895	-0.1952	-0.1949	0.5541	3.3810 -3.9562
67.5	-0.1662	0.0181	-0.0305	-0.0821	-0.1299	-0.1679	-0.1933	-0.2029	-0.1923	-0.1576	-0.1000	-0.0263	-0.0899	1.7609 -0.1954
90.0	-0.3488	0.1172	0.2168	0.2828	0.3099	0.3166	0.3207	0.3311	0.3427	0.3362	0.2832	0.1836	-0.6414	-10.1053 11.1326
112.5	-0.0731	-0.1052	-0.0723	0.0276	0.1426	0.2397	0.2999	0.3096	0.2576	0.1426	-0.0113	-0.1273	-0.5110	-1.2184 -0.9748
135.0	0.1659	-0.0170	-0.1281	-0.1747	-0.1590	-0.1213	-0.1127	-0.1616	-0.2555	-0.3448	-0.3709	-0.3050	-0.1408	4.6966 -4.5286
157.5	0.1478	0.2566	0.1899	0.0766	-0.0589	-0.1875	-0.2904	-0.3543	-0.3684	-0.3305	-0.2605	-0.1926	-0.0195	1.6386 -1.0379
180.0	0.1191	0.3527	0.3090	0.1807	-0.0252	-0.2512	-0.4169	-0.4702	-0.4175	-0.3138	-0.2208	-0.1609	0.0054	1.4871 -1.0278

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.4164	0.4202	0.2994	0.2367	0.2089	0.2081	0.2320	0.2832	0.3687	0.5024	0.7091	1.0478	3.5892	0.1011 -0.0331
22.5	1.2038	0.3841	0.2812	0.2254	0.2008	0.2016	0.2265	0.2778	0.3617	0.4901	0.6823	0.9820	3.1564	0.4856 -0.4321
45.0	0.5378	0.2763	0.2338	0.2002	0.1826	0.1847	0.2087	0.2577	0.3357	0.4473	0.5941	0.7727	1.8470	0.7885 -0.1997
67.5	-0.5539	0.1125	0.2411	0.3023	0.3320	0.3550	0.3857	0.4300	0.4845	0.5325	0.5356	0.4276	-0.2995	-4.3795 5.6537
90.0	-1.1627	-0.2278	0.0560	0.2718	0.4224	0.5264	0.5971	0.6333	0.6144	0.4995	0.2307	-0.2285	-2.1379	-5.0986 3.8467
112.5	-0.2438	-0.4068	-0.3401	-0.1845	-0.0122	0.1261	0.1949	0.1675	0.0253	-0.2352	-0.5873	-0.9256	-1.7034	5.6298 -6.6954
135.0	0.5531	0.1058	-0.0508	-0.1116	-0.0948	-0.0653	-0.0901	-0.2066	-0.4033	-0.6196	-0.7654	-0.7677	-0.4692	3.0197 -2.0859
157.5	0.4925	0.5655	0.4210	0.2168	-0.0140	-0.2345	-0.4225	-0.5599	-0.6277	-0.6132	-0.5258	-0.4309	-0.0651	1.0715 -0.5364
180.0	0.3969	0.7096	0.5979	0.3686	0.0191	-0.3570	-0.6451	-0.7684	-0.7246	-0.5808	-0.4264	-0.3371	0.0180	1.2161 -0.7422

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1554	0.1086	0.0629	0.0327	0.0101	-0.0094	-0.0292	-0.0525	-0.0832	-0.1269	-0.1927	-0.2976	-0.4148	-0.0126
45.0	0.2331	0.1819	0.1117	0.0604	0.0178	-0.0220	-0.0640	-0.1133	-0.1761	-0.2601	-0.3768	-0.5466	-0.6917	-0.1108
67.5	0.1281	0.1235	0.0814	0.0402	-0.0050	-0.0567	-0.1169	-0.1871	-0.2688	-0.3634	-0.4726	-0.6017	-0.6474	-0.6883
90.0	-0.1304	-0.0747	-0.0644	-0.0774	-0.1070	-0.1505	-0.2044	-0.2625	-0.3171	-0.3600	-0.3810	-0.3618	-0.2332	-0.9879
112.5	-0.2226	-0.2022	-0.1951	-0.2114	-0.2381	-0.2647	-0.2853	-0.2959	-0.2917	-0.2637	-0.1949	-0.0578	0.1345	0.0909
135.0	-0.1019	-0.2093	-0.2714	-0.3080	-0.3276	-0.3272	-0.3032	-0.2562	-0.1874	-0.0953	0.0202	0.1396	0.1883	0.3722
157.5	-0.0095	-0.1067	-0.2022	-0.2627	-0.2799	-0.2627	-0.2178	-0.1470	-0.0555	0.0386	0.1071	0.1286	0.1101	0.1192
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	2.161	4.530	6.729	8.496	9.775	10.574	10.851	10.467	9.219	6.951	3.799	0.0	-267.158 287.685

TABLE A12

R/r = 3.0 t/r = 0.02

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0569	-0.0979	-0.0635	-0.0482	-0.0416	-0.0412	-0.0463	-0.0577	-0.0769	-0.1077	-0.1569	-0.2510	-0.1454	-0.4101	0.6525
22.5	-0.0416	-0.0805	-0.0518	-0.0397	-0.0352	-0.0363	-0.0422	-0.0533	-0.0709	-0.0977	-0.1395	-0.2188	-0.1126	-0.7501	1.1964
45.0	0.0042	-0.0197	0.0190	0.0450	0.0594	0.0647	0.0630	0.0548	0.0386	0.0106	-0.0342	-0.1059	-0.0204	-3.5397	3.9969
67.5	0.0665	-0.0285	-0.0063	0.0379	0.0820	0.1162	0.1356	0.1364	0.1146	0.0683	0.0049	-0.0481	0.1034	-1.5497	-0.3298
90.0	0.0368	-0.1287	-0.2562	-0.3274	-0.3530	-0.3559	-0.3576	-0.3687	-0.3842	-0.3821	-0.3289	-0.1943	0.0960	11.5691	-12.7638
112.5	-0.0792	0.0476	0.0178	-0.0621	-0.1544	-0.2332	-0.2882	-0.3123	-0.2955	-0.2333	-0.1455	-0.0888	-0.1398	2.2371	0.3152
135.0	0.0087	0.1181	0.1716	0.2012	0.1784	0.1280	0.0878	0.0786	0.0882	0.0779	0.0099	-0.0994	-0.2342	-4.4837	4.6201
157.5	0.1847	0.1807	0.1330	0.1039	0.0846	0.0588	0.0219	-0.0260	-0.0855	-0.1511	-0.1995	-0.1852	-0.1803	-1.4084	1.0419
180.0	0.2566	0.2512	0.1947	0.1186	0.0653	0.0288	-0.0218	-0.1029	-0.1913	-0.2409	-0.2307	-0.1685	-0.1578	-1.2516	1.0267

INSIDE AXIAL STRESS FACTORS

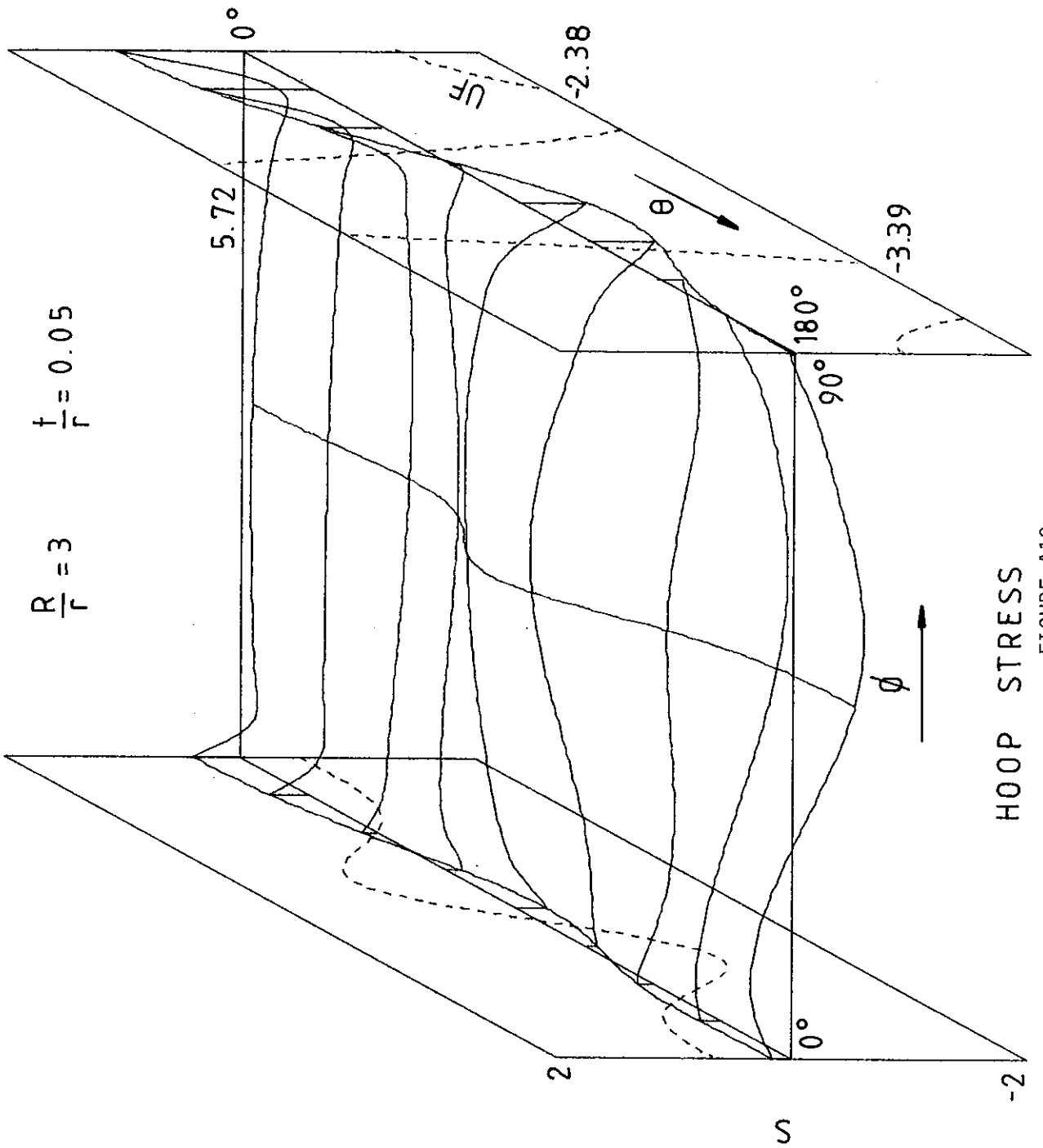
Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.1898	0.4106	0.3011	0.2383	0.2106	0.2100	0.2345	0.2865	0.3731	0.5079	0.7156	1.0261	-0.4846	0.1488	-0.0547
22.5	-0.1387	0.3758	0.2843	0.2293	0.2045	0.2050	0.2279	0.2817	0.3665	0.4957	0.6878	0.9610	-0.3753	0.3571	-0.1669
45.0	0.0138	0.2715	0.2567	0.2388	0.2304	0.2375	0.2641	0.3136	0.3893	0.4927	0.6213	0.7562	-0.0681	-0.7179	1.4053
67.5	0.2218	0.0536	0.2027	0.2896	0.3466	0.3916	0.4351	0.4801	0.5201	0.5371	0.4971	0.3349	0.3445	-3.8747	4.0745
90.0	0.1228	-0.2886	-0.0991	0.0478	0.1664	0.2569	0.3159	0.3350	0.2993	0.1875	-0.0278	-0.4063	0.3202	2.0883	-3.3500
112.5	-0.2640	-0.2271	-0.1940	-0.1329	-0.0696	-0.0244	-0.0167	-0.0613	-0.1656	-0.3293	-0.5440	-0.8126	-0.4661	4.9739	-4.2242
135.0	0.0290	0.1900	0.1319	0.1054	0.0770	0.0327	-0.0320	-0.1197	-0.2326	-0.3680	-0.5073	-0.6019	-0.7807	-1.1087	1.8401
157.5	0.6157	0.4325	0.3387	0.2145	0.0822	-0.0540	-0.1856	-0.3028	-0.3968	-0.4579	-0.4733	-0.4113	-0.6011	-0.9457	0.9351
180.0	0.8553	0.5128	0.4261	0.2579	0.0721	-0.1085	-0.2724	-0.4074	-0.4920	-0.5065	-0.4536	-0.3396	-0.5261	-0.7112	0.7001

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1523	0.1114	0.0630	0.0320	0.0097	-0.0094	-0.0286	-0.0512	-0.0812	-0.1247	-0.1921	-0.3019	-0.4066	0.0590
45.0	0.2284	0.2037	0.1236	0.0654	0.0194	-0.0213	-0.0629	-0.1114	-0.1741	-0.2610	-0.3868	-0.5729	-0.6780	0.2622
67.5	0.1256	0.2042	0.1529	0.0932	0.0306	-0.0346	-0.1057	-0.1881	-0.2880	-0.4101	-0.5546	-0.7143	-0.6345	0.4258
90.0	-0.1278	-0.0573	0.0060	0.0135	-0.0215	-0.0880	-0.1767	-0.2782	-0.3800	-0.4626	-0.4963	-0.4416	-0.2286	-0.4759
112.5	-0.2182	-0.3343	-0.2874	-0.2452	-0.2318	-0.2523	-0.2937	-0.3301	-0.3299	-0.2648	-0.1210	0.0916	0.1319	-1.1383
135.0	-0.0998	-0.2296	-0.3697	-0.4461	-0.4631	-0.4315	-0.3593	-0.2508	-0.1133	0.0350	0.1608	0.2332	0.1846	-0.4825
157.5	-0.0093	-0.0693	-0.2225	-0.3558	-0.4191	-0.3835	-0.2604	-0.0954	0.0526	0.1388	0.1550	0.1323	0.1080	-0.1906
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

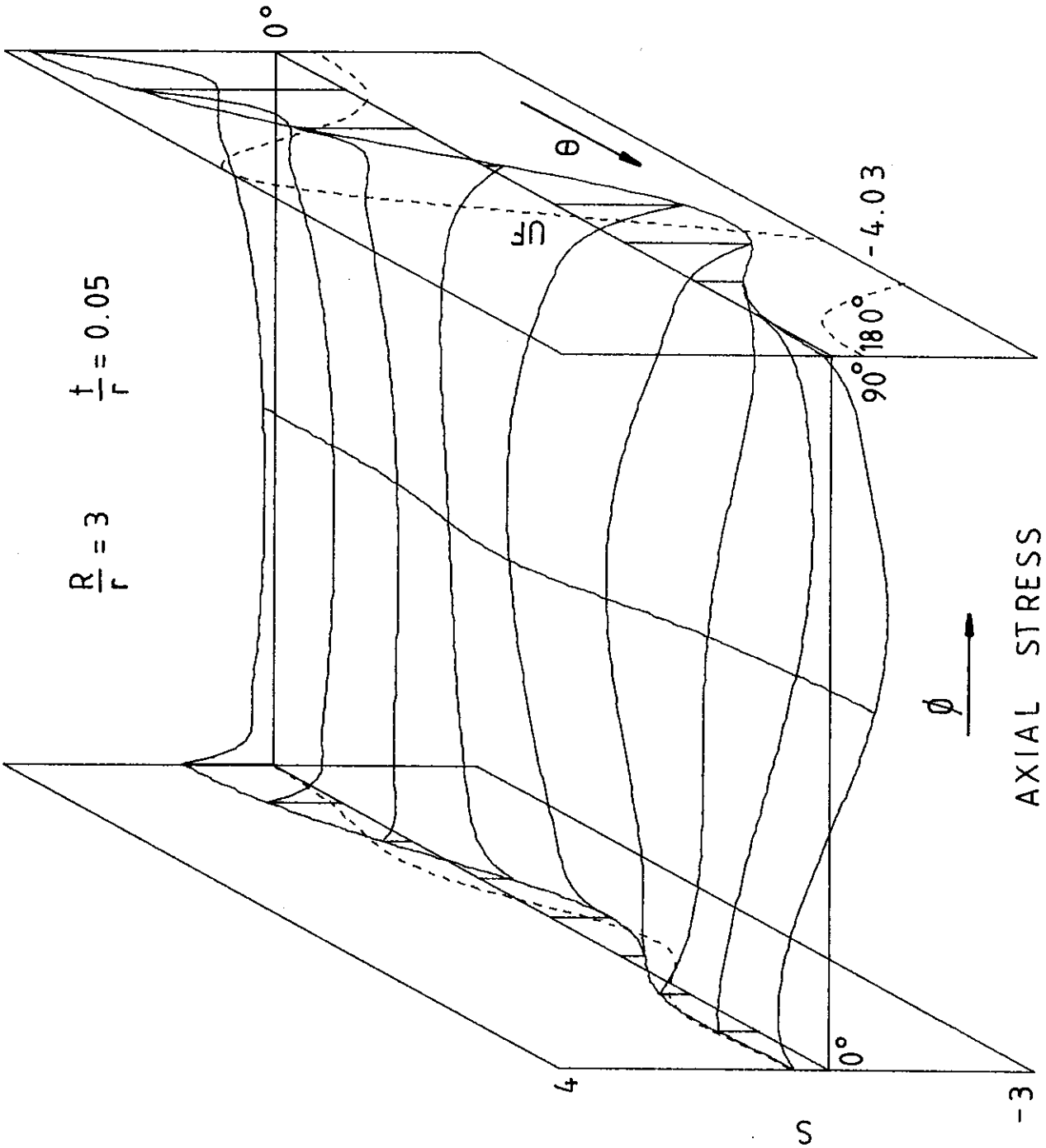
DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-0.848	-1.905	-3.463	-5.314	-7.031	-8.119	-8.257	-7.446	-5.974	-4.233	-2.504	0.0	156.388	-165.306



HOOP STRESS

FIGURE A13



AXIAL STRESS

FIGURE A14

TABLE A13

R/r = 3.0 t/r = 0.05

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3998	-0.1491	-0.1081	-0.0947	-0.0859	-0.0836	-0.0891	-0.1044	-0.1316	-0.1731	-0.2287	-0.3694	1.0905	0.8007 -1.3110
22.5	0.3306	-0.1380	-0.1255	-0.1305	-0.1352	-0.1418	-0.1523	-0.1682	-0.1902	-0.2183	-0.2496	-0.3403	0.9476	1.4880 -1.9614
45.0	0.1289	-0.0772	-0.1133	-0.1586	-0.1988	-0.2325	-0.2580	-0.2735	-0.2764	-0.2638	-0.2327	-0.2169	0.5255	2.1254 -2.1330
67.5	-0.1377	0.0478	0.0532	0.0246	-0.0156	-0.0547	-0.0805	-0.0849	-0.0657	-0.0283	0.0173	0.0281	-0.0834	-0.7810 1.6497
90.0	-0.2674	0.0839	0.2068	0.2957	0.3605	0.4044	0.4344	0.4522	0.4512	0.4162	0.3370	0.1598	-0.5641	-5.1789 5.7116
112.5	-0.1032	-0.0553	0.0035	0.1235	0.2644	0.3888	0.4673	0.4787	0.4139	0.2796	0.1104	-0.0917	-0.5571	-2.4628 1.6253
135.0	0.1367	-0.0316	-0.1454	-0.1707	-0.1459	-0.1103	-0.1007	-0.1383	-0.2192	-0.3123	-0.3655	-0.3301	-0.2159	2.7850 -3.2713
157.5	0.1830	0.2170	0.1177	-0.0236	-0.1804	-0.3298	-0.4495	-0.5216	-0.5357	-0.4925	-0.4027	-0.2451	-0.0003	2.5731 -2.0819
180.0	0.1540	0.3421	0.3006	0.1324	-0.1024	-0.3424	-0.5230	-0.6004	-0.5661	-0.4529	-0.3167	-0.1588	0.0386	1.5761 -0.9225

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.3326	0.3191	0.2442	0.1792	0.1512	0.1498	0.1725	0.2213	0.3038	0.4344	0.6459	0.8574	3.6349	0.5708 -0.5289
22.5	1.1021	0.3059	0.2408	0.1798	0.1500	0.1455	0.1657	0.2139	0.2971	0.4272	0.6296	0.8225	3.1585	0.4949 -0.2930
45.0	0.4296	0.2692	0.2634	0.2395	0.2233	0.2221	0.2429	0.2914	0.3715	0.4841	0.6292	0.7271	1.7518	-0.7256 1.3287
67.5	-0.4591	0.1530	0.2828	0.3695	0.4263	0.4719	0.5184	0.5702	0.6212	0.6520	0.6289	0.4949	-0.2780	-3.3097 3.8530
90.0	-0.8913	-0.1317	0.0759	0.2730	0.4351	0.5626	0.6515	0.6911	0.6632	0.5397	0.2896	-0.0786	-1.8803	-2.6066 2.0959
112.5	-0.3441	-0.3164	-0.2589	-0.1160	0.0417	0.1737	0.2442	0.2240	0.0965	-0.1406	-0.4609	-0.7713	-1.8571	2.3814 -3.1741
135.0	0.4557	0.0245	-0.1243	-0.1703	-0.1763	-0.1848	-0.2312	-0.3359	-0.4981	-0.6904	-0.8533	-0.8813	-0.7198	3.5619 -3.2536
157.5	0.6101	0.5585	0.3826	0.1705	-0.0659	-0.3006	-0.5060	-0.6584	-0.7395	-0.7414	-0.6750	-0.5284	-0.0010	1.5792 -0.8873
180.0	0.5132	0.7660	0.6293	0.3564	0.0014	-0.3585	-0.6463	-0.8066	-0.8161	-0.6966	-0.5255	-0.3525	0.1288	0.9911 -0.4274

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1163	0.0937	0.0563	0.0312	0.0112	-0.0075	-0.0278	-0.0522	-0.0837	-0.1267	-0.1888	-0.2875	-0.3536	-0.0412
45.0	0.1578	0.1266	0.0774	0.0398	0.0071	-0.0269	-0.0656	-0.1121	-0.1695	-0.2428	-0.3420	-0.4818	-0.5677	-0.2372
67.5	0.0746	0.0562	0.0216	-0.0125	-0.0463	-0.0844	-0.1288	-0.1804	-0.2397	-0.3088	-0.3934	-0.4855	-0.5250	-0.6069
90.0	-0.0820	-0.0604	-0.0878	-0.1215	-0.1554	-0.1869	-0.2159	-0.2435	-0.2713	-0.2996	-0.3253	-0.3251	-0.2482	-0.7007
112.5	-0.1597	-0.1250	-0.1577	-0.1990	-0.2395	-0.2675	-0.2801	-0.2807	-0.2736	-0.2579	-0.2200	-0.1485	0.0343	-0.1501
135.0	-0.1078	-0.1534	-0.1808	-0.2075	-0.2346	-0.2580	-0.2720	-0.2703	-0.2463	-0.1918	-0.1001	0.0029	0.1336	0.3110
157.5	-0.0354	-0.1236	-0.1474	-0.1537	-0.1552	-0.1637	-0.1764	-0.1776	-0.1493	-0.0833	0.0062	0.0744	0.0924	0.2034
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	1.274	2.893	4.519	5.992	7.167	7.930	8.175	7.802	6.735	4.976	2.537	0.0	-85.891 92.780

TABLE A14

R/r = 3.0 t/r = 0.05

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
0.0	-0.0771	-0.0498	-0.0226	-0.0089	-0.0061	-0.0092	-0.0160	-0.0260	-0.0403	-0.0632	-0.1054	-0.1708	-0.2113	-0.8600	1.3121
22.5	-0.0540	-0.0320	0.0097	0.0369	0.0510	0.0561	0.0548	0.0473	0.0315	0.0020	-0.0516	-0.1307	-0.1647	-1.5775	1.9794
45.0	0.0112	-0.0266	0.0336	0.0881	0.1334	0.1656	0.1823	0.1804	0.1558	0.1040	0.0226	-0.0821	-0.0318	-2.1935	2.0624
67.5	0.0819	-0.1046	-0.1070	-0.0853	-0.0441	-0.0040	0.0190	0.0148	-0.0186	-0.0729	-0.1251	-0.1698	0.1302	1.1452	-2.2472
90.0	0.0706	-0.1409	-0.2614	-0.3679	-0.4356	-0.4781	-0.5080	-0.5300	-0.5365	-0.5066	-0.4109	-0.2966	0.1640	6.2579	-6.9128
112.5	-0.0268	0.0306	-0.0298	-0.1612	-0.3104	-0.4446	-0.5354	-0.5625	-0.5174	-0.4066	-0.2554	-0.1789	-0.0255	3.4689	-2.4216
135.0	-0.0250	0.1653	0.2361	0.2341	0.1712	0.0858	0.0221	0.0065	0.0336	0.0662	0.0546	-0.0523	-0.2261	-2.4018	3.2124
157.5	0.1257	0.1525	0.1672	0.1992	0.2374	0.2619	0.2589	0.2202	0.1438	0.0365	-0.0739	-0.1310	-0.2472	-2.3558	2.1187
180.0	0.2145	0.1475	0.0991	0.1011	0.1626	0.2322	0.2513	0.1864	0.0472	-0.1140	-0.2159	-0.1825	-0.2199	-1.3405	0.9202

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
0.0	-0.2568	0.4080	0.2567	0.1966	0.1669	0.1638	0.1860	0.2366	0.3230	0.4591	0.6615	1.1028	-0.7042	0.3466	-0.1552
22.5	-0.1801	0.3755	0.2620	0.2164	0.1937	0.1936	0.2172	0.2679	0.3520	0.4794	0.6593	1.0328	-0.5491	-0.0791	0.3870
45.0	0.0373	0.2598	0.2633	0.2728	0.2843	0.3047	0.3386	0.3894	0.4581	0.5434	0.6356	0.7861	-0.1059	-1.3241	1.7294
67.5	0.2729	0.0321	0.1686	0.2566	0.3284	0.3906	0.4445	0.4874	0.5124	0.5073	0.4475	0.2811	0.4339	-1.6084	1.5963
90.0	0.2354	-0.1935	-0.0567	0.0374	0.1195	0.1863	0.2295	0.2390	0.2045	0.1153	-0.0507	-0.3759	0.5467	1.2786	-1.7255
112.5	-0.0893	-0.1357	-0.1017	-0.0926	-0.0919	-0.1027	-0.1283	-0.1725	-0.2413	-0.3410	-0.4868	-0.7186	-0.0852	3.0804	-2.9195
135.0	-0.0833	0.1567	0.1497	0.1015	0.0332	-0.0503	-0.1381	-0.2226	-0.3043	-0.3895	-0.4835	-0.5988	-0.7537	0.5557	0.0782
157.5	0.4189	0.3451	0.3059	0.2400	0.1642	0.0777	-0.0207	-0.1288	-0.2398	-0.3404	-0.4035	-0.4429	-0.8241	-1.0644	1.2644
180.0	0.7150	0.3884	0.3146	0.2387	0.1685	0.0954	0.0024	-0.1169	-0.2506	-0.3662	-0.4136	-0.4088	-0.7330	-1.0043	0.9518

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1107	0.1189	0.0662	0.0347	0.0116	-0.0076	-0.0265	-0.0489	-0.0794	-0.1247	-0.1950	-0.3185	-0.3364	0.1198
45.0	0.1501	0.2110	0.1323	0.0783	0.0326	-0.0100	-0.0549	-0.1081	-0.1768	-0.2703	-0.4007	-0.6064	-0.5400	0.2604
67.5	0.0709	0.1810	0.1429	0.0986	0.0447	-0.0196	-0.0961	-0.1866	-0.2930	-0.4157	-0.5528	-0.7155	-0.4994	0.1838
90.0	-0.0780	-0.0522	-0.0066	-0.0024	-0.0336	-0.0949	-0.1791	-0.2760	-0.3716	-0.4475	-0.4813	-0.4434	-0.2361	-0.3783
112.5	-0.1519	-0.2943	-0.2685	-0.2533	-0.2575	-0.2782	-0.3057	-0.3249	-0.3172	-0.2625	-0.1435	0.0517	0.0326	-0.8909
135.0	-0.1025	-0.2567	-0.3772	-0.4487	-0.4717	-0.4472	-0.3781	-0.2708	-0.1355	0.0130	0.1569	0.2690	0.1270	-0.6591
157.5	-0.0336	-0.0849	-0.2398	-0.3572	-0.4027	-0.3709	-0.2733	-0.1352	0.0087	0.1204	0.1727	0.1597	0.0879	-0.2197
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
180.0	0.0	-0.855	-1.860	-3.230	-4.729	-6.064	-6.946	-7.173	-6.683	-5.573	-4.054	-2.371	0.0	64.094	-68.001

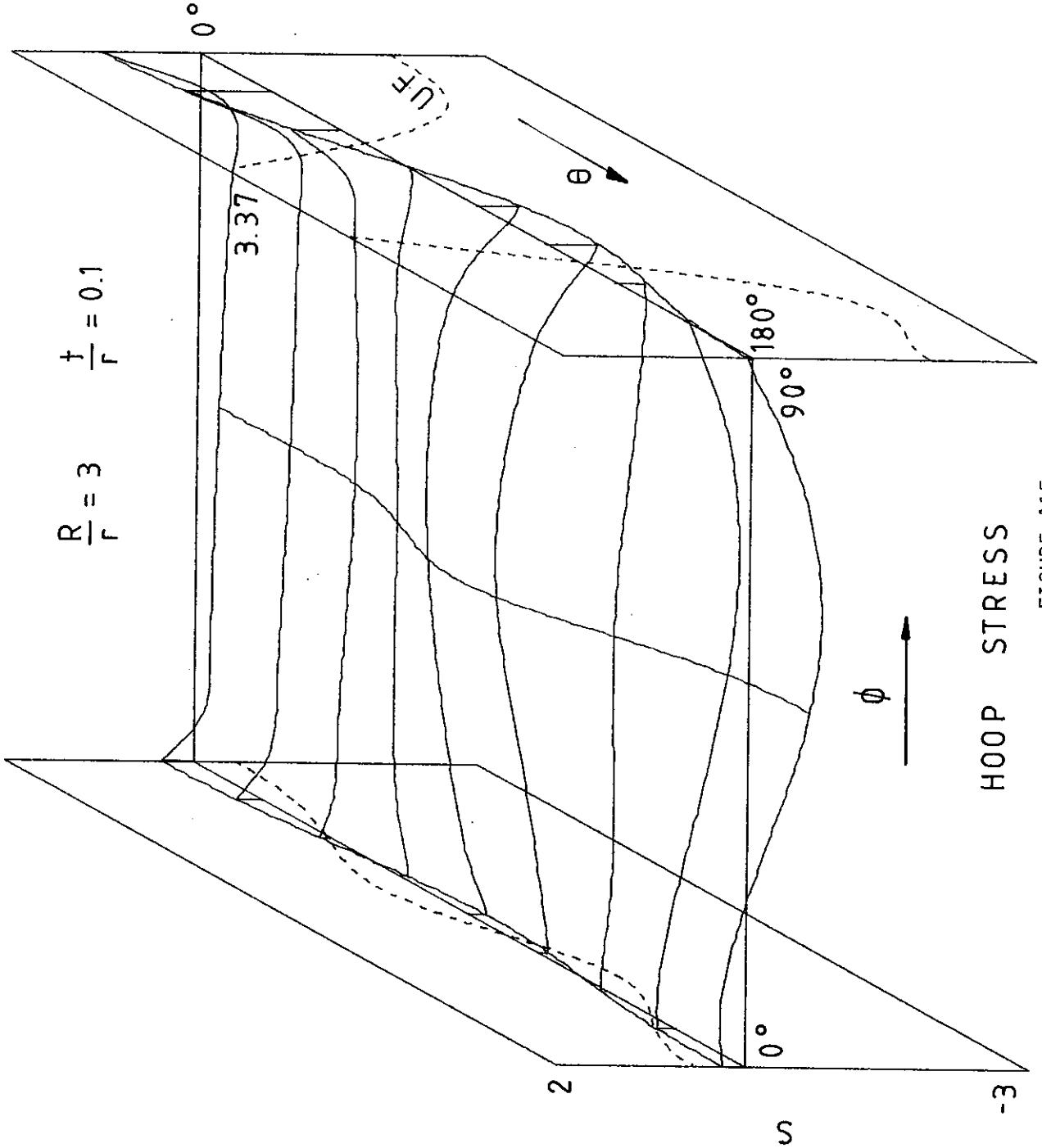


FIGURE A15

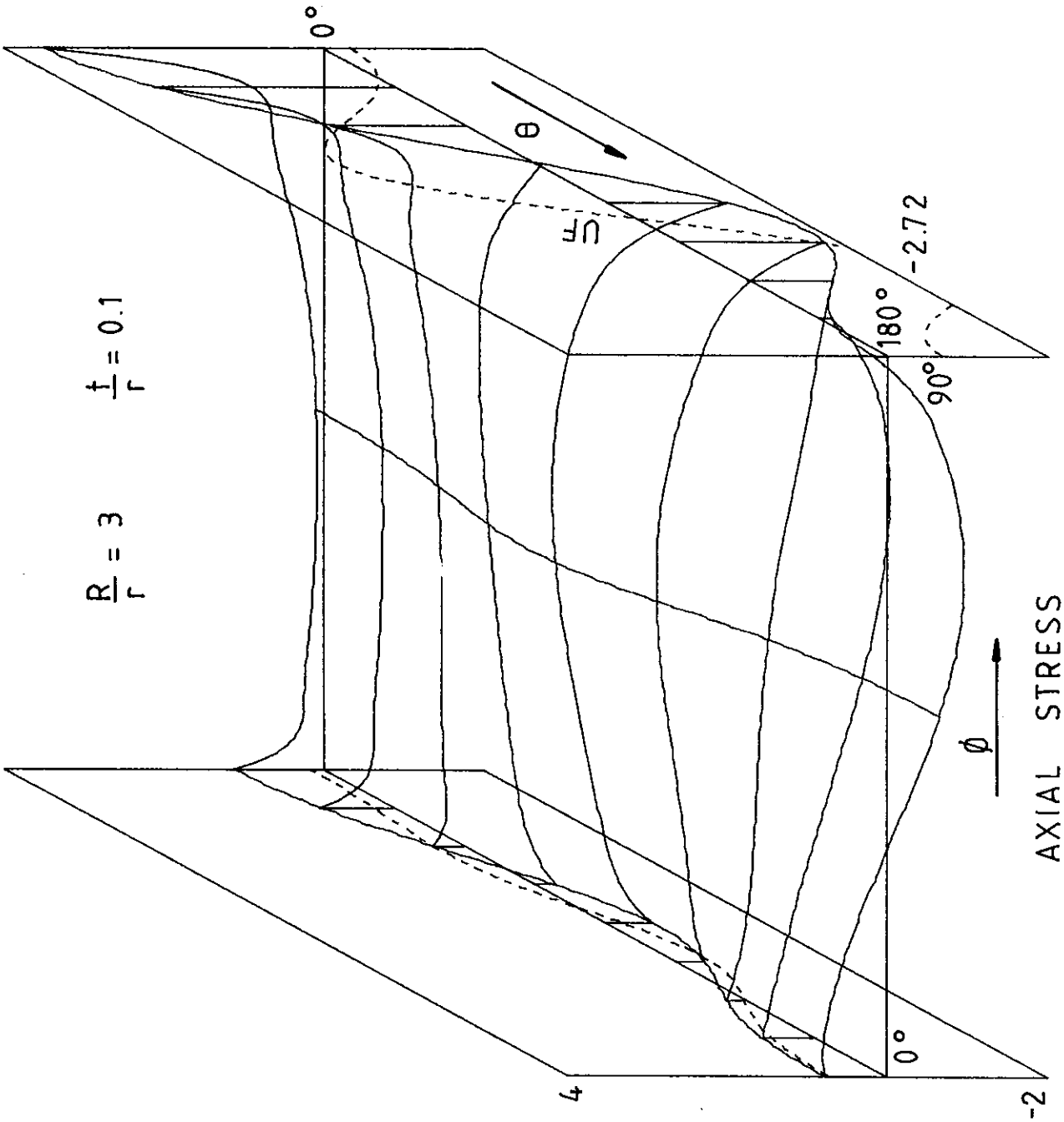


FIGURE A16

TABLE A15

R/r = 3.0 t/r = 0.1

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.3341	-0.1381	-0.1696	-0.1823	-0.2001	-0.2179	-0.2375	-0.2600	-0.2854	-0.3116	-0.3594	-0.3490	1.0486	1.5419 -1.9848
22.5	0.2739	-0.1152	-0.1523	-0.1774	-0.2067	-0.2341	-0.2591	-0.2809	-0.2983	-0.3089	-0.3314	-0.2970	0.9044	1.5240 -1.8438
45.0	0.1138	-0.0503	-0.0728	-0.1084	-0.1498	-0.1877	-0.2164	-0.2315	-0.2302	-0.2111	-0.1906	-0.1473	0.5057	0.8621 -0.8183
67.5	-0.0768	0.0217	0.0767	0.0854	0.0817	0.0752	0.0719	0.0759	0.0872	0.1029	0.1050	0.0297	-0.0237	-1.1551 1.5784
90.0	-0.1800	0.0292	0.1667	0.2635	0.3508	0.4238	0.4756	0.4996	0.4889	0.4392	0.3366	0.0635	-0.4521	-3.0439 3.3624
112.5	-0.1080	-0.0219	0.0690	0.1781	0.3005	0.4094	0.4801	0.4945	0.4437	0.3329	0.1685	-0.1234	-0.5473	-1.9883 1.7555
135.0	0.0738	0.0121	-0.0413	-0.0540	-0.0424	-0.0298	-0.0345	-0.0667	-0.1261	-0.1983	-0.2609	-0.3107	-0.3188	1.0673 -1.4023
157.5	0.2004	0.1700	0.0501	-0.0954	-0.2470	-0.3904	-0.5095	-0.5891	-0.6178	-0.5884	-0.4913	-0.3027	-0.0473	2.4663 -2.2597
180.0	0.2301	0.2640	0.1487	-0.0419	-0.2636	-0.4783	-0.6489	-0.7459	-0.7544	-0.6754	-0.5129	-0.2505	0.0540	2.4164 -1.8824

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.1135	0.2409	0.1968	0.1317	0.0933	0.0805	0.0932	0.1360	0.2174	0.3553	0.5623	0.6834	3.4955	0.4753 -0.3029
22.5	0.9131	0.2437	0.2195	0.1681	0.1376	0.1296	0.1457	0.1909	0.2726	0.4047	0.5941	0.6897	3.0147	0.0758 0.1867
45.0	0.3792	0.2274	0.2708	0.2715	0.2779	0.2957	0.3290	0.3817	0.4562	0.5559	0.6730	0.6620	1.6858	-1.0875 1.4945
67.5	-0.2558	0.1265	0.2700	0.3608	0.4429	0.5183	0.5872	0.6465	0.6888	0.7043	0.6748	0.4565	-0.0789	-2.2142 2.5023
90.0	-0.6001	-0.0756	0.1086	0.2631	0.4103	0.5365	0.6291	0.6734	0.6519	0.5494	0.3573	-0.0524	-1.5071	-1.4965 1.3099
112.5	-0.3601	-0.1939	-0.1150	-0.0101	0.1033	0.1957	0.2452	0.2325	0.1398	-0.0391	-0.2859	-0.6684	-1.8242	1.1480 -1.5775
135.0	0.2459	0.0347	-0.0651	-0.1139	-0.1505	-0.1987	-0.2691	-0.3679	-0.4983	-0.6515	-0.7928	-0.9046	-1.0628	2.7108 -2.6914
157.5	0.6679	0.4958	0.2976	0.0892	-0.1328	-0.3576	-0.5657	-0.7366	-0.8525	-0.8991	-0.8586	-0.6797	-0.1577	2.0410 -1.4797
180.0	0.7669	0.7285	0.5175	0.2412	-0.0696	-0.3800	-0.6516	-0.8487	-0.9435	-0.9236	-0.7905	-0.5001	0.1801	1.3985 -0.6837

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0670	0.0444	0.0294	0.0128	-0.0007	-0.0148	-0.0314	-0.0518	-0.0777	-0.1120	-0.1624	-0.2142	-0.2685	-0.1119
45.0	0.0876	0.0485	0.0251	-0.0032	-0.0267	-0.0502	-0.0769	-0.1090	-0.1491	-0.2021	-0.2780	-0.3434	-0.4300	-0.2930
67.5	0.0405	0.0047	-0.0271	-0.0635	-0.0933	-0.1192	-0.1440	-0.1710	-0.2044	-0.2496	-0.3125	-0.3517	-0.4176	-0.5018
90.0	-0.0461	-0.0483	-0.0942	-0.1398	-0.1763	-0.2019	-0.2183	-0.2298	-0.2421	-0.2604	-0.2841	-0.2883	-0.2539	-0.5289
112.5	-0.1049	-0.0743	-0.1192	-0.1653	-0.2067	-0.2387	-0.2599	-0.2714	-0.2751	-0.2706	-0.2535	-0.2246	-0.0582	-0.2185
135.0	-0.0961	-0.0871	-0.1013	-0.1222	-0.1536	-0.1933	-0.2350	-0.2693	-0.2843	-0.2678	-0.2169	-0.1493	0.0489	0.1667
157.5	-0.0486	-0.0752	-0.0670	-0.0613	-0.0716	-0.1007	-0.1417	-0.1798	-0.1966	-0.1770	-0.1224	-0.0555	0.0508	0.2237
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	0.676	1.728	2.823	3.872	4.756	5.356	5.568	5.317	4.565	3.298	1.492	0.0	-33.951 36.846

TABLE A16

R/r = 3.0 t/r = 0.1

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.0758	0.0377	0.0565	0.1003	0.1262	0.1418	0.1494	0.1484	0.1361	0.1049	0.0297	0.0628	-0.2513	-1.6069	1.9872
22.5	-0.0515	0.0212	0.0483	0.1009	0.1384	0.1650	0.1797	0.1801	0.1625	0.1205	0.0329	0.0399	-0.1949	-1.5883	1.8291
45.0	0.0106	-0.0356	-0.0130	0.0391	0.0874	0.1270	0.1498	0.1489	0.1203	0.0624	-0.0327	-0.0559	-0.0463	-0.8255	0.6534
67.5	0.0734	-0.1120	-0.1508	-0.1611	-0.1583	-0.1518	-0.1524	-0.1664	-0.1936	-0.2256	-0.2567	-0.2252	0.1225	1.5532	-2.1465
90.0	0.0847	-0.1150	-0.2251	-0.3433	-0.4495	-0.5359	-0.5988	-0.6320	-0.6262	-0.5696	-0.4658	-0.3283	0.1900	3.8974	-4.3099
112.5	0.0341	0.0059	-0.0651	-0.2073	-0.3699	-0.5163	-0.6183	-0.6537	-0.6106	-0.4925	-0.3392	-0.2333	0.0729	2.8730	-2.5210
135.0	0.0023	0.1238	0.1636	0.1312	0.0608	-0.0163	-0.0743	-0.0967	-0.0810	-0.0430	-0.0264	-0.0932	-0.1443	-0.5732	1.1824
157.5	0.0545	0.1321	0.1928	0.2614	0.3325	0.3876	0.4085	0.3827	0.3057	0.1849	0.0409	-0.1020	-0.2866	-2.2051	2.2678
180.0	0.1014	0.1123	0.1465	0.2381	0.3663	0.4816	0.5366	0.5008	0.3699	0.1744	-0.0195	-0.1464	-0.3201	-2.1704	1.8776

INSIDE AXIAL STRESS FACTORS

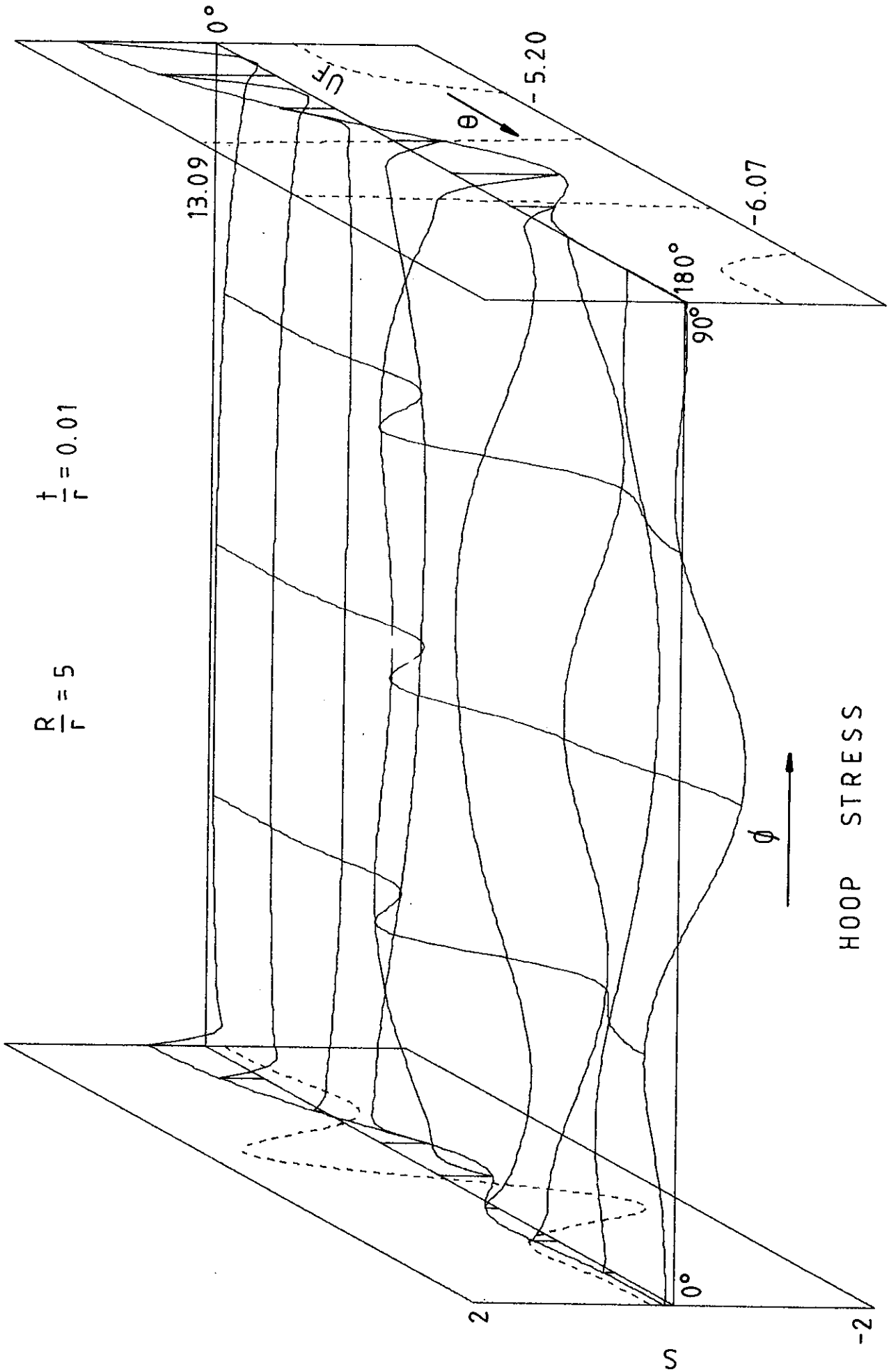
Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.2528	0.3910	0.2469	0.2003	0.1796	0.1793	0.2027	0.2527	0.3381	0.4654	0.6654	1.1803	-0.8376	-0.1919	0.4816
22.5	-0.1715	0.3540	0.2491	0.2226	0.2158	0.2256	0.2546	0.3060	0.3854	0.4969	0.6629	1.0850	-0.6497	-0.4684	0.7644
45.0	0.0352	0.2425	0.2285	0.2529	0.2820	0.3175	0.3605	0.4110	0.4693	0.5316	0.5997	0.7879	-0.1542	-0.9084	1.1429
67.5	0.2447	0.0801	0.1360	0.2037	0.2616	0.3150	0.3622	0.3986	0.4189	0.4114	0.3534	0.3066	0.4085	-0.5530	0.5752
90.0	0.2824	-0.0427	0.0034	0.0558	0.0908	0.1166	0.1319	0.1320	0.1101	0.0506	-0.0819	-0.2072	0.6334	0.9069	-1.0452
112.5	0.1135	-0.0195	-0.0170	-0.0282	-0.0611	-0.1031	-0.1486	-0.1963	-0.2487	-0.3196	-0.4388	-0.5095	0.2431	1.8685	-1.8210
135.0	0.0076	0.1203	0.1229	0.0793	0.0114	-0.0676	-0.1501	-0.2313	-0.3086	-0.3864	-0.4767	-0.5453	-0.4809	0.9211	-0.5912
157.5	0.1818	0.2353	0.2481	0.2263	0.1881	0.1353	0.0636	-0.0288	-0.1367	-0.2485	-0.3563	-0.5057	-0.9553	-0.5699	0.8534
180.0	0.3380	0.2696	0.2756	0.2722	0.2608	0.2334	0.1766	0.0830	-0.0418	-0.1772	-0.3053	-0.4973	-1.0670	-1.0969	1.2586

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0606	0.1166	0.0715	0.0453	0.0243	0.0040	-0.0185	-0.0462	-0.0825	-0.1327	-0.2072	-0.3449	-0.2429	0.1196
45.0	0.0792	0.1855	0.1262	0.0846	0.0463	0.0047	-0.0442	-0.1040	-0.1790	-0.2753	-0.4065	-0.6140	-0.3890	0.1762
67.5	0.0367	0.1447	0.1152	0.0797	0.0348	-0.0228	-0.0945	-0.1811	-0.2824	-0.3979	-0.5305	-0.6810	-0.3778	0.0484
90.0	-0.0417	-0.0274	-0.0186	-0.0335	-0.0697	-0.1236	-0.1916	-0.2686	-0.3473	-0.4168	-0.4608	-0.4467	-0.2297	-0.3246
112.5	-0.0949	-0.2201	-0.2368	-0.2533	-0.2769	-0.3015	-0.3207	-0.3278	-0.3149	-0.2702	-0.1763	-0.0337	-0.0527	-0.6996
135.0	-0.0870	-0.2600	-0.3611	-0.4209	-0.4463	-0.4359	-0.3886	-0.3050	-0.1887	-0.0457	0.1127	0.2280	0.0442	-0.6870
157.5	-0.0440	-0.1443	-0.2597	-0.3350	-0.3619	-0.3420	-0.2796	-0.1820	-0.0615	0.0629	0.1641	0.1891	0.0460	-0.3420
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
180.0	0.0	-0.694	-1.592	-2.640	-3.718	-4.662	-5.317	-5.563	-5.325	-4.597	-3.455	-1.906	0.0	30.678	-32.792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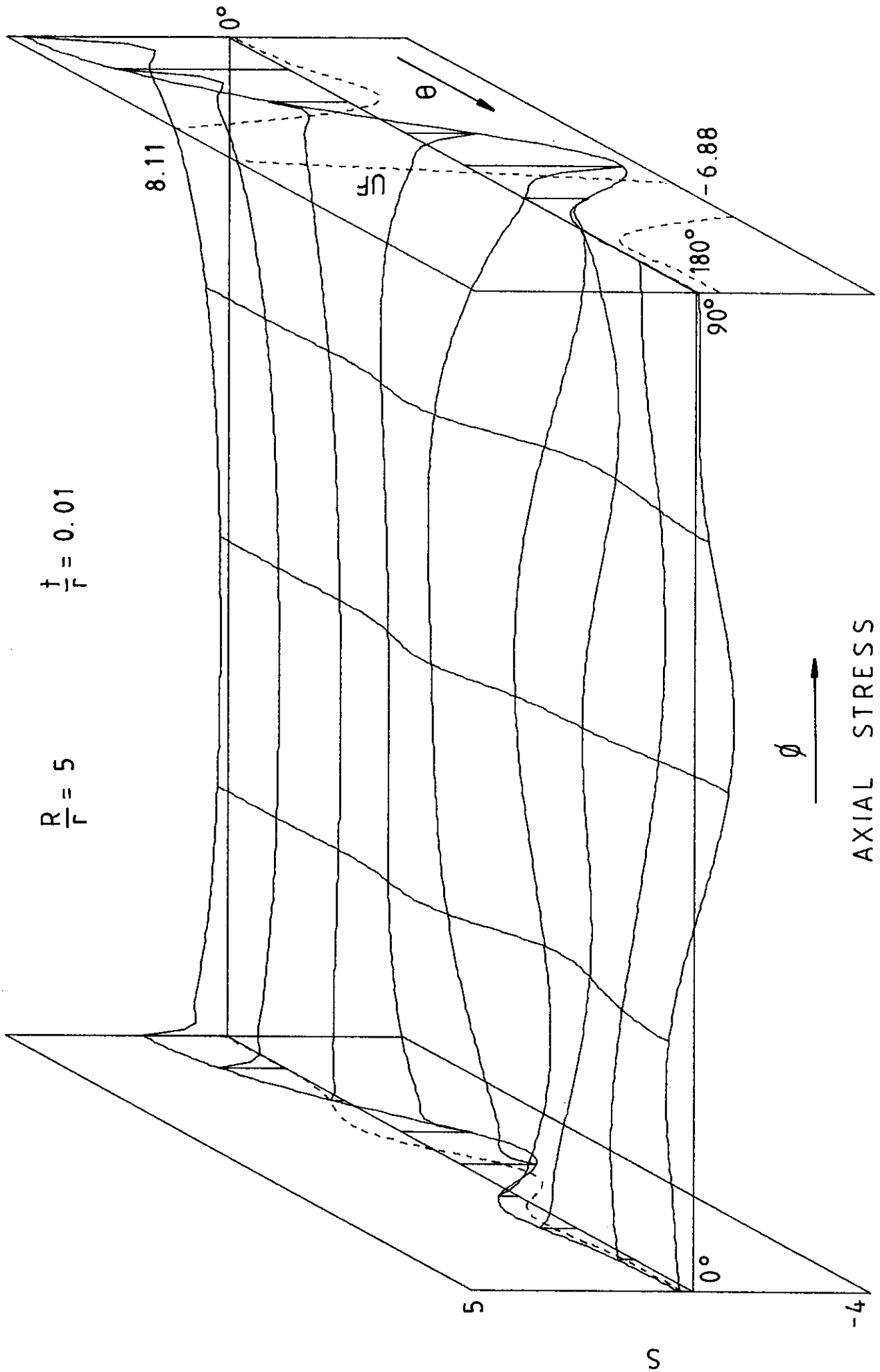
θ
U_T
$\frac{t}{r} = 0.01$
$\frac{R}{r} = 5$
ϕ
HOOP STRESS
2
-2
S

FIGURE A17



AXIAL STRESS
FIGURE A18

TABLE A17

R/r = 5.0 t/r = 0.01

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.5675	-0.1005	-0.0707	-0.0559	-0.0497	-0.0492	-0.0538	-0.0642	-0.0824	-0.1125	-0.1617	-0.2433	1.3837	0.5932 -0.7686
22.5	0.4445	-0.0826	-0.0598	-0.0468	-0.0409	-0.0403	-0.0439	-0.0524	-0.0678	-0.0941	-0.1376	-0.2061	1.1673	0.6870 -0.9662
45.0	0.0739	-0.0892	-0.1443	-0.1700	-0.1767	-0.1769	-0.1776	-0.1815	-0.1898	-0.1993	-0.1990	-0.1726	0.5292	3.7204 -4.1015
67.5	-0.4776	0.0494	-0.0492	-0.1678	-0.2597	-0.3145	-0.3468	-0.3681	-0.3665	-0.3129	-0.1910	-0.0319	-0.4800	2.2738 -1.1074
90.0	-0.5233	0.2354	0.5252	0.6673	0.6625	0.5901	0.5350	0.5463	0.6161	0.6748	0.6093	0.3375	-1.0730	-12.6496 13.0851
112.5	0.1283	-0.2696	-0.2864	-0.0677	0.1874	0.3610	0.4547	0.4943	0.4430	0.2380	-0.0733	-0.2599	-0.4498	0.2267 -1.7045
135.0	0.2446	0.0232	-0.2635	-0.4700	-0.4209	-0.1906	-0.0163	-0.0821	-0.3428	-0.5602	-0.5154	-0.2292	-0.0032	4.5276 -4.2777
157.5	0.1153	0.1802	0.2119	0.0876	-0.0890	-0.2340	-0.3297	-0.3704	-0.3387	-0.2122	-0.0381	0.0290	-0.0029	1.2406 -0.9446
180.0	0.0874	0.1168	0.2409	0.3254	0.1267	-0.2918	-0.6153	-0.5986	-0.2854	0.0209	0.0774	0.0010	-0.0077	1.1948 -0.9729

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.8918	0.5121	0.3098	0.2082	0.1619	0.1524	0.1740	0.2298	0.3314	0.5037	0.7957	1.3077	4.6124	0.1293 -0.0788
22.5	1.4816	0.4396	0.2765	0.1903	0.1509	0.1446	0.1679	0.2243	0.3242	0.4882	0.7547	1.1956	3.8910	0.4155 -0.3898
45.0	0.2465	0.2095	0.1594	0.1085	0.0801	0.0780	0.1018	0.1541	0.2427	0.3799	0.5754	0.8140	1.7641	1.1308 -0.8044
67.5	-1.5921	-0.0626	0.2248	0.3149	0.3252	0.3227	0.3373	0.3789	0.4479	0.5223	0.5217	0.2591	-1.6000	-4.8372 5.6610
90.0	-1.7445	-0.5875	-0.0726	0.3053	0.5260	0.6327	0.6960	0.7566	0.7757	0.6379	0.1935	-0.6893	-3.5767	-5.1888 4.2467
112.5	0.4275	-0.5829	-0.7399	-0.5825	-0.3041	-0.0405	0.1162	0.1029	-0.1134	-0.5257	-1.0446	-1.4197	-1.4995	6.4888 -6.8774
135.0	0.8155	0.3639	-0.0386	-0.2918	-0.3046	-0.1731	-0.0941	-0.2166	-0.5205	-0.8186	-0.8789	-0.5875	-0.0106	2.0601 -1.4846
157.5	0.3842	0.5336	0.5062	0.3005	0.0256	-0.2574	-0.4904	-0.6163	-0.6179	-0.4988	-0.2801	-0.0921	-0.0098	0.5904 -0.3459
180.0	0.2915	0.4492	0.5993	0.5642	0.1967	-0.3391	-0.7629	-0.8762	-0.6560	-0.2982	-0.0887	-0.0705	-0.0255	0.7341 -0.5141

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.2195	0.1290	0.0667	0.0329	0.0120	-0.0040	-0.0196	-0.0390	-0.0667	-0.1106	-0.1855	-0.3222	-0.5270	-0.0206
45.0	0.2871	0.1979	0.1134	0.0604	0.0225	-0.0090	-0.0409	-0.0801	-0.1353	-0.2186	-0.3487	-0.5590	-0.8033	-0.0807
67.5	0.0346	0.0685	0.0580	0.0423	0.0162	-0.0208	-0.0681	-0.1273	-0.2008	-0.2889	-0.3908	-0.5081	-0.5381	-0.4884
90.0	-0.3075	-0.1747	-0.1176	-0.0876	-0.0733	-0.0846	-0.1246	-0.1770	-0.2166	-0.2273	-0.2013	-0.1114	0.1579	-0.6071
112.5	-0.1431	-0.1668	-0.1494	-0.1684	-0.1925	-0.1998	-0.1850	-0.1566	-0.1247	-0.0855	-0.0121	0.1503	0.3567	0.1665
135.0	0.0903	-0.0572	-0.1154	-0.1487	-0.1933	-0.2135	-0.1809	-0.1149	-0.0516	0.0097	0.1012	0.1925	0.1327	0.2123
157.5	0.0741	0.0350	-0.0714	-0.1299	-0.1170	-0.0959	-0.1043	-0.1042	-0.0407	0.0677	0.1253	0.0833	0.0350	0.0618
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	6.121	15.595	24.418	30.587	34.080	35.853	36.555	35.639	31.576	23.119	11.153	0.0	-583.737 598.848

TABLE A18

R/r = 5.0 t/r = 0.01

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0204	-0.0697	-0.0325	-0.0137	-0.0046	-0.0020	-0.0047	-0.0130	-0.0287	-0.0560	-0.1041	-0.1925	-0.0384	-0.6205	0.7688
22.5	-0.0076	-0.0554	-0.0290	-0.0157	-0.0092	-0.0078	-0.0113	-0.0203	-0.0359	-0.0607	-0.1000	-0.1674	-0.0119	-0.7200	0.9700
45.0	0.0227	0.0373	0.0987	0.1321	0.1429	0.1423	0.1364	0.1268	0.1130	0.0902	0.0464	-0.0307	0.0481	-3.8054	4.1374
67.5	0.0395	-0.0307	0.0406	0.1523	0.2424	0.2949	0.3232	0.3392	0.3307	0.2692	0.1450	0.0109	0.0914	-2.0951	0.8029
90.0	-0.0782	-0.2619	-0.5771	-0.7237	-0.7117	-0.6306	-0.5701	-0.5808	-0.6559	-0.7237	-0.6617	-0.3719	-0.0671	13.6544	-14.1285
112.5	-0.1032	0.2273	0.2256	0.0019	-0.2395	-0.3856	-0.4602	-0.5097	-0.4956	-0.3379	-0.0716	0.0754	-0.2677	0.2588	1.3597
135.0	0.0969	0.0756	0.2917	0.4646	0.4043	0.1671	-0.0213	0.0177	0.2336	0.3947	0.3104	0.0469	-0.1148	-4.4917	4.3291
157.5	0.1297	0.0392	-0.0282	0.0294	0.1193	0.1620	0.1666	0.1541	0.1120	0.0063	-0.1147	-0.0994	-0.0237	-1.1788	0.9459
180.0	0.1148	0.1156	0.0289	-0.1244	-0.0726	0.1912	0.3901	0.2998	-0.0077	-0.2220	-0.1639	-0.0370	-0.0215	-1.1332	0.9726

INSIDE AXIAL STRESS FACTORS

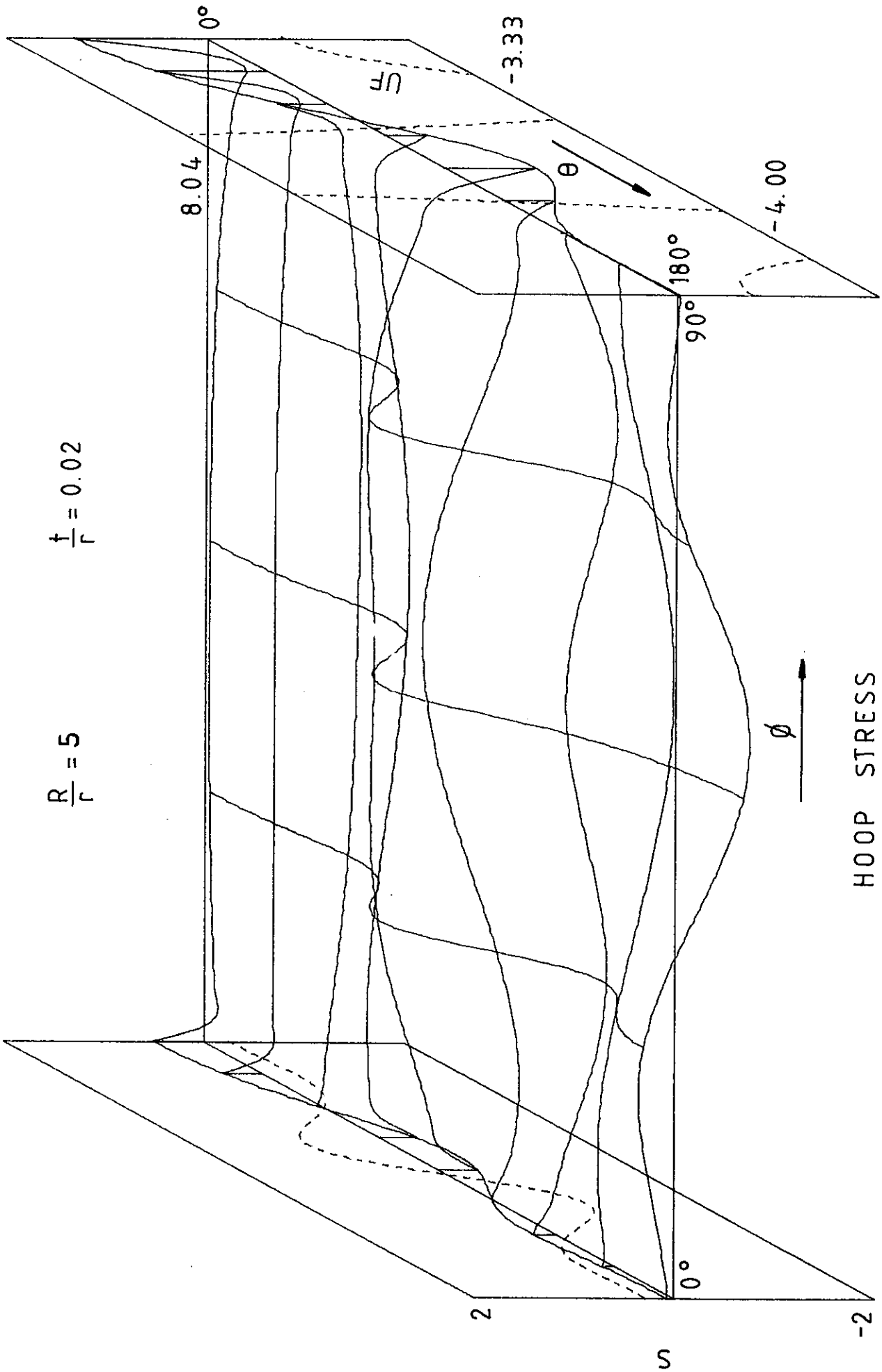
Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0680	0.5118	0.3134	0.2134	0.1681	0.1592	0.1814	0.2377	0.3400	0.5127	0.8037	1.3101	-0.1279	-0.0142	0.1070
22.5	-0.0253	0.4368	0.2774	0.1919	0.1525	0.1464	0.1698	0.2260	0.3257	0.4896	0.7555	1.1915	-0.0396	0.2317	-0.1054
45.0	0.0756	0.2292	0.2178	0.1857	0.1628	0.1605	0.1830	0.2341	0.3215	0.4540	0.6325	0.8299	0.1603	-0.7254	1.1871
67.5	0.1315	-0.1161	0.2024	0.3558	0.4215	0.4532	0.4870	0.5395	0.6030	0.6383	0.5610	0.2181	0.3048	-5.1145	5.2009
90.0	-0.2607	-0.6806	-0.4039	-0.1517	0.0561	0.2068	0.3046	0.3492	0.3109	0.1336	-0.2436	-0.8833	-0.2236	2.9811	-3.9271
112.5	-0.3439	-0.3337	-0.4522	-0.4575	-0.3790	-0.2565	-0.1781	-0.2228	-0.3963	-0.6472	-0.9265	-1.1738	-0.8922	5.3559	-4.7217
135.0	0.3229	0.3266	0.1772	0.1082	0.0480	-0.0370	-0.1269	-0.2001	-0.2784	-0.3939	-0.5113	-0.4961	-0.3826	-1.3351	1.7084
157.5	0.4322	0.4468	0.3674	0.2584	0.1203	-0.0571	-0.2278	-0.3398	-0.3863	-0.3888	-0.3296	-0.1824	-0.0791	-0.6477	0.6539
180.0	0.3827	0.4543	0.4648	0.2984	0.0821	-0.0806	-0.2224	-0.3835	-0.4930	-0.4352	-0.2418	-0.0976	-0.0717	-0.4604	0.4826

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.2173	0.1328	0.0681	0.0340	0.0128	-0.0034	-0.0193	-0.0387	-0.0664	-0.1103	-0.1862	-0.3278	-0.5218	0.0392
45.0	0.2842	0.2219	0.1250	0.0645	0.0233	-0.0095	-0.0422	-0.0819	-0.1368	-0.2204	-0.3557	-0.5821	-0.7953	0.1691
67.5	0.0343	0.1713	0.1467	0.0960	0.0406	-0.0120	-0.0644	-0.1265	-0.2115	-0.3289	-0.4782	-0.6359	-0.5327	0.2808
90.0	-0.3044	-0.1963	-0.0386	0.0328	0.0337	-0.0137	-0.0900	-0.1833	-0.2801	-0.3499	-0.3382	-0.1692	0.1563	-0.3977
112.5	-0.1416	-0.3378	-0.3107	-0.2165	-0.1339	-0.1130	-0.1588	-0.2198	-0.2198	-0.1099	0.1076	0.3656	0.3532	-0.6730
135.0	0.0894	0.0011	-0.1967	-0.3178	-0.3507	-0.3173	-0.2297	-0.1024	0.0458	0.1889	0.2679	0.2172	0.1314	-0.2067
157.5	0.0734	0.0946	0.0160	-0.1663	-0.3226	-0.3349	-0.1897	0.0284	0.1906	0.2056	0.1036	0.0220	0.0346	-0.0800
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-1.536	-3.235	-7.271	-14.890	-23.976	-30.072	-29.854	-23.716	-15.385	-8.647	-4.253	0.0	324.114	-330.281



HOOP STRESS
FIGURE A19

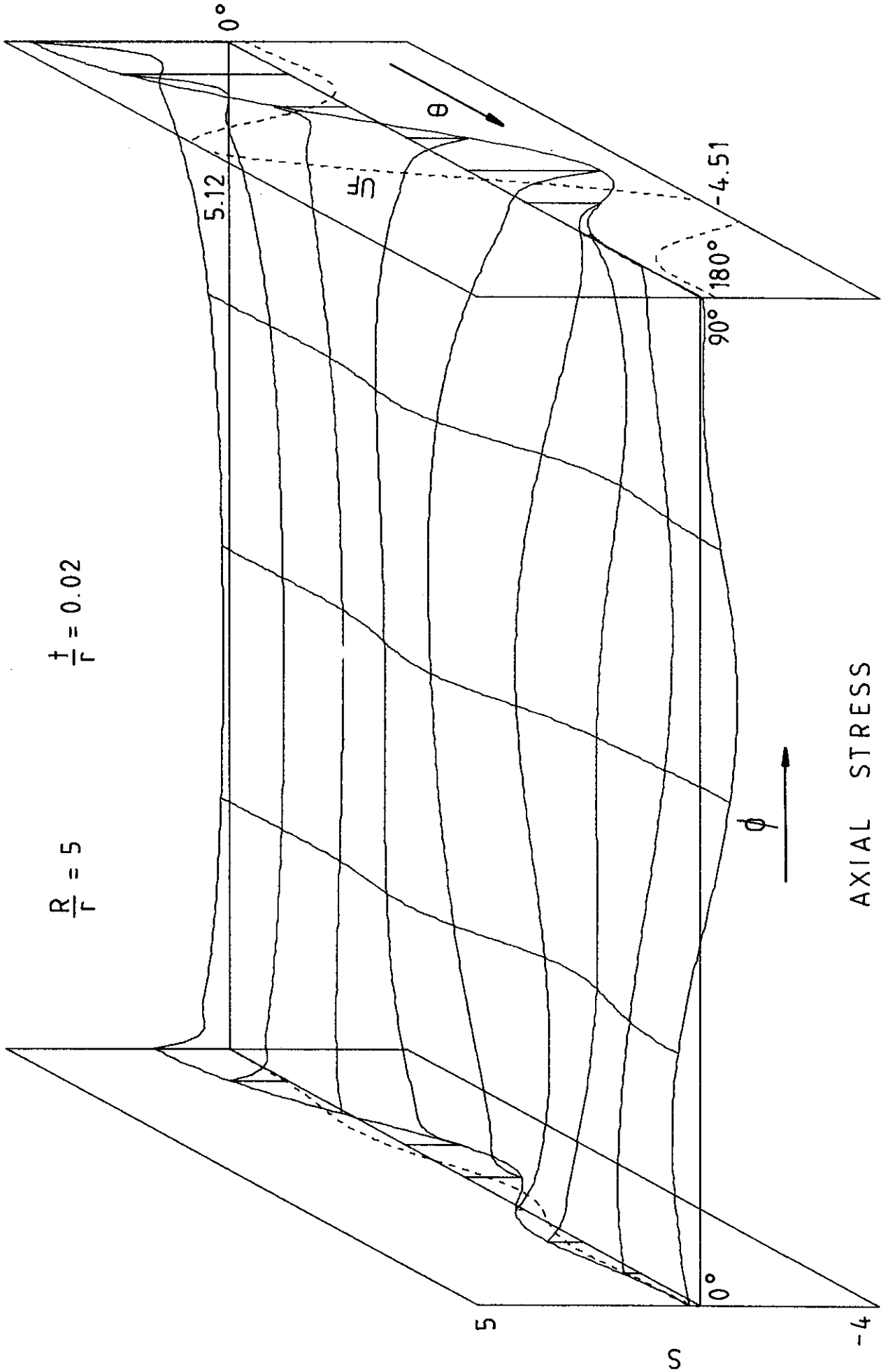


FIGURE A20

TABLE A19

R/r = 5.0 t/r = 0.02

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.4995	-0.0937	-0.0654	-0.0479	-0.0391	-0.0369	-0.0402	-0.0490	-0.0664	-0.0978	-0.1512	-0.2351	1.3300	0.4985 -0.7486
22.5	0.3838	-0.1052	-0.1115	-0.1115	-0.1075	-0.1036	-0.1038	-0.1110	-0.1275	-0.1541	-0.1901	-0.2334	1.1207	1.4076 -1.7219
45.0	0.0373	-0.0864	-0.1822	-0.2591	-0.3079	-0.3339	-0.3489	-0.3614	-0.3677	-0.3532	-0.3008	-0.2052	0.4860	3.2761 -3.3249
67.5	-0.3786	0.1248	0.1181	0.0394	-0.0709	-0.1761	-0.2480	-0.2682	-0.2294	-0.1375	-0.0187	0.0701	-0.4168	-0.5156 1.3038
90.0	-0.3845	0.1791	0.4401	0.6258	0.6975	0.6888	0.6677	0.6844	0.7293	0.7328	0.6077	0.3187	-0.9052	-7.7677 8.0354
112.5	0.0513	-0.1941	-0.1738	0.0216	0.2939	0.5558	0.7307	0.7642	0.6415	0.3878	0.0731	-0.1554	-0.5192	-2.0428 1.1808
135.0	0.2286	-0.0943	-0.3617	-0.4941	-0.4182	-0.2282	-0.0858	-0.1099	-0.2989	-0.5141	-0.5576	-0.3446	-0.0532	3.8366 -3.9828
157.5	0.1183	0.1745	0.1454	0.0065	-0.1853	-0.3781	-0.5189	-0.5664	-0.5101	-0.3677	-0.1799	-0.0344	0.0082	1.9620 -1.6276
180.0	0.0661	0.1905	0.3430	0.3159	0.0315	-0.3690	-0.6695	-0.7124	-0.4807	-0.1306	0.0877	0.0658	-0.0155	1.0258 -0.7488

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	1.6651	0.4224	0.2443	0.1578	0.1212	0.1173	0.1408	0.1949	0.2907	0.4515	0.7242	1.2060	4.4333	0.3458 -0.3361
22.5	1.2794	0.3586	0.2047	0.1203	0.0813	0.0755	0.0978	0.1502	0.2437	0.4006	0.6606	1.0934	3.7356	0.6694 -0.5878
45.0	0.1244	0.2183	0.1962	0.1476	0.1052	0.0847	0.0940	0.1398	0.2307	0.3759	0.5758	0.8011	1.6201	-0.1553 0.5610
67.5	-1.2621	0.0019	0.2920	0.4228	0.4651	0.4711	0.4852	0.5343	0.6132	0.6789	0.6452	0.3542	-1.3895	-4.1560 4.5687
90.0	-1.2817	-0.4419	-0.0689	0.2453	0.4843	0.6546	0.7686	0.8270	0.8030	0.6336	0.2268	-0.5166	-3.0174	-3.1733 2.6695
112.5	0.1711	-0.5008	-0.5916	-0.4792	-0.2528	-0.0007	0.1700	0.1708	-0.0267	-0.3889	-0.8415	-1.2455	-1.7308	3.6436 -4.0627
135.0	0.7621	0.1721	-0.1567	-0.3270	-0.3515	-0.3174	-0.3139	-0.4023	-0.5986	-0.8400	-0.9690	-0.8064	-0.1773	3.0907 -2.7148
157.5	0.3944	0.5223	0.4547	0.2682	0.0092	-0.2758	-0.5198	-0.6630	-0.6815	-0.5864	-0.4013	-0.1806	0.0273	0.7237 -0.3891
180.0	0.2205	0.5055	0.6328	0.4995	0.1366	-0.2981	-0.6539	-0.8200	-0.7375	-0.4507	-0.1477	-0.0377	-0.0518	0.5408 -0.3233

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1708	0.1099	0.0586	0.0299	0.0110	-0.0038	-0.0183	-0.0365	-0.0633	-0.1059	-0.1771	-0.3029	-0.4613	-0.0169
45.0	0.2000	0.1408	0.0813	0.0468	0.0203	-0.0062	-0.0372	-0.0767	-0.1300	-0.2054	-0.3177	-0.4980	-0.6822	-0.1455
67.5	0.0051	0.0194	0.0045	-0.0024	-0.0117	-0.0333	-0.0716	-0.1231	-0.1819	-0.2463	-0.3229	-0.4251	-0.4524	-0.4565
90.0	-0.2035	-0.1220	-0.1096	-0.1151	-0.1216	-0.1294	-0.1406	-0.1549	-0.1693	-0.1791	-0.1773	-0.1390	0.0585	-0.4757
112.5	-0.1222	-0.1092	-0.1022	-0.1431	-0.1920	-0.2121	-0.1922	-0.1506	-0.1156	-0.0953	-0.0577	0.0655	0.2854	0.0256
135.0	0.0579	-0.0518	-0.0762	-0.0973	-0.1255	-0.1490	-0.1589	-0.1497	-0.1186	-0.0632	0.0264	0.1470	0.1590	0.2239
157.5	0.0762	-0.0059	-0.0776	-0.0722	-0.0377	-0.0354	-0.0776	-0.1237	-0.1148	-0.0270	0.0848	0.1148	0.0396	0.0873
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	3.720	9.744	16.180	21.696	25.715	28.102	28.761	27.364	23.397	16.641	8.017	0.0	-251.707 258.322

TABLE A20

R/r = 5.0 t/r = 0.02

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0390	-0.0481	-0.0206	-0.0098	-0.0061	-0.0062	-0.0103	-0.0193	-0.0341	-0.0568	-0.0942	-0.1660	-0.0866	-0.5257	0.7491
22.5	-0.0207	-0.0078	0.0397	0.0618	0.0677	0.0647	0.0575	0.0481	0.0354	0.0142	-0.0270	-0.1086	-0.0520	-1.4519	1.7356
45.0	0.0314	0.0423	0.1450	0.2305	0.2840	0.3093	0.3182	0.3183	0.3046	0.2596	0.1644	0.0184	0.0456	-3.3293	3.3199
67.5	0.0608	-0.1262	-0.1454	-0.0709	0.0428	0.1515	0.2236	0.2391	0.1904	0.0856	-0.0409	-0.1098	0.1319	0.7837	-1.6739
90.0	-0.0356	-0.2049	-0.5000	-0.7015	-0.7712	-0.7503	-0.7191	-0.7369	-0.7933	-0.8082	-0.6803	-0.3613	0.0153	8.5665	-8.8648
112.5	-0.1050	0.1658	0.1314	-0.0783	-0.3554	-0.6147	-0.7879	-0.8281	-0.7232	-0.4942	-0.2040	-0.0026	-0.2163	2.5811	-1.6151
135.0	0.0310	0.1586	0.4013	0.5222	0.4230	0.1948	0.0147	0.0147	0.1876	0.3768	0.3784	0.1395	-0.1904	-3.7475	3.9928
157.5	0.1312	0.0163	0.0114	0.0988	0.2205	0.3329	0.3974	0.3864	0.2989	0.1556	-0.0038	-0.0871	-0.0569	-1.9110	1.6420
180.0	0.1343	0.0517	-0.1154	-0.1751	0.0066	0.3131	0.5262	0.4891	0.2081	-0.1242	-0.2490	-0.1240	-0.0230	-0.9642	0.7481

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.1299	0.4205	0.2457	0.1575	0.1190	0.1140	0.1371	0.1912	0.2878	0.4507	0.7261	1.2040	-0.2888	0.2585	-0.1621
22.5	-0.0691	0.3686	0.2358	0.1593	0.1208	0.1126	0.1328	0.1849	0.2797	0.4376	0.6926	1.1023	-0.1734	0.0593	0.1400
45.0	0.1048	0.2239	0.2603	0.2605	0.2503	0.2470	0.2650	0.3151	0.4028	0.5268	0.6755	0.8150	0.1519	-1.6561	2.0064
67.5	0.2028	-0.0969	0.1531	0.3115	0.4145	0.4857	0.5445	0.6009	0.6457	0.6461	0.5415	0.2286	0.4397	-2.9207	2.8580
90.0	-0.1186	-0.4793	-0.3275	-0.1747	-0.0133	0.1408	0.2535	0.2910	0.2343	0.0734	-0.2148	-0.6837	0.0512	1.9357	-2.4121
112.5	-0.3499	-0.2715	-0.3478	-0.3755	-0.3675	-0.3404	-0.3252	-0.3533	-0.4425	-0.5924	-0.7922	-1.0163	-0.7209	4.1620	-3.9197
135.0	0.1035	0.2282	0.1608	0.1140	0.0182	-0.1231	-0.2542	-0.3311	-0.3667	-0.4185	-0.5156	-0.5759	-0.6348	0.0424	0.3945
157.5	0.4373	0.3978	0.3421	0.2688	0.1737	0.0575	-0.0686	-0.1888	-0.2857	-0.3436	-0.3434	-0.2583	-0.1896	-0.9611	1.0297
180.0	0.4476	0.4218	0.3534	0.2177	0.1195	0.0616	-0.0205	-0.1690	-0.3437	-0.4334	-0.3551	-0.1771	-0.0768	-0.5535	0.5388

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.1674	0.1210	0.0618	0.0295	0.0095	-0.0053	-0.0195	-0.0369	-0.0622	-0.1035	-0.1763	-0.3130	-0.4522	0.0628
45.0	0.1960	0.2061	0.1254	0.0691	0.0270	-0.0069	-0.0386	-0.0764	-0.1314	-0.2175	-0.3538	-0.5718	-0.6687	0.1876
67.5	0.0050	0.1322	0.1307	0.1023	0.0599	0.0086	-0.0513	-0.1245	-0.2172	-0.3337	-0.4698	-0.6035	-0.4434	0.1531
90.0	-0.1995	-0.1628	-0.0490	0.0140	0.0291	-0.0048	-0.0821	-0.1830	-0.2780	-0.3365	-0.3246	-0.1905	0.0573	-0.3231
112.5	-0.1198	-0.2865	-0.2626	-0.2060	-0.1626	-0.1525	-0.1717	-0.1962	-0.1888	-0.1101	0.0594	0.2915	0.2797	-0.5907
135.0	0.0567	-0.0435	-0.1990	-0.3027	-0.3510	-0.3334	-0.2482	-0.1157	0.0311	0.1643	0.2583	0.2663	0.1558	-0.2914
157.5	0.0747	0.0988	-0.0281	-0.1937	-0.2959	-0.2920	-0.1904	-0.0291	0.1296	0.2086	0.1627	0.0503	0.0388	-0.0733
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
180.0	0.0	-1.224	-3.135	-7.182	-13.174	-19.395	-23.578	-24.072	-20.652	-14.724	-8.605	-3.999	0.0	163.781-167.112

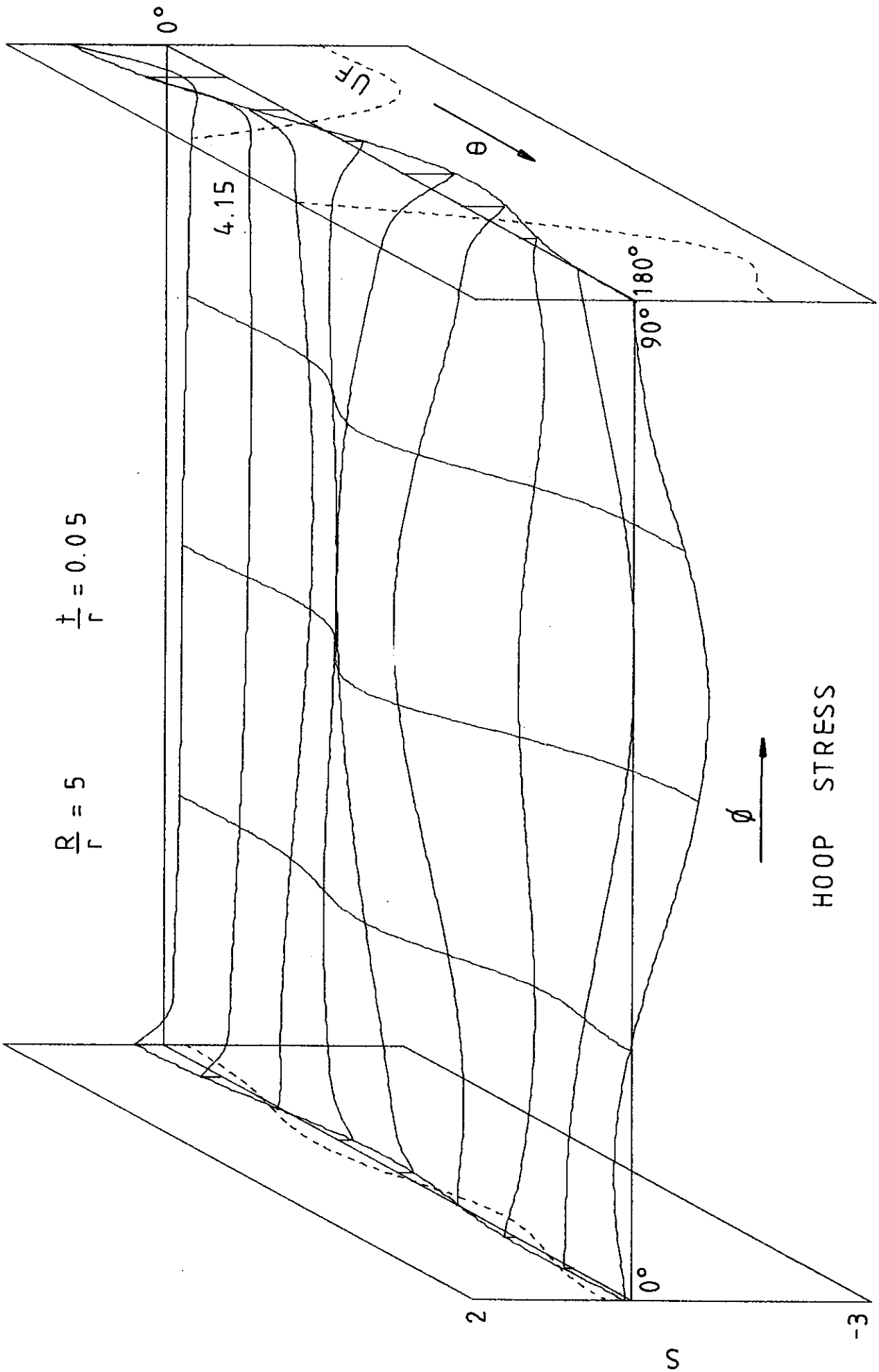
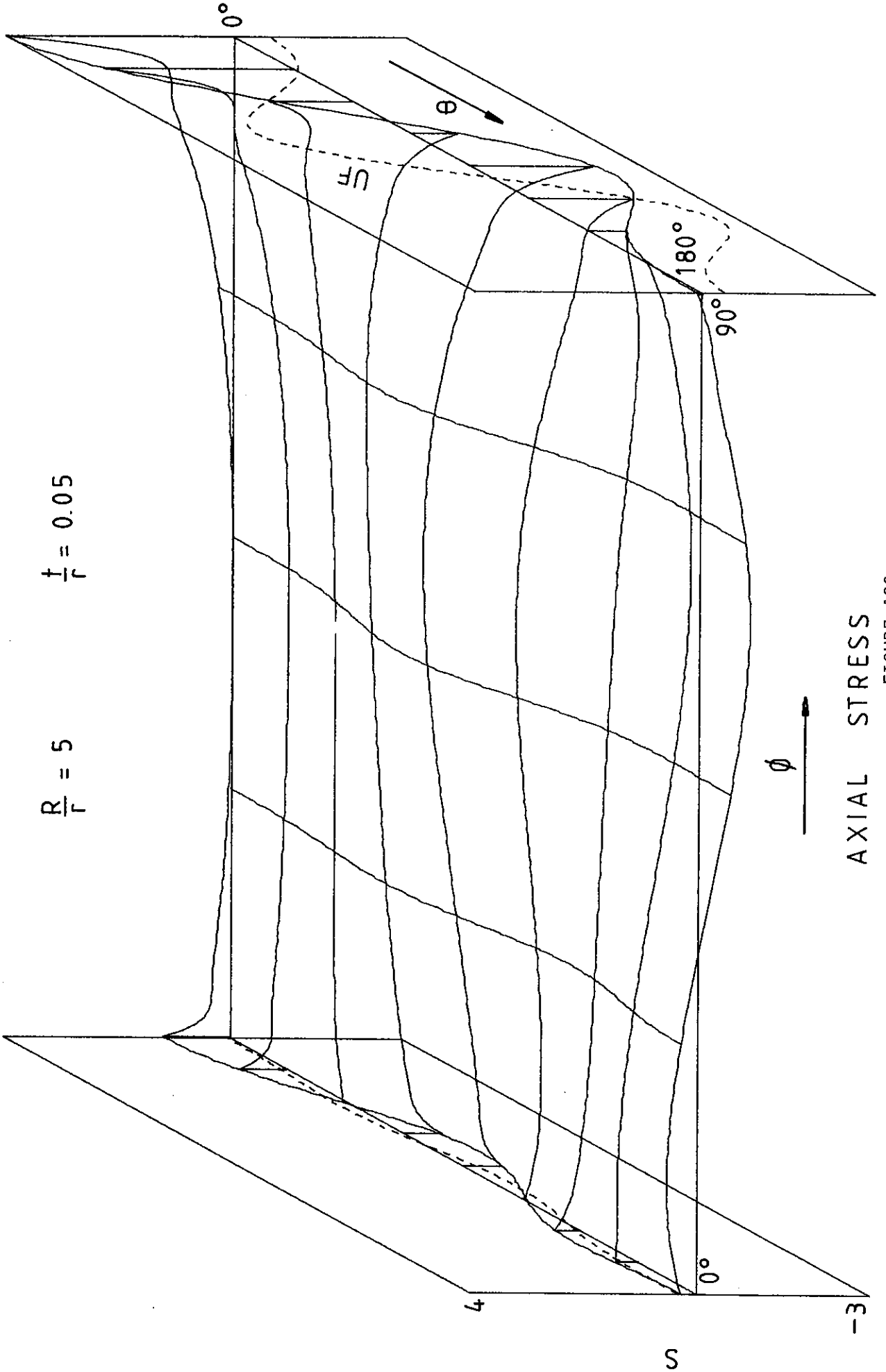


FIGURE A21



AXIAL STRESS

FIGURE A22

TABLE A21

R/r = 5.0 t/r = 0.05

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
0.0	0.3503	-0.1398	-0.1741	-0.1994	-0.2116	-0.2157	-0.2188	-0.2275	-0.2446	-0.2682	-0.2928	-0.3247	1.2020	1.6114	-1.9001
22.5	0.2568	-0.1135	-0.1653	-0.2142	-0.2537	-0.2836	-0.3054	-0.3204	-0.3287	-0.3281	-0.3143	-0.2953	0.9951	1.8095	-2.0043
45.0	0.0252	-0.0105	-0.0557	-0.1257	-0.2081	-0.2877	-0.3479	-0.3746	-0.3609	-0.3088	-0.2279	-0.1423	0.4348	1.2559	-1.1647
67.5	-0.1902	0.1271	0.1906	0.2026	0.1712	0.1196	0.0745	0.0578	0.0783	0.1249	0.1639	0.1527	-0.2459	-1.4989	1.8438
90.0	-0.2035	0.1048	0.2622	0.4235	0.5672	0.6839	0.7631	0.7945	0.7709	0.6843	0.5198	0.2850	-0.6513	-4.0081	4.1482
112.5	-0.0165	-0.0850	-0.0395	0.1194	0.3464	0.5806	0.7565	0.8188	0.7383	0.5263	0.2411	0.0031	-0.5529	-2.2327	1.9449
135.0	0.1349	-0.1101	-0.2213	-0.2391	-0.1827	-0.0989	-0.0325	-0.0199	-0.0811	-0.2005	-0.3065	-0.2811	-0.2099	1.3876	-1.6195
157.5	0.1249	0.0883	0.0161	-0.1291	-0.3153	-0.5043	-0.6546	-0.7296	-0.7073	-0.5879	-0.3992	-0.1963	-0.0071	2.3723	-2.2201
180.0	0.0866	0.2055	0.2062	0.0369	-0.2480	-0.5600	-0.8109	-0.9261	-0.8583	-0.6169	-0.2990	-0.0722	0.0299	2.0405	-1.7172

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
0.0	1.1677	0.2764	0.1285	0.0445	-0.0022	-0.0202	-0.0103	0.0324	0.1193	0.2731	0.5368	1.0031	4.0067	0.6615	-0.5706
22.5	0.8559	0.2653	0.1618	0.0944	0.0499	0.0274	0.0320	0.0727	0.1610	0.3137	0.5593	0.9563	3.3170	0.2504	-0.0882
45.0	0.0840	0.2129	0.2455	0.2511	0.2451	0.2412	0.2541	0.2971	0.3791	0.5008	0.6519	0.8066	1.4494	-1.1466	1.4157
67.5	-0.6341	0.0486	0.2387	0.3721	0.4763	0.5643	0.6396	0.7012	0.7449	0.7547	0.6864	0.4500	-0.8196	-2.6083	2.7620
90.0	-0.6783	-0.2190	-0.0318	0.1600	0.3584	0.5477	0.6970	0.7721	0.7455	0.5945	0.2866	-0.2236	-2.1711	-1.6119	1.4342
112.5	-0.0549	-0.3033	-0.3104	-0.2294	-0.1012	0.0348	0.1389	0.1699	0.0885	-0.1300	-0.4775	-0.8736	-1.8431	1.4395	-1.6735
135.0	0.4498	-0.0012	-0.1444	-0.2274	-0.2913	-0.3569	-0.4253	-0.4989	-0.5928	-0.7232	-0.8679	-0.9124	-0.6996	2.5896	-2.4956
157.5	0.4162	0.3875	0.2935	0.1231	-0.0954	-0.3331	-0.5574	-0.7332	-0.8273	-0.8149	-0.6883	-0.4744	-0.0237	1.4577	-1.1395
180.0	0.2888	0.5357	0.5026	0.3108	0.0389	-0.2561	-0.5345	-0.7517	-0.8483	-0.7691	-0.5167	-0.2268	0.0998	0.7374	-0.3935

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0784	0.0493	0.0235	0.0136	0.0072	-0.0010	-0.0140	-0.0325	-0.0573	-0.0914	-0.1437	-0.2385	-0.3284	-0.0725
45.0	0.0793	0.0451	0.0100	-0.0038	-0.0123	-0.0235	-0.0414	-0.0681	-0.1050	-0.1557	-0.2314	-0.3652	-0.4719	-0.2112
67.5	-0.0047	-0.0121	-0.0440	-0.0648	-0.0785	-0.0876	-0.0954	-0.1070	-0.1282	-0.1648	-0.2240	-0.3219	-0.3447	-0.3645
90.0	-0.0838	-0.0552	-0.0832	-0.1227	-0.1534	-0.1657	-0.1597	-0.1440	-0.1317	-0.1351	-0.1558	-0.1740	-0.0577	-0.3400
112.5	-0.0661	-0.0479	-0.0634	-0.1041	-0.1437	-0.1691	-0.1769	-0.1694	-0.1531	-0.1350	-0.1105	-0.0402	0.1485	-0.0806
135.0	0.0108	-0.0375	-0.0328	-0.0310	-0.0440	-0.0759	-0.1217	-0.1664	-0.1891	-0.1683	-0.0893	0.0493	0.1627	0.1409
157.5	0.0397	-0.0324	-0.0242	0.0081	0.0230	0.0029	-0.0481	-0.1099	-0.1508	-0.1351	-0.0467	0.0735	0.0807	0.1307
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	Unflanged + const.
90.0	0.0	1.572	4.198	7.451	10.855	13.898	16.038	16.812	15.946	13.413	9.446	4.650	0.0	-78.377	80.504

TABLE A22

R/r = 5.0 t/r = 0.05

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.0478	0.0409	0.1205	0.1642	0.1836	0.1867	0.1818	0.1744	0.1641	0.1421	0.0898	-0.0397	-0.1525	-1.6412	1.9006
22.5	-0.0224	0.0324	0.1182	0.1831	0.2300	0.2605	0.2761	0.2766	0.2595	0.2173	0.1360	-0.0161	-0.0973	-1.8453	2.0037
45.0	0.0329	-0.0334	0.0160	0.0939	0.1841	0.2689	0.3283	0.3457	0.3121	0.2284	0.1044	-0.0416	0.0386	-1.2251	1.0762
67.5	0.0582	-0.1463	-0.2391	-0.2583	-0.2239	-0.1657	-0.1165	-0.1029	-0.1353	-0.1992	-0.2505	-0.2185	0.1521	1.7994	-2.2132
90.0	0.0075	-0.1189	-0.3140	-0.4973	-0.6542	-0.7785	-0.8617	-0.8952	-0.8732	-0.7856	-0.6098	-0.3210	0.1073	4.5970	-4.7591
112.5	-0.0569	0.0861	0.0303	-0.1495	-0.4076	-0.6757	-0.8783	-0.9526	-0.8687	-0.6443	-0.3496	-0.0989	-0.0821	2.7342	-2.3859
135.0	-0.0216	0.1631	0.2805	0.2836	0.1898	0.0575	-0.0549	-0.1006	-0.0548	0.0608	0.1552	0.1064	-0.2038	-1.1952	1.5193
157.5	0.0860	0.0437	0.0931	0.2073	0.3576	0.5044	0.6042	0.6216	0.5414	0.3759	0.1674	-0.0071	-0.1619	-2.3072	2.2301
180.0	0.1400	-0.0310	-0.0789	0.0436	0.2938	0.5708	0.7728	0.8189	0.6685	0.3564	0.0219	-0.1268	-0.1108	-1.9753	1.7163

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
0.0	-0.1593	0.3007	0.1957	0.1334	0.0963	0.0809	0.0910	0.1350	0.2245	0.3781	0.6288	1.0356	-0.5082	-0.0950	0.2952
22.5	-0.0746	0.2727	0.2154	0.1816	0.1632	0.1602	0.1778	0.2240	0.3090	0.4459	0.6558	0.9718	-0.3245	-0.5533	0.7651
45.0	0.1096	0.1624	0.2140	0.2544	0.2944	0.3374	0.3853	0.4402	0.5050	0.5809	0.6641	0.7308	0.1286	-1.3887	1.5468
67.5	0.1942	-0.0454	0.0695	0.1658	0.2638	0.3612	0.4468	0.5079	0.5340	0.5157	0.4338	0.2263	0.5069	-1.0258	0.9868
90.0	0.0251	-0.2104	-0.1545	-0.1020	-0.0410	0.0245	0.0825	0.1166	0.1088	0.0402	-0.1126	-0.4088	0.3576	1.1072	-1.2547
112.5	-0.1897	-0.1229	-0.1500	-0.1889	-0.2456	-0.3076	-0.3587	-0.3911	-0.4140	-0.4547	-0.5503	-0.7413	-0.2737	2.3715	-2.3170
135.0	-0.0720	0.1312	0.0963	0.0371	-0.0630	-0.1857	-0.3036	-0.3949	-0.4535	-0.4948	-0.5478	-0.6220	-0.6792	1.0720	-0.8242
157.5	0.2868	0.2899	0.2531	0.2192	0.1805	0.1263	0.0456	-0.0653	-0.1971	-0.3254	-0.4133	-0.4115	-0.5396	-0.5214	0.6925
180.0	0.4666	0.3228	0.2710	0.2459	0.2502	0.2507	0.2074	0.0958	-0.0776	-0.2642	-0.3808	-0.3426	-0.3693	-0.9677	1.0481

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0745	0.1006	0.0621	0.0383	0.0206	0.0048	-0.0118	-0.0321	-0.0606	-0.1046	-0.1772	-0.3029	-0.3124	0.0915
45.0	0.0754	0.1450	0.1050	0.0762	0.0500	0.0197	-0.0187	-0.0681	-0.1323	-0.2187	-0.3419	-0.5260	-0.4489	0.1367
67.5	-0.0045	0.0715	0.0787	0.0744	0.0573	0.0220	-0.0344	-0.1107	-0.2030	-0.3070	-0.4190	-0.5306	-0.3279	0.0287
90.0	-0.0797	-0.0946	-0.0456	-0.0233	-0.0249	-0.0490	-0.0937	-0.1551	-0.2241	-0.2823	-0.3004	-0.2365	-0.0549	-0.2489
112.5	-0.0628	-0.1805	-0.1786	-0.1835	-0.1937	-0.2002	-0.1971	-0.1835	-0.1580	-0.1098	-0.0150	0.1518	0.1413	-0.4477
135.0	0.0102	-0.0877	-0.1903	-0.2644	-0.3038	-0.3027	-0.2581	-0.1715	-0.0515	0.0848	0.2110	0.2947	0.1547	-0.3573
157.5	0.0378	0.0184	-0.0991	-0.1853	-0.2263	-0.2256	-0.1856	-0.1061	0.0069	0.1264	0.1993	0.1746	0.0767	-0.1446
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos	+ const.
180.0	0.0	-1.075	-2.950	-5.815	-9.187	-12.385	-14.701	-15.539	-14.561	-11.830	-7.926	-3.876	0.0	66.568	-67.994

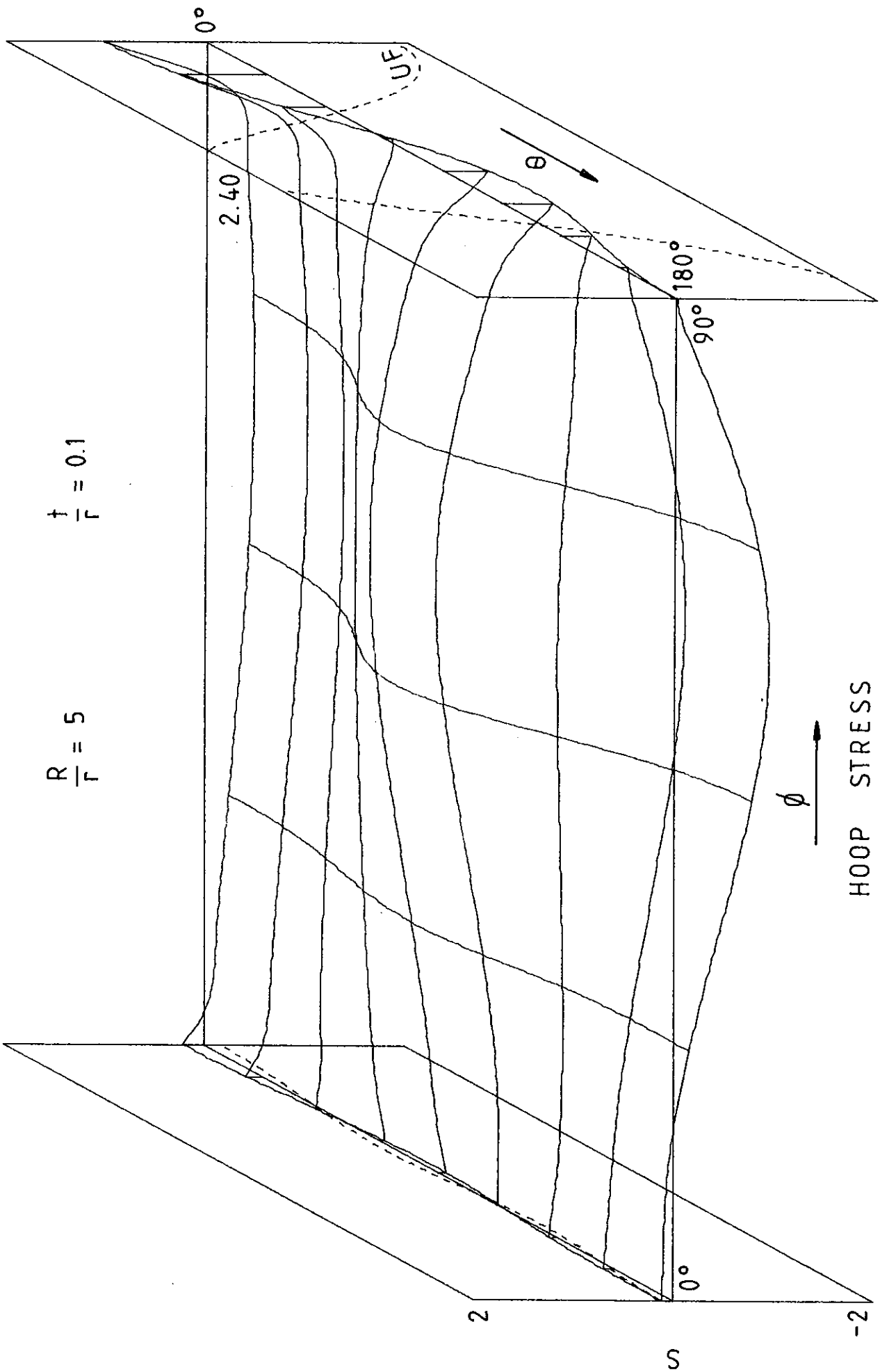
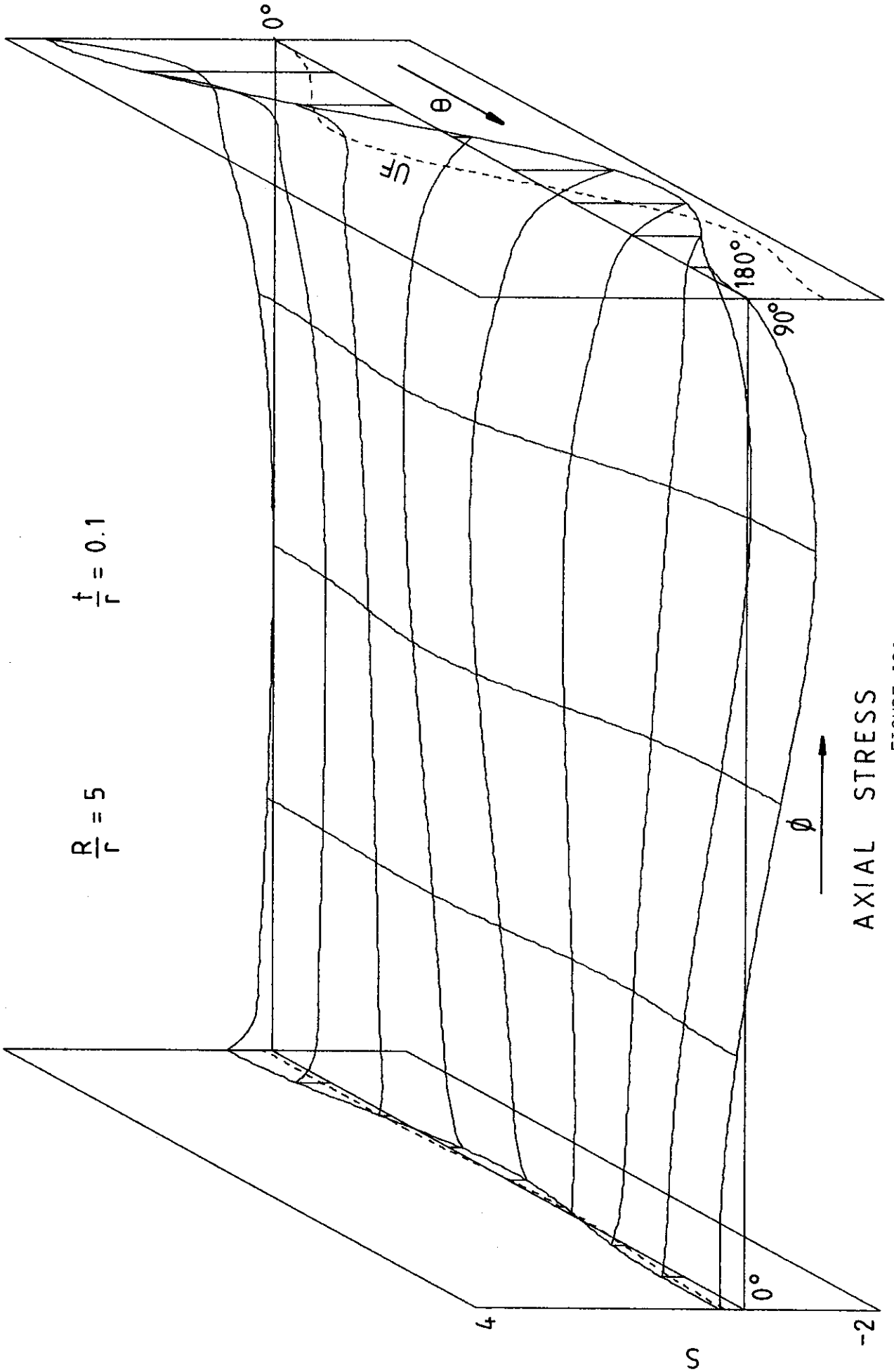


FIGURE A23



AXIAL STRESS

FIGURE A24

TABLE A23

R/r = 5.0 t/r = 0.1

OUTSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.1991	-0.1160	-0.1757	-0.2464	-0.3167	-0.3813	-0.4335	-0.4673	-0.4788	-0.4661	-0.4265	-0.4014	1.0266	1.7145 -1.8737
22.5	0.1539	-0.0840	-0.1331	-0.1976	-0.2660	-0.3314	-0.3856	-0.4204	-0.4299	-0.4110	-0.3626	-0.3264	0.8627	1.4259 -1.5312
45.0	0.0452	-0.0052	-0.0129	-0.0432	-0.0847	-0.1299	-0.1704	-0.1972	-0.2024	-0.1817	-0.1387	-0.1157	0.4329	0.4101 -0.3864
67.5	-0.0574	0.0636	0.1240	0.1710	0.2093	0.2390	0.2587	0.2673	0.2652	0.2520	0.2209	0.1377	-0.0846	-1.2123 1.3368
90.0	-0.0827	0.0562	0.1559	0.2779	0.4110	0.5395	0.6436	0.7029	0.6997	0.6225	0.4696	0.2412	-0.4507	-2.3004 2.3883
112.5	-0.0198	-0.0104	0.0445	0.1545	0.2943	0.4386	0.5607	0.6315	0.6228	0.5162	0.3221	0.0877	-0.5067	-1.6041 1.5639
135.0	0.0641	-0.0291	-0.0604	-0.0592	-0.0417	-0.0189	0.0008	0.0075	-0.0102	-0.0594	-0.1263	-0.1605	-0.3124	0.3462 -0.4198
157.5	0.1031	0.0369	-0.0374	-0.1508	-0.2887	-0.4320	-0.5600	-0.6493	-0.6768	-0.6251	-0.4921	-0.2839	-0.0865	1.8394 -1.8049
180.0	0.1073	0.0842	0.0067	-0.1507	-0.3550	-0.5720	-0.7671	-0.9013	-0.9333	-0.8328	-0.6064	-0.2985	0.0034	2.2729 -2.1632

OUTSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
0.0	0.6636	0.1915	0.1296	0.0789	0.0396	0.0125	0.0053	0.0301	0.1020	0.2408	0.4806	0.8131	3.4220	0.1238 0.0116
22.5	0.5129	0.1878	0.1538	0.1252	0.1054	0.0957	0.1013	0.1338	0.2042	0.3298	0.5369	0.8054	2.8757	-0.2277 0.3788
45.0	0.1507	0.1571	0.1917	0.2229	0.2596	0.3023	0.3503	0.4046	0.4692	0.5506	0.6536	0.7360	1.4430	-1.0429 1.2039
67.5	-0.1913	0.0653	0.1613	0.2572	0.3616	0.4707	0.5735	0.6571	0.7088	0.7161	0.6587	0.4896	-0.2821	-1.5510 1.6493
90.0	-0.2757	-0.0639	0.0271	0.1343	0.2550	0.3816	0.4990	0.5852	0.6122	0.5468	0.3498	0.0072	-1.5022	-0.8993 0.8777
112.5	-0.0659	-0.1106	-0.0939	-0.0550	-0.0098	0.0373	0.0810	0.1078	0.0912	-0.0072	-0.2274	-0.5311	-1.6889	0.6506 -0.7144
135.0	0.2135	0.0229	-0.0351	-0.0957	-0.1707	-0.2565	-0.3443	-0.4281	-0.5106	-0.6039	-0.7206	-0.7970	-1.0413	1.6963 -1.6442
157.5	0.3435	0.2478	0.1646	0.0353	-0.1252	-0.3085	-0.5031	-0.6905	-0.8427	-0.9244	-0.9017	-0.7294	-0.2885	1.6431 -1.4255
180.0	0.3577	0.3571	0.2745	0.1235	-0.0636	-0.2774	-0.5092	-0.7377	-0.9214	-0.9993	-0.9134	-0.6367	0.0114	1.3992 -1.1114

OUTSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0210	0.0023	-0.0122	-0.0187	-0.0219	-0.0238	-0.0260	-0.0307	-0.0403	-0.0582	-0.0902	-0.1528	-0.2064	-0.1014
45.0	0.0192	-0.0078	-0.0349	-0.0506	-0.0595	-0.0635	-0.0650	-0.0676	-0.0767	-0.0992	-0.1460	-0.2382	-0.3076	-0.2092
67.5	-0.0062	-0.0249	-0.0617	-0.0897	-0.1081	-0.1164	-0.1161	-0.1113	-0.1091	-0.1197	-0.1569	-0.2328	-0.2572	-0.2863
90.0	-0.0301	-0.0307	-0.0683	-0.1045	-0.1323	-0.1493	-0.1550	-0.1513	-0.1430	-0.1390	-0.1503	-0.1747	-0.1016	-0.2609
112.5	-0.0271	-0.0214	-0.0416	-0.0679	-0.0958	-0.1231	-0.1481	-0.1678	-0.1786	-0.1779	-0.1616	-0.1181	0.0492	-0.1159
135.0	-0.0035	-0.0144	-0.0053	-0.0048	-0.0196	-0.0503	-0.0944	-0.1448	-0.1890	-0.2069	-0.1723	-0.0740	0.1095	0.0417
157.5	0.0096	-0.0118	0.0084	0.0235	0.0219	0.0014	-0.0357	-0.0836	-0.1299	-0.1522	-0.1214	-0.0327	0.0773	0.0806
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.
90.0	0.0	0.616	1.755	3.246	4.916	6.538	7.851	8.582	8.492	7.433	5.423	2.680	0.0	-27.849 28.768

TABLE A24

R/r = 5.0 t/r = 0.1

INSIDE HOOP STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0267	0.0530	0.1419	0.2243	0.3008	0.3667	0.4144	0.4358	0.4240	0.3721	0.2684	0.0924	-0.1686	-1.7487	1.8790
22.5	-0.0122	0.0260	0.0978	0.1722	0.2470	0.3150	0.3665	0.3910	0.3792	0.3238	0.2175	0.0513	-0.1151	-1.4381	1.5097
45.0	0.0187	-0.0415	-0.0280	0.0050	0.0503	0.0983	0.1383	0.1588	0.1486	0.1009	0.0195	-0.0801	0.0140	-0.3212	0.2535
67.5	0.0368	-0.0968	-0.1706	-0.2285	-0.2741	-0.3098	-0.3348	-0.3488	-0.3537	-0.3500	-0.3248	-0.2595	0.1331	1.5039	-1.6729
90.0	0.0219	-0.0697	-0.1903	-0.3371	-0.4959	-0.6490	-0.7732	-0.8445	-0.8426	-0.7550	-0.5745	-0.3339	0.1455	2.7713	-2.8760
112.5	-0.0066	0.0293	-0.0385	-0.1760	-0.3528	-0.5371	-0.6951	-0.7905	-0.7885	-0.6677	-0.4388	-0.2036	0.0268	2.0468	-1.9741
135.0	-0.0023	0.0867	0.1117	0.0922	0.0443	-0.0158	-0.0752	-0.1192	-0.1303	-0.0968	-0.0319	-0.0170	-0.1336	-0.0967	0.2374
157.5	0.0422	0.0514	0.1097	0.2133	0.3373	0.4593	0.5548	0.5983	0.5672	0.4491	0.2565	0.0376	-0.2297	-1.7321	1.7682
180.0	0.0703	0.0159	0.0682	0.2179	0.4169	0.6215	0.7891	0.8745	0.8335	0.6404	0.3266	0.0213	-0.2530	-2.1989	2.1553

INSIDE AXIAL STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
0.0	-0.0889	0.2285	0.1919	0.1869	0.1922	0.2068	0.2332	0.2779	0.3507	0.4669	0.6475	1.0139	-0.5621	-0.6968	0.8759
22.5	-0.0406	0.2022	0.1853	0.1942	0.2132	0.2411	0.2783	0.3285	0.3983	0.4990	0.6457	0.9336	-0.3837	-0.7985	0.9630
45.0	0.0625	0.1247	0.1473	0.1822	0.2273	0.2804	0.3382	0.3978	0.4577	0.5187	0.5811	0.6748	0.0468	-0.8350	0.9476
67.5	0.1227	0.0201	0.0597	0.0978	0.1437	0.1968	0.2532	0.3063	0.3473	0.3650	0.3430	0.2394	0.4438	-0.3125	0.3451
90.0	0.0731	-0.0451	-0.0293	-0.0285	-0.0296	-0.0273	-0.0187	-0.0051	0.0056	-0.0031	-0.0585	-0.2477	0.4851	0.7191	-0.7305
112.5	-0.0220	-0.0096	-0.0281	-0.0716	-0.1314	-0.1964	-0.2559	-0.3018	-0.3333	-0.3609	-0.4095	-0.5662	0.0894	1.3662	-1.3302
135.0	-0.0076	0.0987	0.0709	0.0243	-0.0419	-0.1219	-0.2086	-0.2947	-0.3746	-0.4464	-0.5133	-0.6187	-0.4455	0.9545	-0.8310
157.5	0.1408	0.1902	0.1699	0.1561	0.1353	0.0982	0.0368	-0.0540	-0.1736	-0.3112	-0.4387	-0.5368	-0.7658	0.0296	0.1343
180.0	0.2345	0.2205	0.2042	0.2100	0.2179	0.2102	0.1700	0.0842	-0.0508	-0.2217	-0.3849	-0.4905	-0.8432	-0.4110	0.5764

INSIDE SHEAR STRESS FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x sin
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.5	0.0190	0.0573	0.0420	0.0354	0.0290	0.0187	0.0021	-0.0223	-0.0557	-0.1010	-0.1656	-0.2776	-0.1867	0.0536
45.0	0.0174	0.0774	0.0609	0.0528	0.0426	0.0246	-0.0053	-0.0499	-0.1114	-0.1927	-0.3010	-0.4682	-0.2783	0.0553
67.5	-0.0056	0.0370	0.0336	0.0273	0.0151	-0.0061	-0.0400	-0.0901	-0.1593	-0.2480	-0.3523	-0.4777	-0.2327	-0.0378
90.0	-0.0273	-0.0453	-0.0429	-0.0539	-0.0712	-0.0916	-0.1155	-0.1458	-0.1849	-0.2302	-0.2668	-0.2675	-0.0919	-0.2100
112.5	-0.0245	-0.1039	-0.1264	-0.1560	-0.1836	-0.2024	-0.2087	-0.2007	-0.1775	-0.1365	-0.0678	0.0503	0.0445	-0.3508
135.0	-0.0031	-0.0905	-0.1524	-0.2013	-0.2359	-0.2536	-0.2484	-0.2125	-0.1390	-0.0273	0.1114	0.2523	0.0991	-0.3427
157.5	0.0087	-0.0386	-0.0991	-0.1399	-0.1653	-0.1775	-0.1724	-0.1416	-0.0769	0.0211	0.1323	0.2112	0.0699	-0.1950
180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIAMETER EXPANSION FACTORS

Theta	Phi=0.0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	Unflanged x cos + const.	
180.0	0.0	-0.638	-1.687	-3.142	-4.808	-6.446	-7.789	-8.557	-8.497	-7.455	-5.468	-2.882	0.0	26.780	-27.652