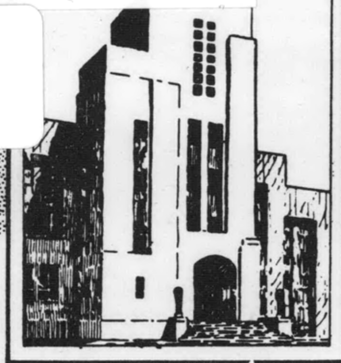

NAVY DEPARTMENT

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SECTION MODULI AND INCIPIENT CAVITATION DIAGRAMS FOR A NUMBER OF NACA SECTIONS

by

A. B. Milam and W. B. Morgan

[redacted]

RESEARCH AND DEVELOPMENT REPORT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Con'td.)

NOTATION

A	Area of section
C_L	Lift coefficient
f	Maximum camber of section
H_o	Total head ($p_o + q_o$)
I_{x_o}	Moment of inertia about the x_o-axis
I_{y_o}	Moment of inertia about the y_o-axis
ℓ	Section length
M_{x_o}	Bending moment about x_o-axis
M_{y_o}	Bending moment about y_o-axis
p_v	Vapor pressure of the fluid
p_o	Static pressure in free stream
p_1	Static pressure at a point on the body
q_o	Dynamic pressure ($1/2 \rho V^2$)
S	Pressure coefficient
S_{crit}	Pressure coefficient at inception of cavitation
t	Maximum thickness of section
V	Free stream velocity
v	Perturbation velocity resulting from the thickness distribution
Δv	Perturbation velocity resulting from the mean line distribution
Δv_a	Perturbation velocity resulting from the angle of attack

x Abscissa measured from the leading edge parallel to the nose-tail line

x_o Abscissa measured from the centroid parallel to the nose-tail line

x_1 Abscissa of nose with reference to axis through the centroid

x_2 Abscissa of tail with reference to axis through the centroid

x_3 Abscissa of point of maximum thickness with reference to axis through the centroid

y_o Ordinate measured from the centroid

y_1 Ordinate of nose with reference to axis through the centroid

y_2 Ordinate of back with reference to axis through the centroid

y_3 Ordinate of point of maximum thickness with reference to axis through the centroid

ρ Density of the fluid

σ Cavitation number of the section

ABSTRACT

The section moduli for the TMB EPH, NACA 16, 65A and 66 TMB modified sections are given in this report along with incipient cavitation curves for the NACA 16, 65A, 0000-1.10 40/1.575 sections with a = 1.0 and 0.8 mean lines and the NACA 66 TMB modified section with an a = 0.8 mean line.

INTRODUCTION

In obtaining the maximum stress in a propeller blade or a hydrofoil it is necessary to know the section modulus. The geometric properties usually calculated in determining the section modulus are (1) the area of the section, (2) the position of the center of gravity and (3) the moments of inertia. In this report these properties have been combined into coefficients for a number of sections which have different camber ratios and thickness ratios.

The cavitation number at which cavitation first begins on the section is known as the incipient cavitation number. This value is derived theoretically by assuming that cavitation begins at the point of minimum pressure on the section. Incipient cavitation diagrams have been prepared for a number of NACA sections operating at shock free entry. From these diagrams it is possible to determine the section chord length which is necessary to prevent cavitation.

GEOMETRIC COEFFICIENTS

The geometric properties were programmed and computed on the Burroughs E-102 electronic computer for the TMB EPH, NACA 16, NACA 65A and NACA 66 TMB modified sections. Table 1 gives the half-ordinates for the sections investigated when the camber is zero and the thickness ratio is 0.10.

The basic equations involved in calculating the geometric coefficients for a coordinate system as shown in Figure 1 gives:

for the area

$$A = \int \int dy_o dx_o ,$$

for the moment of inertia about an axis (x_o) parallel to the nose-tail line and through the centroid

$$I_{x_o} = \int \int y_o^2 dy_o dx_o ,$$

and for the moment of inertia about the vertical axis (y_o) through the centroid and perpendicular to the nose-tail line

$$I_{y_o} = \int \int x_o^2 dy_o dx_o ,$$

Table 1

Half-ordinates for Various Sections

x (per cent ℓ)	Half Ordinates (per cent ℓ)			
	EPH	16	65A	66 TMB Mod
0	0	0	0	0
1.25	1.188	1.077	1.183	1.155
2.5	1.668	1.504	1.623	1.530
5.0	2.325	2.091	2.182	2.095
7.5	2.834	2.527	2.650	2.540
10.0	3.186	2.881	3.040	2.920
20.0	4.204	3.887	4.127	4.002
30.0	4.750	4.514	4.742	4.637
40.0	4.983	4.879	4.995	4.952
45.0	4.997	4.970	4.983	5.000
50.0	4.946	5.000	4.863	4.962
60.0	4.647	4.862	4.304	4.653
70.0	4.085	4.391	3.432	4.035
80.0	3.260	3.499	2.352	3.110
90.0	2.170	2.098	1.188	1.877
95.0	1.480	1.179	0.604	1.143
100.0	0.000	0.100	0.021	0.333

where

x_o is the abscissa measured from the centroid parallel to the nose-tail line

y_o is the ordinate measured from the centroid

These basic equations have been simplified by numerical integration and it is this simplified form which was used in the computations for this report. The equations solved for the TMB EPH section and for the NACA 16 and 65A sections may be found in Reference 1. For the NACA 66 TMB modified section, the equations solved may be found in Reference 2.

The equations for finding the stresses at different points on the section are[1*]:

$$\text{Stress at leading edge} = -\frac{y_1 M_{x_o}}{I_{x_o}} - \frac{x_1 M_{y_o}}{I_{y_o}} \qquad (1)$$

$$\text{Stress at trailing edge} = -\frac{y_2 M_{x_o}}{I_{x_o}} - \frac{x_2 M_{y_o}}{I_{y_o}} \qquad (2)$$

Stress on back at point of maximum thickness

$$= -\frac{y_3 M_{x_o}}{I_{x_o}} - \frac{x_3 M_{y_o}}{I_{y_o}} \qquad (3)$$

*References are listed on page 10

As shown in Figure 1, the abscissas x_1, x_2, and x_3 and the ordinates y_1, y_2, and y_3 are used to denote the abscissas and ordinates of the leading edge, trailing edge, and point of maximum back ordinate, respectively, when the center of the coordinate system is at the centroid of the section. The moments M_{x_o} and M_{y_o} are bending moments about the x_o and y_o axis. Also, it should be noted that in the above equations a positive stress denotes tension and a negative stress denotes compression.

The numerical values for the geometric properties for the four sections were computed for values of the camber ratio (f/ℓ) from 0 to 0.05 and for the thickness ratio (t/ℓ) from 0.02 to 0.20 where ℓ is the section chord. The results were combined to form non-dimensional coefficients in the form of $\frac{y_o \ell^3}{I_{x_o}}$ and $\frac{x_o \ell^3}{I_{y_o}}$ and are tabulated in Appendix A. The section area (A) is also tabulated in Appendix A. It should be noted that these values are practically independent of the shape of the camber line and depend only on the magnitude of the camber ratio. For the range of camber ratios investigated the results hold for a circular arc, NACA a = 1.0 or 0.8 mean line.

With these coefficients it is a rather easy operation to compute an approximate value for the stresses in a section by using Equations (1) to (3). It must be noted that the geometric coefficients must be divided by ℓ^3 and the units of the stress will depend upon the unit of ℓ and the bending moments.

INCIPIENT CAVITATION DIAGRAMS

The incipient cavitation number is used to determine when a hydrofoil section should be free from cavitation. This value is theoretically derived by assuming that cavitation begins at the point of minimum pressure on the section. Diagrams have been prepared using results derived from NACA data[3,4,5], for the NACA 16, 65A and four digit series -1.10 40/1.575 with a = 1.0 and 0.8 mean lines and the NACA 66 TMB modified section with an a = 0.8 mean line, all operating at shock-free entry. With these diagrams it is possible to obtain the maximum thickness ratio that the section can have and still be free from cavitation. These diagrams also include the effect of the camber ratio (f/ℓ).

The cavitation number can be expressed in terms of the pressure coefficient on the body. Reference (3) describes the pressure coefficient (S) at any point on the body as

$$S = \frac{H_o - p_1}{q_o} = \frac{p_o - p_1}{q_o} + 1 \qquad (4)$$

where

H_o is the total head $(p_o + q_o)$

p_o is the static pressure in the free stream

p_1 is the static pressure at a point on the body

q_o is the dynamic pressure $(1/2 \rho V^2)$

V is the velocity of the free stream

ρ is the density of the fluid

The cavitation number at which the section is operating is given by

$$\sigma = \frac{p_o - p_v}{1/2 \rho V^2} \qquad (5)$$

where p_v is the vapor pressure of the fluid.

If it is assumed that cavitation occurs at any point on a body when $p_1 = p_v$ then $S = S_{crit}$ and the cavitation number is

$$\sigma = S_{crit} - 1 \qquad (6)$$

From Reference 3, S has been derived in terms of increments of velocity ratios

$$S = \left(\frac{v}{V} \pm \frac{\Delta v}{V} \pm \frac{\Delta v_a}{V}\right)^2 \qquad (7)$$

where

$\frac{v}{V}$ is the local velocity ratio resulting from the thickness distribution

$\frac{\Delta v}{V}$ is the change in velocity ratio resulting from the mean line distribution

$\frac{\Delta v_a}{V}$ is the change in velocity ratio resulting from the angle of attack

Figure 2 shows a pressure distribution (1 - S) on the NACA 16-512 section as calculated from Equation (7). From this plot it can be seen that cavitation will first occur at 0.55 of the section length and at $1 - S_{crit} = - 0.6$.

The incipient cavitation charts were derived by using the critical cavitation number of the various sections. To facilitate the plotting and the use of the diagrams the results were plotted in terms of the coefficient $\frac{C_L \ell}{t}$. These charts are for shock free entry in which case $\frac{\Delta v_a}{V}$ is zero. The angle of attack may be taken into consideration using the method shown in Reference 3.

Calculations were performed for the NACA 16, 65A and 0000-1.10 40/1.575 sections with NACA a = 1.0 and 0.8 mean lines and the NACA 66 TMB modified section with an a = 0.8 mean line and the results are plotted in Figures 3 to 9 and given in Appendix B.

CONCLUSIONS

This report gives the geometric coefficients which are necessary to calculate the stresses in a propeller blade or hydrofoil. These have been computed and compiled in table form for the TMB EPH, NACA 16, 65A and 66 TMB modified sections. By substituting these values in Equations (1) to (3), stresses in a section may be found with a minimum of work.

The cavitation number of a section must be determined to give the best cavitation characteristics for the design. This report gives the theoretically derived incipient cavitation charts for the NACA 16, 65A, 0000-1.10 40/1.575 and 66 TMB modified sections.

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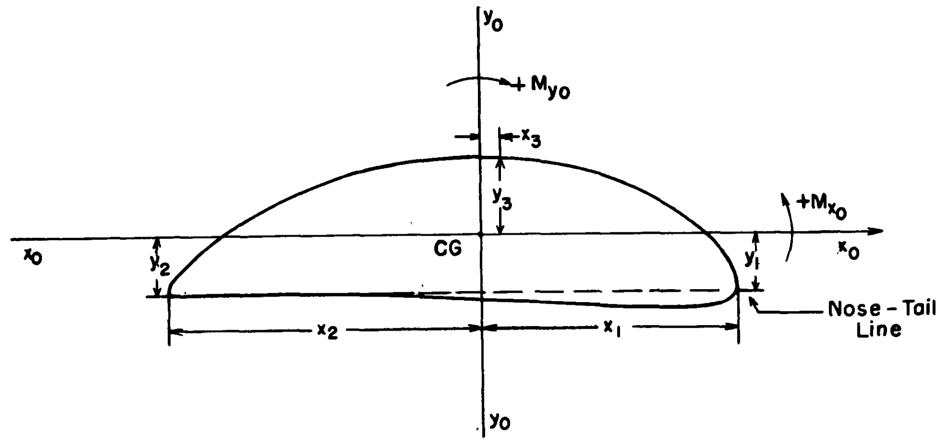


Figure 1 - Coordinate System for a Section

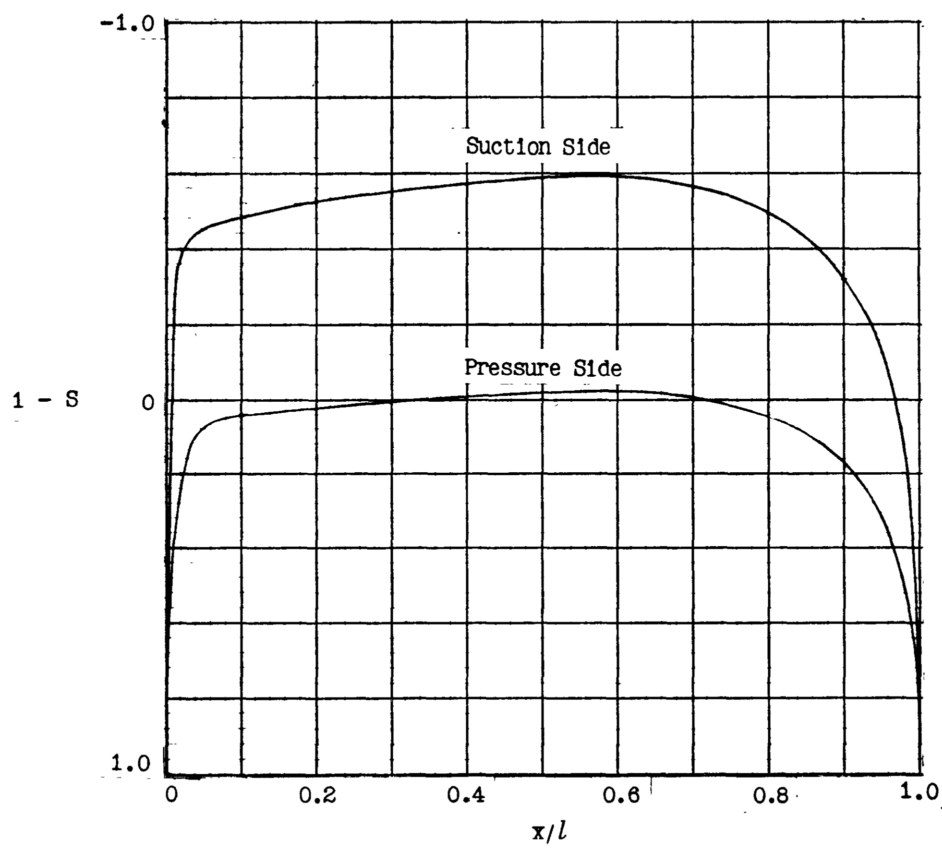


Figure 2 - Pressure Distribution on NACA 16-512 Section

APPENDIX A

Geometric Coefficients for TMB EPH,

NACA 16, 65A and 66 TMB Modified Sections

Table 2 - Geometric Coefficients for TMB EPH Section

t/l	$\frac{1}{l^2}$ Area	$-(y_1/I_{x_0})l^3$ and $-(y_2/I_{x_0})l^3$	$(y_3/I_{x_0})l^3$	$(x_1/I_{y_0})l^3$	$-(x_2/I_{y_0})l^3$	$(x_3/I_{y_0})l^3$
			$f/l = 0$			
0.02	.0149	0.0	27858	53.59	596.5	42.07
0.04	.0298	0.0	6964	26.79	298.2	21.03
0.06	.0447	0.0	3095	17.86	198.8	14.02
0.08	.0596	0.0	1741	13.39	149.1	10.51
0.10	.0746	0.0	1114	10.71	119.3	8.41
0.12	.0895	0.0	773	8.93	99.4	7.01
0.14	.1044	0.0	568	7.65	85.2	6.01
0.16	.1193	0.0	435	6.69	74.5	5.25
0.18	.1342	0.0	343	5.95	66.2	4.67
0.20	.1492	0.0	278	5.35	59.6	4.20
			$f/l = 0.01$			
0.02	.0149	18049.0	27148	53.62	597.5	41.84
0.04	.0298	2625.1	7233	26.81	298.7	20.92
0.06	.0447	802.3	3209	17.87	199.1	13.94
0.08	.0596	342.9	1795	13.40	149.3	10.46
0.10	.0746	176.9	1144	10.72	119.5	8.36
0.12	.0895	102.9	791	8.93	99.5	6.97
0.14	.1044	65.1	579	7.66	85.3	5.97
0.16	.1193	43.7	442	6.70	74.6	5.23
0.18	.1342	30.8	349	5.95	66.3	4.64
0.20	.1492	22.5	282	5.36	59.7	4.18
			$f/l = 0.02$			
0.02	.0149	23338.0	20375	53.79	599.9	41.75
0.04	.0298	4551.1	6812	26.89	299.9	20.87
0.06	.0447	1496.1	3167	17.93	199.9	13.91
0.08	.0597	657.8	1798	13.44	149.9	10.43
0.10	.0746	344.3	1152	10.75	119.9	8.35
0.12	.0895	201.8	798	8.96	99.9	6.95
0.14	.1045	128.2	585	7.68	85.7	5.96
0.16	.1194	86.5	446	6.72	74.9	5.21
0.18	.1343	61.1	352	5.97	66.6	4.63
0.20	.1493	44.7	284	5.37	59.9	4.1[illegible]
			$f/l = 0.03$			
0.02	.0149	22028.9	14598	54.07	603.7	41.79
0.04	.0298	5586.7	6019	27.03	301.8	20.89
0.06	.0448	2016.9	3004	18.02	201.2	13.93
0.08	.0597	924.0	1755	13.51	150.9	10.44
0.10	.0747	494.1	1140	10.81	120.7	8.35
0.12	.0896	293.2	795	9.01	100.6	6.96
0.14	.1046	187.6	584	7.72	86.2	5.97
0.16	.1195	127.1	447	6.75	75.4	5.22
0.18	.1345	90.1	352	6.00	67.0	4.64
0.20	.1494	66.1	285	5.40	60.3	4.17
			$f/l = 0.04$			
0.02	.0149	19336.1	10780	54.46	608.7	41.96
0.04	.0299	5938.7	5153	27.23	304.3	20.98
0.06	.0449	2355.4	2770	18.15	202.9	13.98
0.08	.0599	1131.3	1677	13.61	152.1	10.49
0.10	.0749	621.3	1110	10.89	121.7	8.39
0.12	.0898	374.4	782	9.07	101.4	6.99
0.14	.1048	241.7	578	7.78	86.9	5.99
0.16	.1198	164.8	443	6.80	76.0	5.24
0.18	.1348	117.4	351	6.05	67.6	4.66
0.20	.1498	86.5	284	5.44	60.8	4.19
			$f/l = 0.05$			
0.02	.0150	16792.9	8302	54.94	614.7	42.22
0.04	.0300	5888.5	4368	27.47	307.3	21.11
0.06	.0450	2539.0	2508	18.31	204.9	14.07
0.08	.0601	1279.6	1577	13.73	153.6	10.55
0.10	.0751	723.6	1067	10.98	122.9	8.44
0.12	.0901	443.8	762	9.15	102.4	7.03
0.14	.1051	289.6	567	7.84	87.8	6.03
0.16	.1202	199.0	437	6.86	76.8	5.27
0.18	.1352	142.6	347	6.10	68.3	4.69
0.20	.1502	105.4	281	5.49	61.4	4.22

Table 3 - Geometric Coefficients for NACA 16 Section

t/l	$\frac{1}{l^2}$ Area	$-(y_1/I_{x_0})l^3$ and $-(y_2/I_{x_0})l^3$	$(y_3/I_{x_0})l^3$	$(x_1/I_{y_0})l^3$	$-(x_2/I_{y_0})l^3$	$(x_3/I_{y_0})l^3$
			$f/l = 0$			
0.02	.0147	0.0	28068	579.1	617.9	−193.9
0.04	.0294	0.0	7017	289.5	308.9	− 96.9
0.06	.0441	0.0	3118	193.0	205.9	− 64.6
0.08	.0588	0.0	1754	144.7	154.4	− 48.4
0.10	.0735	0.0	1122	115.8	123.5	− 38.7
0.12	.0882	0.0	779	96.5	102.9	− 32.3
0.14	.1029	0.0	572	82.7	88.2	− 27.7
0.16	.1176	0.0	438	72.3	77.2	− 24.2
0.18	.1324	0.0	346	64.3	68.6	− 21.5
0.20	.1471	0.0	280	57.9	61.7	− 19.3
			$f/l = 0.01$			
0.02	.0147	18001.3	27905	579.5	618.9	−197.2
0.04	.0294	2618.2	7368	289.7	309.4	− 98.6
0.06	.0441	800.1	3257	193.1	206.3	− 65.7
0.08	.0588	342.0	1819	144.8	154.7	− 49.3
0.10	.0735	176.4	1158	115.9	123.7	− 39.4
0.12	.0882	102.6	800	96.5	103.1	− 32.8
0.14	.1029	64.9	586	82.7	88.4	− 28.1
0.16	.1177	43.6	447	72.4	77.3	− 24.6
0.18	.1324	30.7	352	64.3	68.7	− 21.9
0.20	.1471	22.5	285	57.9	61.8	− 19.7
			$f/l = 0.02$			
0.02	.0147	23276.3	21242	581.3	621.5	−201.1
0.04	.0294	4539.1	7003	290.6	310.7	−100.5
0.06	.0441	1492.2	3237	193.7	207.1	− 67.0
0.08	.0588	656.1	1832	145.3	155.3	− 50.2
0.10	.0736	343.4	1171	116.2	124.3	− 40.2
0.12	.0883	201.3	811	96.8	103.5	− 33.5
0.14	.1030	127.9	593	83.0	88.7	− 28.7
0.16	.1177	86.2	452	72.6	77.6	− 25.1
0.18	.1325	60.9	356	64.5	69.0	− 22.3
0.20	.1472	44.6	288	58.1	62.1	− 20.1
			$f/l = 0.03$			
0.02	.0147	21970.7	15382	584.3	625.4	−205.4
0.04	.0294	5571.9	6235	292.1	312.7	−102.7
0.06	.0442	2011.6	3089	194.7	208.4	− 68.4
0.08	.0589	921.6	1796	146.0	156.3	− 51.3
0.10	.0736	492.8	1163	116.8	125.0	− 41.0
0.12	.0884	292.4	810	97.3	104.2	− 34.2
0.14	.1031	187.1	594	83.4	89.3	− 29.3
0.16	.1179	126.8	454	73.0	78.1	− 25.6
0.18	.1326	89.8	358	64.9	69.4	− 22.8
0.20	.1473	66.0	289	58.4	62.5	− 20.5
			$f/l = 0.04$			
0.02	.0147	19285.0	11452	588.6	630.6	−210.1
0.04	.0295	5923.1	5373	294.3	315.3	−105.0
0.06	.0443	2349.2	2862	196.2	210.2	− 70.0
0.08	.0590	1128.3	1724	147.1	157.6	− 52.5
0.10	.0738	619.7	1137	117.7	126.1	− 42.0
0.12	.0886	373.4	800	98.1	105.1	− 35.0
0.14	.1033	241.1	589	84.0	90.0	− 30.0
0.16	.1181	164.4	452	73.5	78.8	− 26.2
0.18	.1329	117.1	357	65.4	70.0	− 23.3
0.20	.1477	86.2	289	58.8	63.0	− 21.0
			$f/l = 0.05$			
0.02	.0148	16748.6	8878	593.7	636.8	−215.3
0.04	.0296	5872.9	4580	296.8	318.4	−107.6
0.06	.0444	2532.3	2604	197.9	212.2	− 71.7
0.08	.0592	1276.3	1627	148.4	159.2	− 53.8
0.10	.0740	721.7	1097	118.7	127.3	− 43.0
0.12	.0889	442.6	781	98.9	106.1	− 35.8
0.14	.1037	288.8	580	84.8	90.9	− 30.7
0.16	.1185	198.5	446	74.2	79.6	− 26.9
0.18	.1333	142.2	354	65.9	70.7	− 23.9
0.20	.1481	105.1	287	59.3	63.6	− 21.5

Table 4 - Geometric Coefficients for NACA 65-A Section

t/l	$\frac{1}{l^2}$ Area	$-(y_1/I_{x_0})l^3$ and $-(y_2/I_{x_0})l^3$	$(y_3/I_{x_0})l^3$	$(x_1/I_{y_0})l^3$	$-(x_2/I_{y_0})l^3$	$(x_3/I_{y_0})l^3$
			$f/l = 0$			
0.02	.0134	0.0	32243	641.1	794.1	67.03
0.04	.0269	0.0	8060	320.5	397.0	33.51
0.06	.0404	0.0	3582	213.7	264.7	22.34
0.08	.0538	0.0	2015	160.2	198.5	16.75
0.10	.0673	0.0	1289	128.2	158.8	13.40
0.12	.0808	0.0	895	106.8	132.3	11.17
0.14	.0943	0.0	658	91.5	113.4	9.57
0.16	.1077	0.0	503	80.1	99.2	8.37
0.18	.1212	0.0	398	71.2	88.2	7.44
0.20	.1347	0.0	322	64.1	79.4	6.70
			$f/l = 0.01$			
0.02	.0134	21101.5	30577	641.5	795.4	66.77
0.04	.0269	3069.1	8249	320.7	397.7	33.38
0.06	.0404	937.9	3676	213.8	265.1	22.25
0.08	.0538	400.9	2062	160.3	198.8	16.69
0.10	.0673	206.8	1316	128.3	159.0	13.35
0.12	.0808	120.3	911	106.9	132.5	11.12
0.14	.0943	76.1	668	91.6	113.6	9.53
0.16	.1077	51.1	510	80.1	99.4	8.34
0.18	.1212	36.0	402	71.2	88.3	7.41
0.20	.1347	26.3	325	64.1	79.5	6.67
			$f/l = 0.02$			
0.02	.0134	27285.0	22491	643.4	798.7	66.75
0.04	.0269	5320.8	7673	321.7	399.3	33.37
0.06	.0404	1749.1	3596	214.4	266.2	22.25
0.08	.0539	769.1	2051	160.8	199.6	16.68
0.10	.0674	402.5	1318	128.6	159.7	13.35
0.12	.0809	236.0	915	107.2	133.1	11.12
0.14	.0943	149.9	671	91.9	114.1	9.53
0.16	.1078	101.1	513	80.4	99.8	8.34
0.18	.1213	71.4	404	71.4	88.7	7.41
0.20	.1348	52.3	327	64.3	79.8	6.67
			$f/l = 0.03$			
0.02	.0134	25754.6	15866	646.7	803.6	66.94
0.04	.0269	6531.5	6706	323.3	401.8	33.47
0.06	.0404	2358.0	3384	215.5	267.8	22.31
0.08	.0539	1080.3	1989	161.6	200.9	16.73
0.10	.0674	577.7	1296	129.3	160.7	13.38
0.12	.0809	342.8	907	107.7	133.9	11.15
0.14	.0944	219.3	667	92.3	114.8	9.56
0.16	.1079	148.6	511	80.8	100.4	8.36
0.18	.1214	105.3	404	71.8	89.2	7.43
0.20	.1349	77.3	327	64.6	80.3	6.69
			$f/l = 0.04$			
0.02	.0135	22606.3	11572	651.4	810.3	67.35
0.04	.0270	6943.1	5687	325.7	405.1	33.67
0.06	.0405	2753.7	3096	217.1	270.1	22.45
0.08	.0541	1322.6	1888	162.8	202.5	16.83
0.10	.0676	726.4	1256	130.2	162.0	13.47
0.12	.0811	437.7	888	108.5	135.0	11.22
0.14	.0946	282.6	658	93.0	115.7	9.62
0.16	.1082	192.7	506	81.4	101.2	8.41
0.18	.1217	137.2	400	72.3	90.0	7.48
0.20	.1352	101.1	325	65.1	81.0	6.73
			$f/l = 0.05$			
0.02	.0135	19633.0	8824	657.1	818.2	67.94
0.04	.0271	6884.3	4781	328.5	409.1	33.97
0.06	.0407	2968.3	2784	219.0	272.7	22.64
0.08	.0542	1496.0	1765	164.2	204.5	16.98
0.10	.0678	846.0	1202	131.4	163.6	13.58
0.12	.0814	518.9	861	109.5	136.3	11.32
0.14	.0949	338.6	643	93.8	116.8	9.70
0.16	.1085	232.6	496	82.1	102.2	8.49
0.18	.1221	166.7	395	73.0	90.9	7.54
0.20	.1357	123.2	321	65.7	81.8	6.79

Table 5 - Geometric Coefficients for NACA 66 (TMB Modified) Section

t/l	$\frac{1}{l^2}$ Area	$-(y_1/I_{x_0})l^3$ and $-(y_2/I_{x_0})l^3$	$(y_3/I_{x_0})l^3$	$(x_1/I_{y_0})l^3$	$-(x_2/I_{y_0})l^3$	$(x_3/I_{y_0})l^3$
			$f/l = 0$			
0.02	.0143	0.0	29479	586.0	652.9	28.49
0.04	.0287	0.0	7369	293.0	326.4	14.24
0.06	.0431	0.0	3275	195.3	217.6	9.49
0.08	.0574	0.0	1842	146.5	163.2	7.12
0.10	.0718	0.0	1179	117.2	130.5	5.69
0.12	.0862	0.0	818	97.6	108.8	4.74
0.14	.1005	0.0	601	83.7	93.2	4.07
0.16	.1149	0.0	460	73.2	81.6	3.56
0.18	.1293	0.0	363	65.1	72.5	3.16
0.20	.1436	0.0	294	58.6	65.2	2.84
			$f/l = 0.01$			
0.02	.0143	19341.0	28631	586.4	654.0	28.23
0.04	.0287	2813.0	7640	293.2	327.0	14.13
0.06	.0431	859.7	3391	195.4	218.0	9.43
0.08	.0574	367.4	1898	146.6	163.5	7.08
0.10	.0718	189.6	1209	117.2	130.8	5.67
0.12	.0862	110.3	837	97.7	109.0	4.73
0.14	.1005	69.7	613	83.7	93.4	4.05
0.16	.1149	46.9	468	73.3	81.7	3.55
0.18	.1293	33.0	369	65.1	72.6	3.16
0.20	.1436	24.1	298	58.6	65.4	2.85
			$f/l = 0.02$			
0.02	.0143	25008.6	21436	588.2	656.7	28.04
0.04	.0287	4876.8	7185	294.1	328.3	14.05
0.06	.0431	1603.2	3344	196.0	218.9	9.38
0.08	.0575	704.9	1899	147.0	164.1	7.05
0.10	.0718	368.9	1217	117.6	131.3	5.65
0.12	.0862	216.3	844	98.0	109.4	4.72
0.14	.1006	137.4	618	84.0	93.8	4.05
0.16	.1150	92.6	472	73.5	82.0	3.55
0.18	.1294	65.4	372	65.3	72.9	3.16
0.20	.1437	47.9	301	58.8	65.6	2.85
			$f/l = 0.03$			
0.02	.0143	23605.9	15330	591.2	660.8	27.91
0.04	.0287	5986.5	6339	295.6	330.4	14.00
0.06	.0431	2161.3	3168	197.0	220.2	9.36
0.08	.0575	990.1	1852	147.8	165.2	7.04
0.10	.0719	529.5	1204	118.2	132.1	5.65
0.12	.0863	314.2	840	98.5	110.1	4.72
0.14	.1007	201.0	617	84.4	94.4	4.06
0.16	.1151	136.2	472	73.9	82.6	3.56
0.18	.1295	96.5	372	65.6	73.4	3.18
0.20	.1439	70.9	301	59.1	66.0	2.87
			$f/l = 0.04$			
0.02	.0144	20720.3	11304	595.5	666.3	27.83
0.04	.0288	6363.8	5421	297.7	333.1	13.97
0.06	.0432	2523.9	2918	198.5	222.1	9.35
0.08	.0577	1212.3	1769	148.8	166.5	7.04
0.10	.0721	665.8	1172	119.1	133.2	5.66
0.12	.0865	401.2	826	99.2	111.0	4.73
0.14	.1009	259.0	610	85.0	95.1	4.07
0.16	.1154	176.6	468	74.4	83.2	3.58
0.18	.1298	125.8	370	66.1	74.0	3.20
0.20	.1442	92.6	300	59.5	66.6	2.89
			$f/l = 0.05$			
0.02	.0144	17995.1	8695	600.7	672.8	27.79
0.04	.0289	6309.9	4590	300.3	336.4	13.97
0.06	.0434	2720.7	2640	200.2	224.2	9.36
0.08	.0578	1371.2	1662	150.1	168.2	7.06
0.10	.0723	775.4	1126	120.1	134.5	5.68
0.12	.0868	475.5	804	100.1	112.1	4.75
0.14	.1013	310.3	598	85.8	96.1	4.10
0.16	.1157	213.2	461	75.0	84.1	3.60
0.18	.1302	152.8	366	66.7	74.7	3.22
0.20	.1447	113.0	297	60.0	67.2	2.91

APPENDIX B

Incipient Cavitation Curves for NACA 16, 65A, 0000-1.10 40/1.575 and 66 TMB Modified Sections

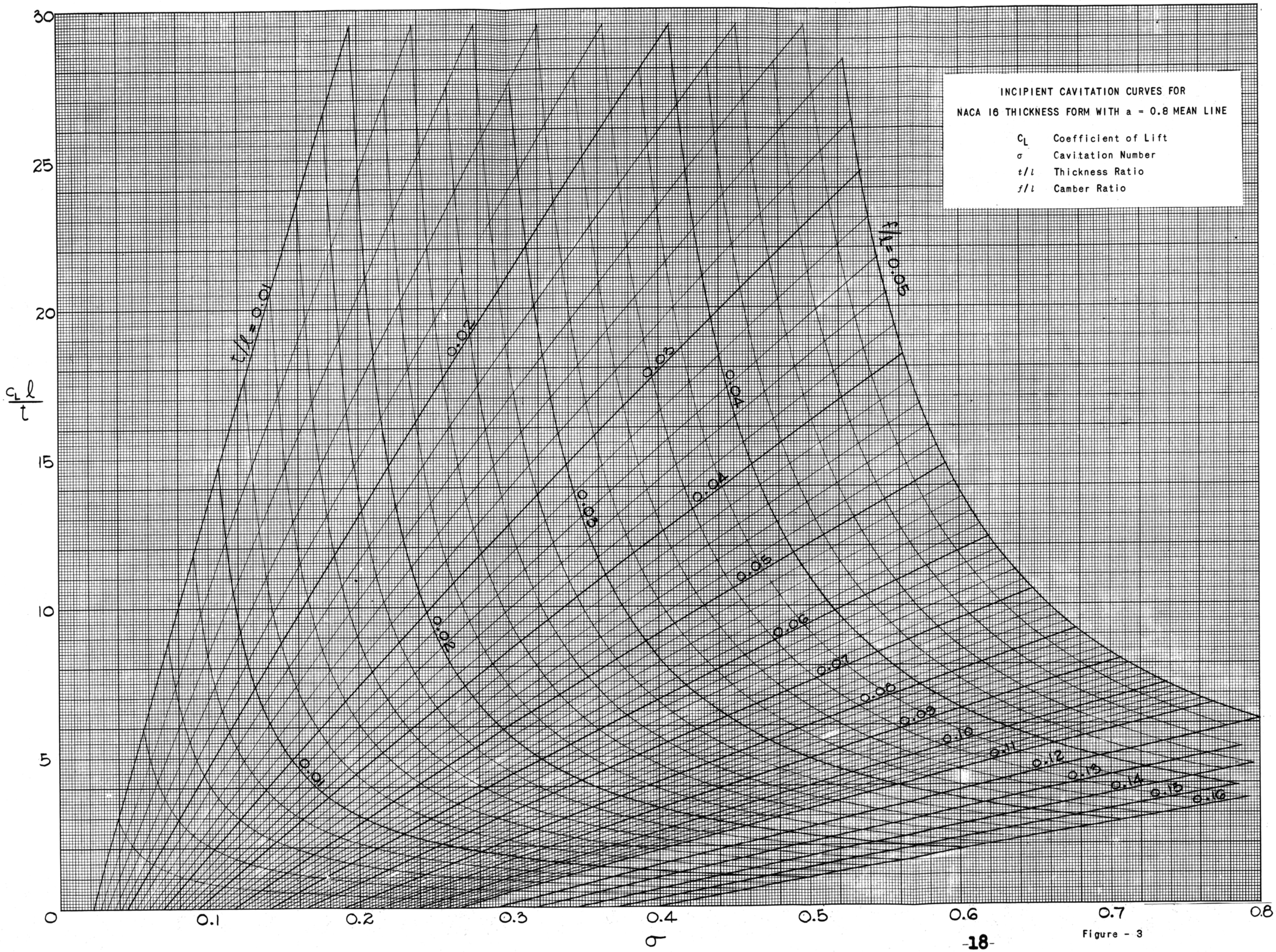
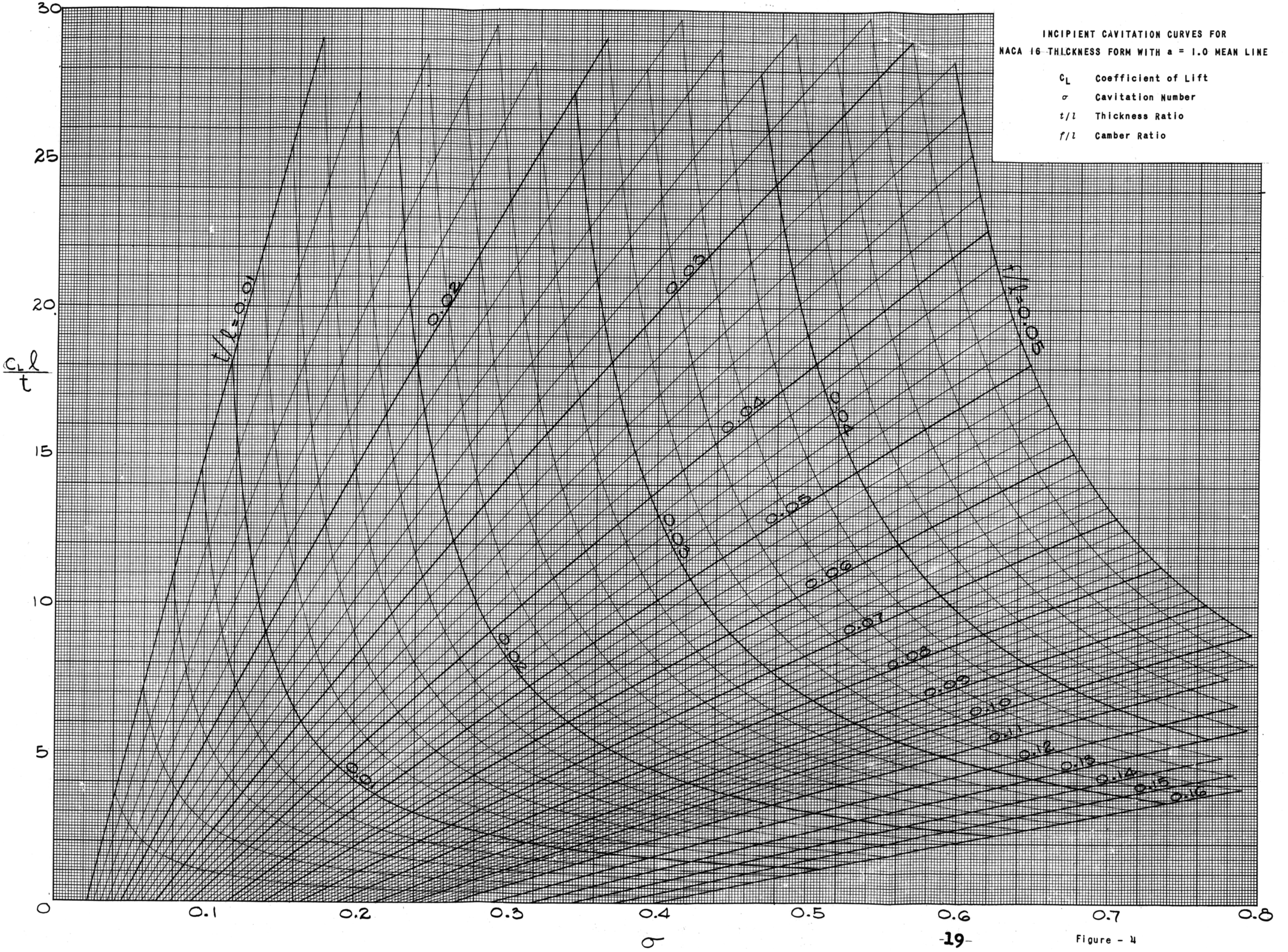
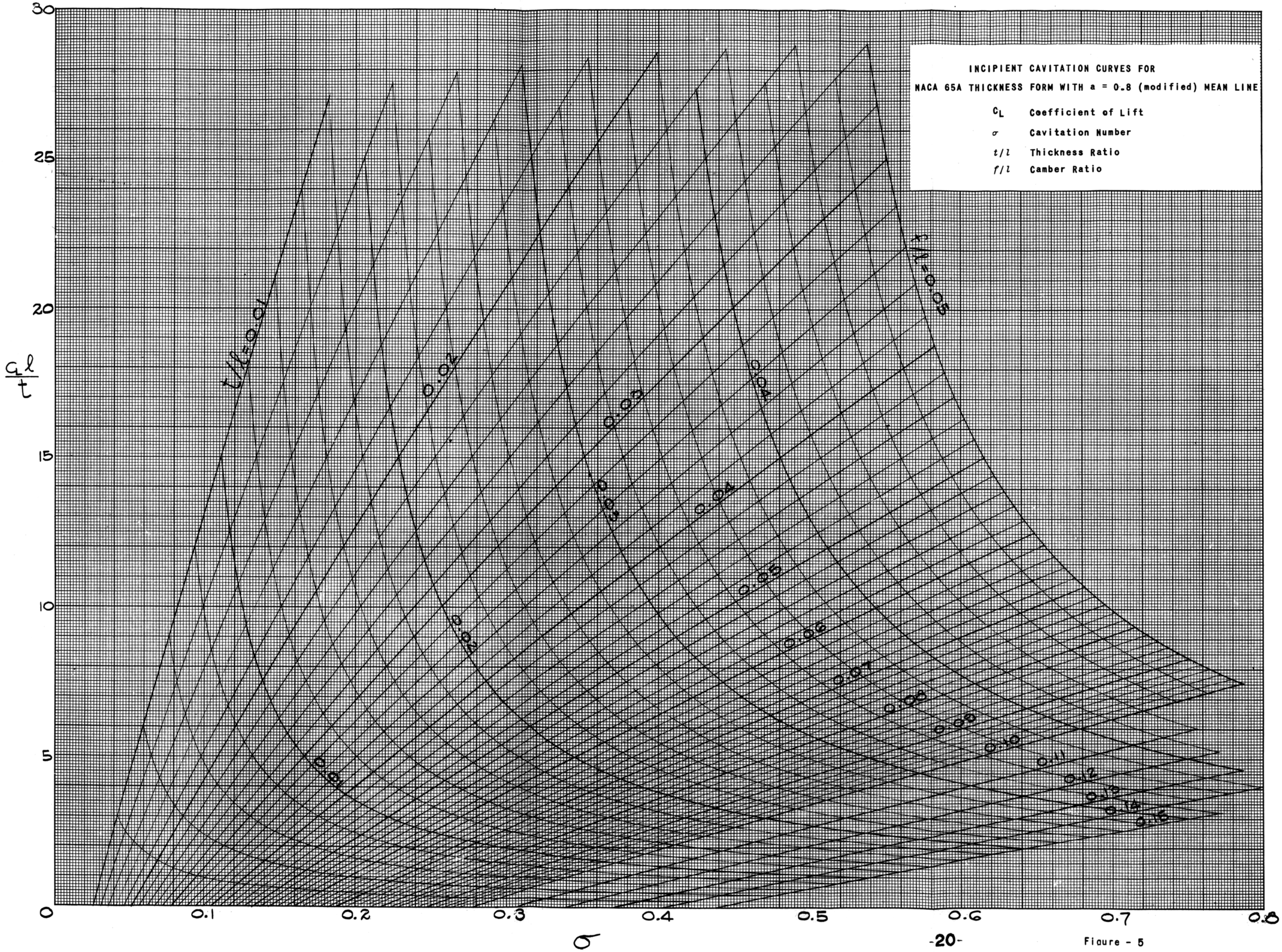

INCIPIENT CAVITATION CURVES FOR
NACA 16 THICKNESS FORM WITH a = 0.8 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
t/l = 0.01
0.02
0.03
0.04
f/l = 0.05
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
$\frac{C_L l}{t}$
σ
0
5
10
15
20
25
30
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Figure - 3



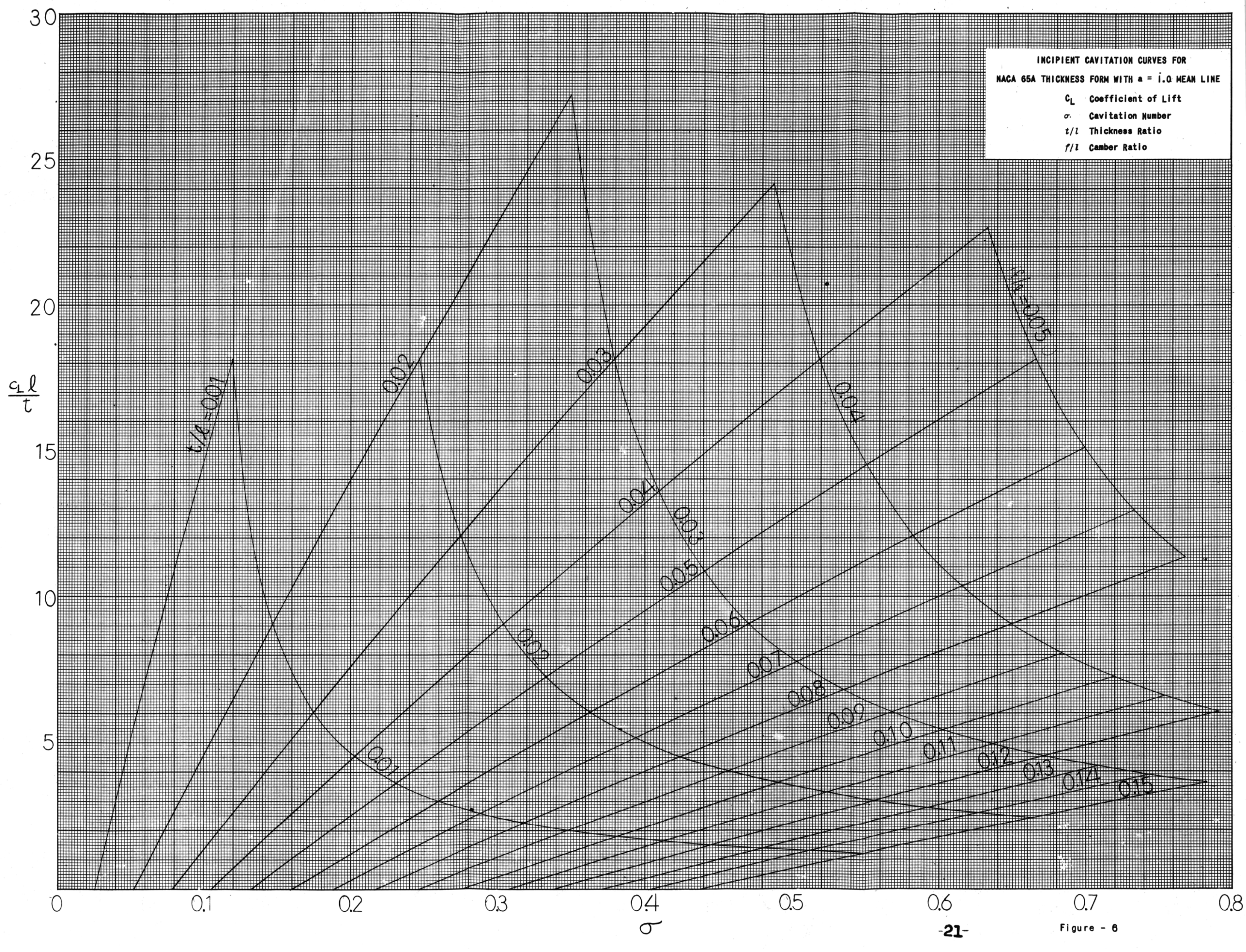
INCIPIENT CAVITATION CURVES FOR
NACA 16 THICKNESS FORM WITH a = 1.0 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
$\frac{C_L l}{t}$
σ
t/l = 0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
f/l = 0.05
0.04
0.03
0.02
0.01
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
10
15
20
25
30

Figure - 4



INCIPIENT CAVITATION CURVES FOR
NACA 65A THICKNESS FORM WITH a = 0.8 (modified) MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio

Figure - 5


INCIPIENT CAVITATION CURVES FOR
NACA 65A THICKNESS FORM WITH a = 1.0 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
$\frac{c_L l}{t}$
σ
t/l = 0.01
0.02
0.03
0.04
t/l = 0.05
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
10
15
20
25
30

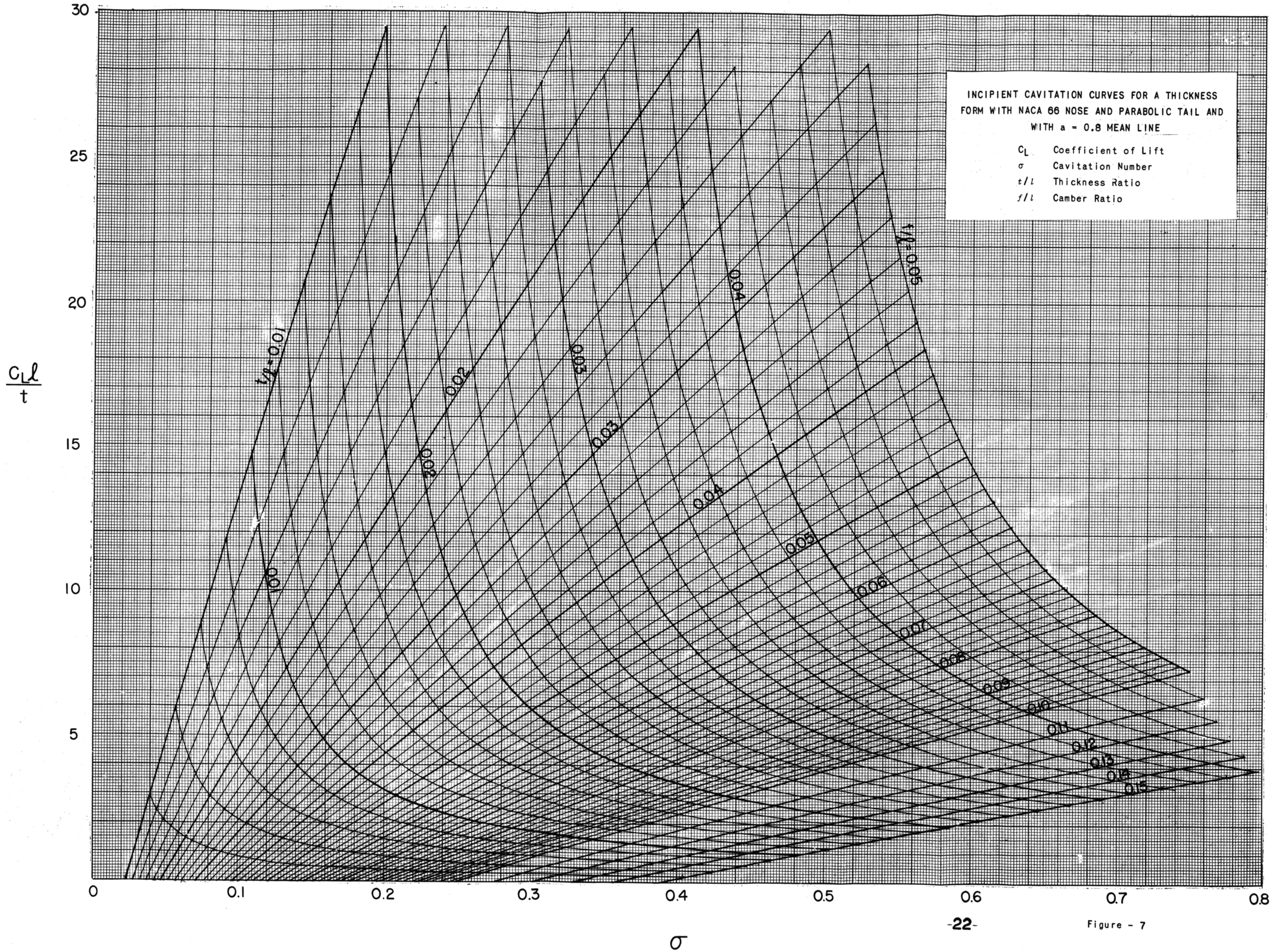

INCIPIENT CAVITATION CURVES FOR A THICKNESS FORM WITH NACA 66 NOSE AND PARABOLIC TAIL AND WITH a = 0.8 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
t/l = 0.01
0.02
0.03
0.04
t/l = 0.05
f/l = 0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
$\frac{C_L l}{t}$
σ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
10
15
20
25
30

Figure - 7

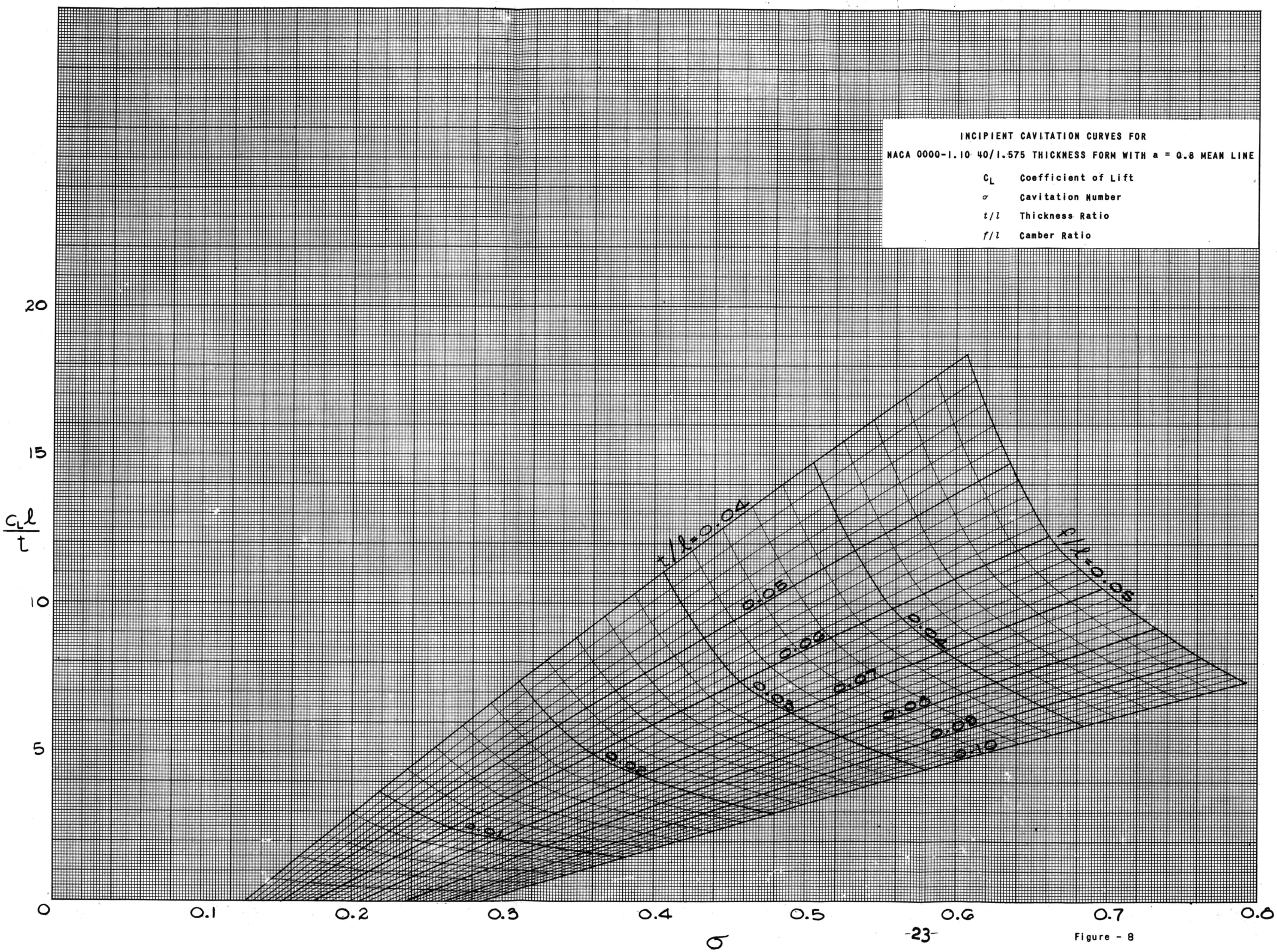

INCIPIENT CAVITATION CURVES FOR
NACA 0000-1.10 40/1.575 THICKNESS FORM WITH a = 0.8 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
t/l = 0.04
f/l = 0.05
0.05
0.06
0.07
0.08
0.10
0.04
0.03
0.02
0.01
$\frac{C_L l}{t}$
σ
0
5
10
15
20
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Figure - 8

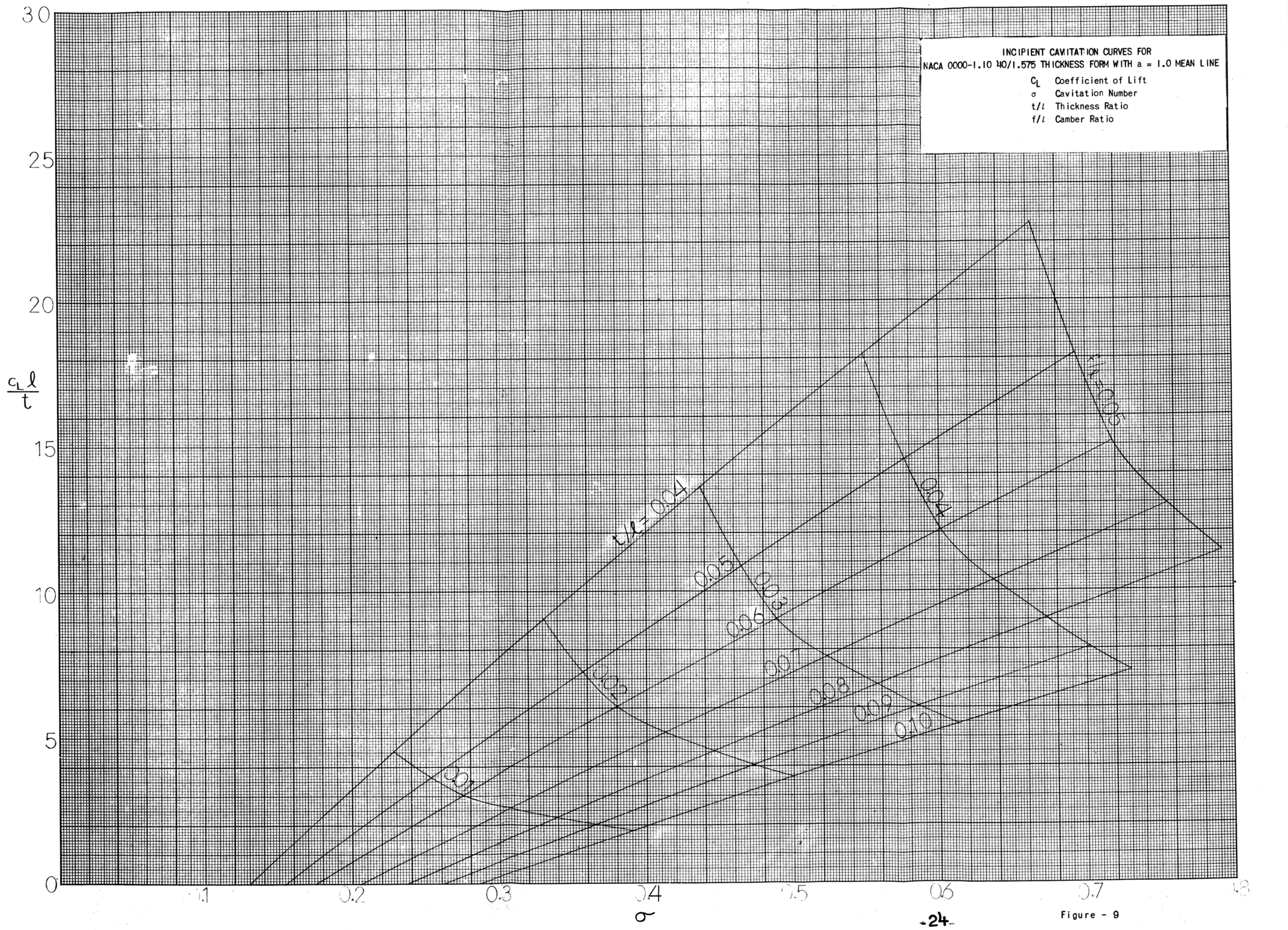

INCIPIENT CAVITATION CURVES FOR
NACA 0000-1.10 40/1.575 THICKNESS FORM WITH a = 1.0 MEAN LINE
C_L Coefficient of Lift
σ Cavitation Number
t/l Thickness Ratio
f/l Camber Ratio
30
25
20
15
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
$\frac{c_L l}{t}$
σ
t/l = 0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.01
0.02
0.03
0.04
f/l = 0.05

Figure - 9

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