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THRUST COEFFICIENTS, THRUST DEFLECTION ANGLES, AND NONDIMENSIONAL MOMENTS FOR NOZZLES WITH OBLIQUE EXIT PLANES

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13. ABSTRACT

Nozzles with oblique exit planes, scarfed nozzles, are encountered in aerospace applications such as reaction control and thrust reversal systems. This document provides thrust coefficient, thrust deflection angle, and nondimensional turning moment data for scarfed conical nozzles on machine-generated graphs. Based on one-dimensional isentropic flow of a perfect gas, the data cover specific heat ratios from 1.18 to 1.40, nozzle half-angles from 5 to 25 degrees, scarf angles from 10 to 60 degrees, area ratios at the upstream scarf point from 1.5 to 15, and ratios of chamber pressure to ambient pressure from 20 to infinity (vacuum).

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Nozzles, thrust reversal						
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THRUST COEFFICIENTS, THRUST DEFLECTION ANGLES, AND NONDIMENSIONAL MOMENTS FOR NOZZLES WITH OBLIQUE EXIT PLANES

March 1968

MAR 17 1969

Missile and Information Systems Division
Aerospace Group
THE BOEING COMPANY
Seattle, Washington

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LIST OF GRAPHS

Graphs of thrust coefficient, deflection angle, and nondimensional moment are listed below.

γ	α	Figures
1.18	5	1-27
	10	28-54
	15	55-81
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1.20	5	136-162
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	25	514-540

PREFACE

Nozzles with oblique exit planes, scarfed nozzles, are encountered in aerospace applications such as reaction control and thrust reversal systems. This document provides thrust coefficient, thrust deflection angle, and nondimensional turning moment data for scarfed conical nozzles on machine-generated graphs. Based on one-dimensional isentropic flow of a perfect gas, the data cover specific heat ratios from 1.18 to 1.40, nozzle half-angles from 5 to 25 degrees, scarf angles from 10 to 60 degrees, area ratios at the upstream scarf point from 1.5 to 15, and ratios of chamber pressure to ambient pressure from 20 to infinity (vacuum).

The data presented herein were developed by the Rocket Propulsion Research Staff of the Missile and Information Systems Division of The Boeing Company. An original analysis by Robert Hopcroft was extended in scope and programmed for computation by Ross Fiedler and William Phillips. Mike Whitaker programmed the machine plotting. William Phillips wrote the text and coordinated printing.

SYMBOLS

(See Figures A and B on Page vii)

A_t	Nozzle throat area
$C_{F_{sc}}$	Total thrust coefficient
C_{F_o}	Thrust coefficient for symmetrical section of nozzle (corrected for flow divergence)
C_{T_x}	Total thrust coefficient in x-direction
C_{T_y}	Total thrust coefficient in y-direction
F_x	Thrust produced by scarfed section of nozzle in x-direction
F_y	Thrust produced by scarfed section of nozzle in y-direction
L	Length of scarfed section of nozzle
$M_{zo_{ND}}$	Nondimensional moment produced about z-axis at point o (positive in clockwise direction)
P	Pressure at any point inside scarfed section
P_a	Ambient pressure
P_c	Chamber pressure
R	Radius of nozzle at any point inside scarfed section
R_o	Radius of nozzle at upstream scarf point
R_t	Nozzle throat radius
T	Total thrust produced by the nozzle
T_x	Total thrust in x-direction
T_y	Total thrust in y-direction
x	Axial distance inside nozzle from point o
y	Distance inside nozzle perpendicular to axis
α	Nozzle half-angle
β	Direction of radius vector R
γ	Specific heat ratio
θ	Thrust deflection angle
ϕ	Nozzle scarf angle

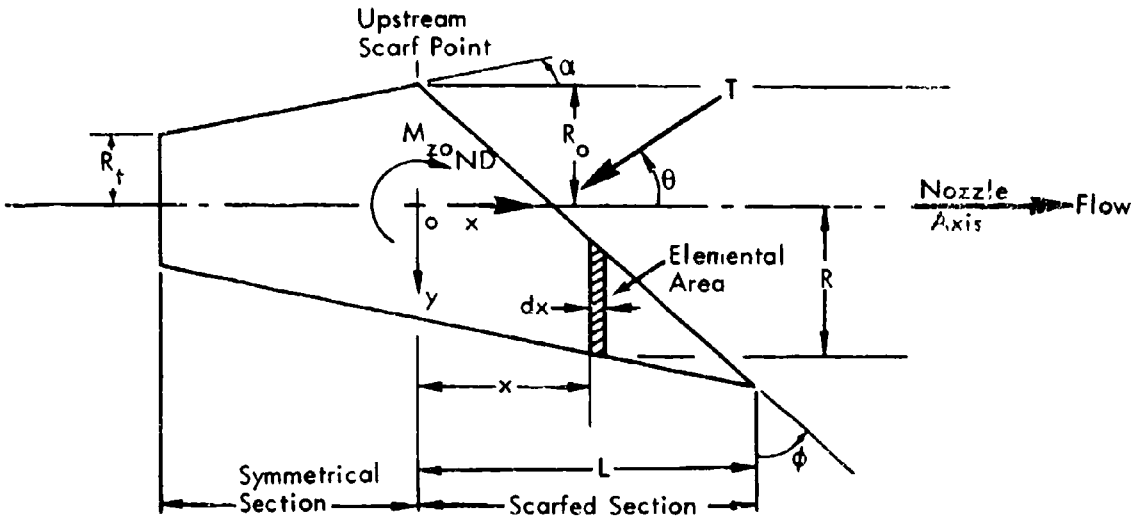

Figure A: SIDE VIEW OF SCARFED CONICAL NOZZLE

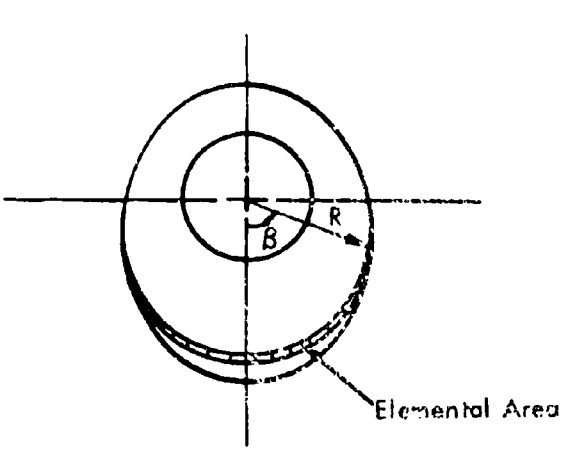

Figure B: END VIEW OF SCARFED CONICAL NOZZLE

ANALYSIS

ASSUMPTIONS AND LIMITATIONS

1) The flow is accelerated from stagnation conditions.

2) The gases obey the perfect gas laws.

3) The flow is one-dimensional, steady, and isentropic.

4) The momentum term of the thrust equation is corrected for divergence of the gas flow.

5) The data provided exclude those cases where:

   a) Expansion fans originating from the upstream scarf point would intersect the opposite wall of the nozzle;

   b) Flow separation would occur inside the nozzle.

EQUATIONS

The scarfed nozzle thrust coefficient, deflection angle, and nondimensional moment are defined as follows:

$$C_{F_{sc}} = \frac{T}{P_c A_t}$$

$$\theta = \tan^{-1}\left(\frac{T_y}{T_x}\right)$$

$$M_{zo_{ND}} = \frac{\int_o^L x \, dF_y + \int_o^L y \, dF_x}{P_c R_t^3}$$

The thrust coefficient and deflection angle are calculated from:

$$C_{F_{sc}} = \sqrt{C_{T_x}^2 + C_{T_y}^2}$$

$$\theta = \tan^{-1}\left(\frac{C_{T_y}}{C_{T_x}}\right)$$

where,

$$C_{T_x} = \frac{2 \tan \alpha}{\pi} \int_0^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right) \frac{R}{R_t} \beta \, d\left(\frac{x}{R_t}\right) + C_{F_o}$$

$$C_{T_y} = \frac{2}{\pi} \int_0^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right) \frac{R}{R_t} \sin \beta \, d\left(\frac{x}{R_t}\right)$$

The nondimensional moment is calculated from:

$$M_{zo_{ND}} = 2 \tan \alpha \int_0^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right)\left(\frac{R}{R_t}\right)^2 \sin \beta \, d\left(\frac{x}{R_t}\right)$$

$$+ 2 \int_0^{L/R_t} \left(\frac{P}{P_c} - \frac{P_a}{P_c}\right)\left(\frac{R}{R_t}\right) \sin \beta \, \frac{x}{R_t} \, d\left(\frac{x}{R_t}\right)$$

The moment axis is perpendicular to the nozzle plane of symmetry at a point on the nozzle axis opposite the upstream scarf point (point o in the diagram on Page vii). The pressure ratio, P/P_c, is determined from one-dimensional isentropic flow theory. The parameters R/R_t, L/R_t, and β are expressed in terms of the nozzle half-angle, scarf angle, and initial area ratio.

COMPUTATIONAL ACCURACY

The implicit relationship between pressure ratio and area ratio requires that an iterative computation be carried out to determine the pressure ratio at the upstream scarf point and the pressure profile in the scarfed section of the nozzle, which is required for numerical integration of the forces. The number of increments in the integration procedure has been selected to ensure an accuracy of 0.006% in the calculations.

EXPLANATION OF GRAPHS

USE OF GRAPHS

The plots of the performance parameters as functions of the ratio of chamber pressure to ambient pressure are discontinued at the maximum *calculated* value of initial expansion ratio (less than 15.0) for which separation does not occur downstream in the scarfed section. The performance parameters were calculated for each half-unit of expansion ratio from 1.5 to 15. Separation criteria from the accumulation of data presented* are employed to provide limits to the calculated data for initial expansion ratios of less than 15.

With initial expansion ratios equal to or greater than 1.5, the minimum for which data are calculated, expansion waves originating from the upstream scarf point will not intersect the opposite wall (thus influencing the pressure distribution on the nozzle wall), provided the scarf angle is not greater than 60 degrees for nozzle half-angles of 5 degrees or more. Any extrapolation of the curves below a scarf-point area ratio of 1.5 must be checked for this condition.

Linear interpolation may be used to obtain values of the performance parameters for low intermediate values of scarf angle and nozzle half-angle without incurring errors greater than 1%. For values of scarf angle greater than 40 degrees and nozzle half-angle greater than 20 degrees, errors of up to 10% may be incurred.

PLOTTING ACCURACY

These graphs were machine-plotted with an accuracy of 0.5% compared to the computed data.

SEQUENCE OF GRAPHS

The graphs are divided into four sections, one for each value of specific heat ratio of 1.18, 1.20, 1.22, and 1.40. For each specific heat ratio there are five values of nozzle half-angle: 5, 10, 15, 20, and 25 degrees. For each nozzle half-angle there are 27 graphs, of which the first three are carpet plots of each of the performance parameters as functions of initial area ratio and scarf angle for vacuum conditions. On the following 24 pages, the graphs of thrust coefficient, deflection angle, and moment as functions of initial area ratio and ambient pressure are arranged together for each value of scarf angle: 10, 20, 30, 40, 45, 50, 55, and 60 degrees.

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* Arens, M., and E. Spiegler, "Shock-Induced Boundary Layer Separation in Overexpanded Conical Exhaust Nozzles," *AIAA Journal*, March 1963.

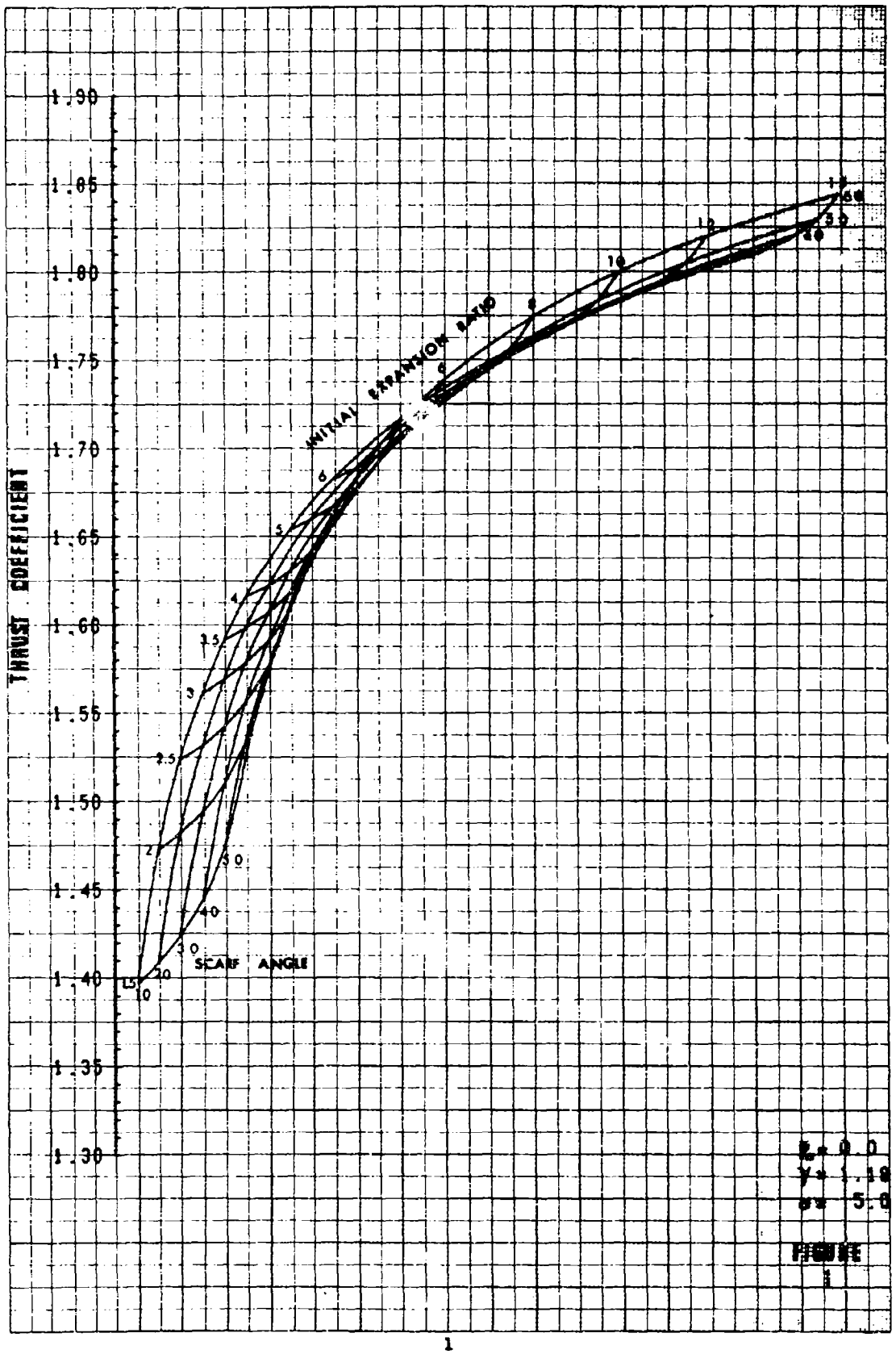
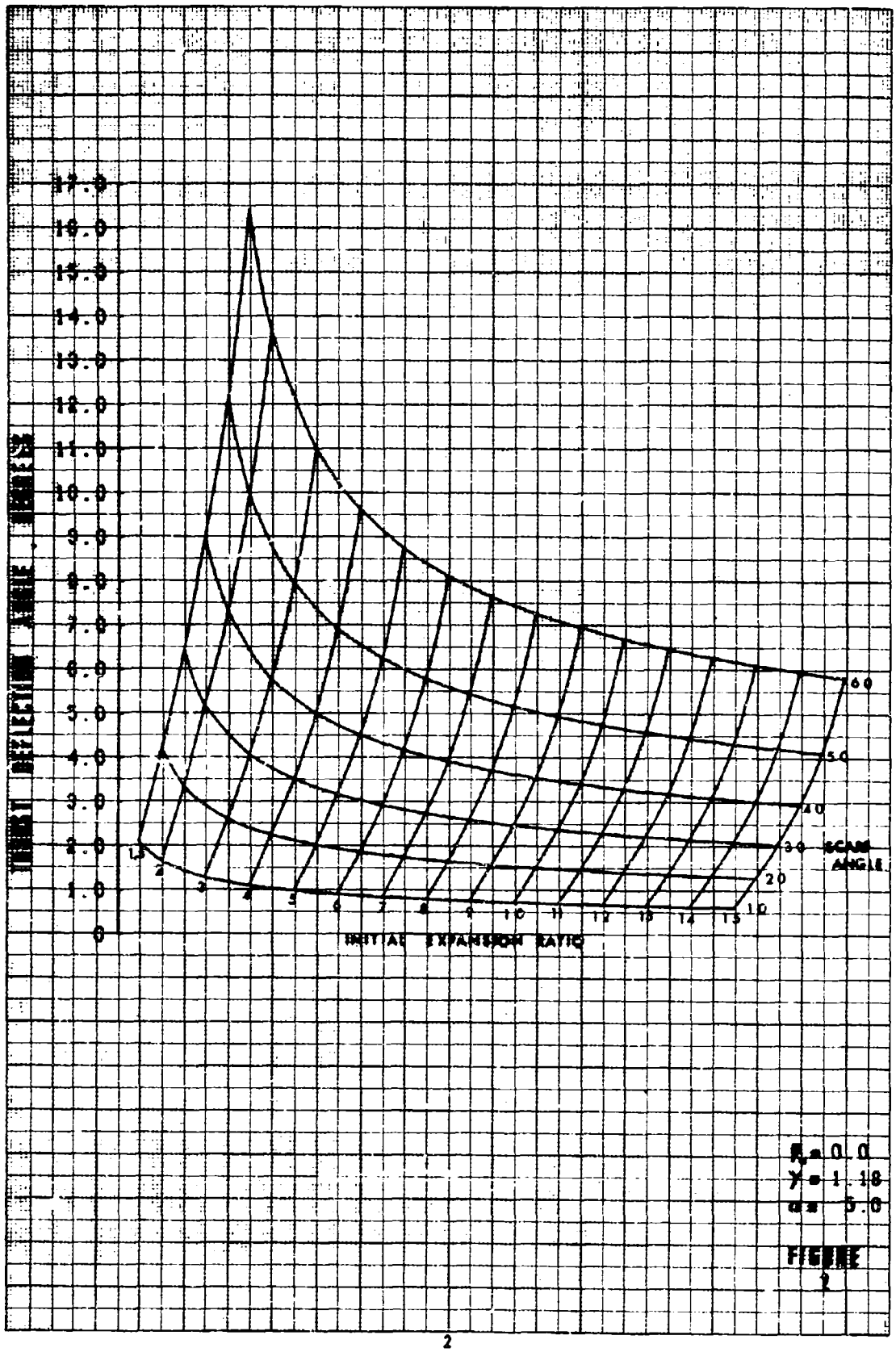

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
10
20
30
40
50
60
P_o = 0.0
γ = 1.18
σ = 5.0

FIGURE 1



17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
10
20
30
40
50
60
SCARF ANGLE
γ = 1.18
α = 5.0

FIGURE 2

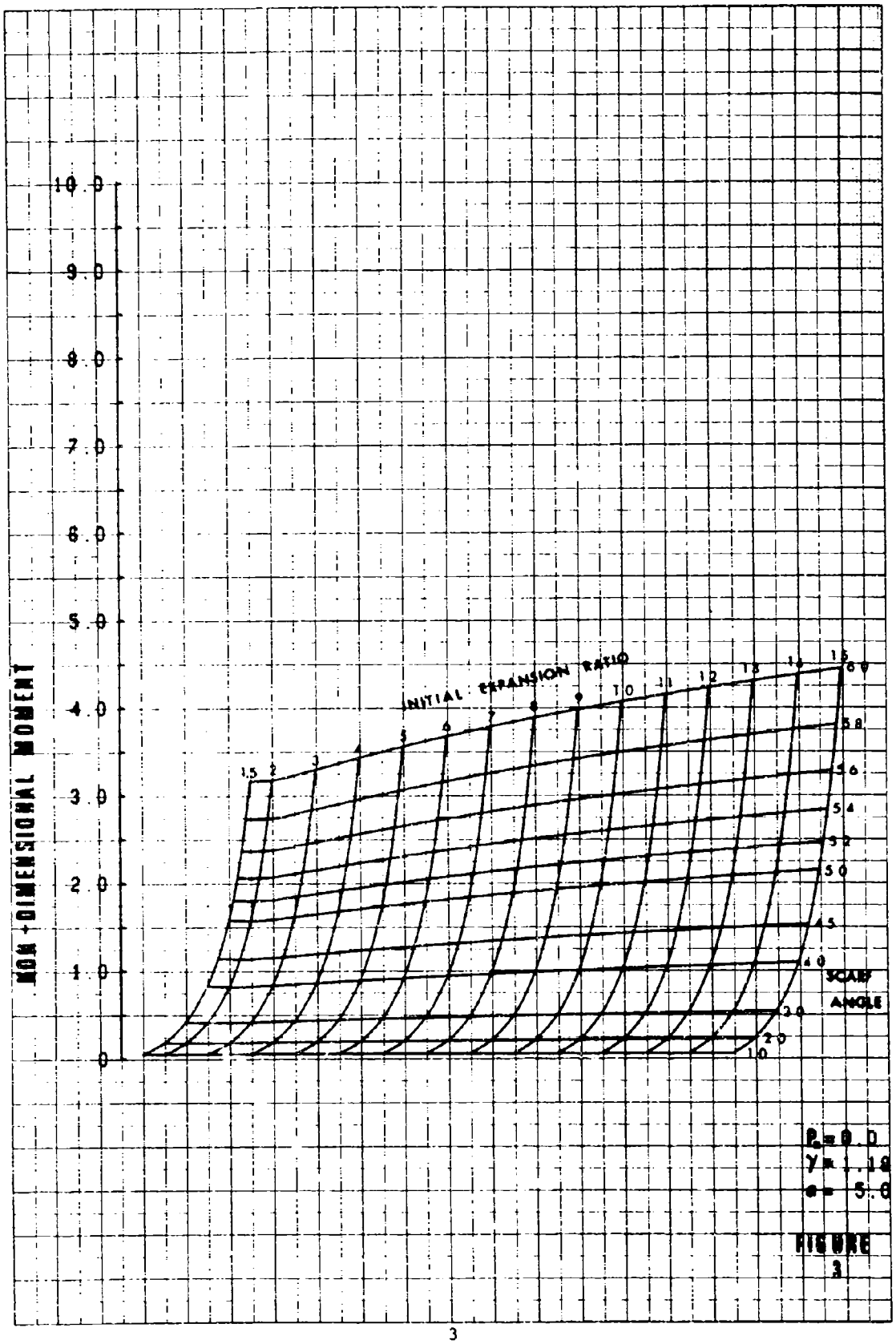
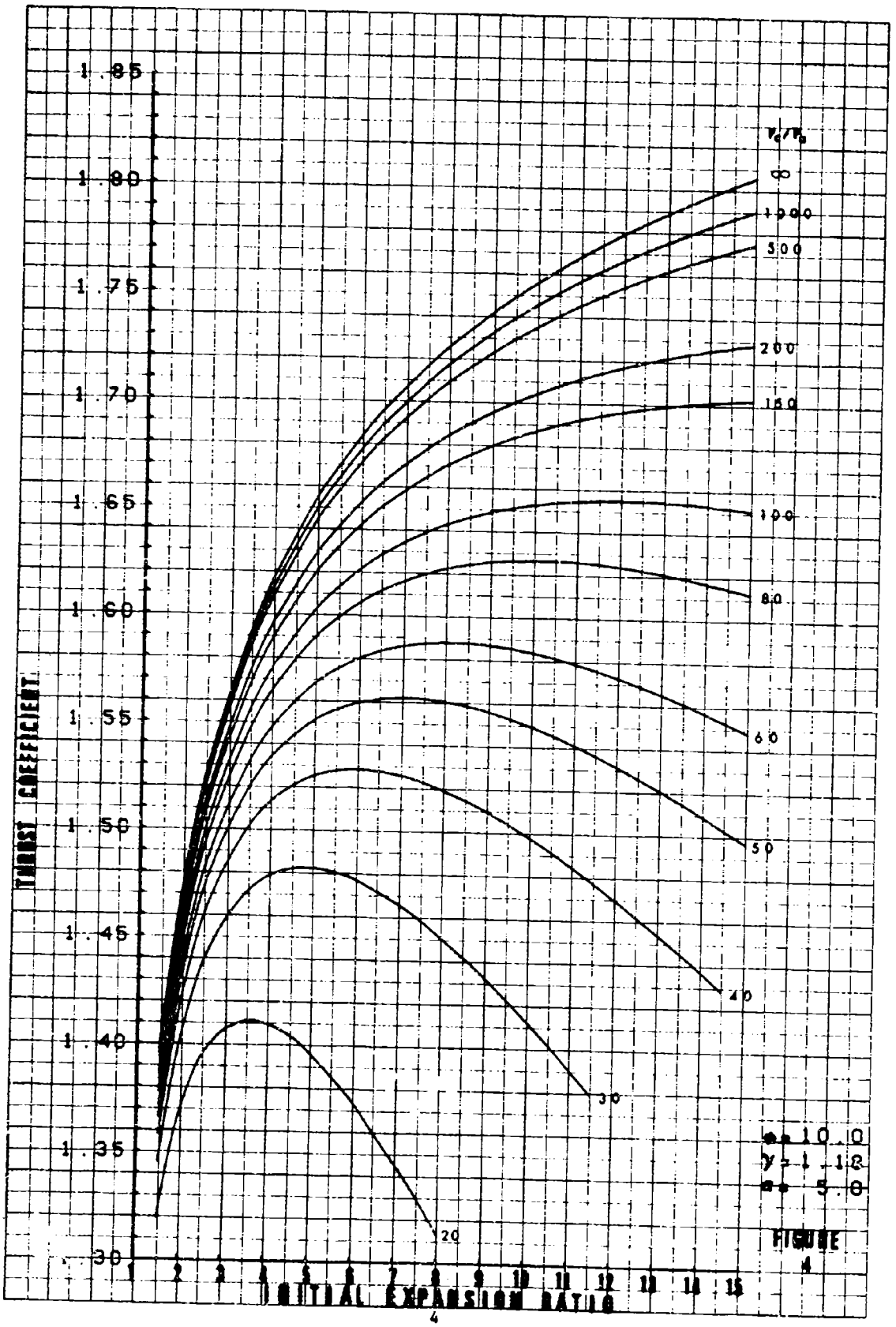

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
6.0
5.8
5.6
5.4
5.2
5.0
4.5
4.0
3.0
2.0
1.0
SCARF ANGLE
$P_c = 0.0$
$\gamma = 1.18$
$\sigma = 5.0$

FIGURE 3



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
V_c/V_a
∞
1000
500
200
150
100
80
60
50
40
30
20
α = 10.0
γ = 1.18
σ = 5.0

FIGURE 4

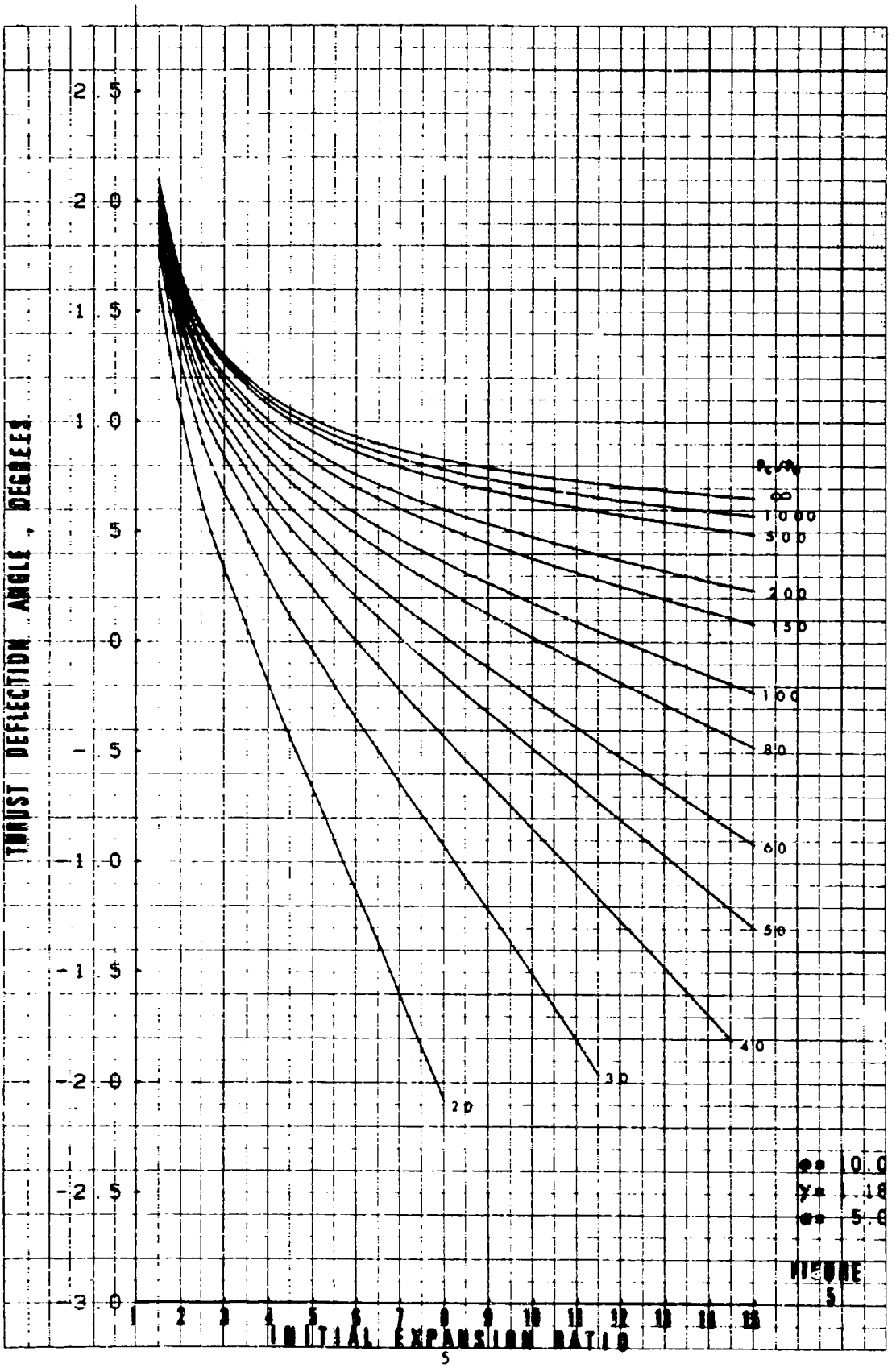
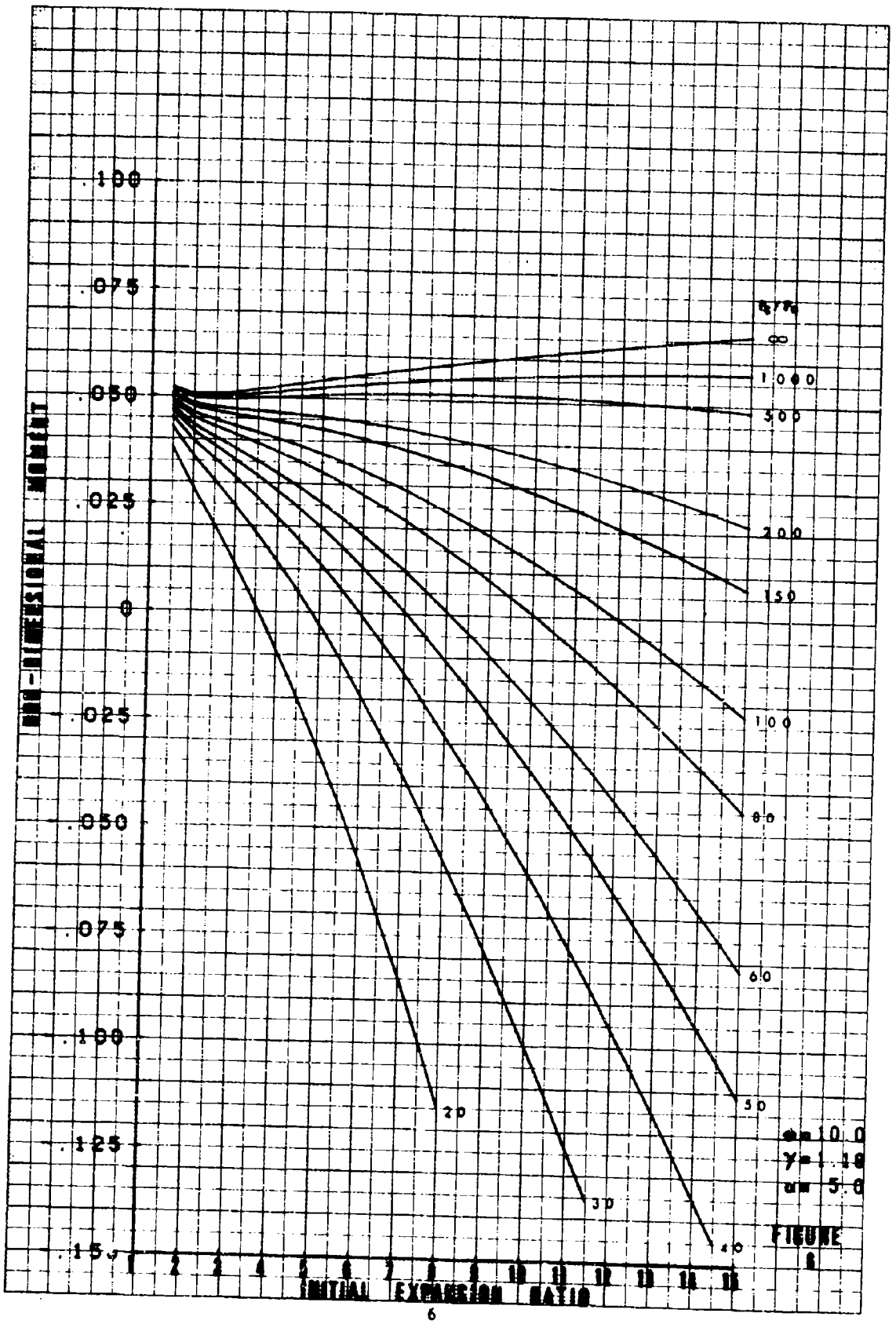
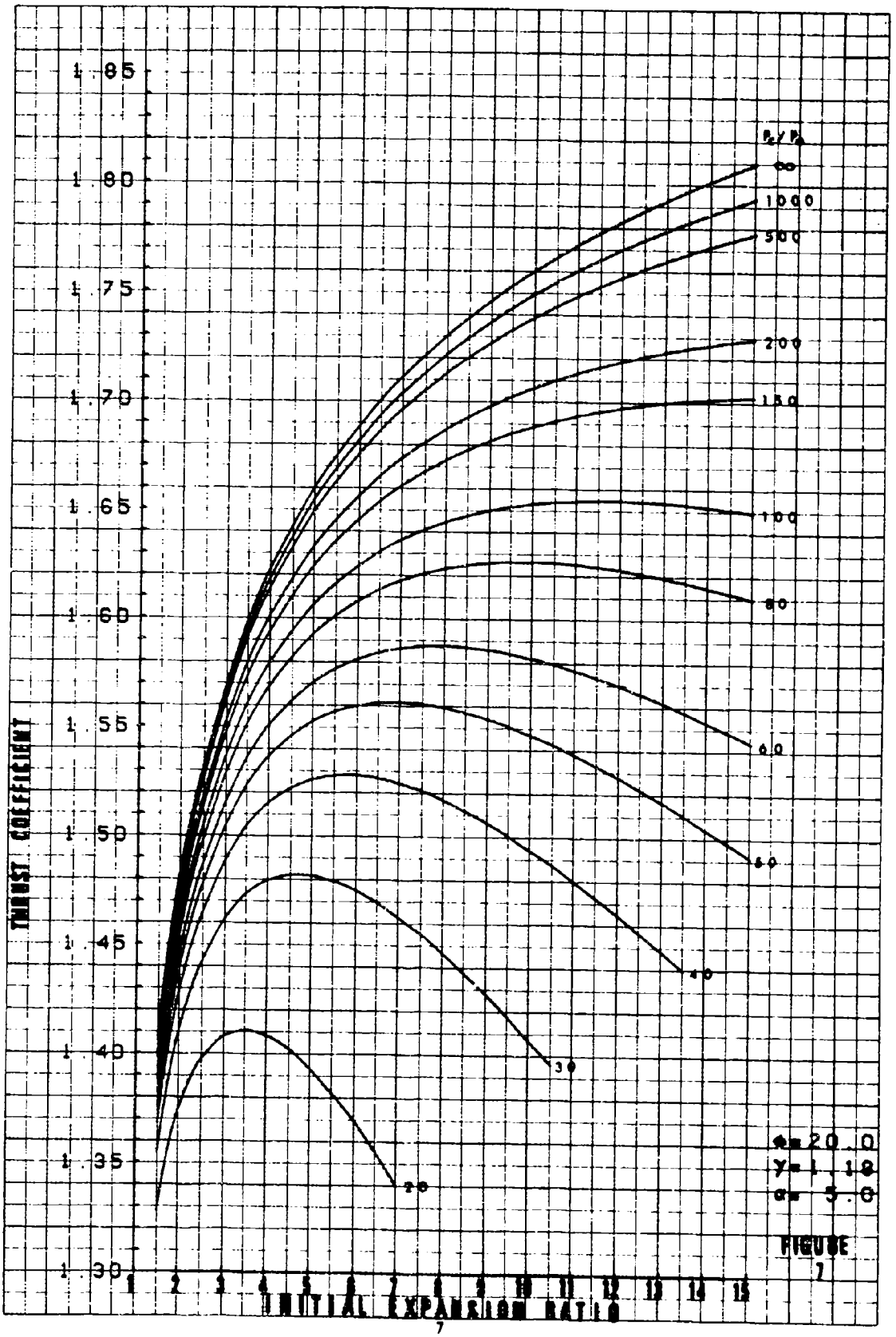

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
-2.5
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.18
α= 5.0

FIGURE 5



.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 6



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.18
α= 5.0

FIGURE 7

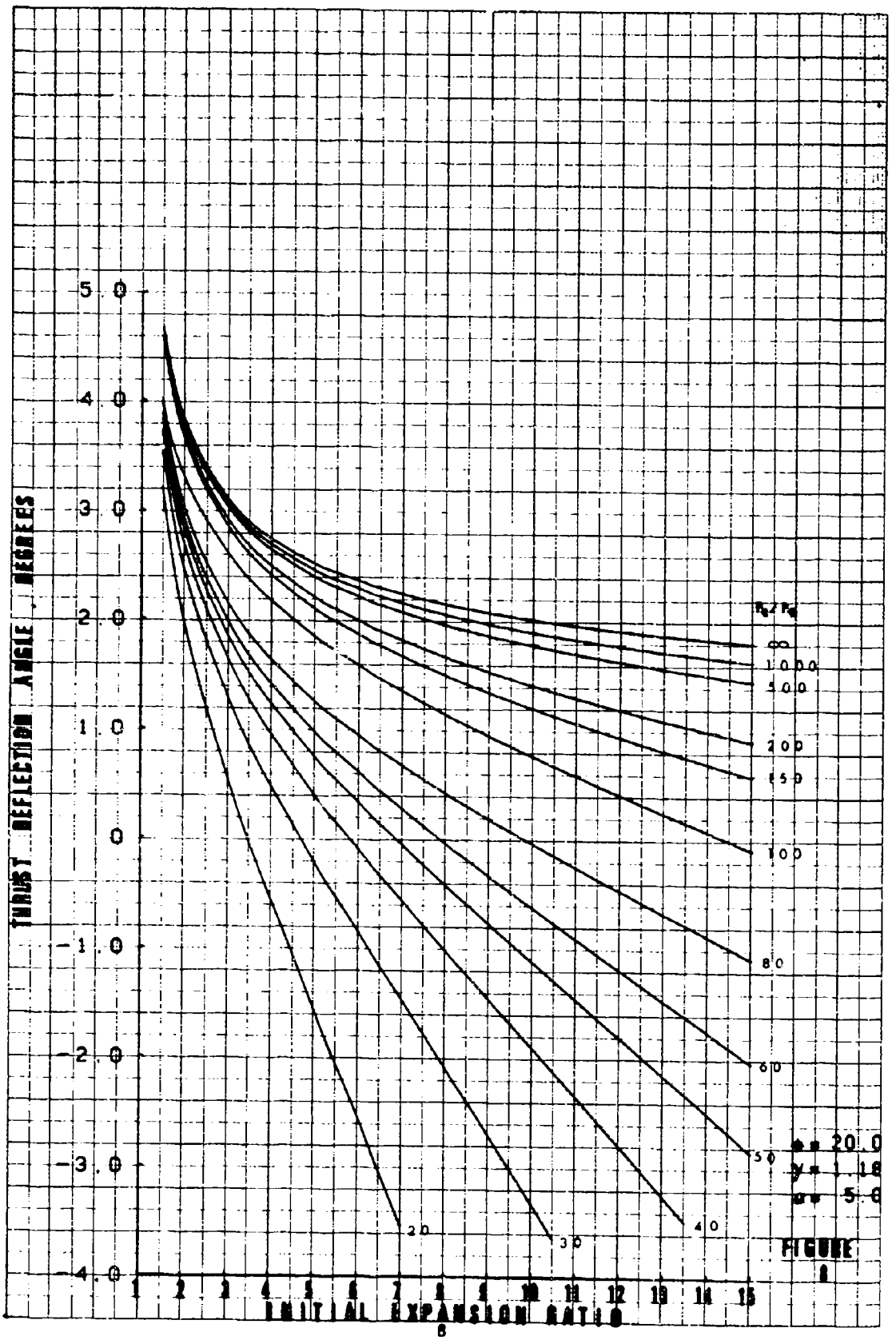

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_a/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 20.0
γ = 1.18
α = 5.0

FIGURE 1

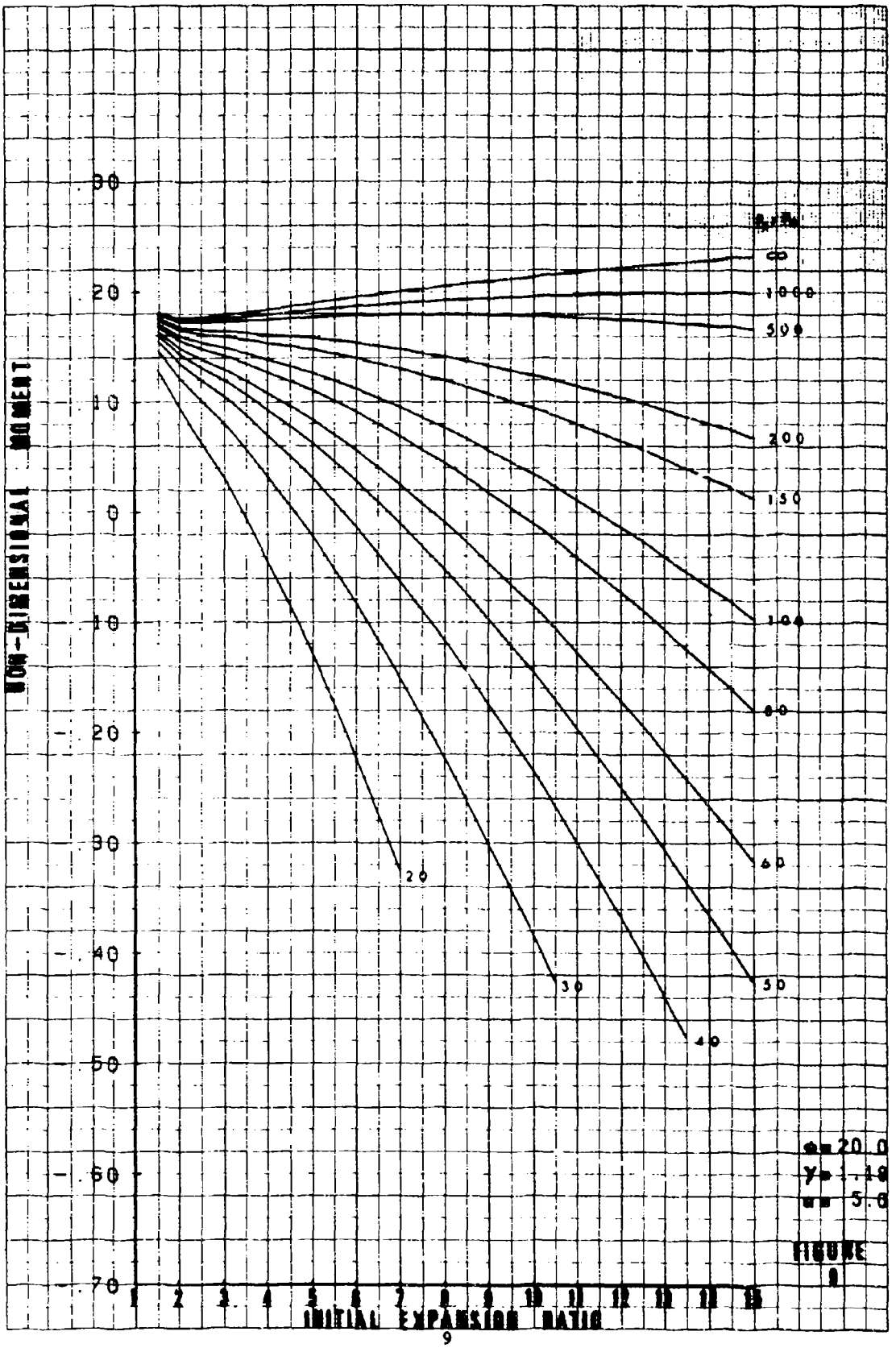

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
α=20.0
γ=1.19
m=5.6

FIGURE 8

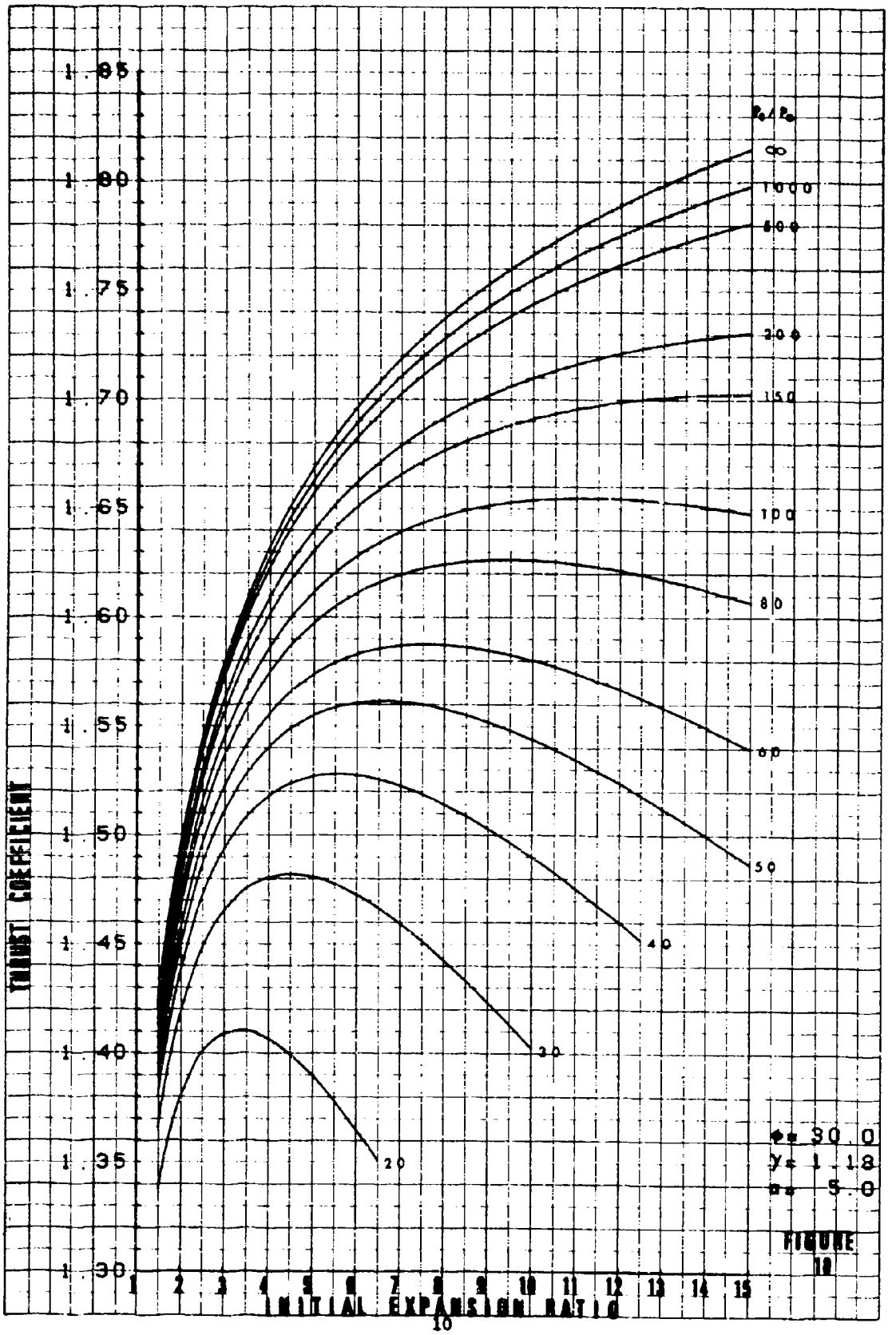
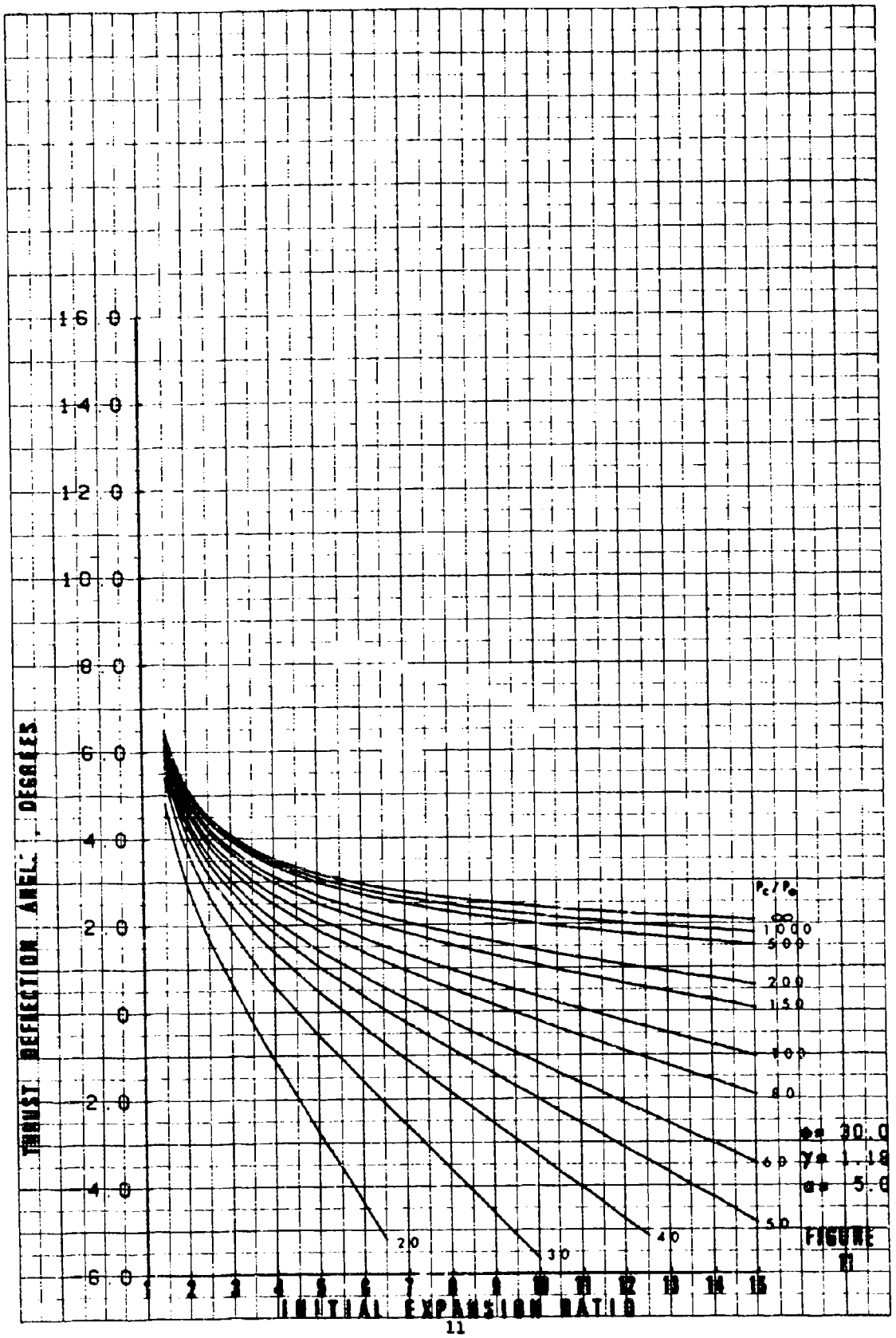

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.18
n = 5.0

FIGURE 10



THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.18
α= 5.0

FIGURE 11

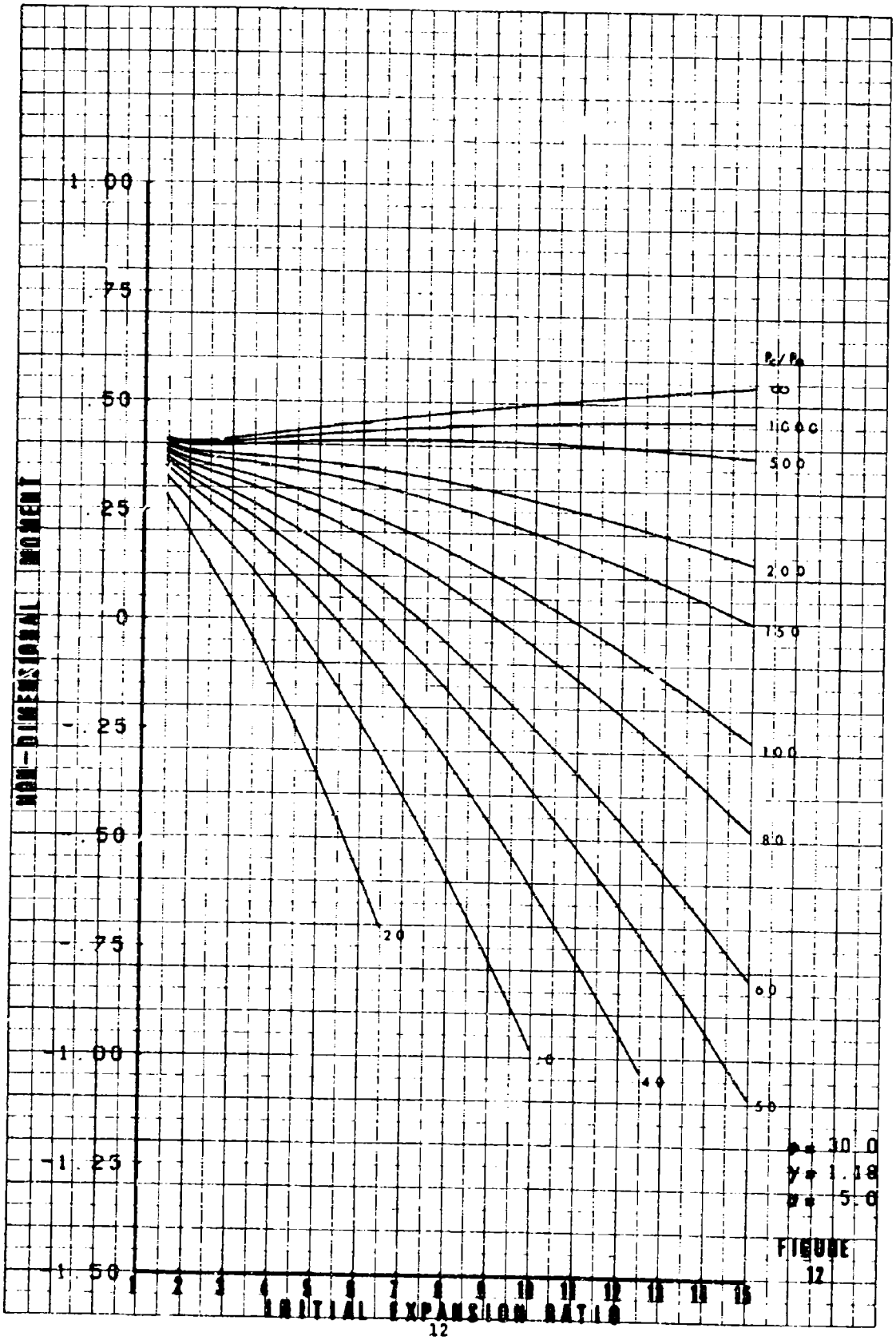

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.23
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
β = 30.0
γ = 1.18
σ = 5.6

FIGURE 12

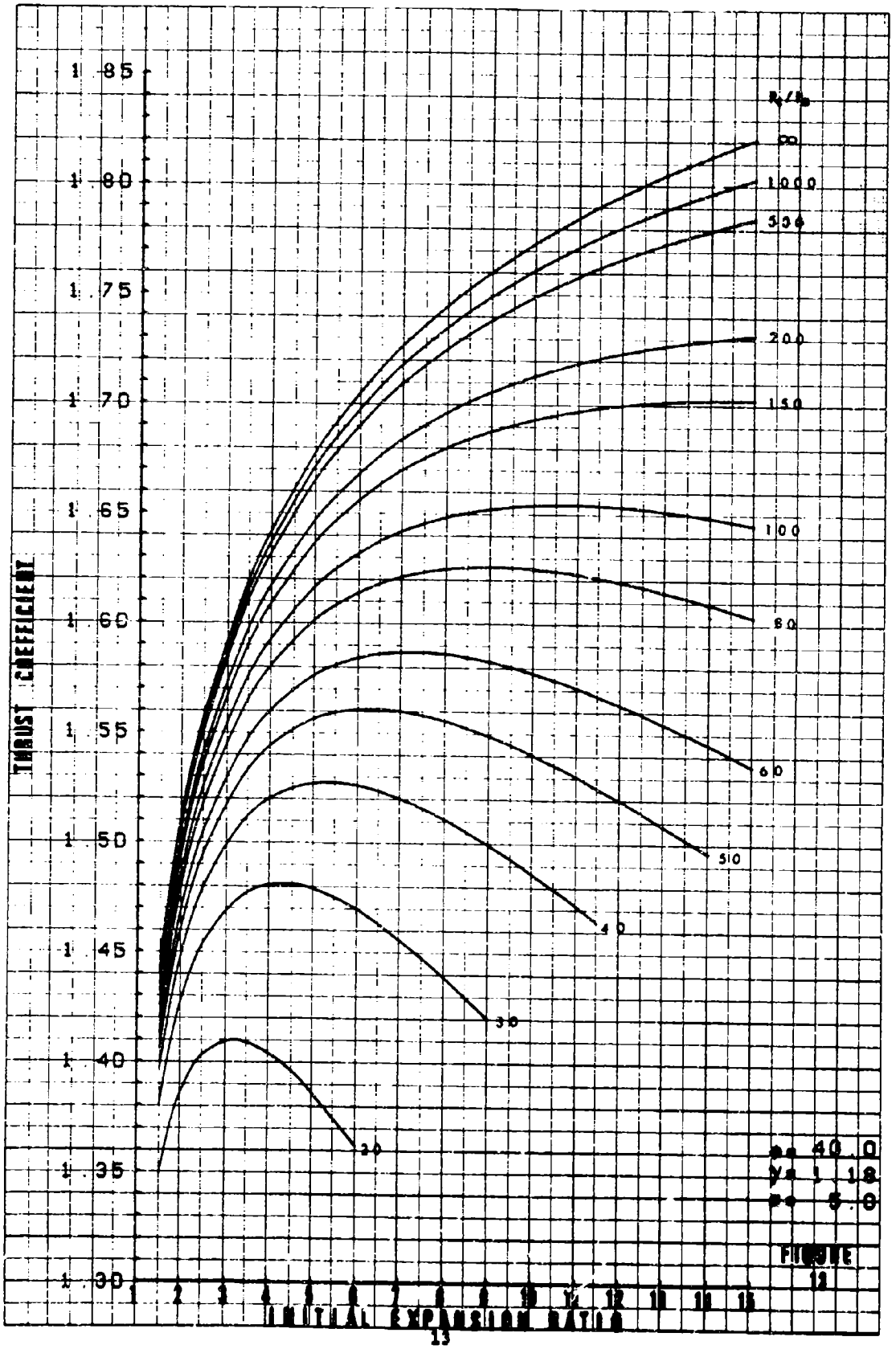

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
40.0
1.18
5.0

FIGURE 12

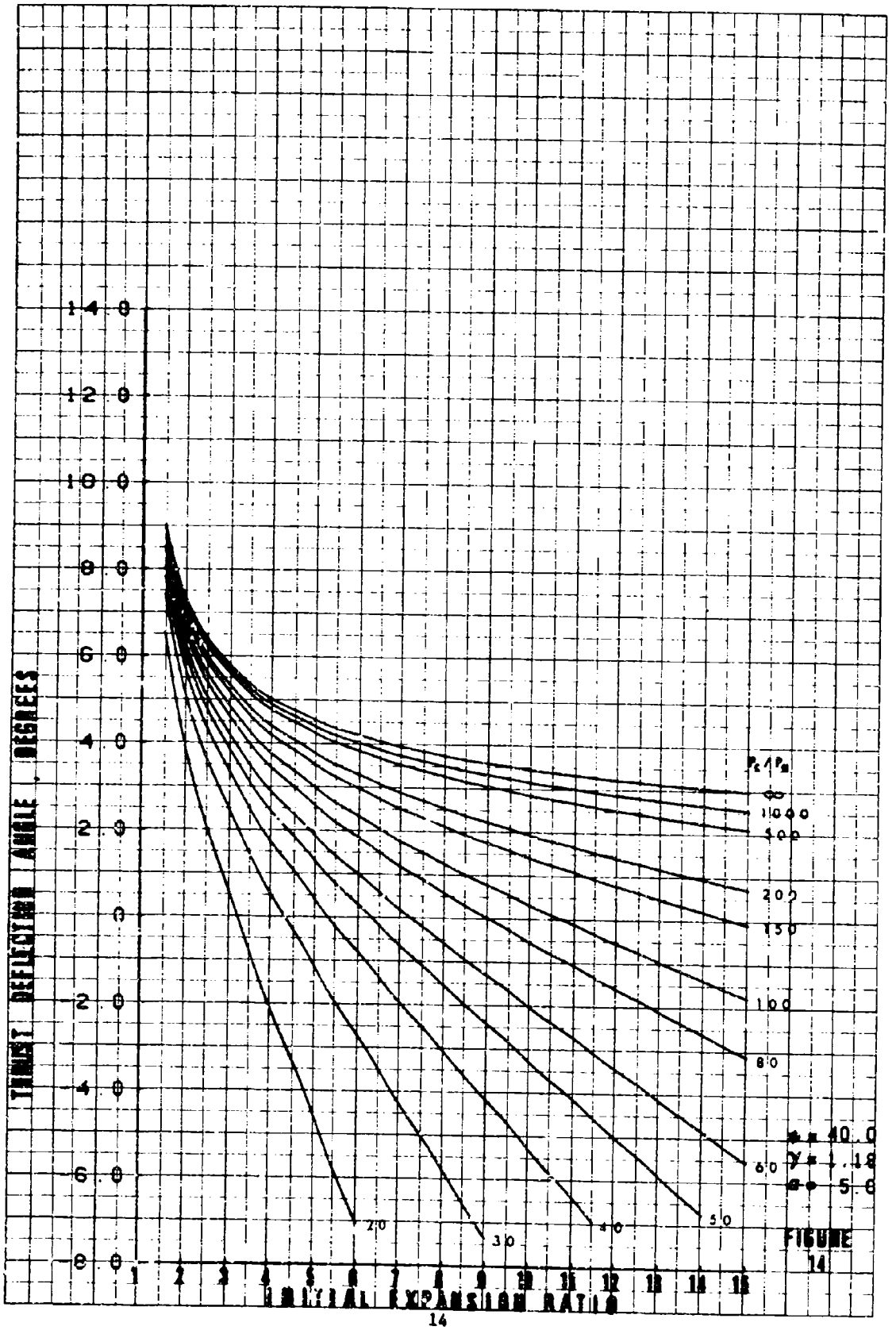
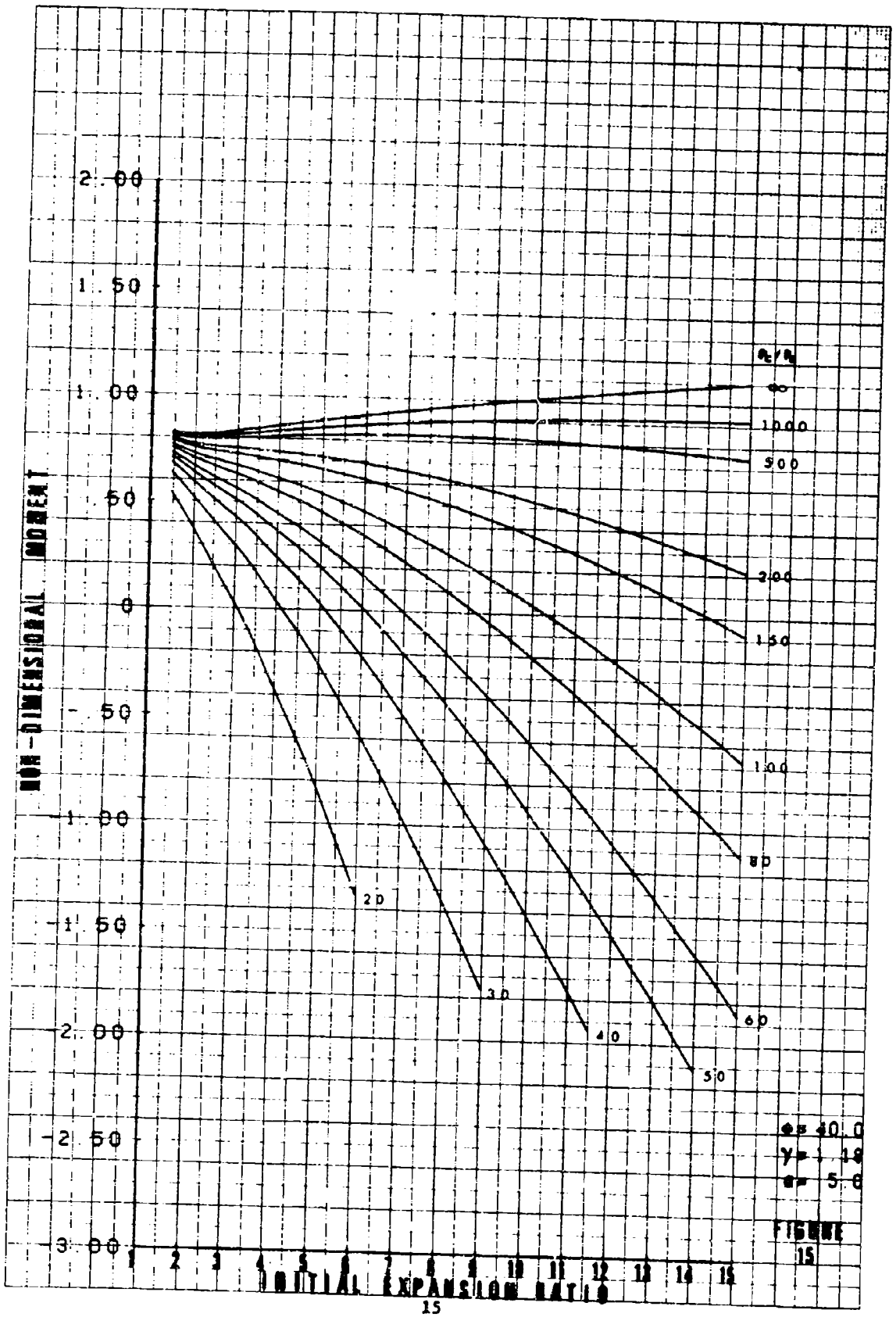

THRUST DEFLECTION ANGLE, DEGREES
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.18
α = 5.0

FIGURE 14



NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 40.0
γ= 1.18
α= 5.0

FIGURE 15

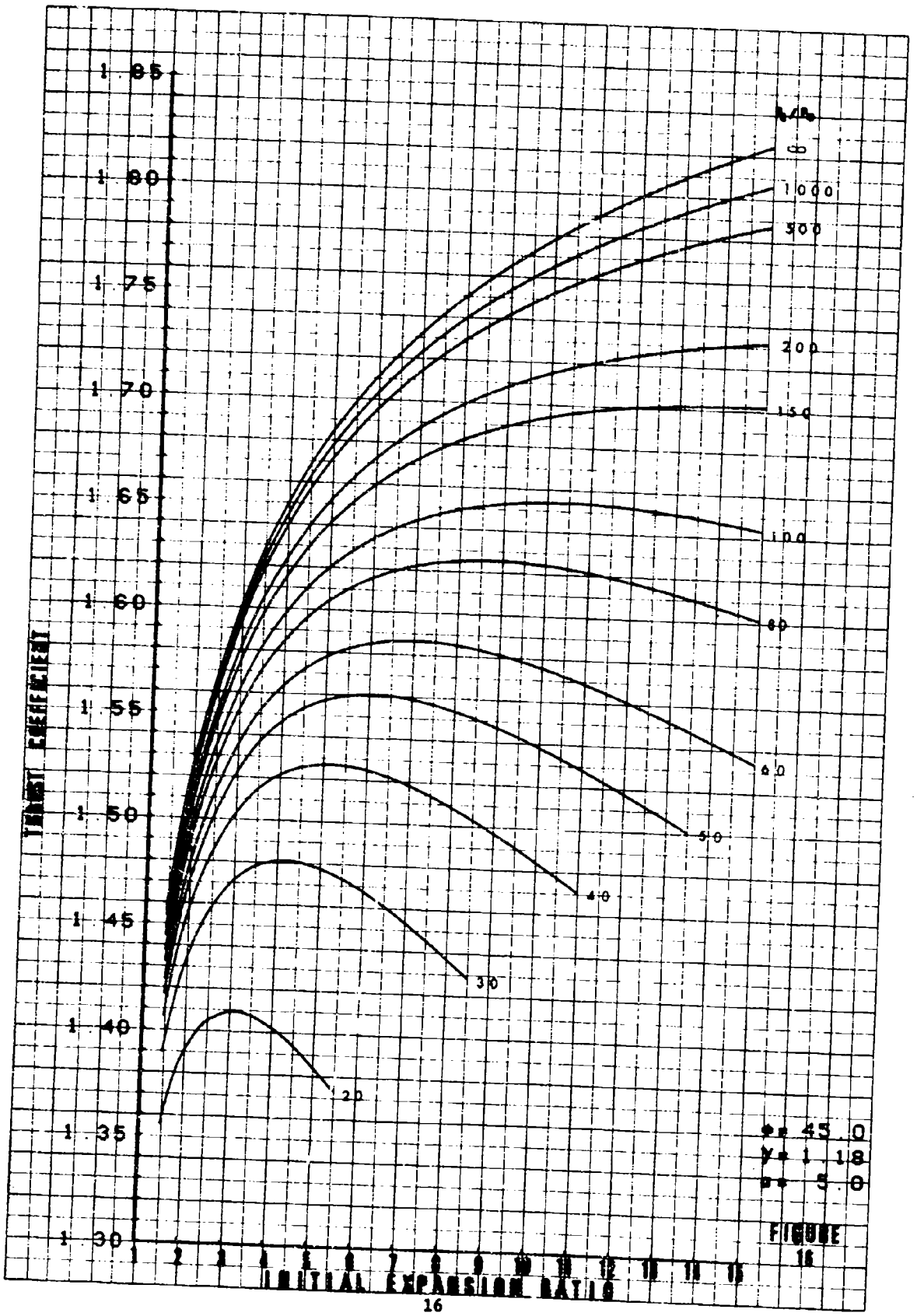

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.18
p = 5.0

FIGURE 16

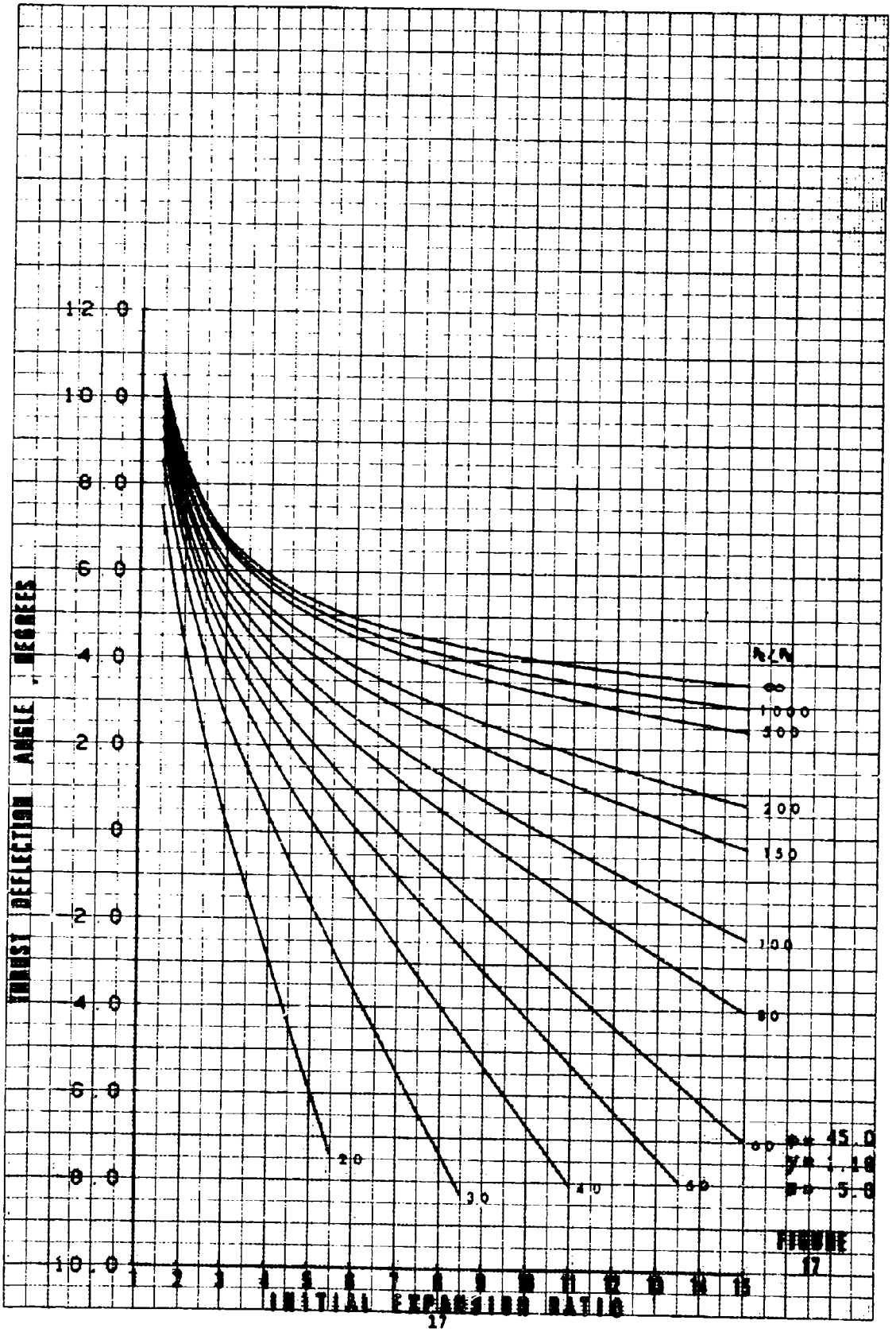
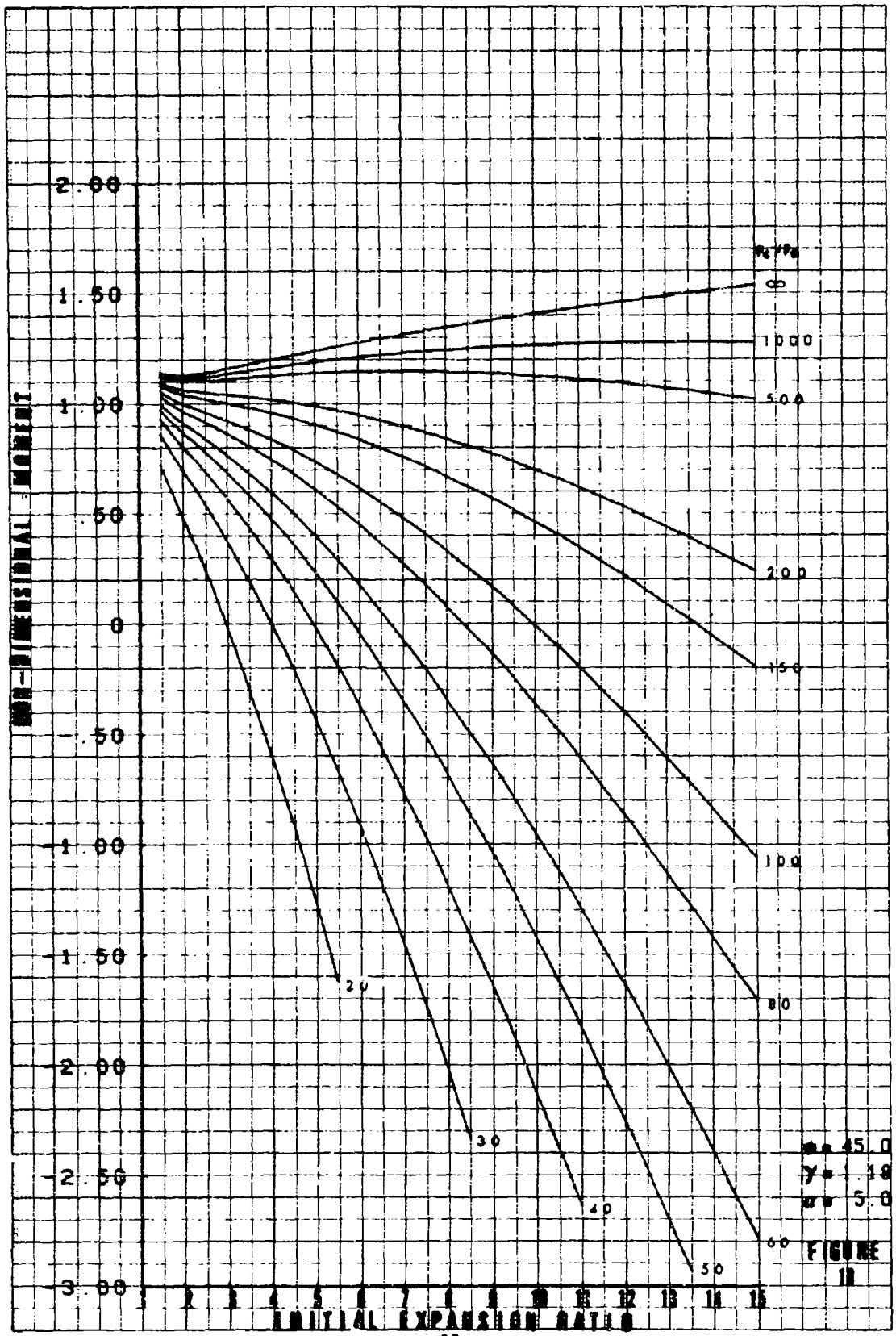

THRUST DEFLECTION ANGLE, DEGREES
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
-10.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 45.0
γ= 1.10
θ= 5.0

FIGURE 17


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = .18
FIGURE 11

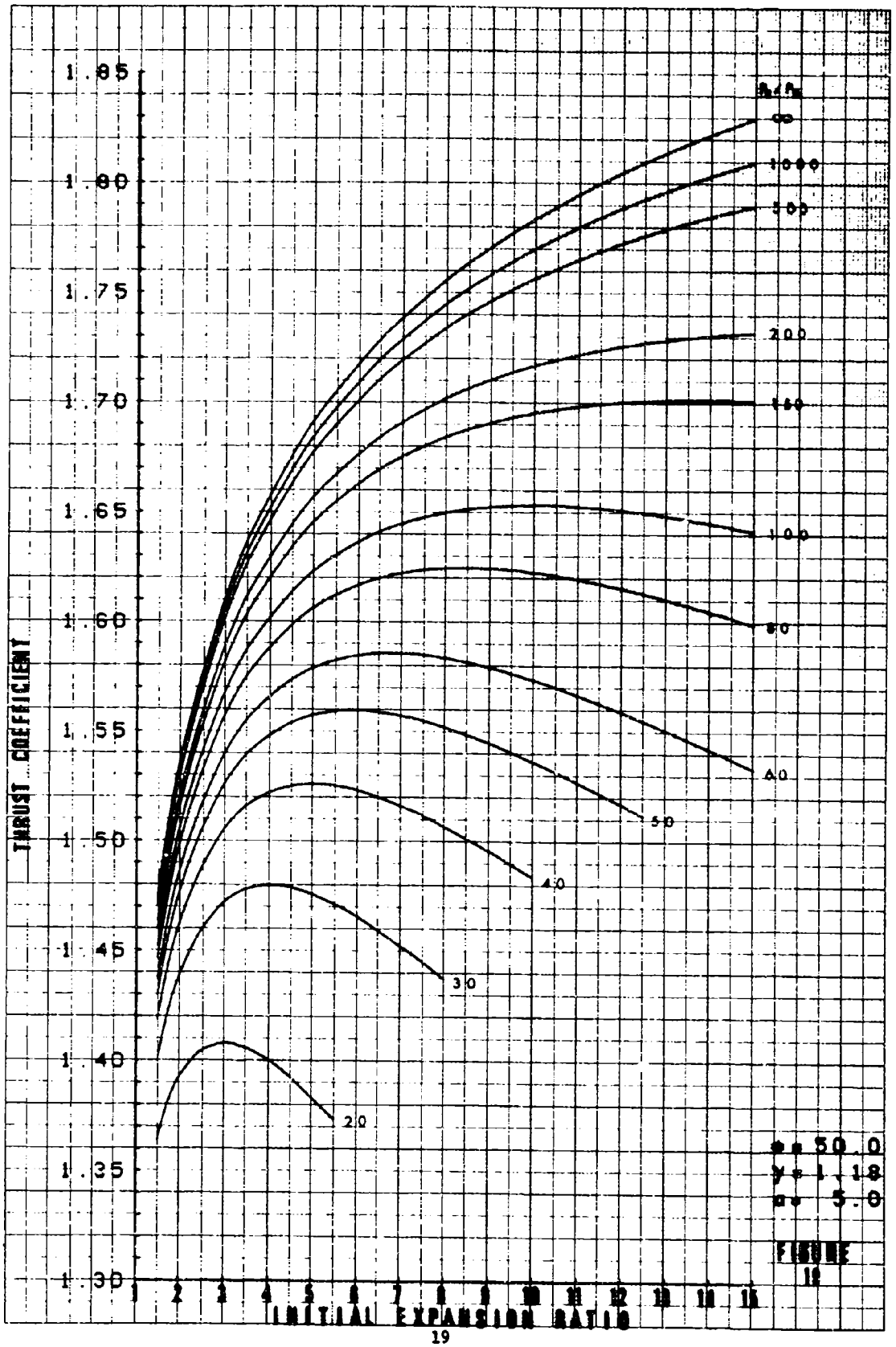

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 50.0
= 1.18
= 5.0

FIGURE 12

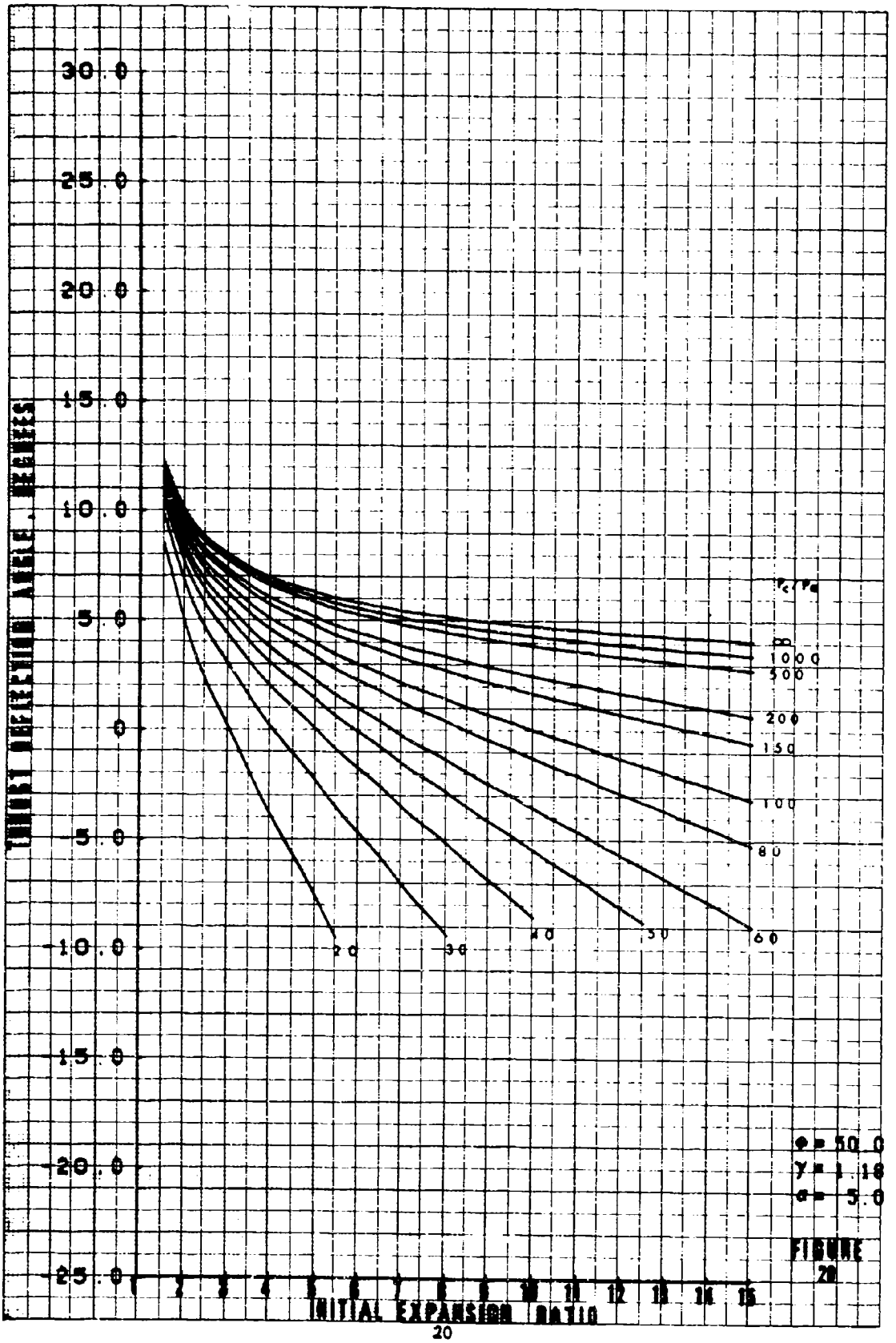

THRUST DEFLECTION ANGLE, DEGREES
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.18
α = 5.0

FIGURE 20

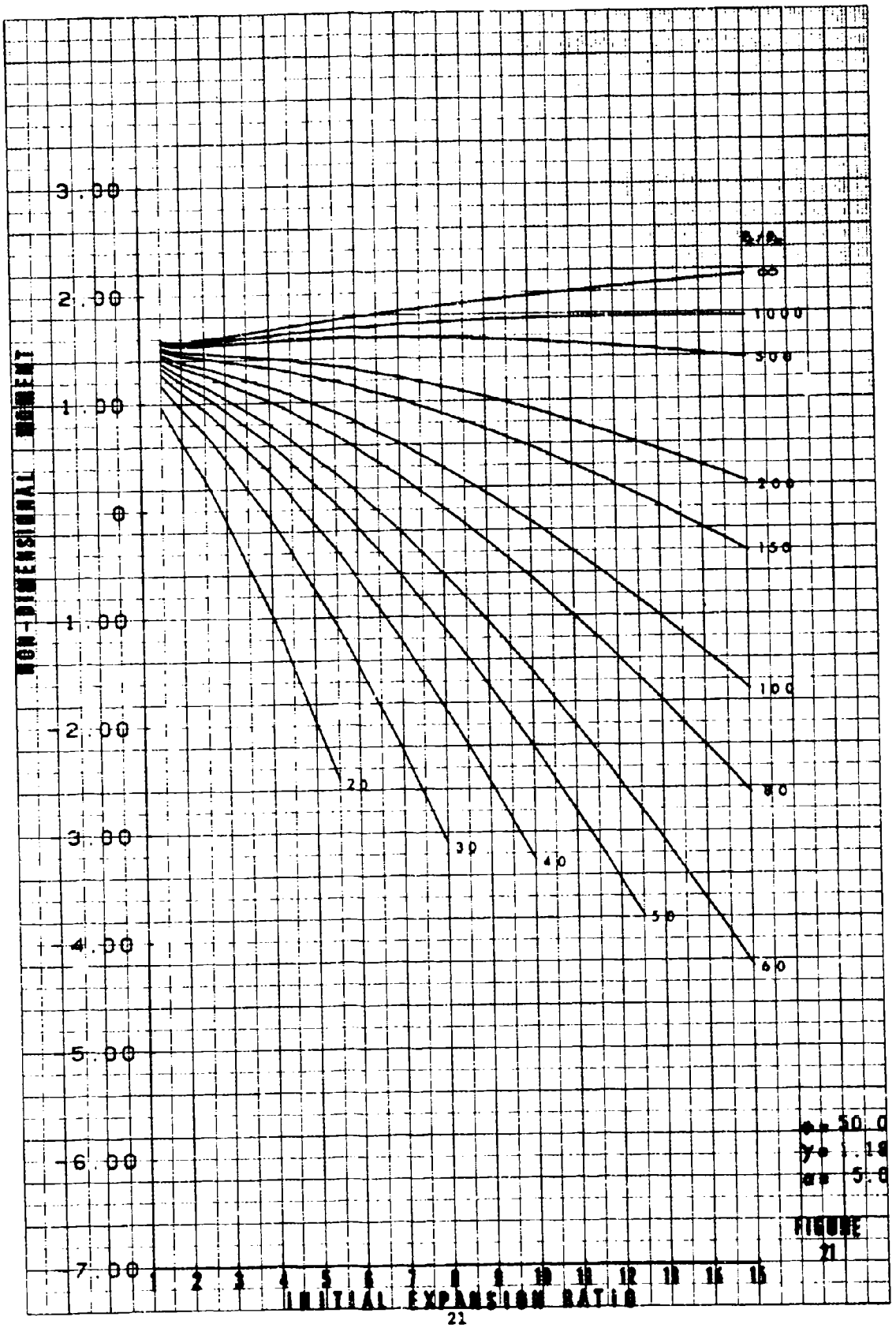

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 50.0
= 1.19
= 5.0

FIGURE 21

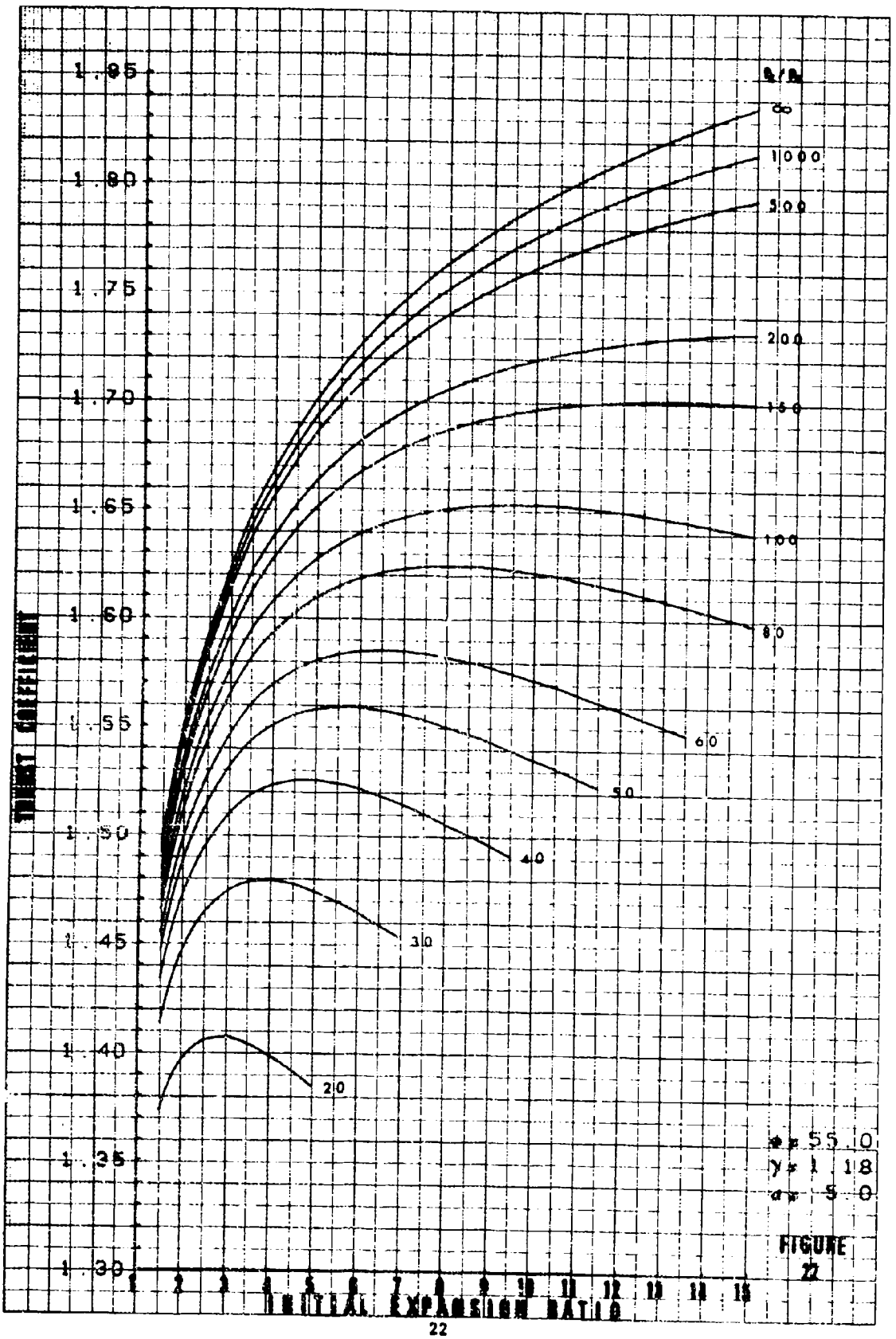
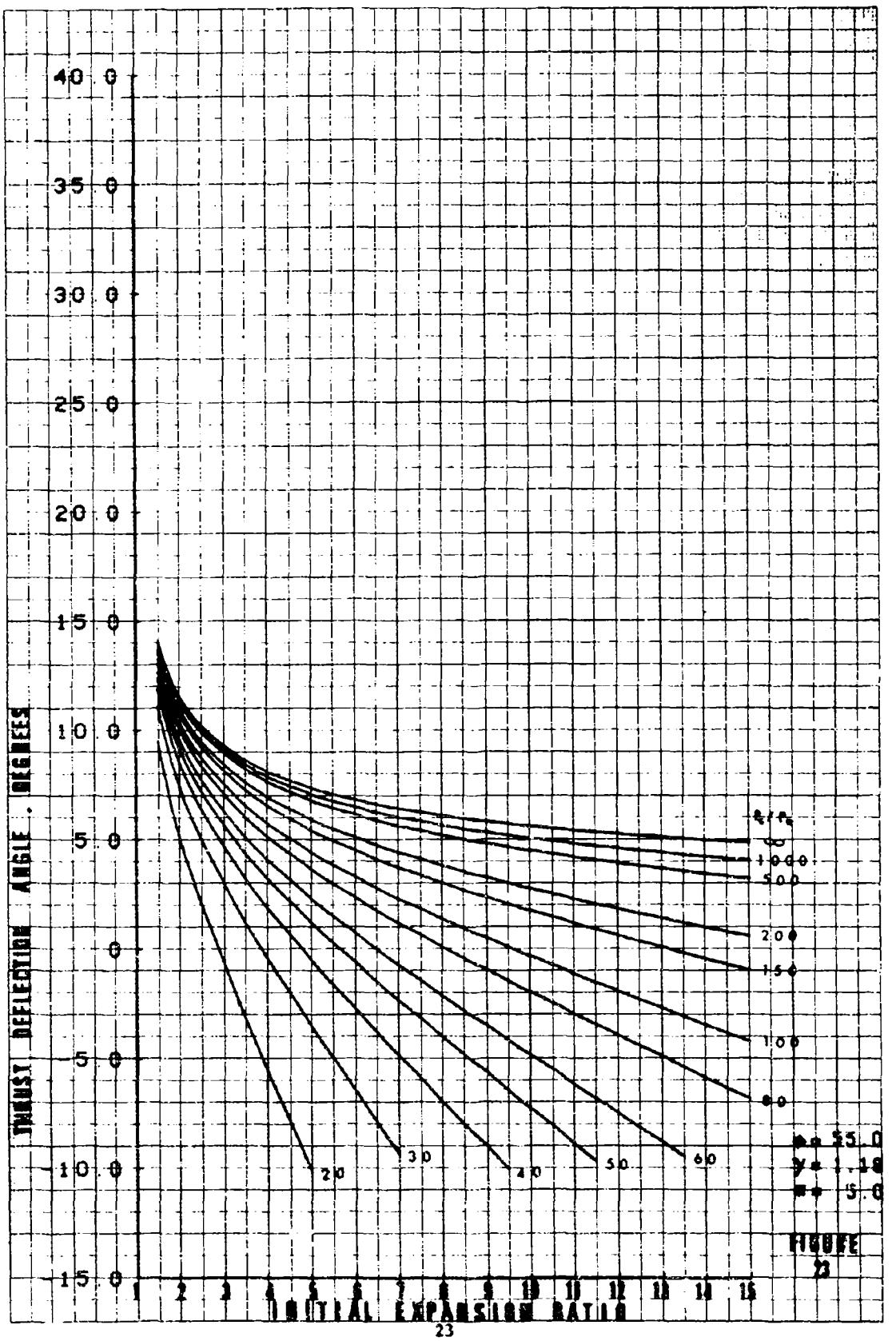

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 55.0
γ = 1.18
= 5.0

FIGURE 22



40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 23

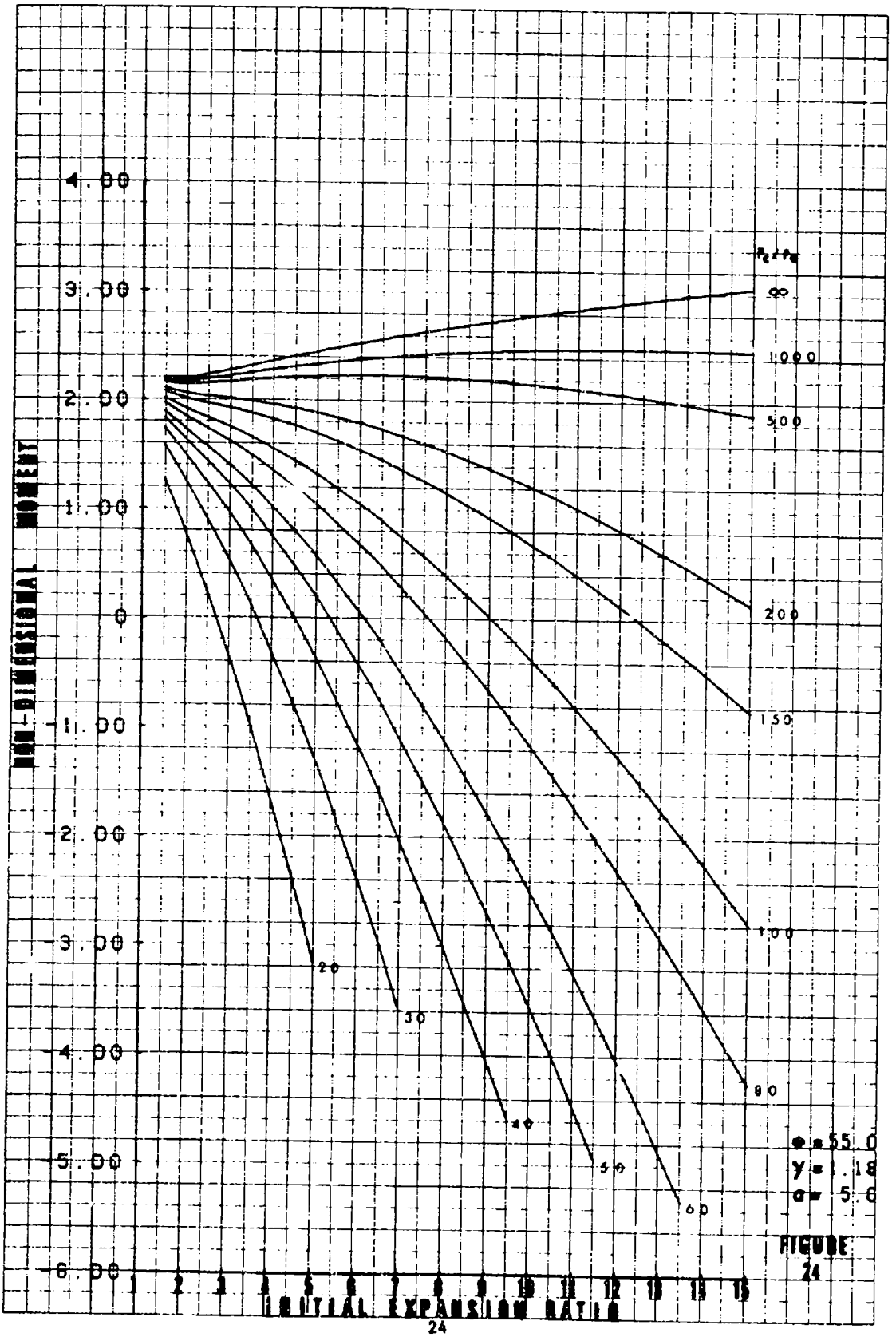

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.18
α = 5.6

FIGURE 24

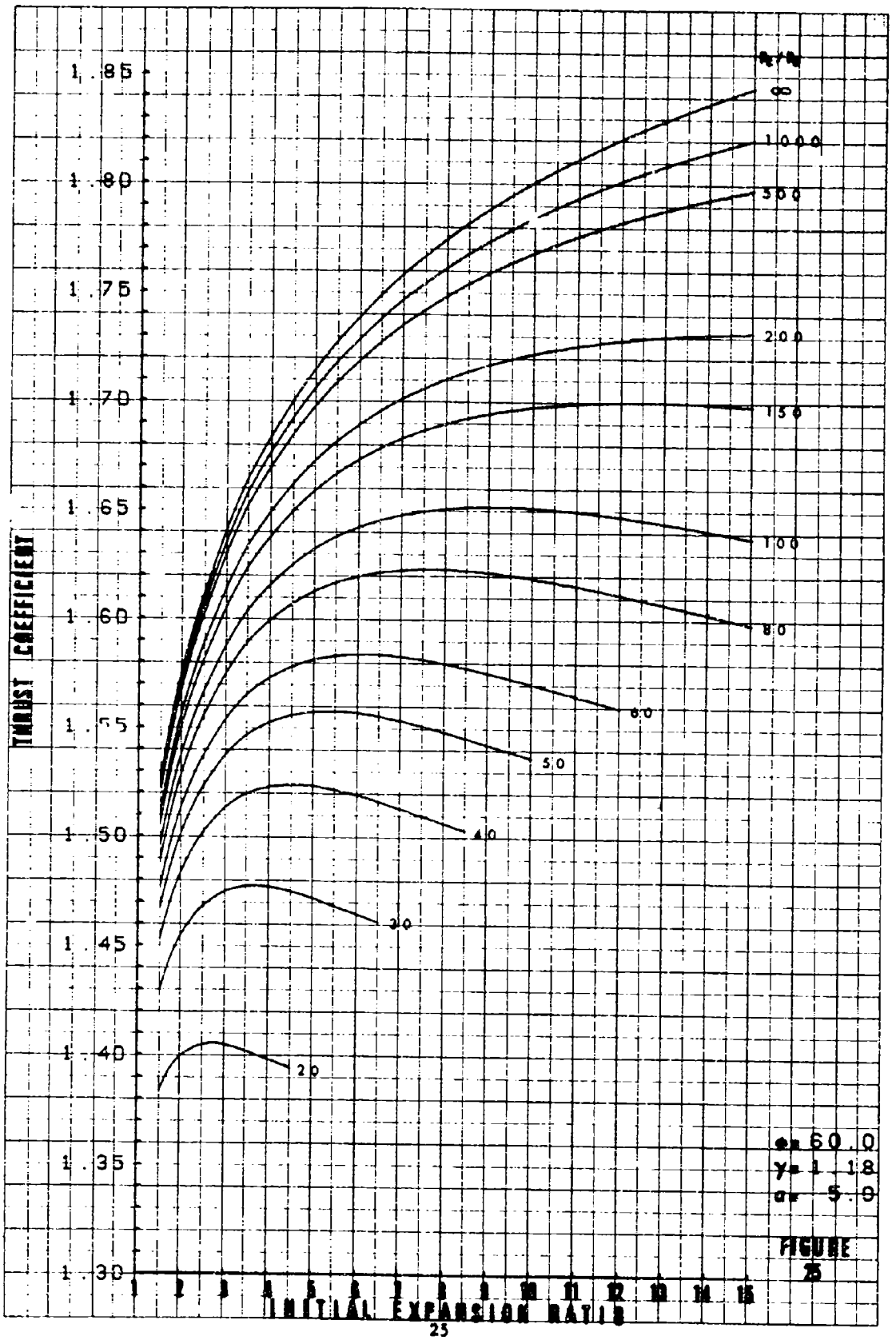

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.18
α= 5.0

FIGURE 25

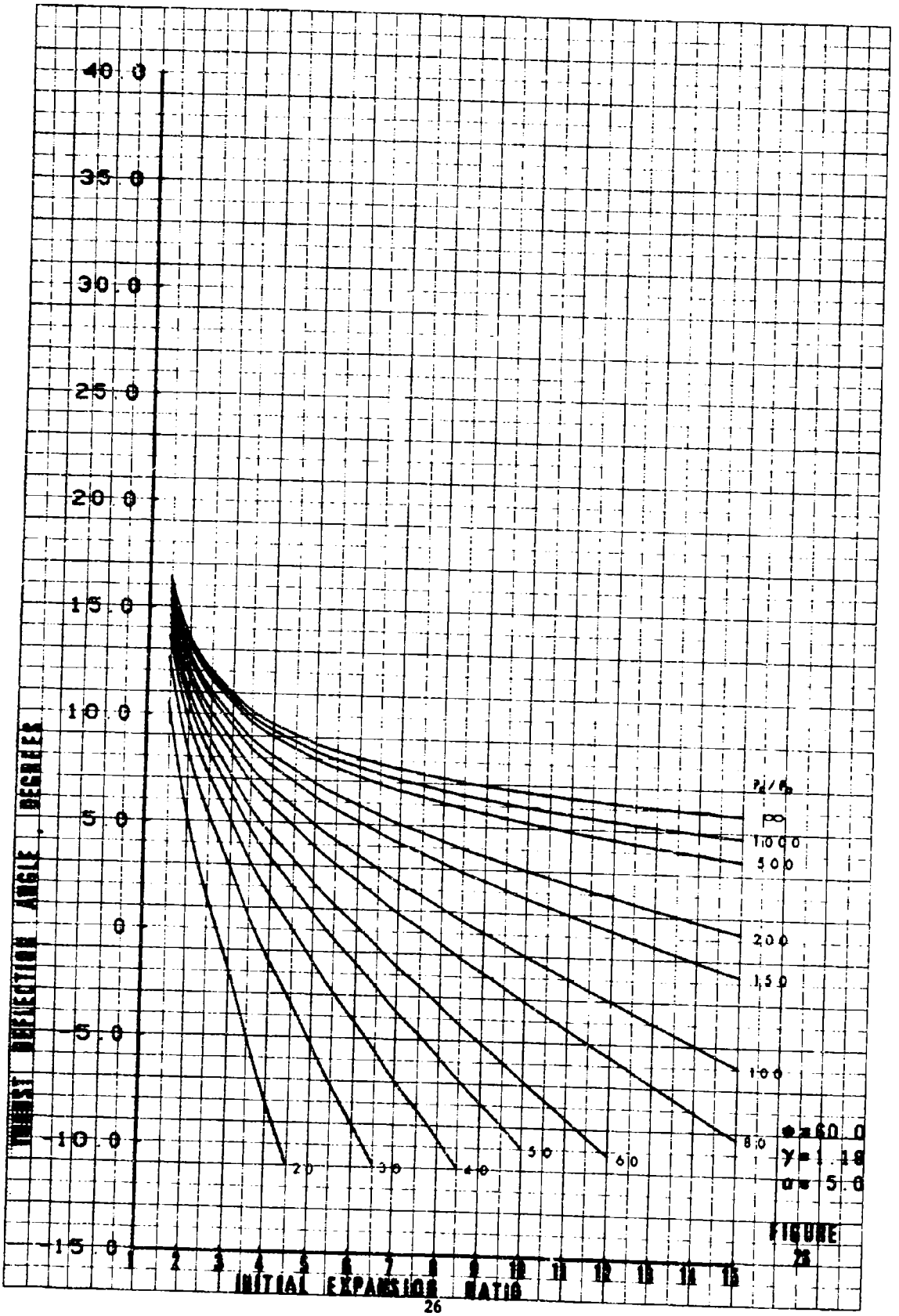

40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_2/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 60.0
γ = 1.18
α = 5.0

FIGURE 23

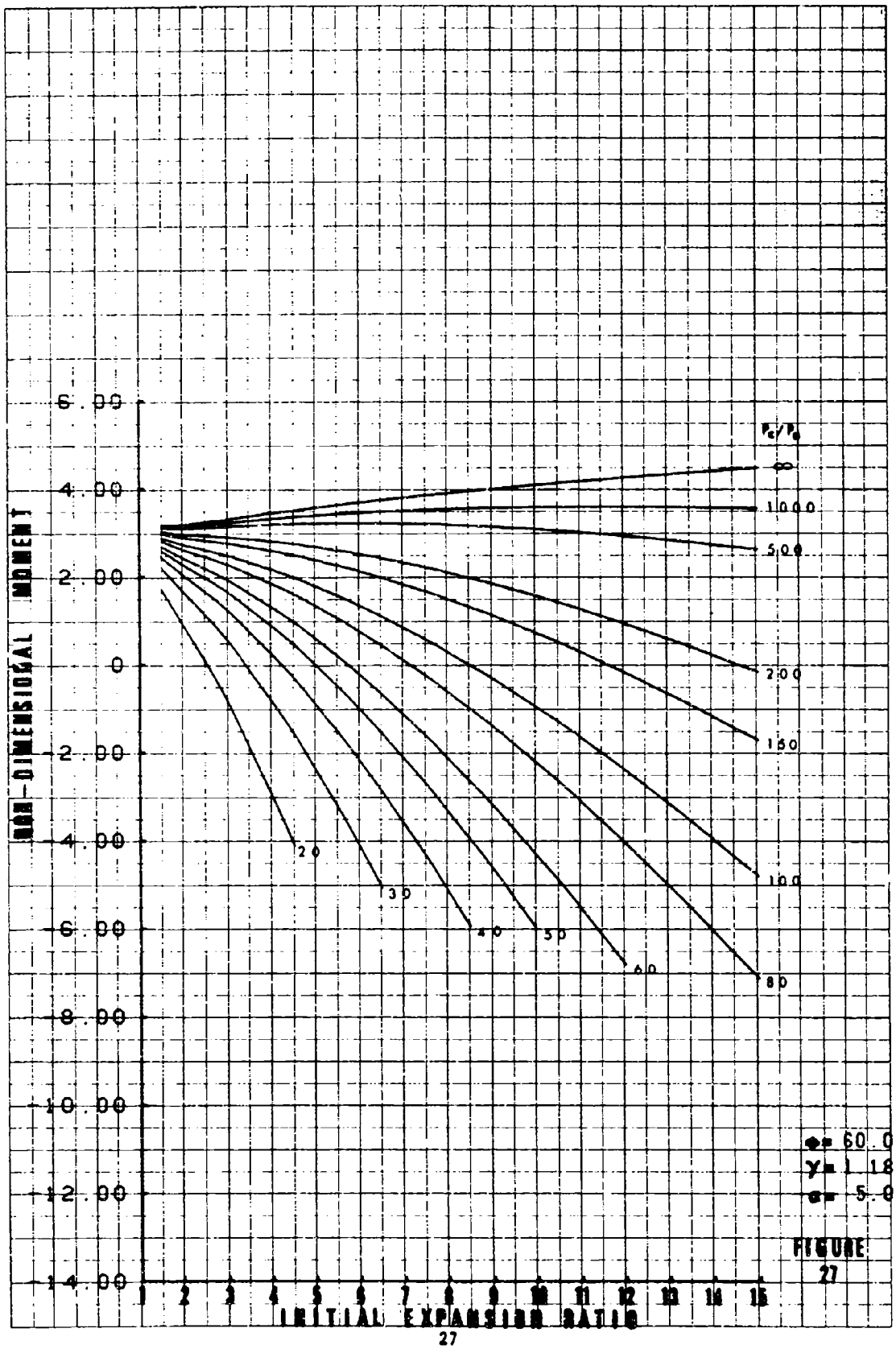

NON-DIMENSIONAL MOMENT
6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.18
σ= 5.0

FIGURE 27

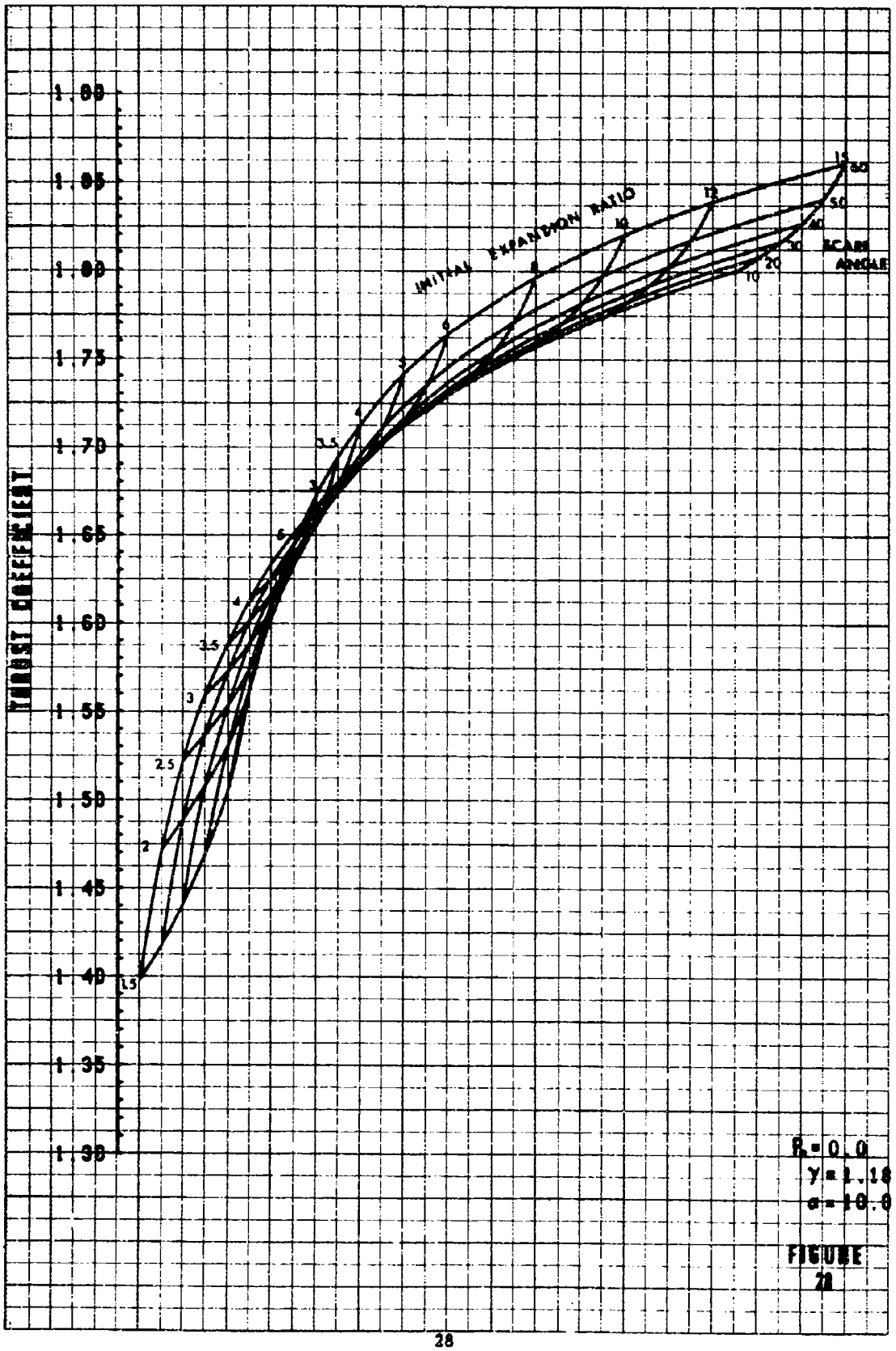

THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
8
10
12
15
10
20
30
40
50
60
R = 0.0
γ = 1.18
α = 10.0

FIGURE 28

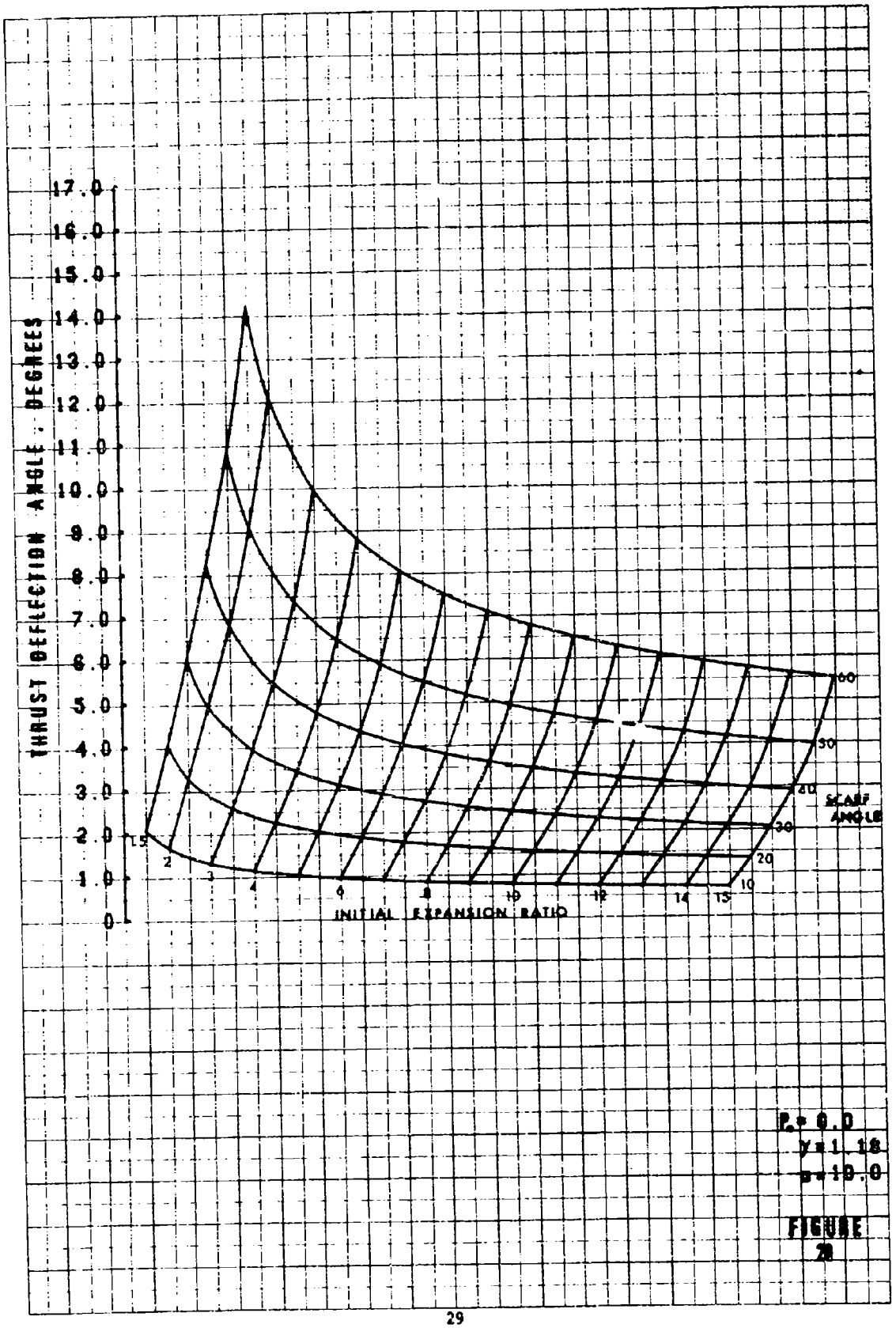

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
6
8
10
12
14
15
INITIAL EXPANSION RATIO
60
50
40
30
20
10
SCARF ANGLE
$P_e = 0.0$
$\gamma = 1.18$
$\beta = 10.0$

FIGURE 28

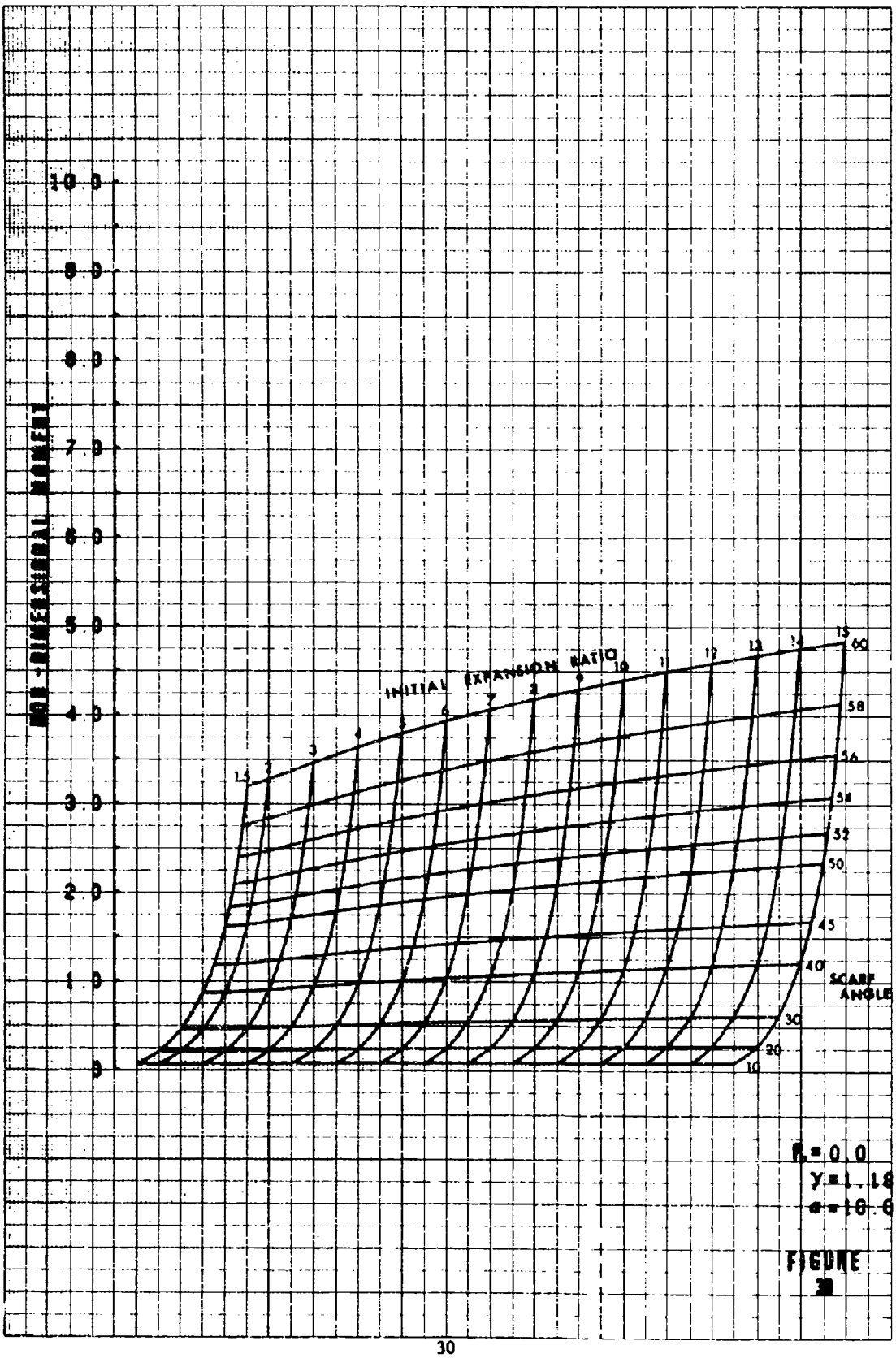

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
$R_0 = 0.0$
$\gamma = 1.18$
$\alpha = 10.0$

FIGURE 30

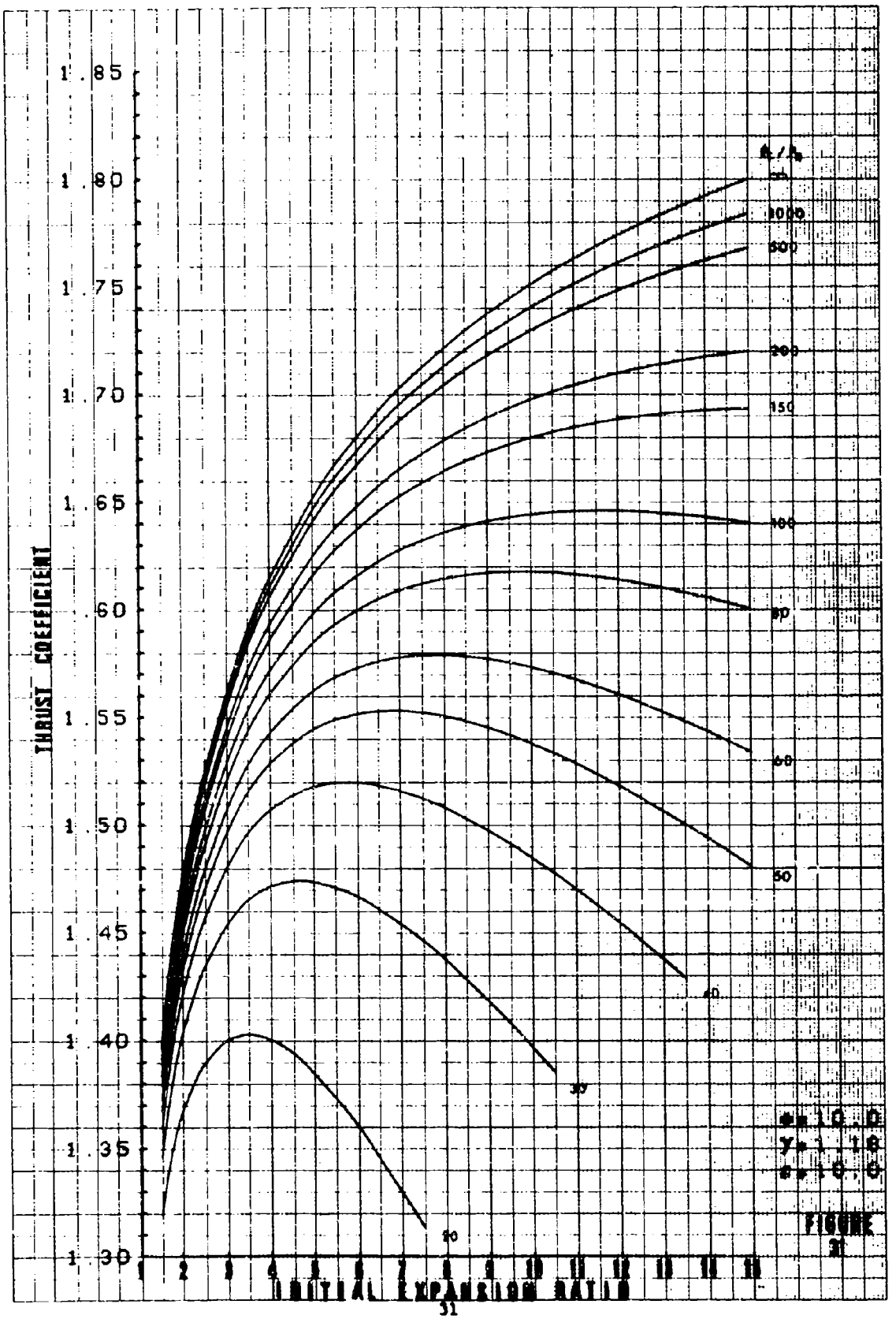

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
10

FIGURE 31

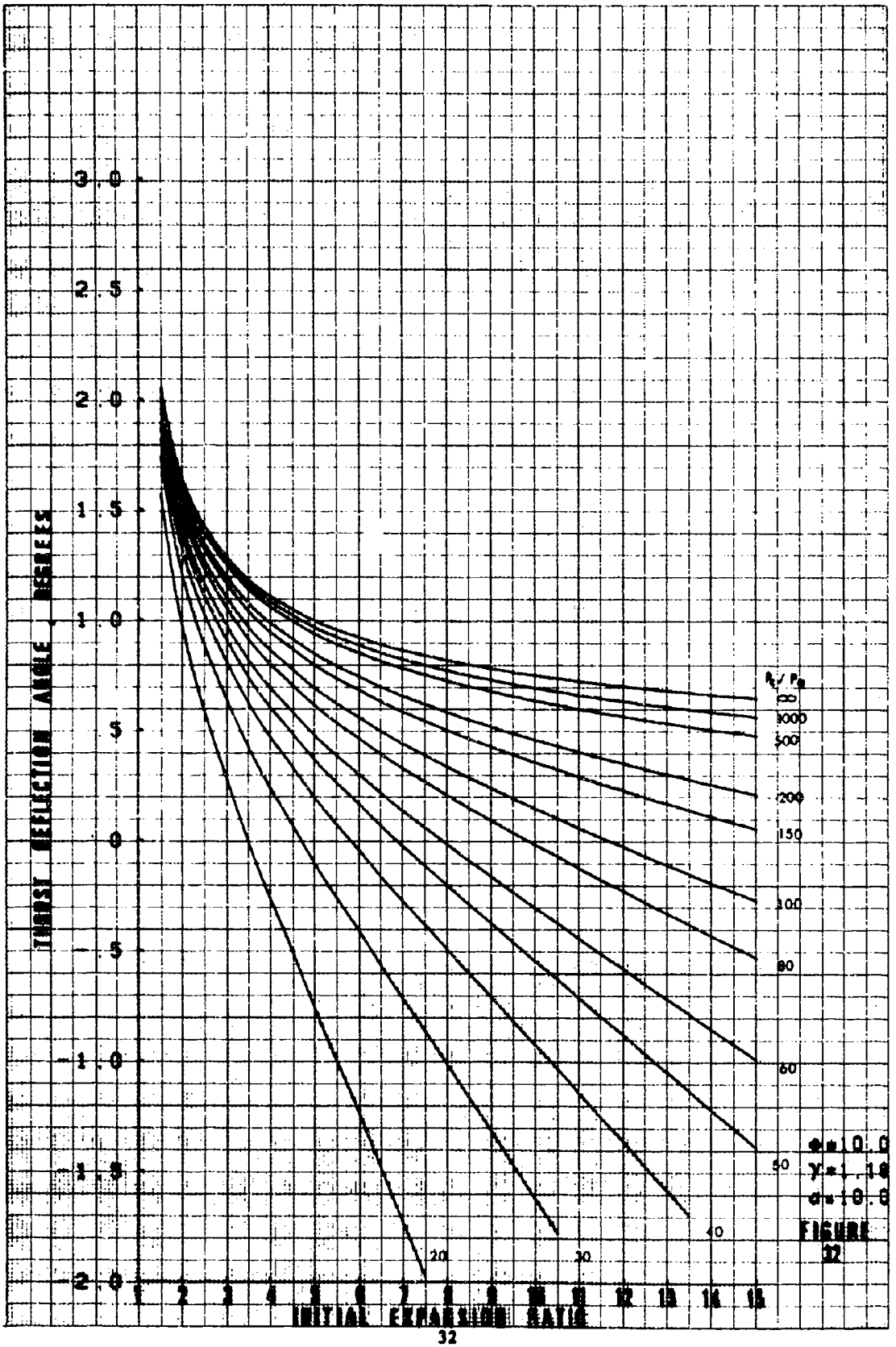
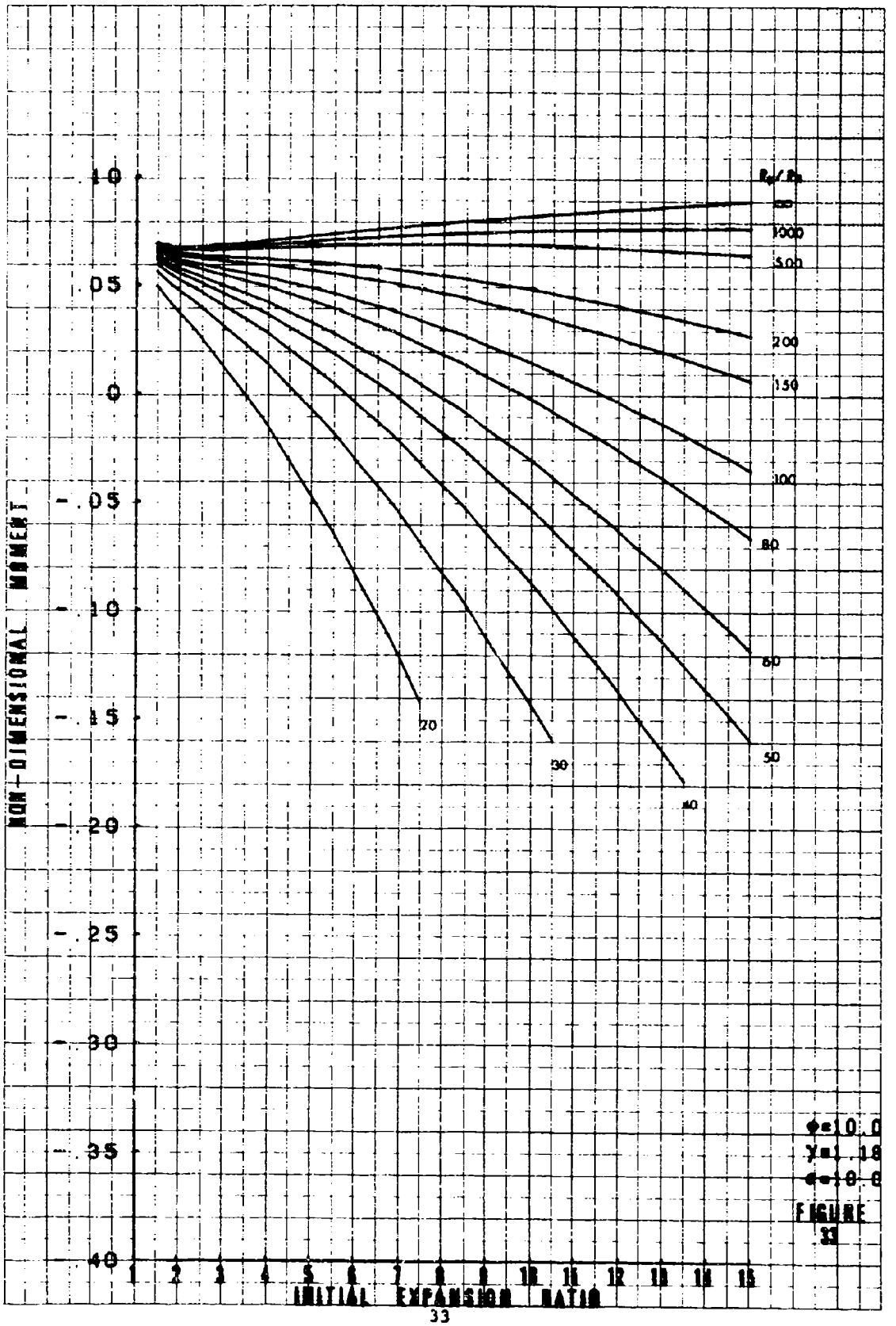

THRUST DEFLECTION ANGLE - DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
3000
500
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = 1.18
α = 10.0

FIGURE 32


.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
FIGURE 33

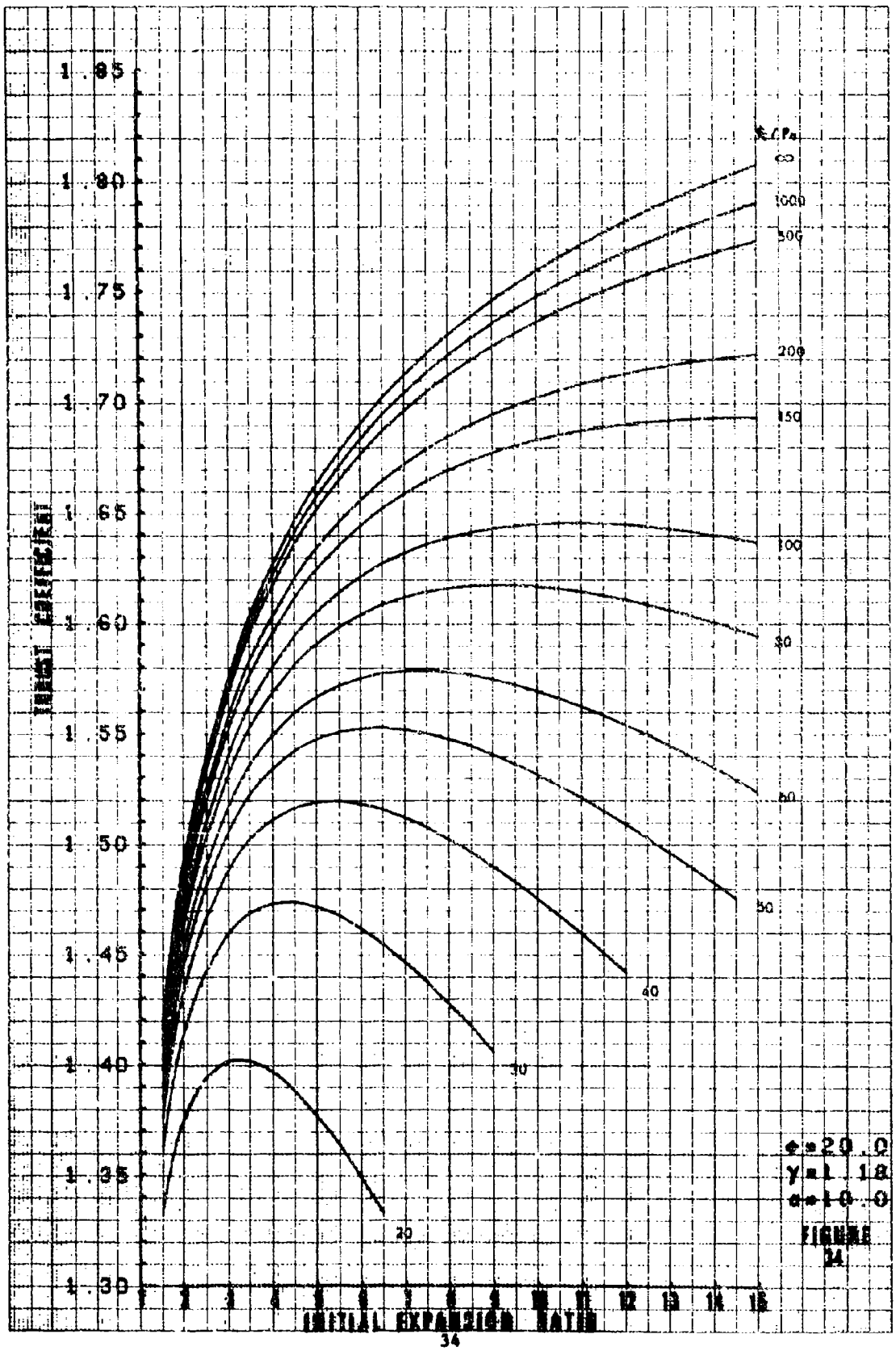

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.18
α=10.0

FIGURE 34

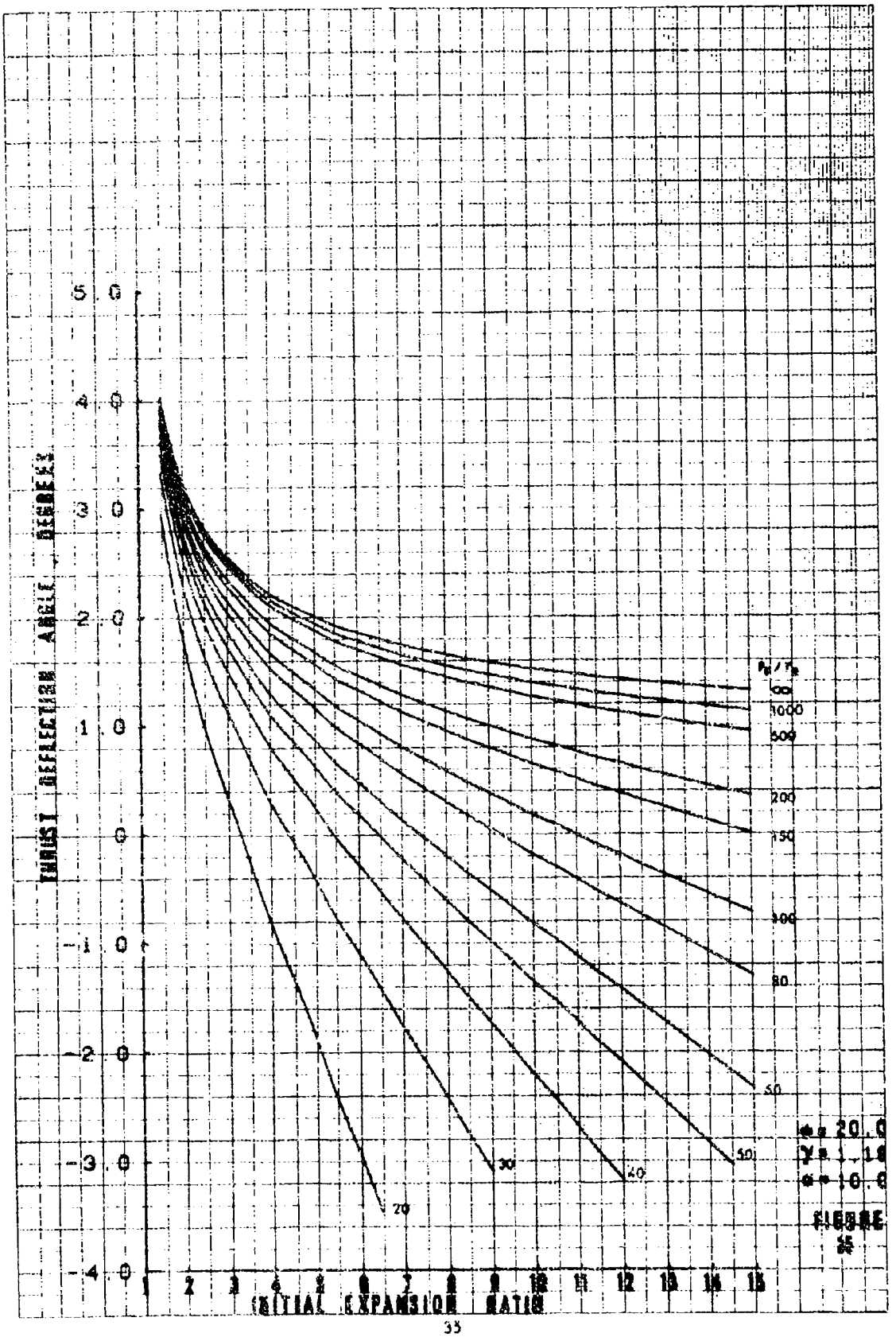
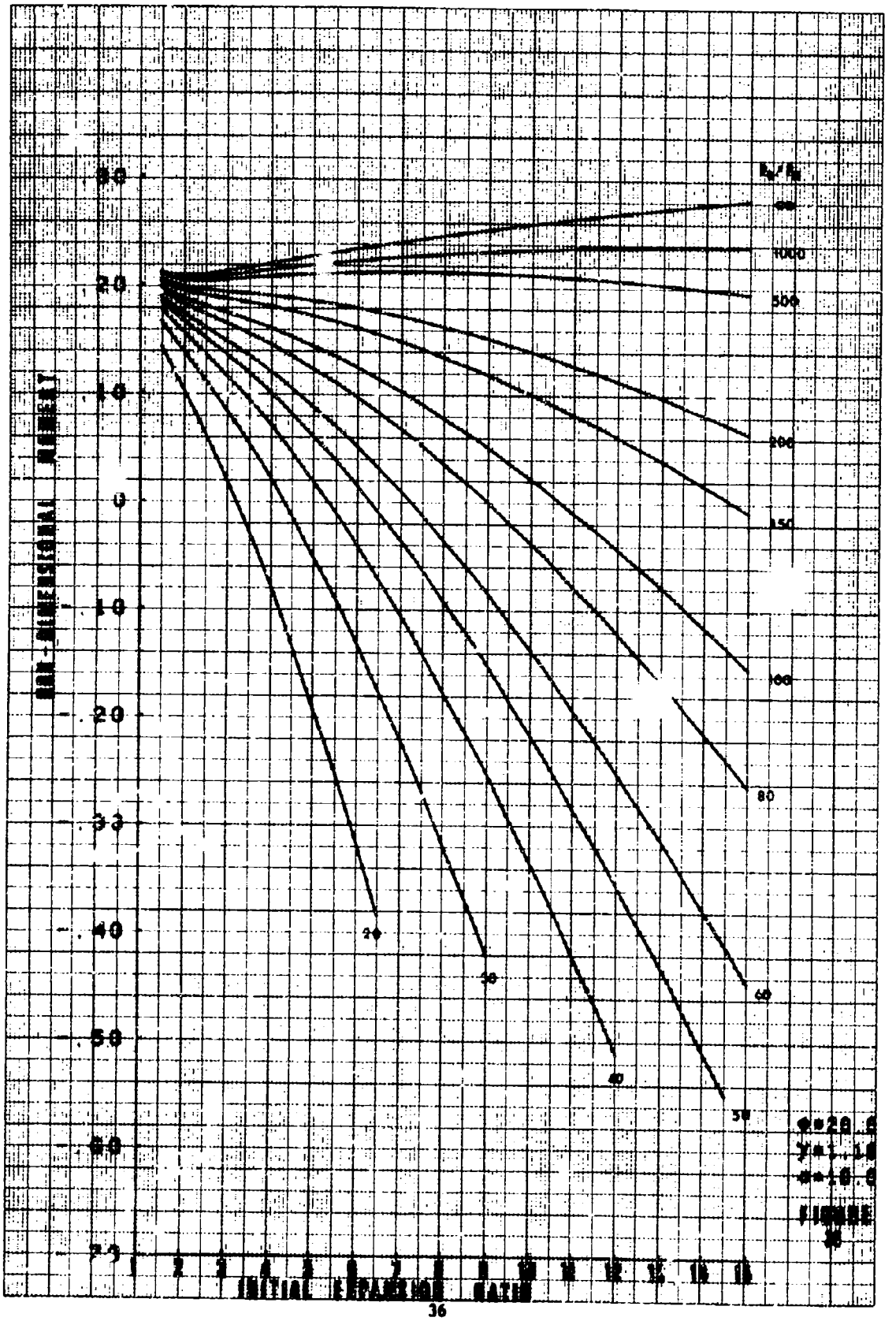
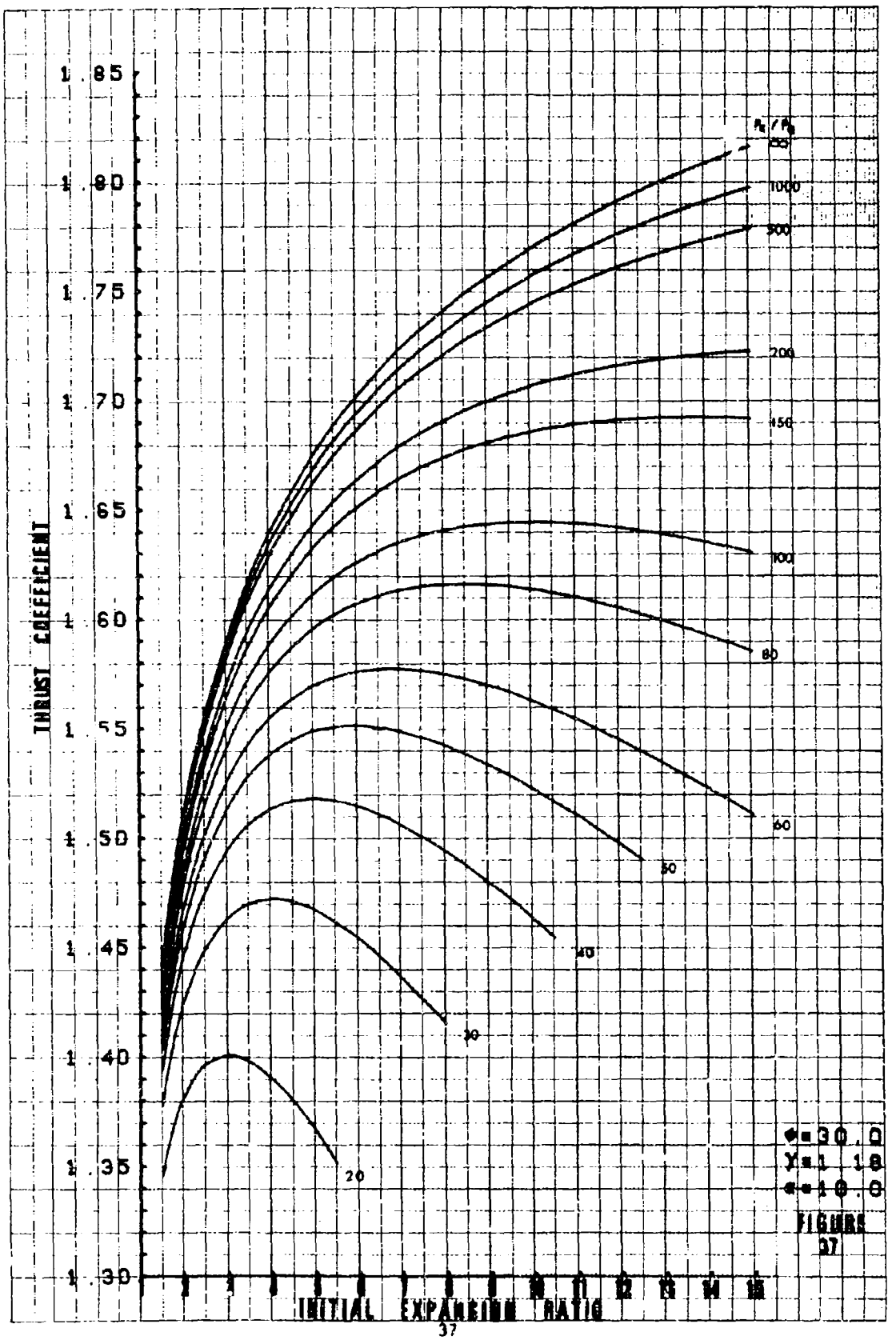

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.1
α = 10.0

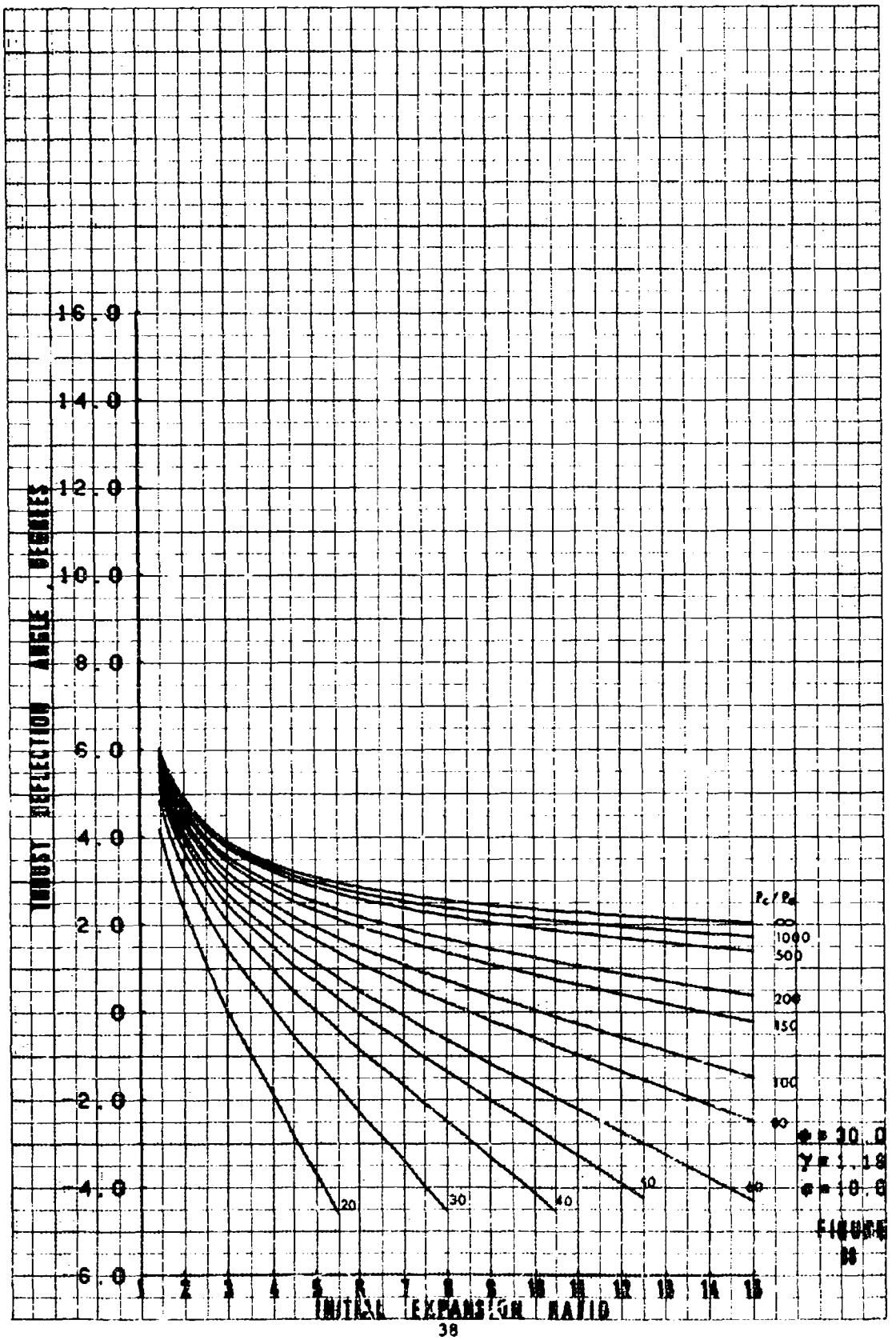
FIGURE 35



.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1000
500
200
150
100
80
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

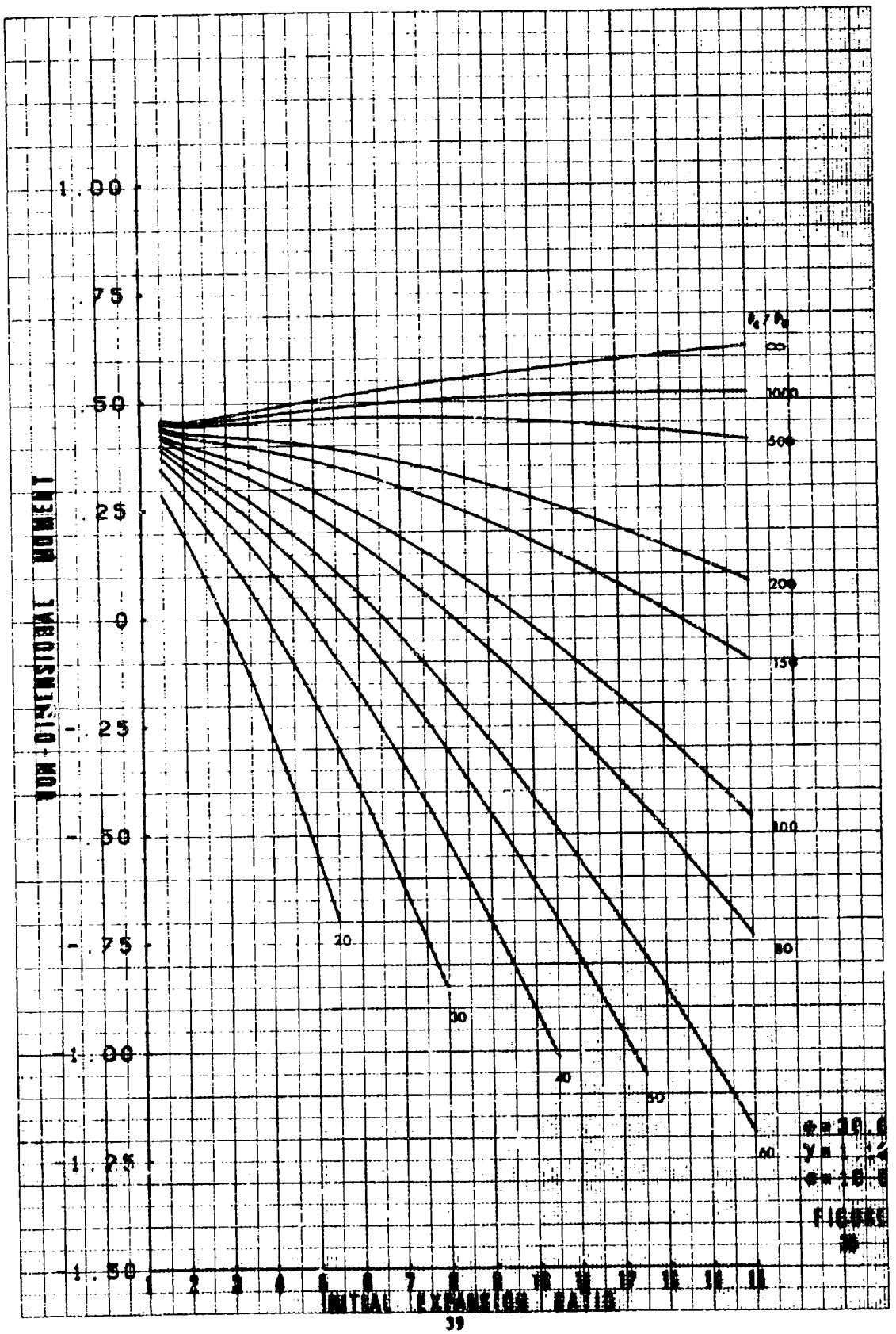
FIGURE 36


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
FIGURE
37



THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.18
φ = 10.0

FIGURE 38


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE

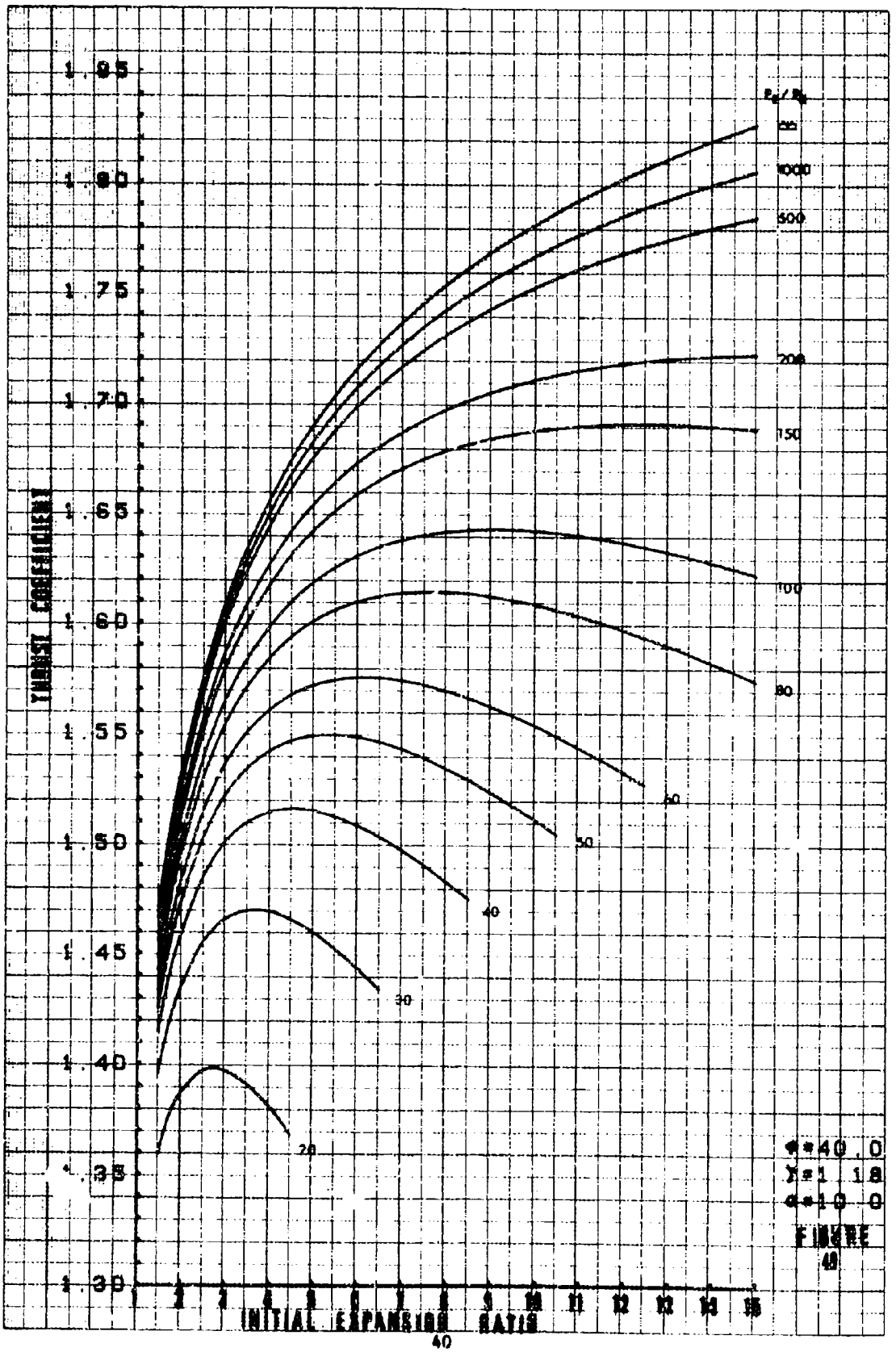

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
1000
500
200
150
100
80
60
50
40
30
20
φ=40.0
γ=1.18
α=10.0

FIGURE 49

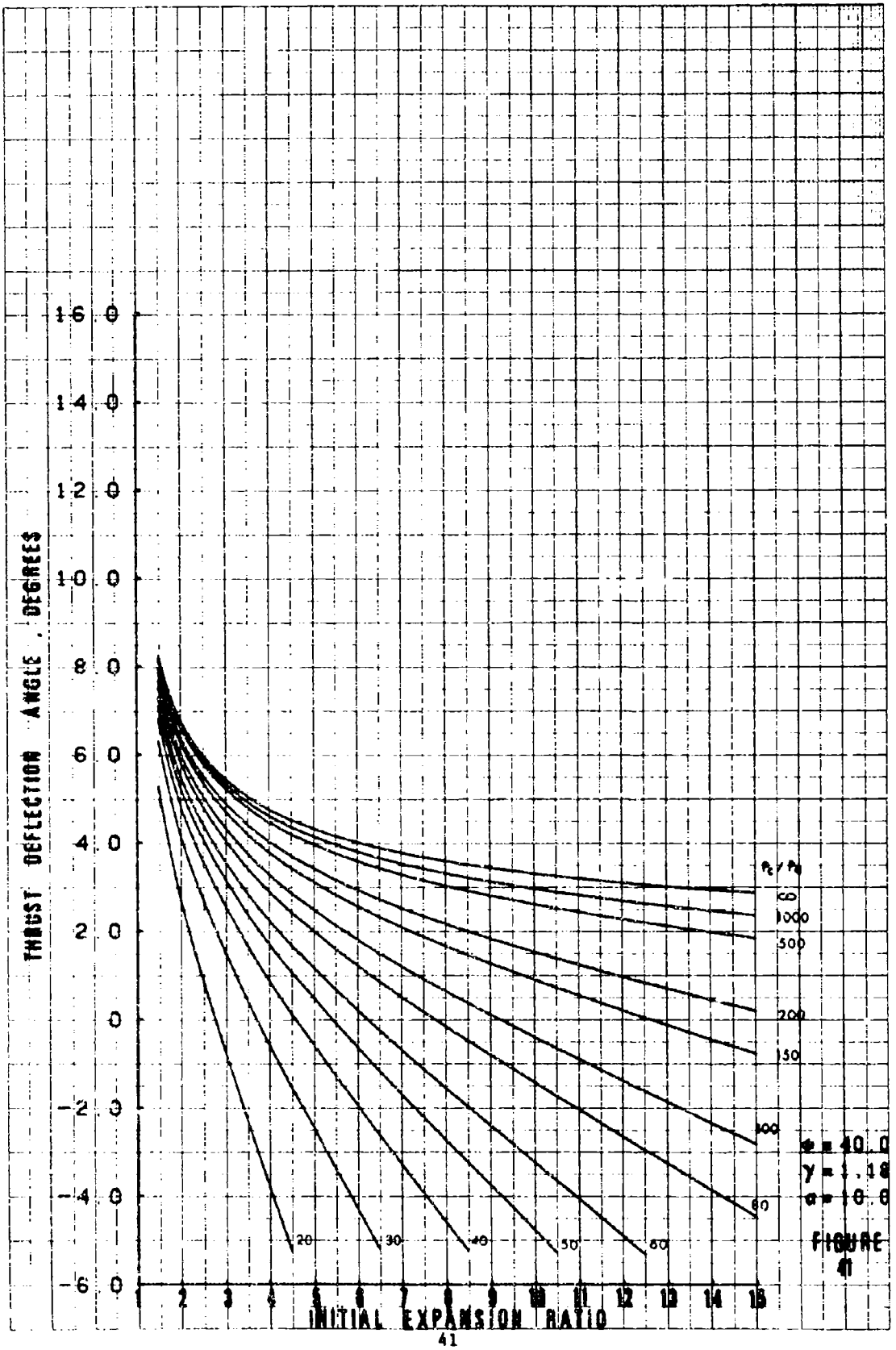
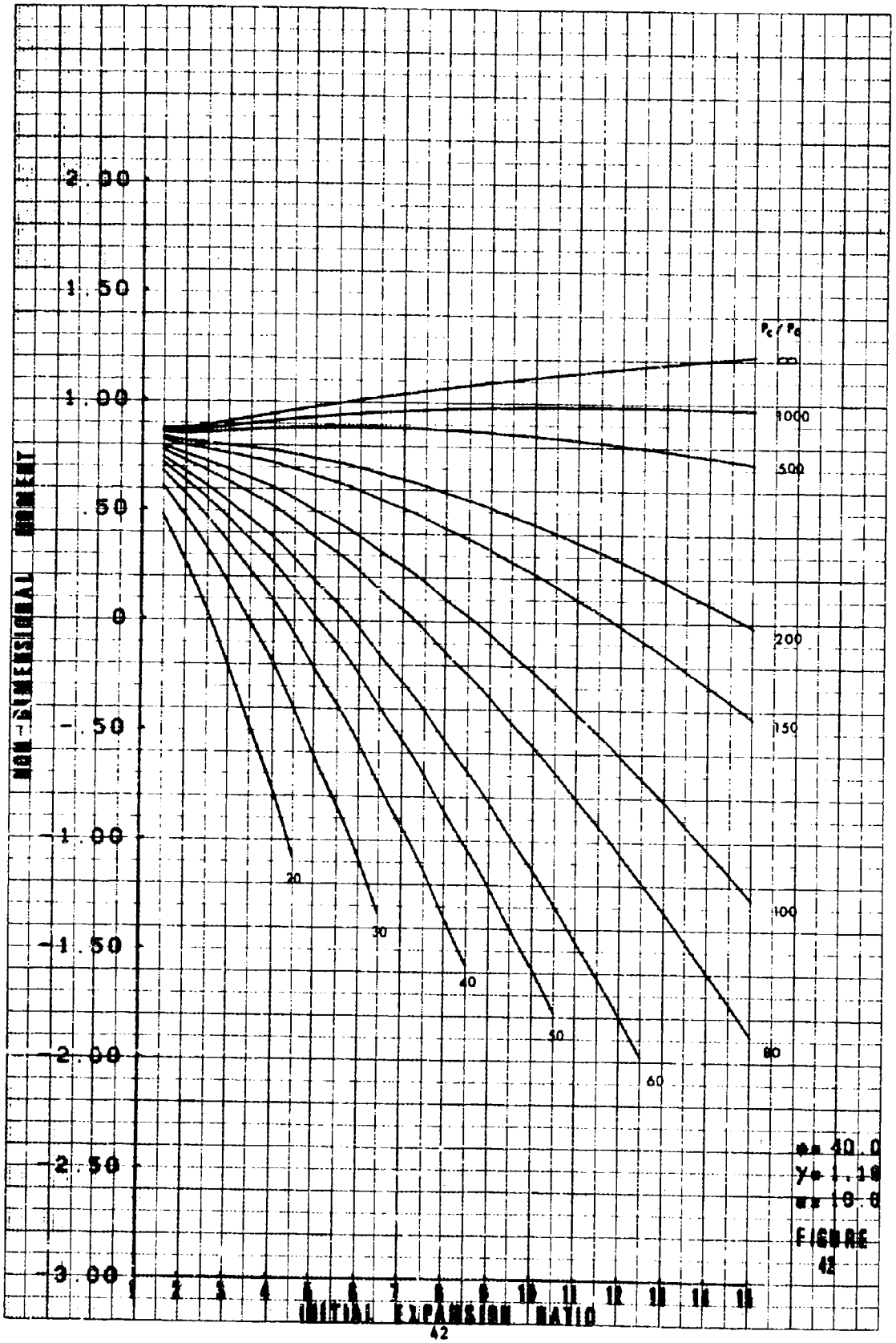

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
P_c/P_e
∞
1000
500
200
150
100
80
ϕ = 40.0
γ = 1.18
α = 10.0

FIGURE 41


NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c / P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE
42

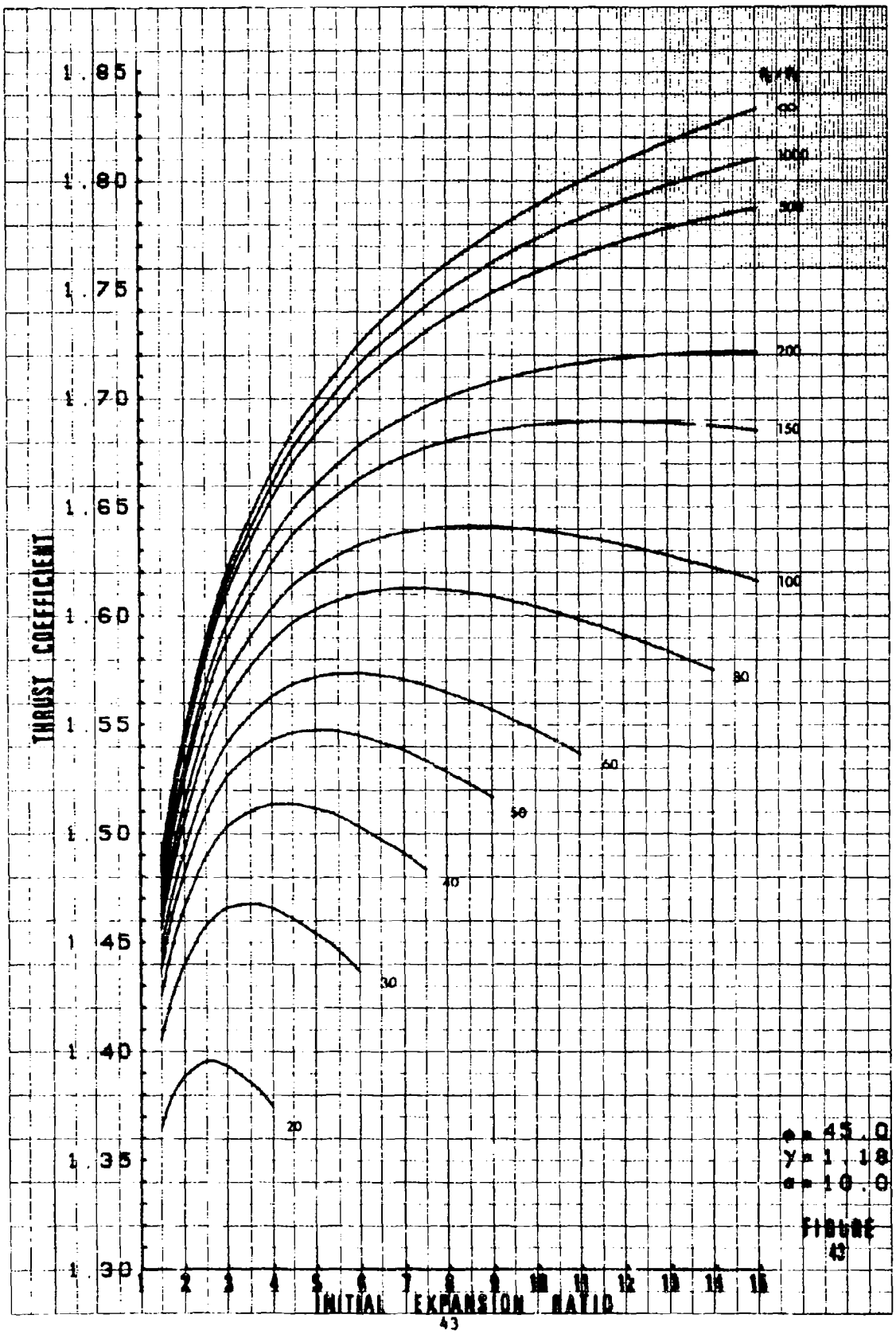

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.18
α = 10.0

Figure 43

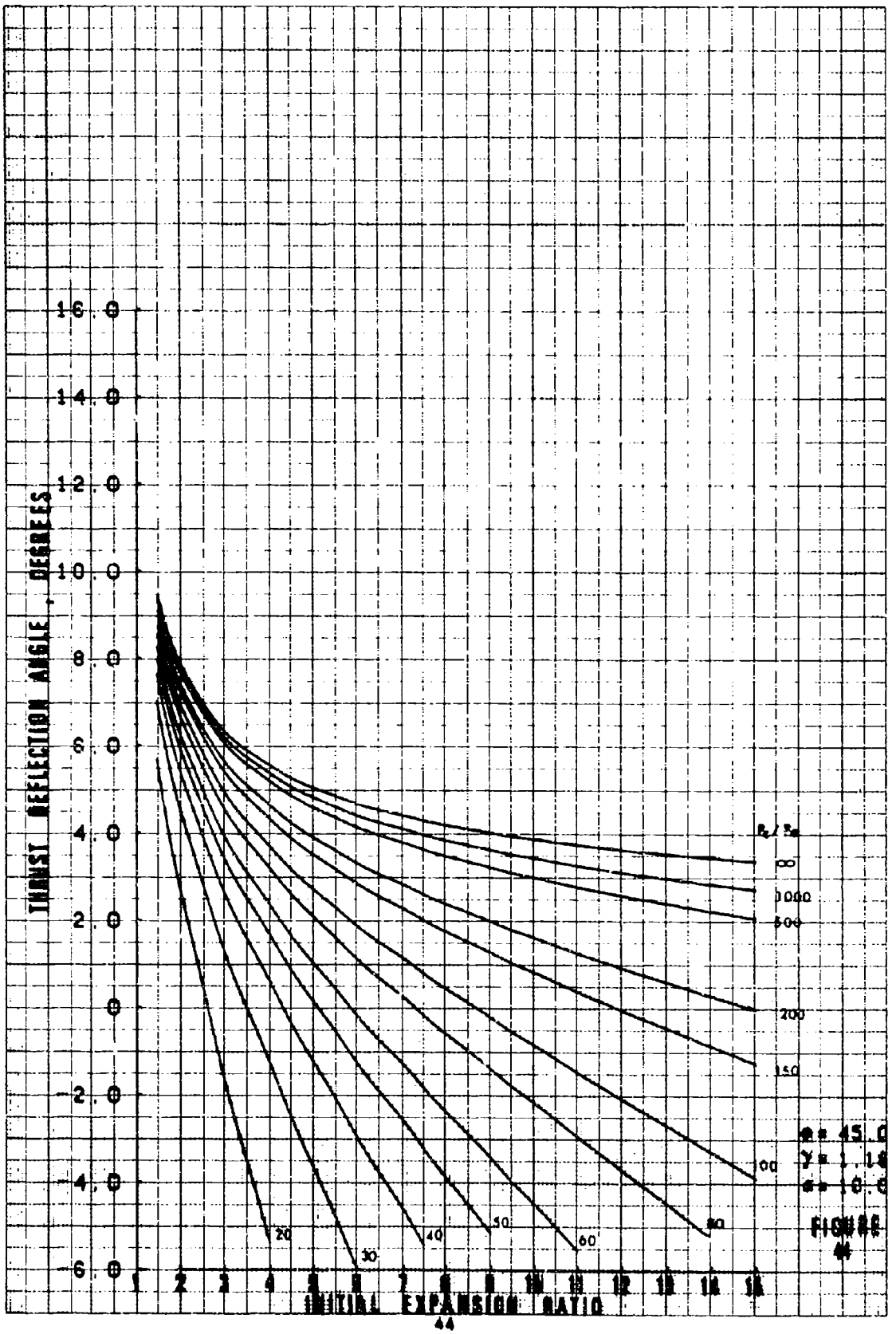
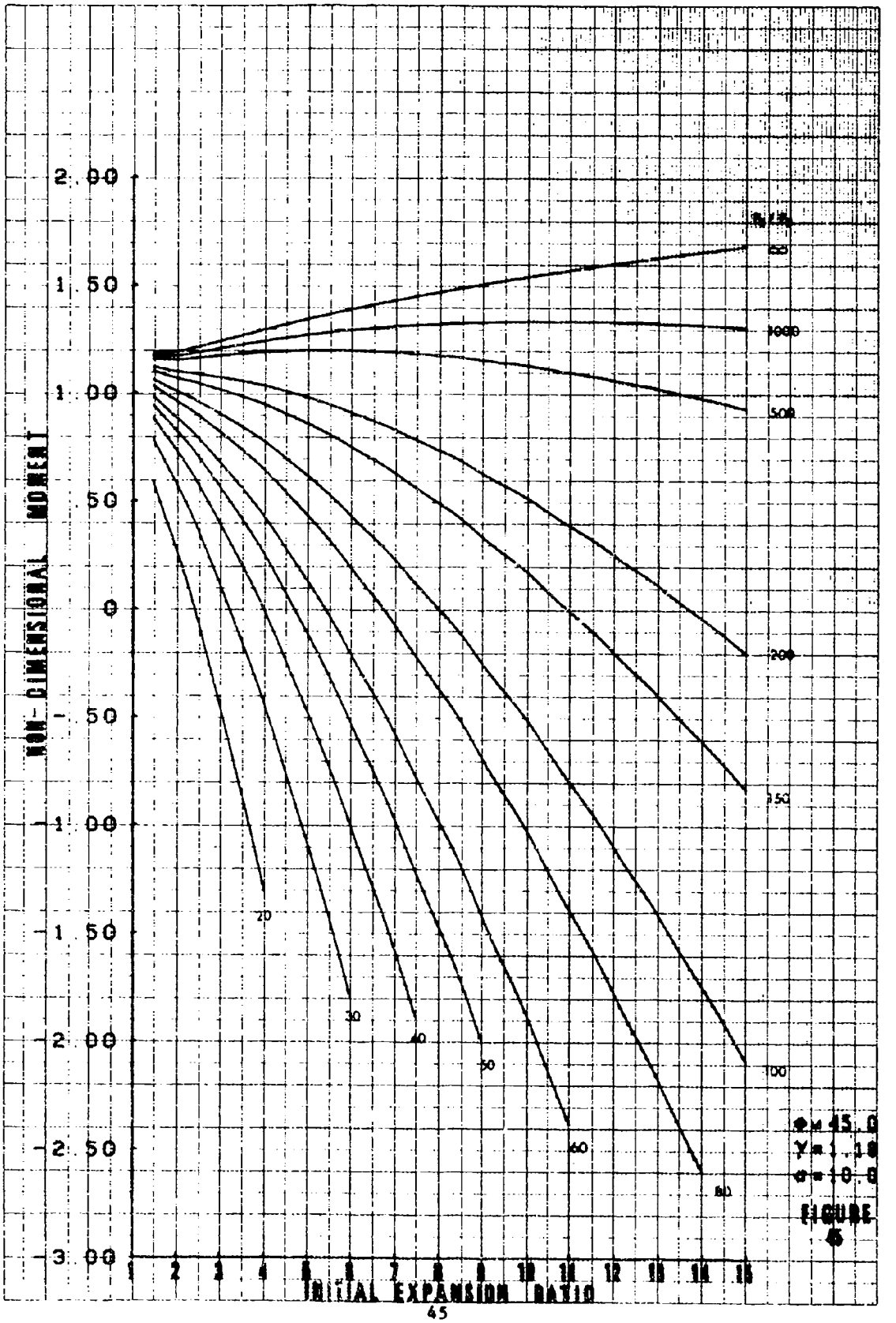
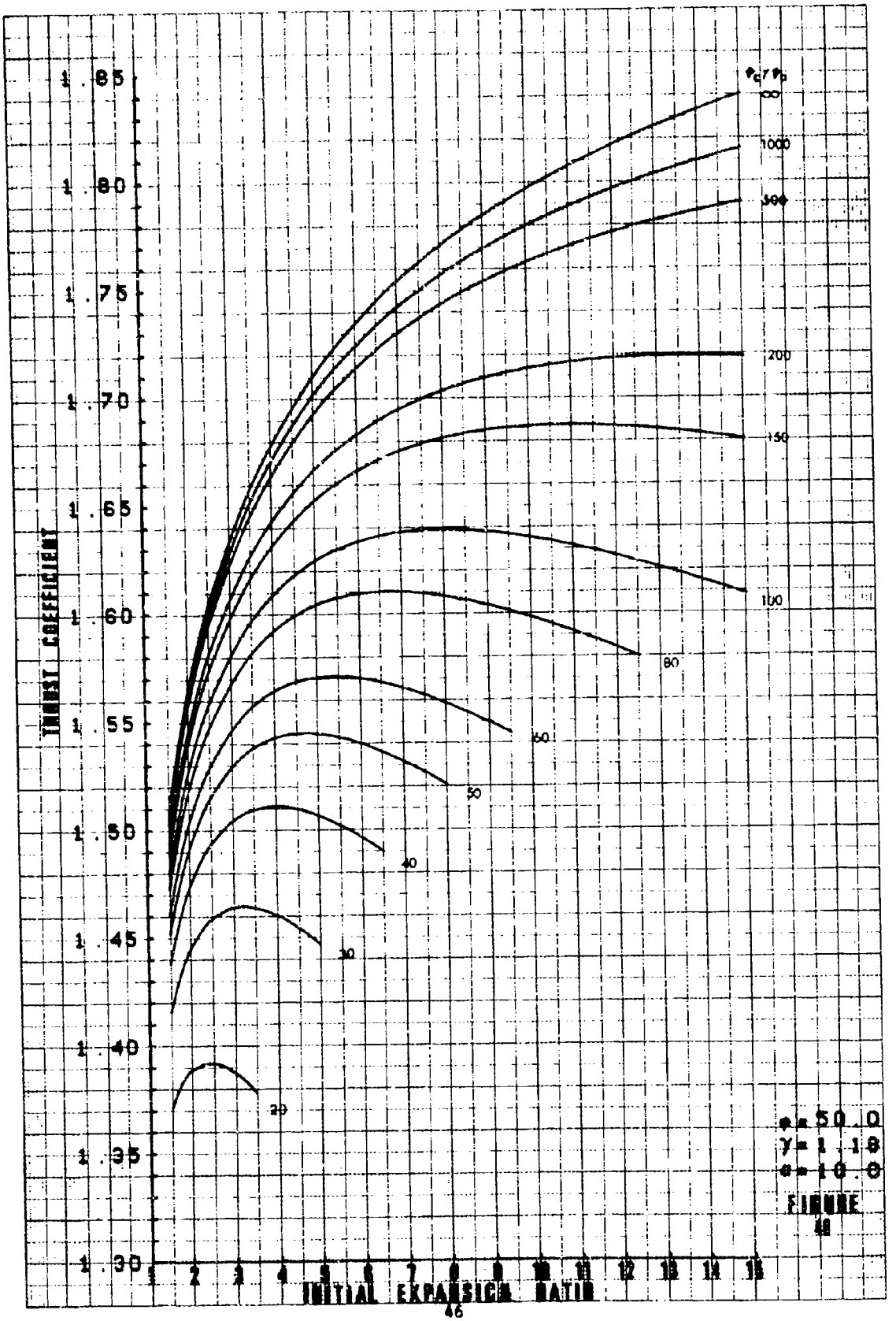

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞

FIGURE 44



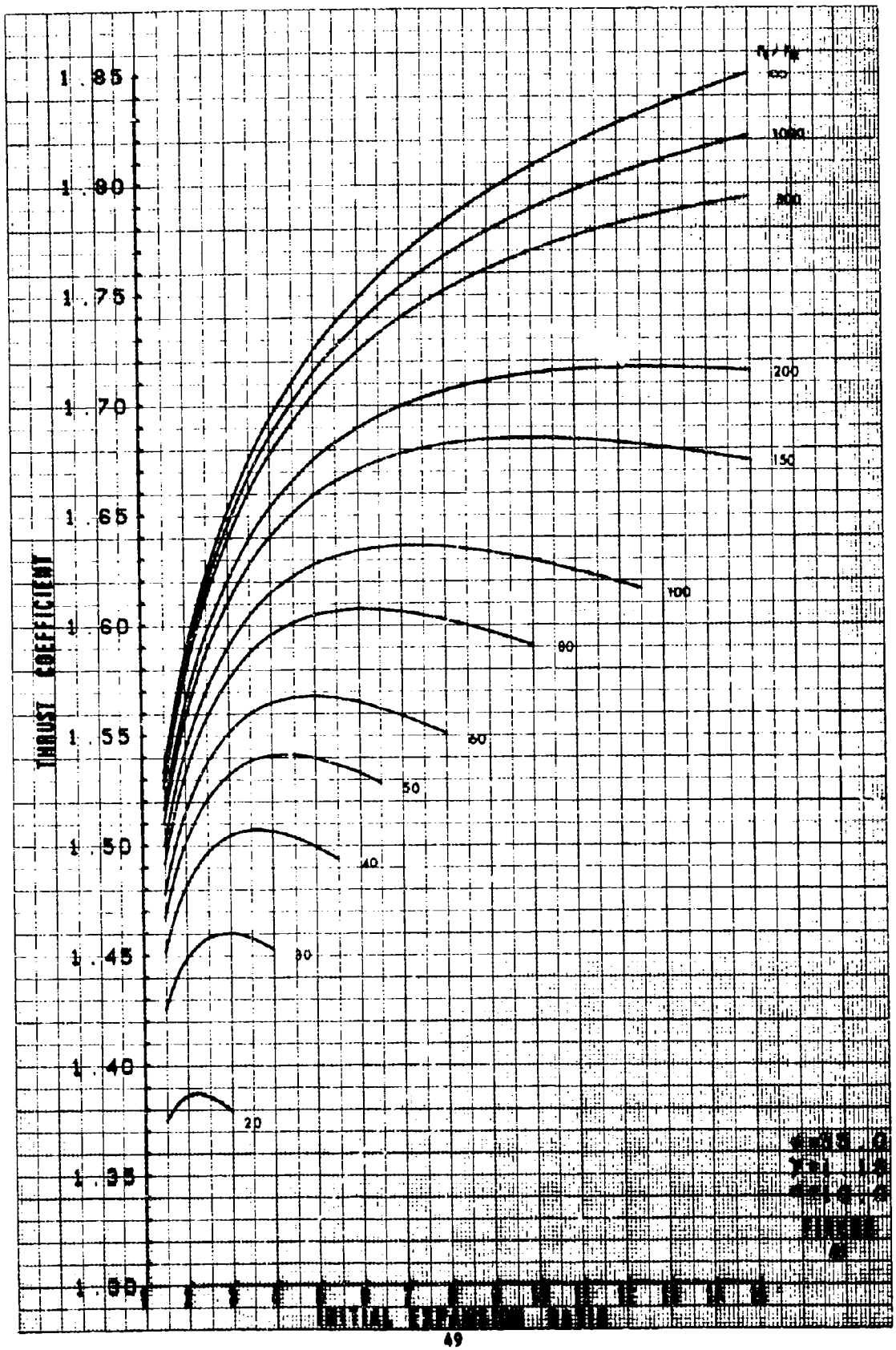
NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 45



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
ϕ_c/ϕ_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.18
α = 10.0

FIGURE 48


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
800
200
150
100
80
60
50
40
30
20

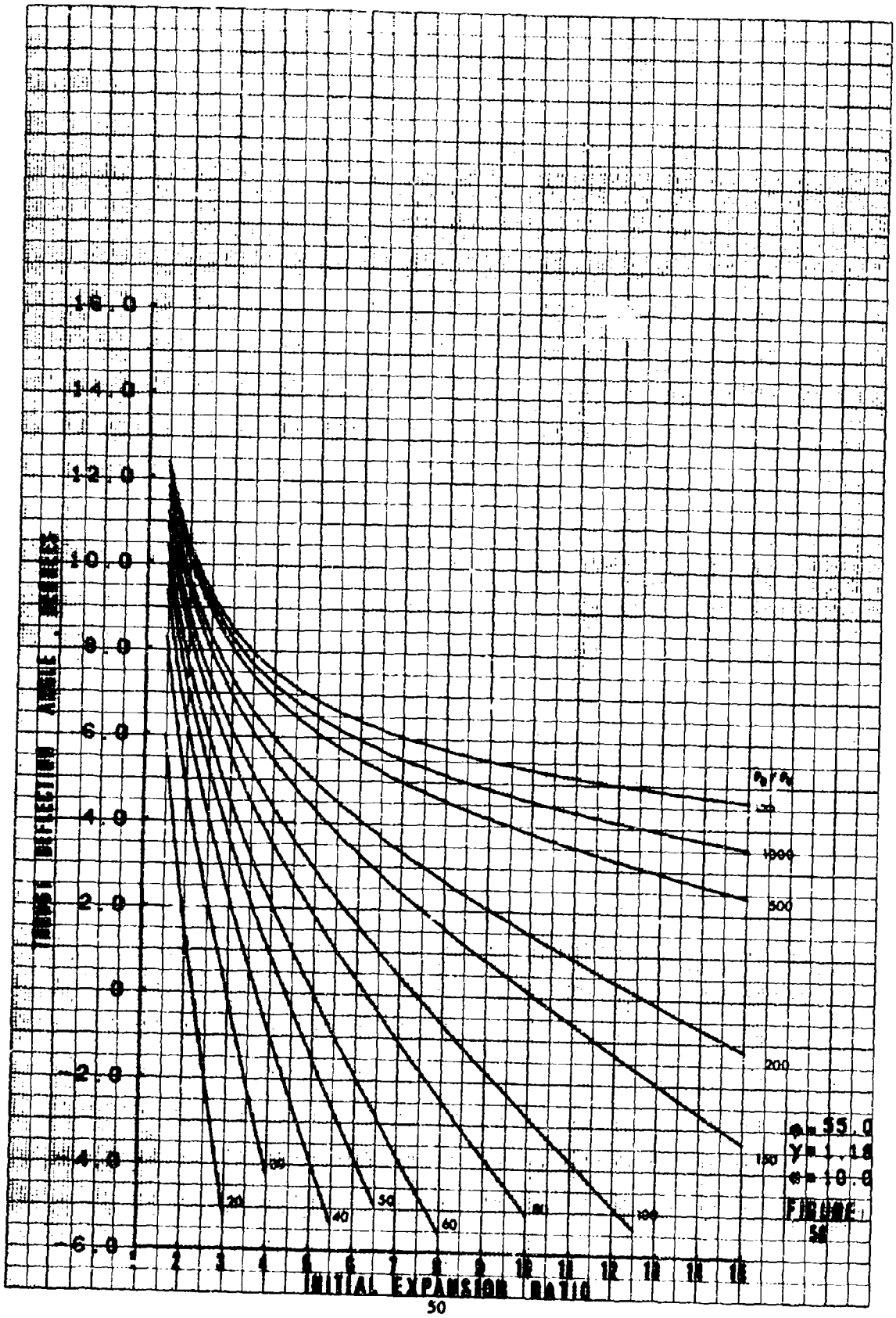

16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
20
φ = 55.0
γ = 1.18
α = 10.0

FIGURE 58

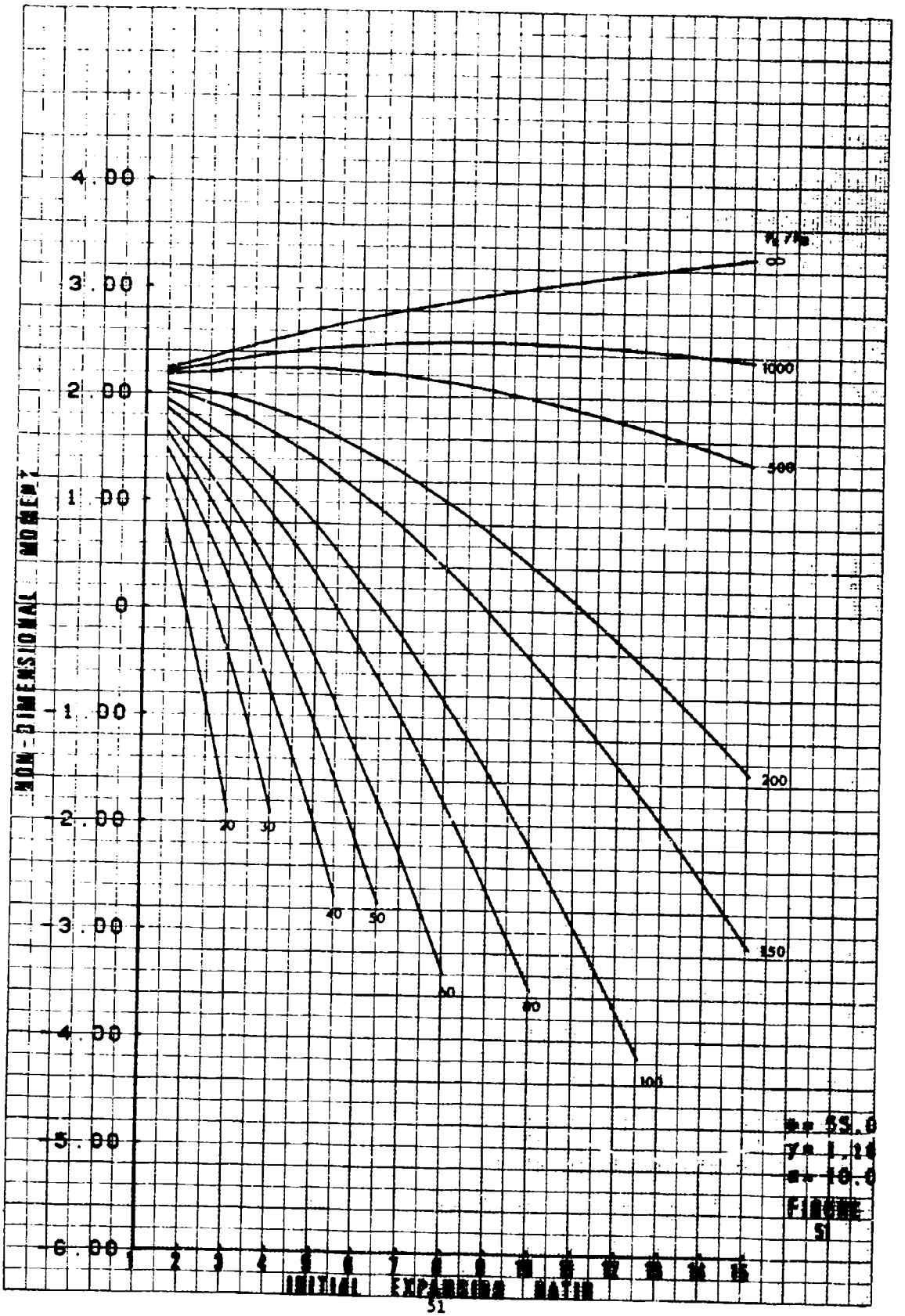

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 51

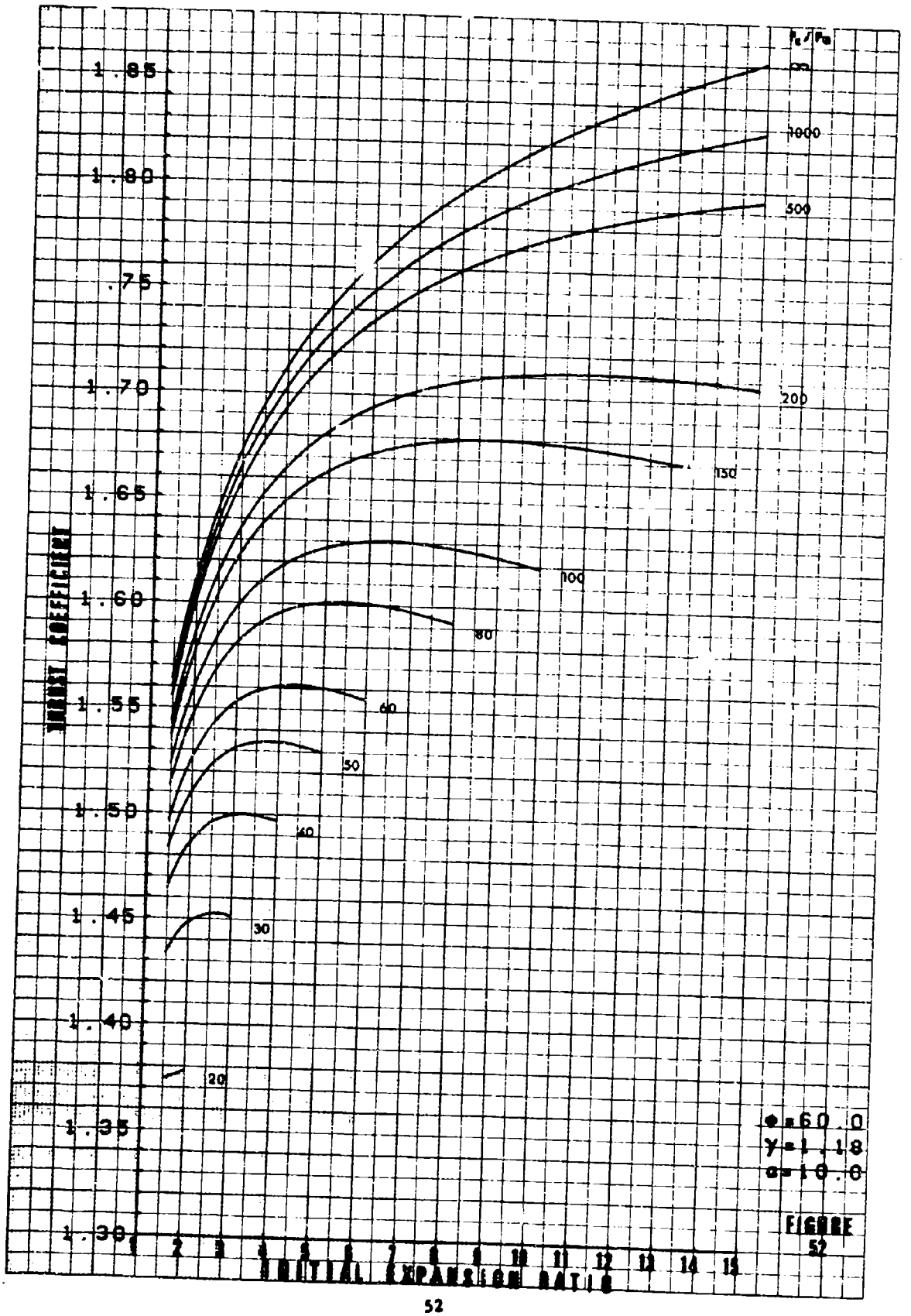
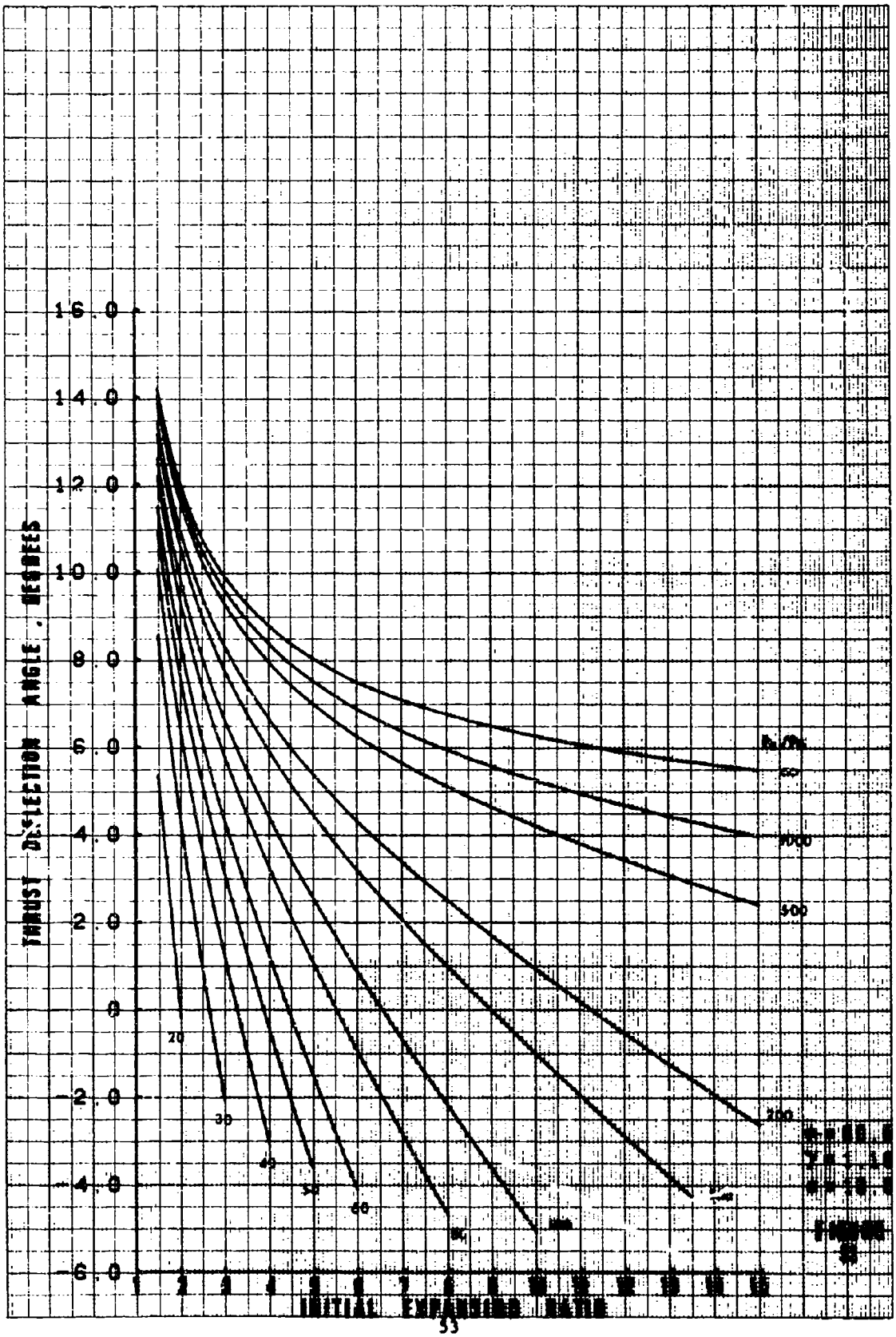
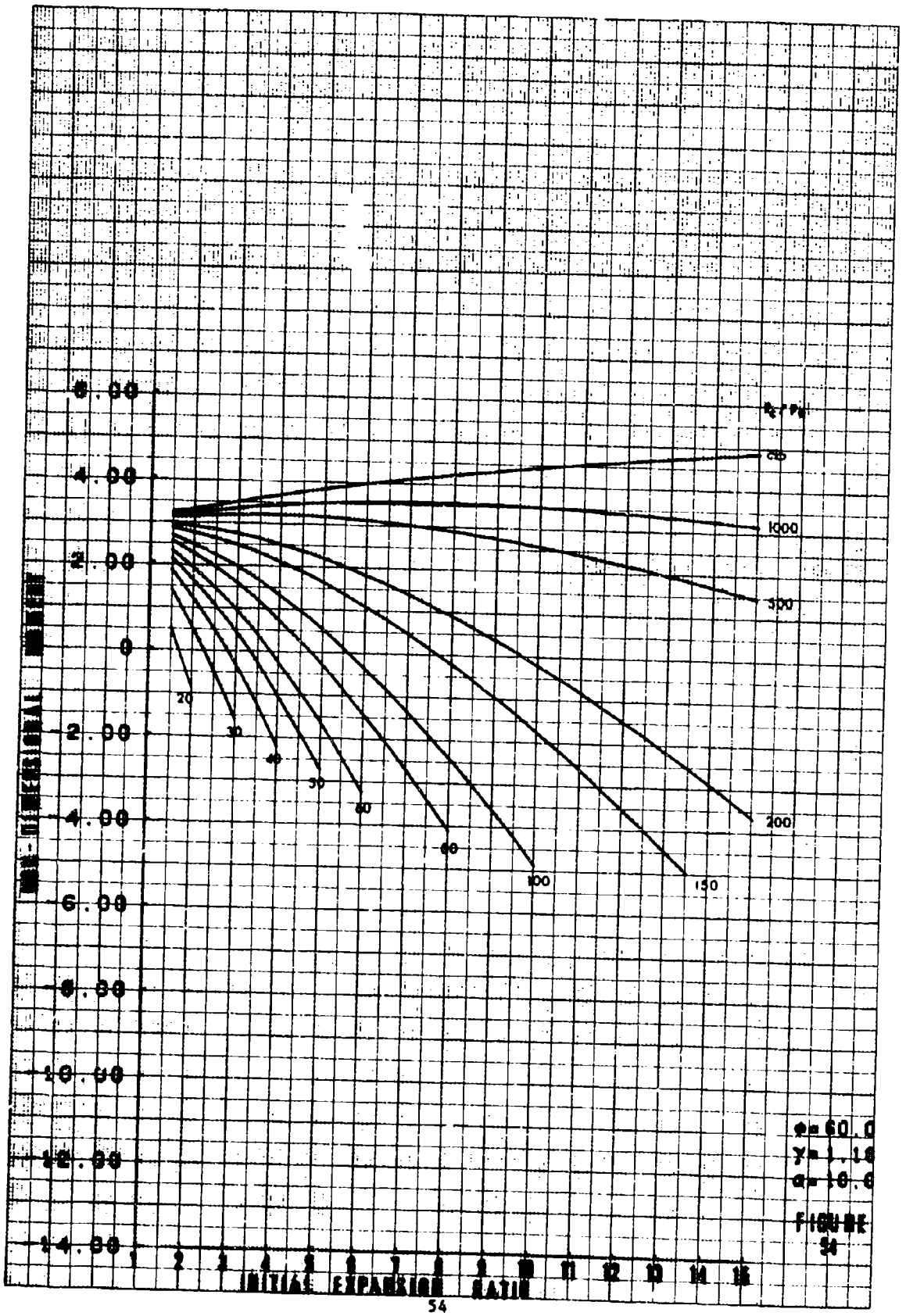

1.85
1.80
.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=60.0
γ=1.18
α=10.0

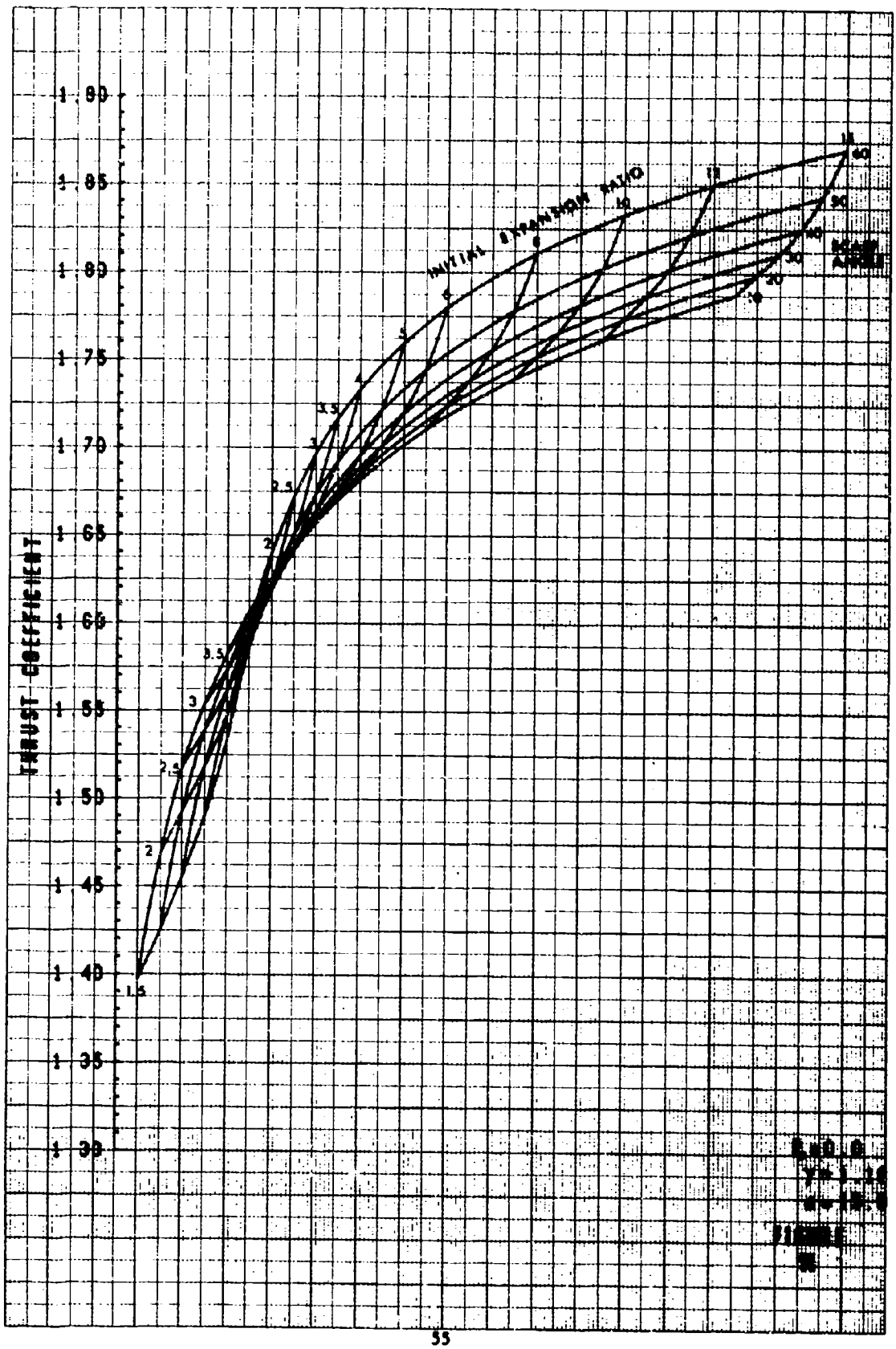
FIGURE 52


THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
20
30
40
50
60
80
100
200
500
1000
INITIAL EXPANSION RATIO



6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=60.0
γ=1.16
α=10.0

FIGURE 54


THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1.5
2
2.5
3
3.5
4
5
6
10
12
15
20
30
40
50
60

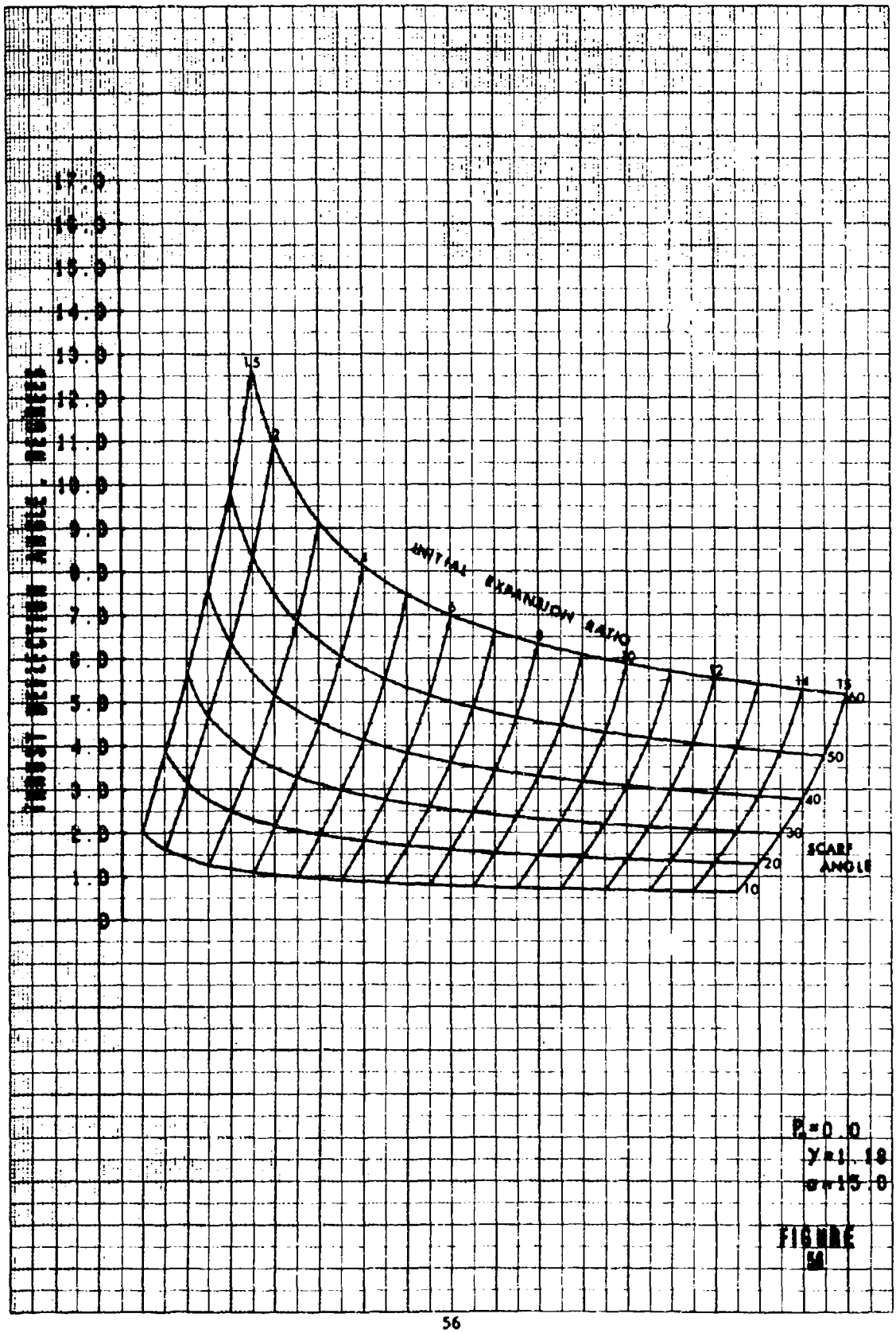

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
15
2
4
6
8
10
12
14
15
60
50
40
30
20
10
SCARF ANGLE
P=0.0
γ=1.18
σ=15.0

FIGURE 56

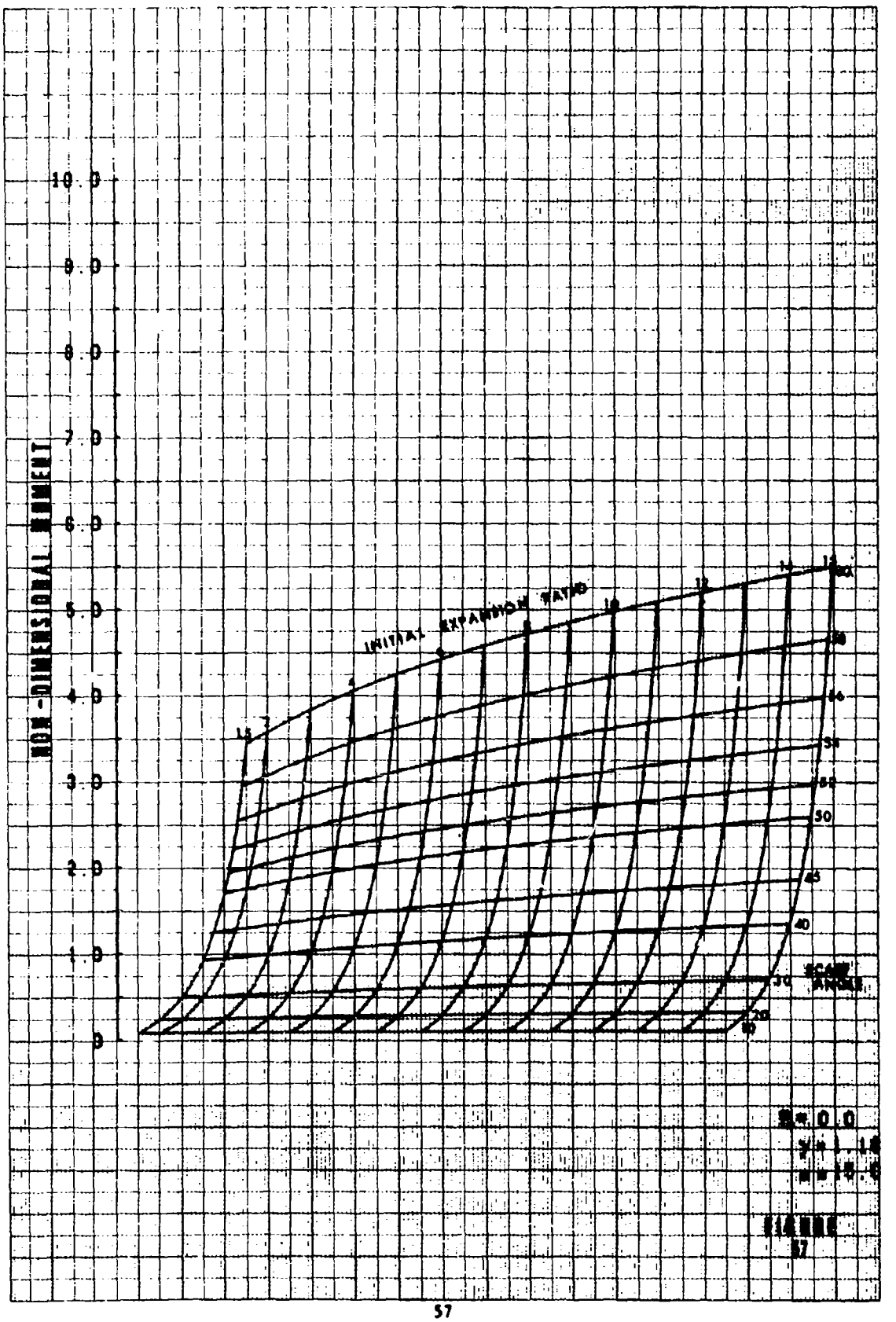

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCALE ANGLE
50
40
30
20
10
R = 0.0

FIGURE 57

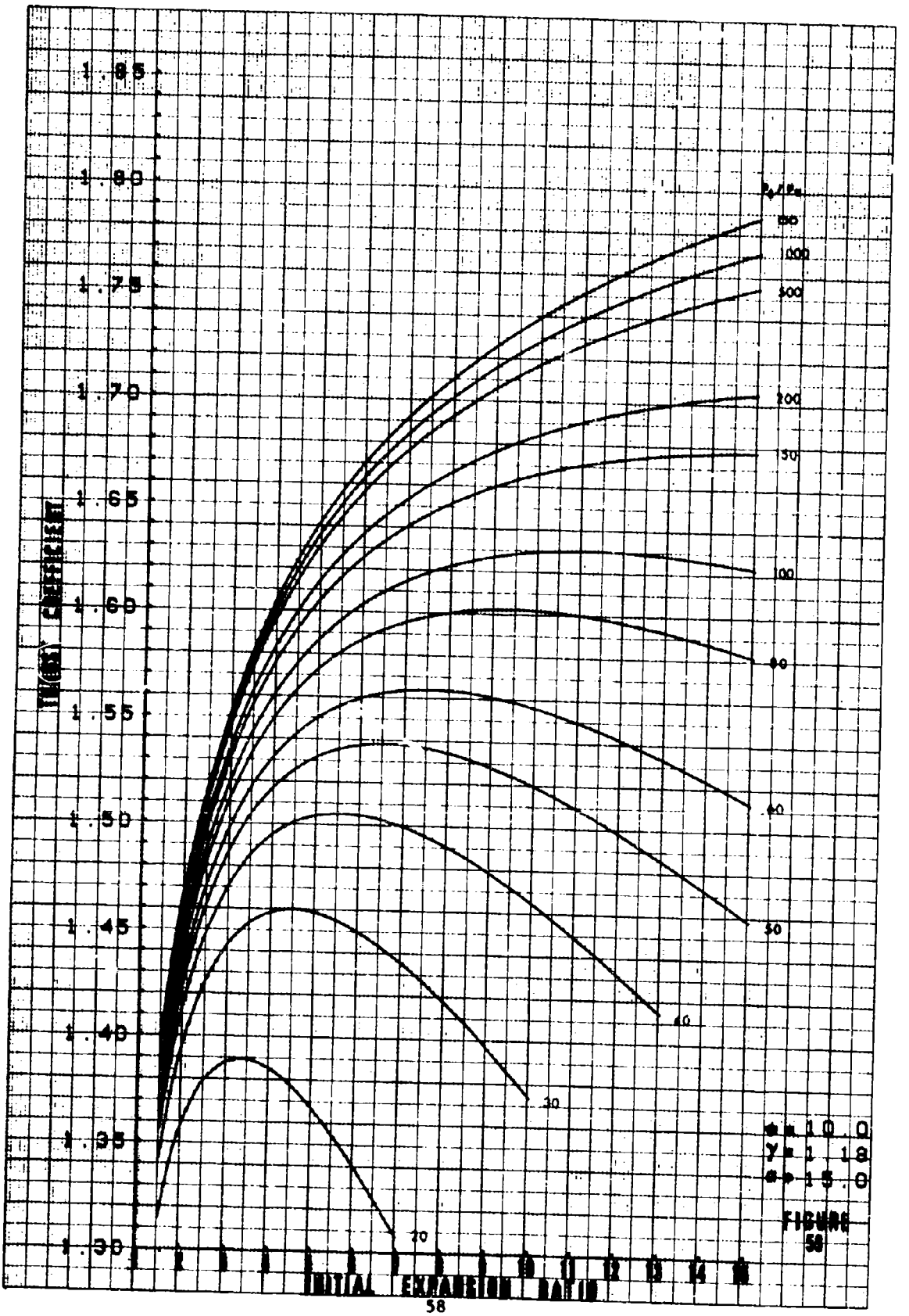
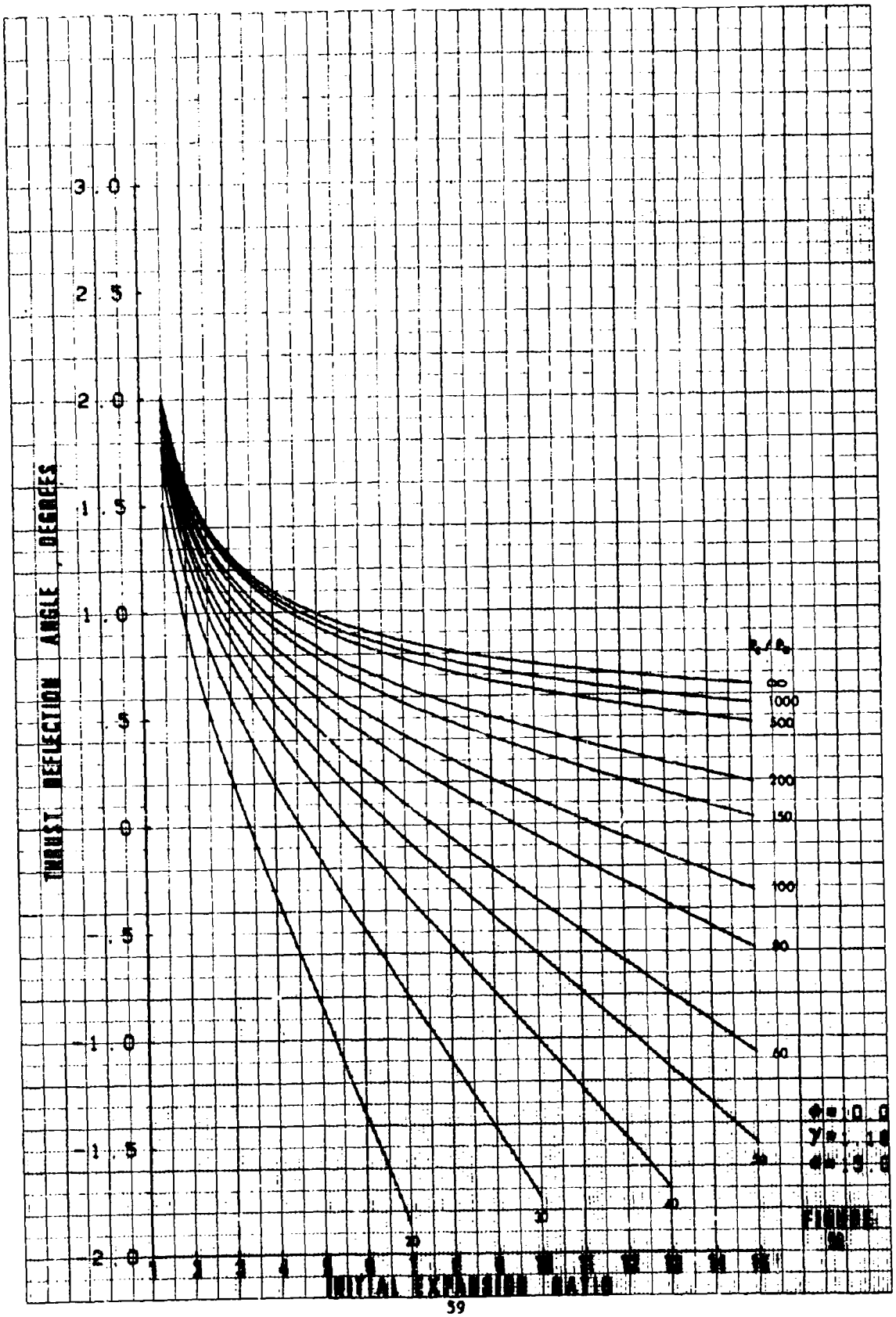

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
TH(RS) COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
10.0
1.18
15.0

FIGURE 58


THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
40
30
20

FIGURE

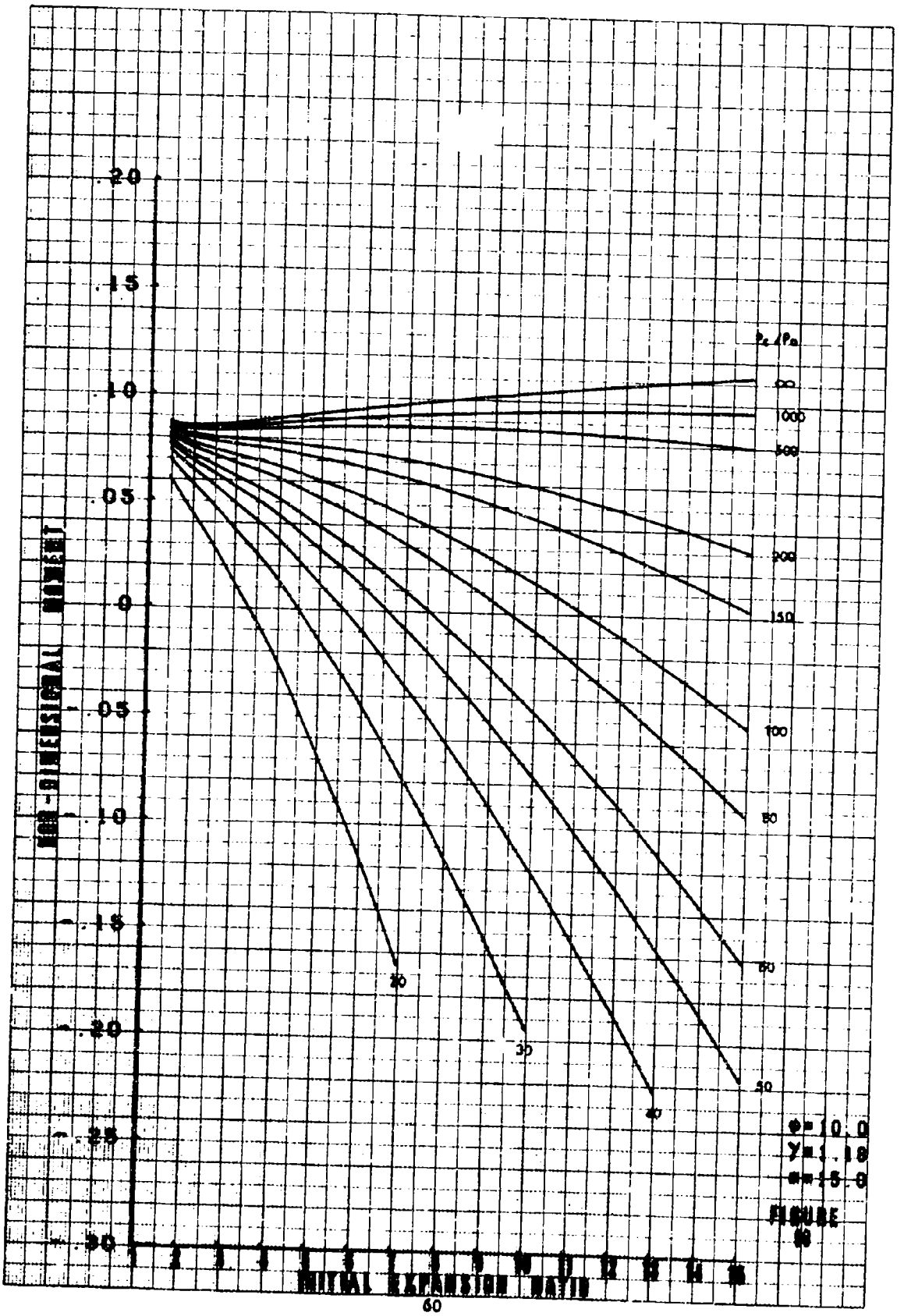
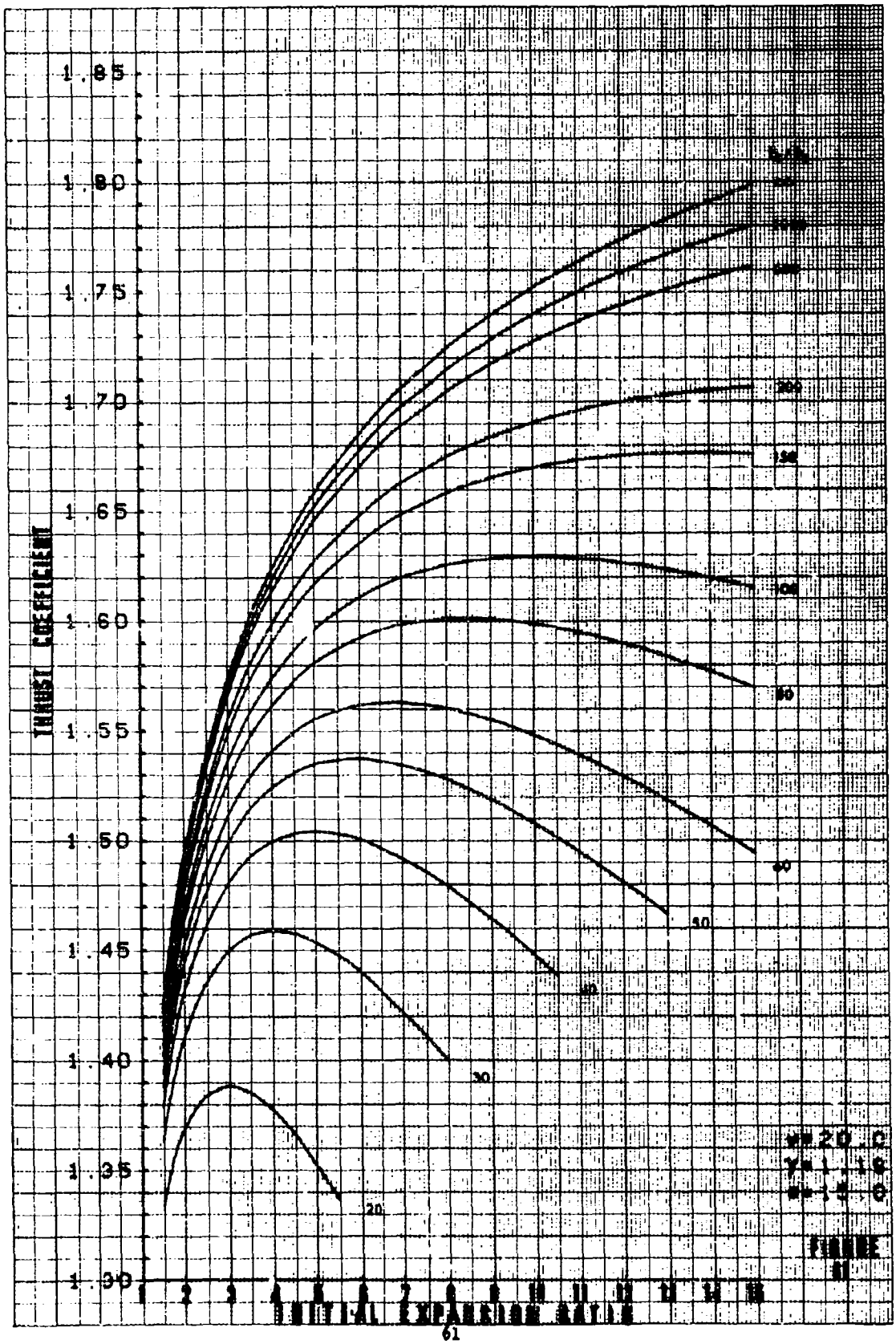

.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.18
α = 15.0

FIGURE 46


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
200
150
100
80
60
50
40
30
20
FIGURE
61

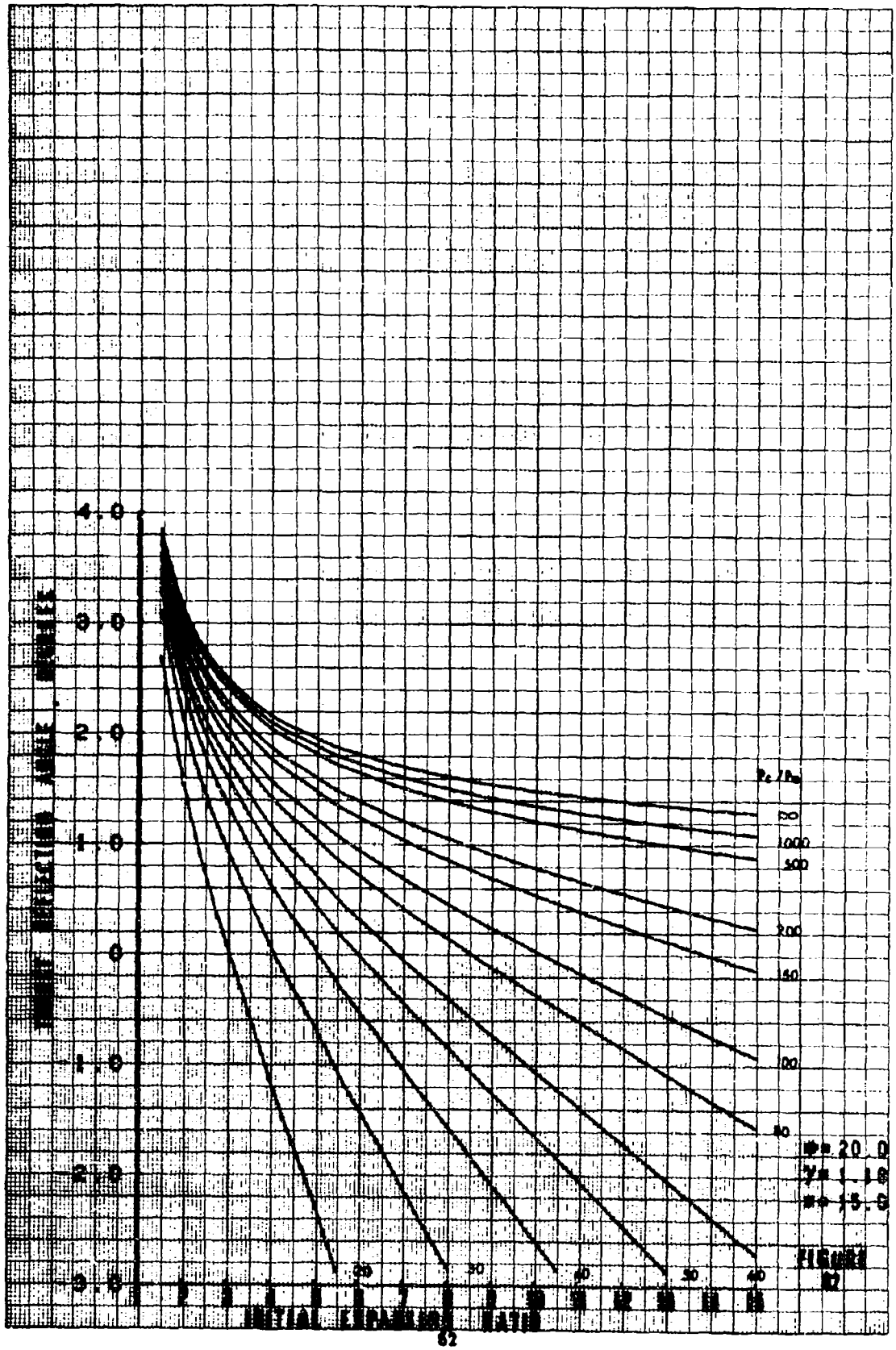
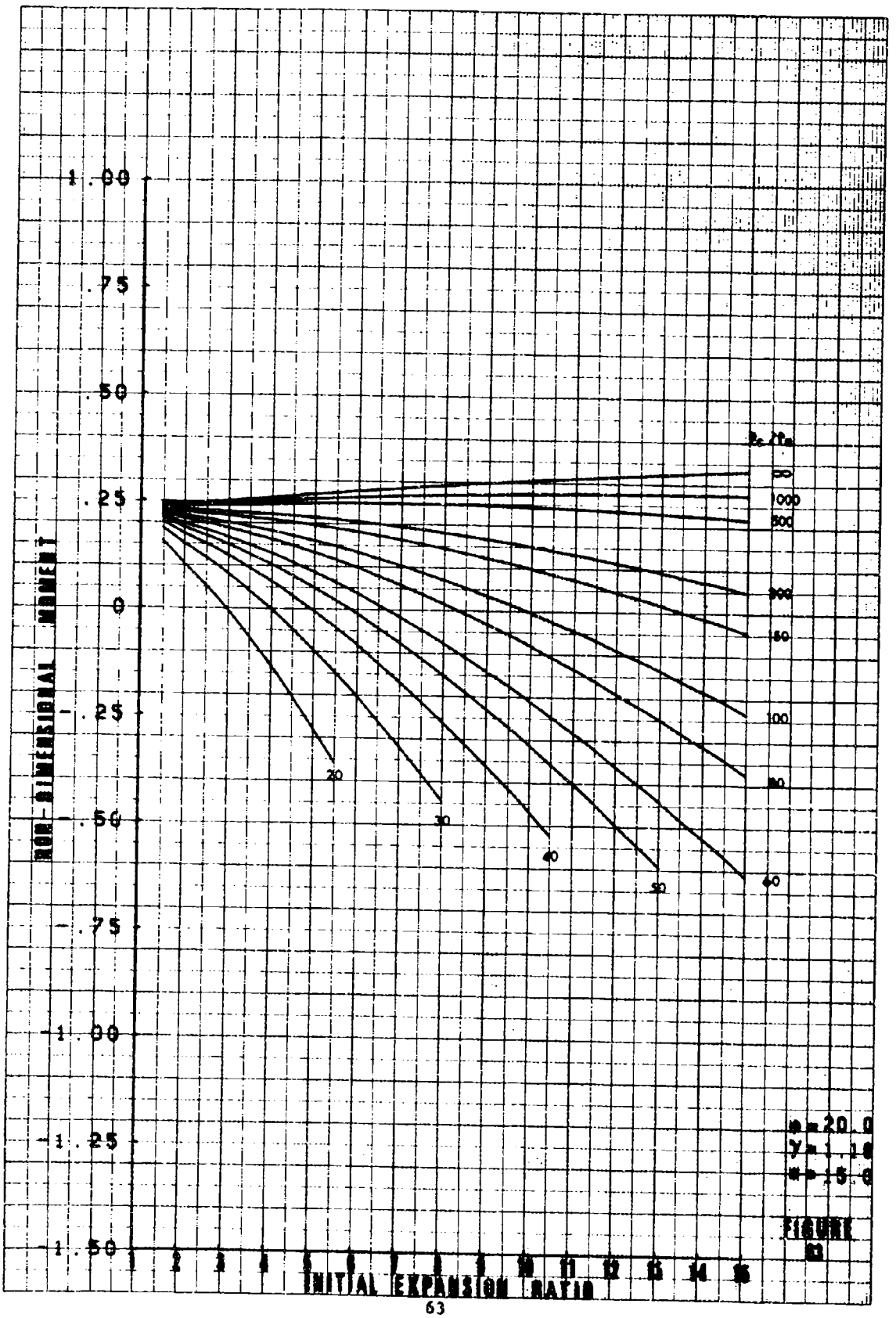
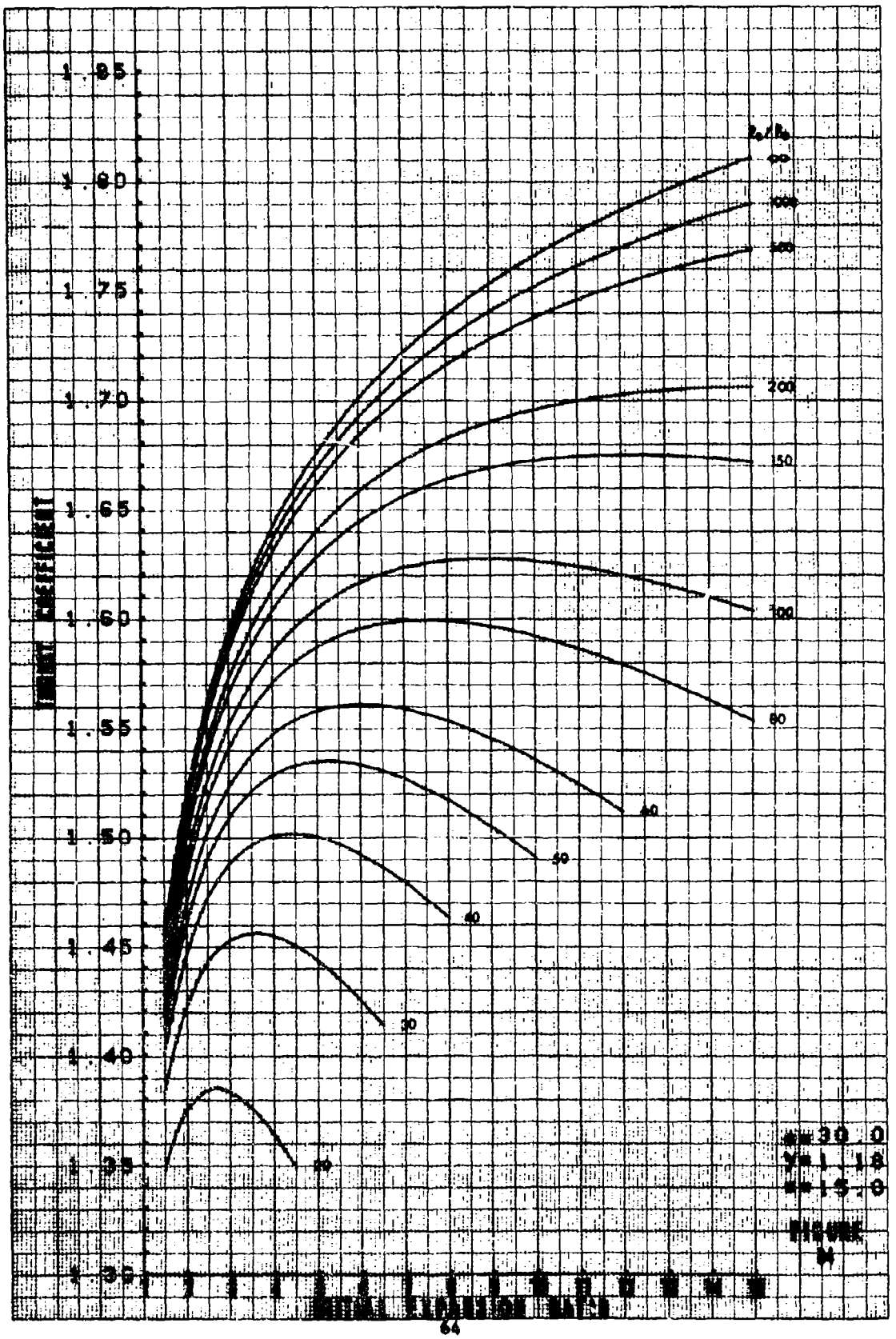

4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
20
30
40
50
60
INITIAL EXPANSION RATIO
P_c/P_m
∞
1000
500
200
150
100
50
φ = 20.0
γ = 1.18
ε = 15.0

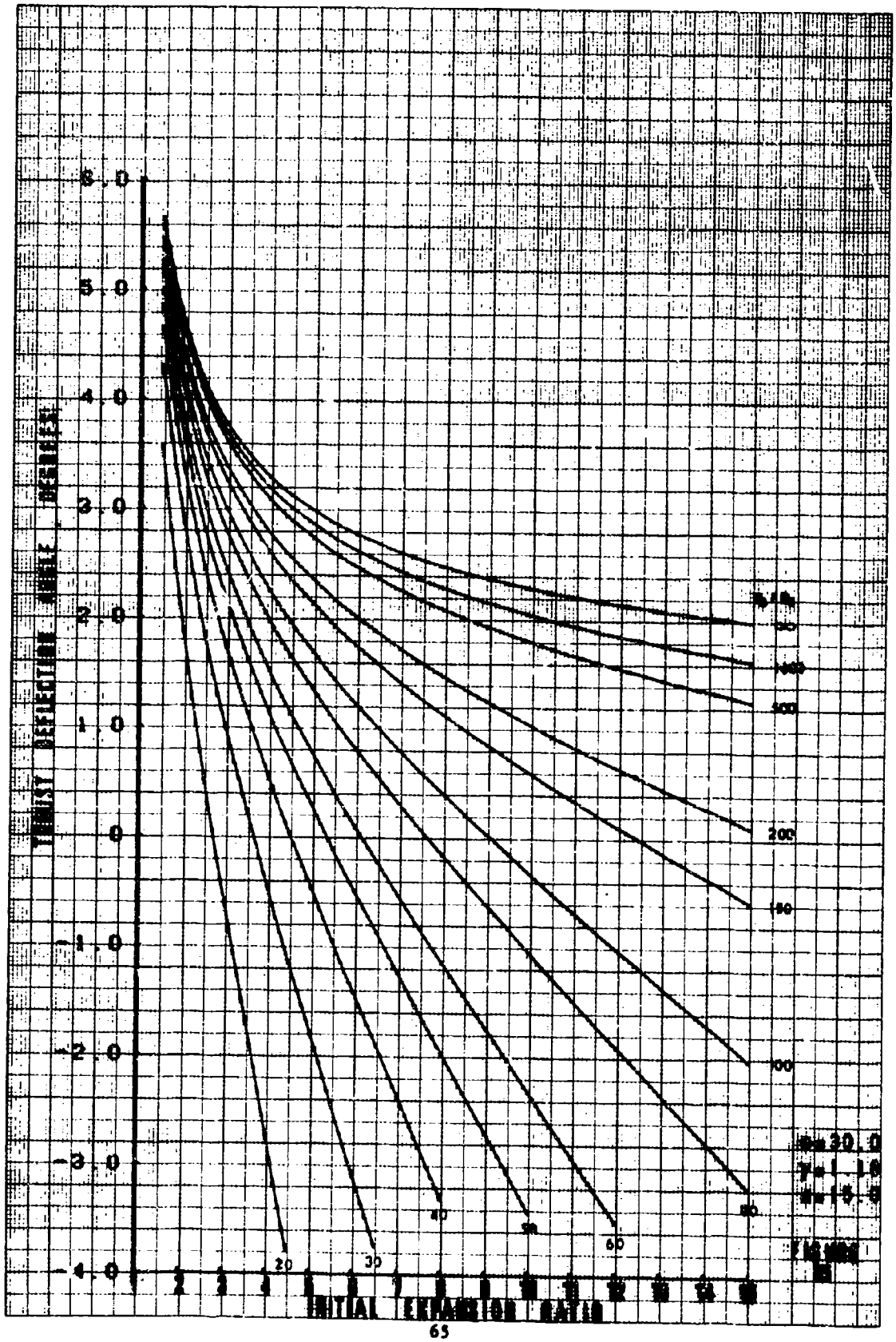
FIGURE 87



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
100
150
200
500
1000
∞

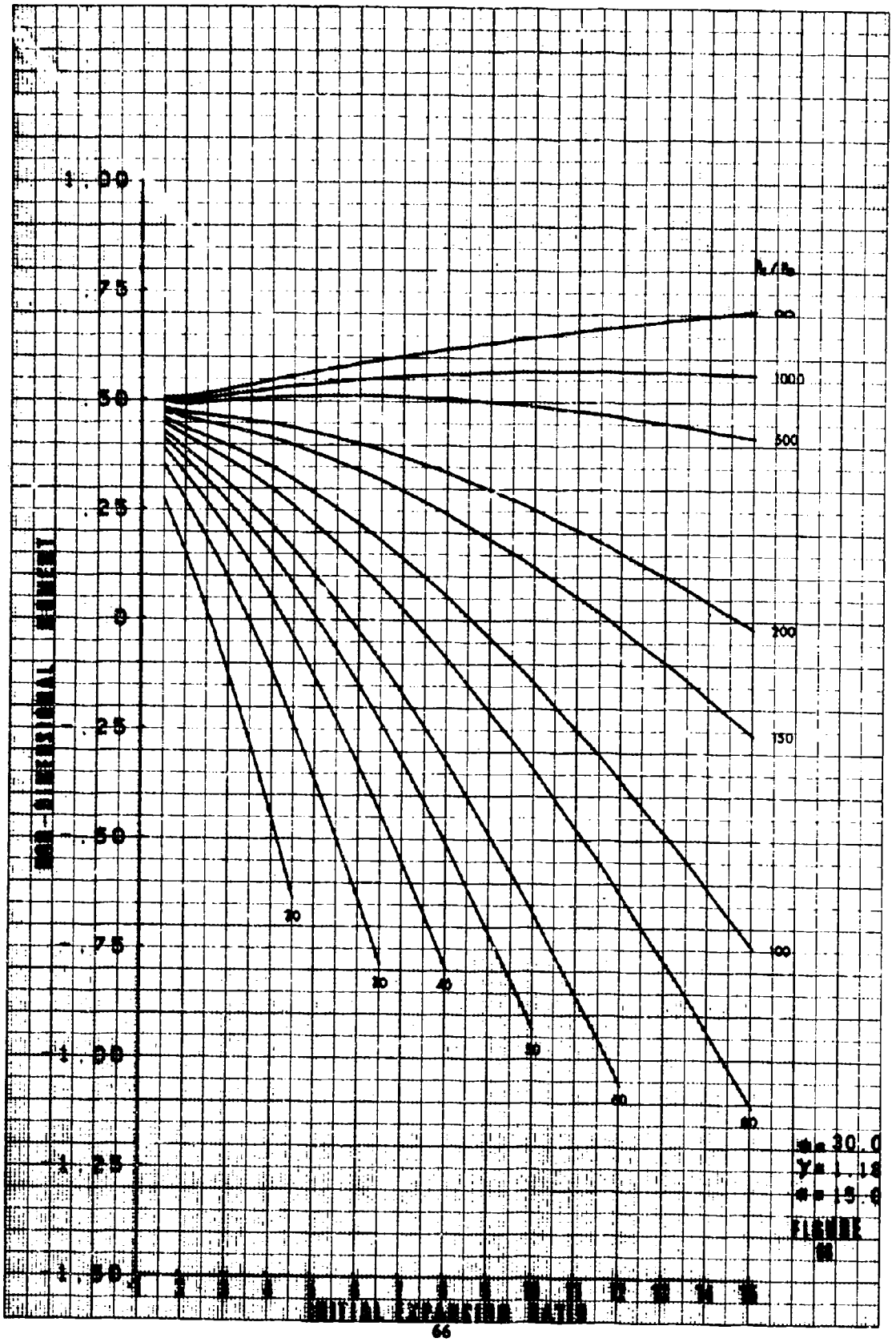
FIGURE 63


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
200
150
100
80
60
50
40
30
20
FIGURE
34



6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
TRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000

FIGURE 15


1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1000
500
200
150
100
20
30
40
50
60
80
INITIAL EXPANSION RATIO

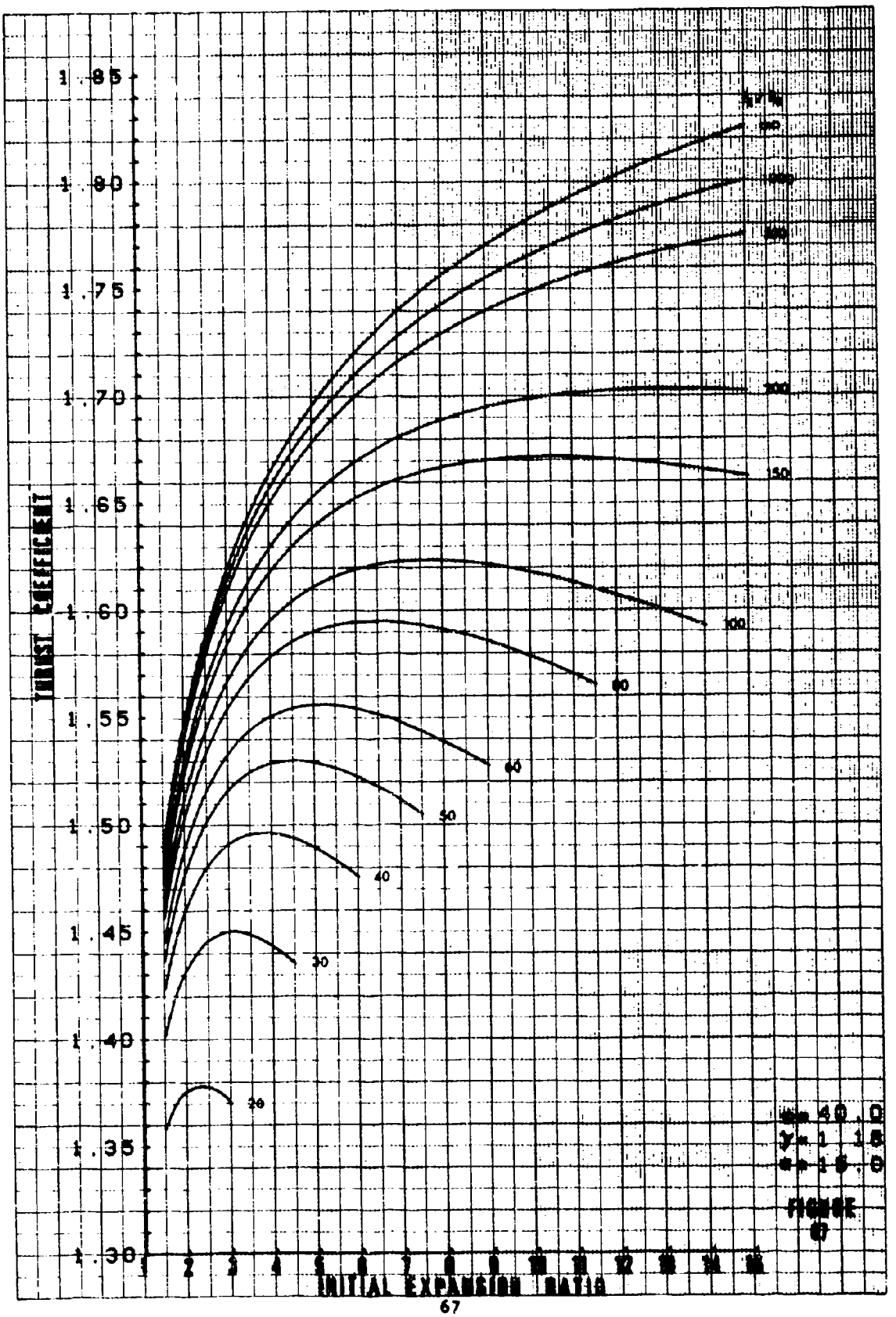
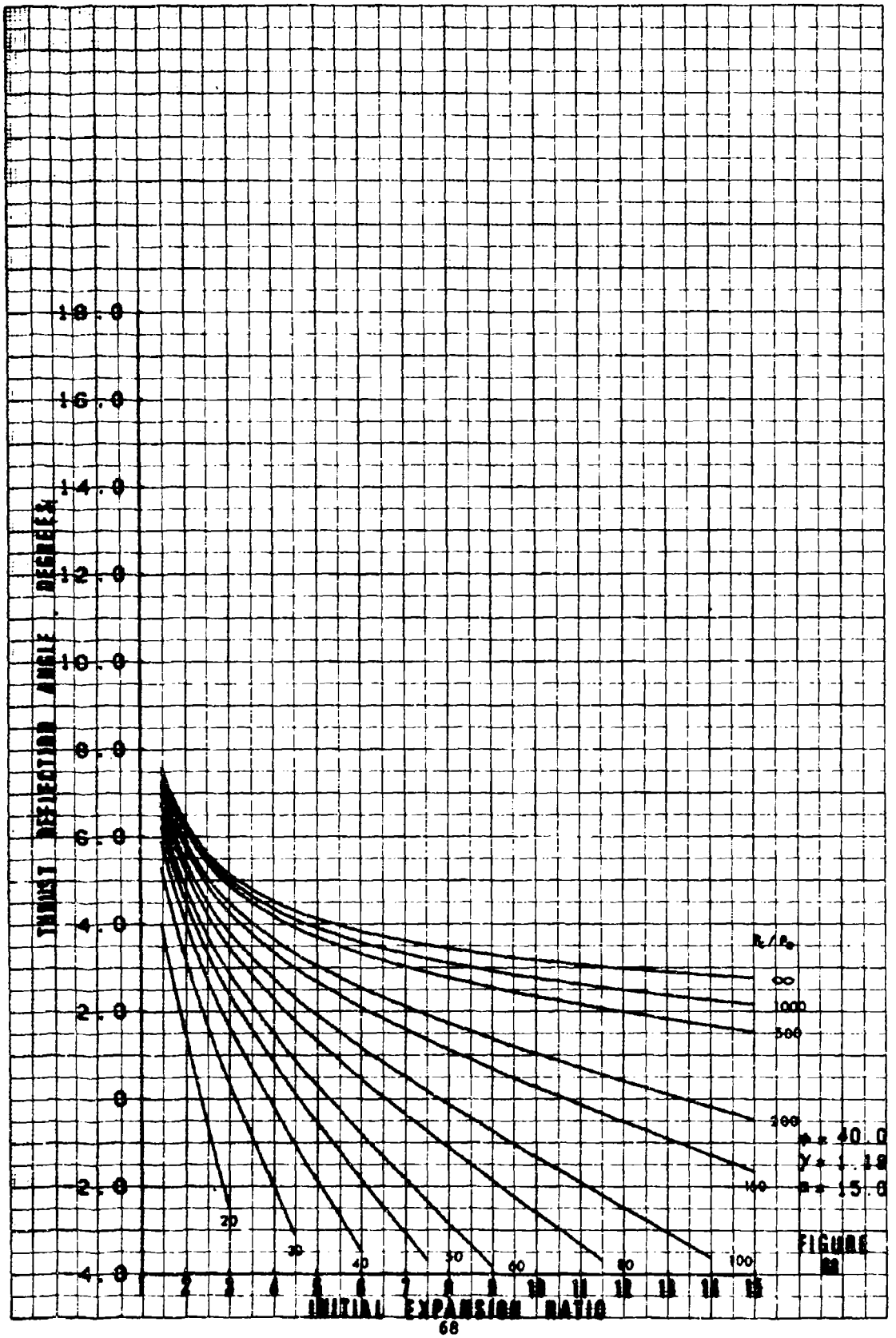
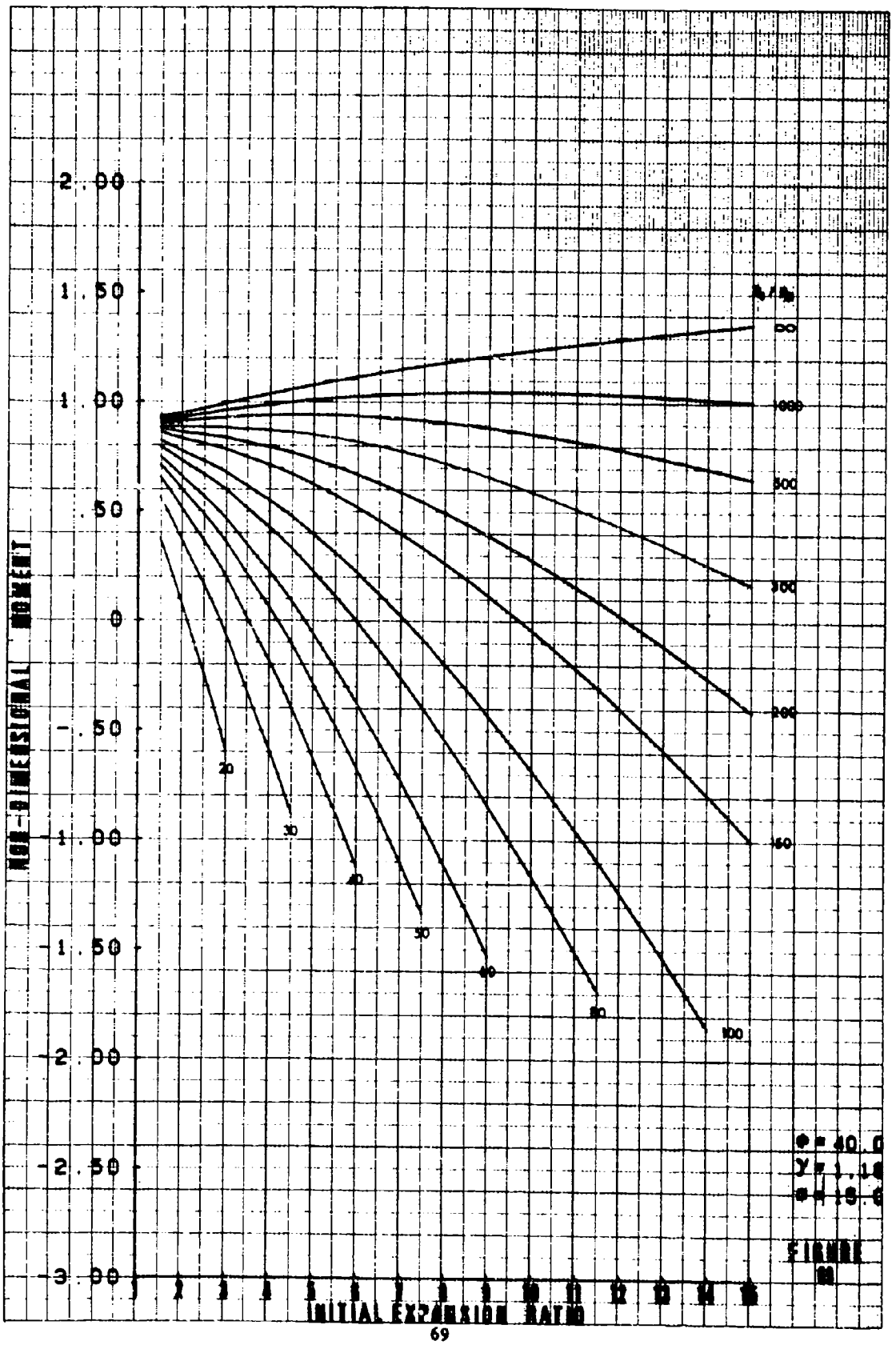

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
300
400
500
1000
100
α = 40.0
γ = 1.18
α = 15.0

FIGURE 67


THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
160
200
500
1000
∞
φ = 40.0
γ = 1.18
n = 15.0

FIGURE



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

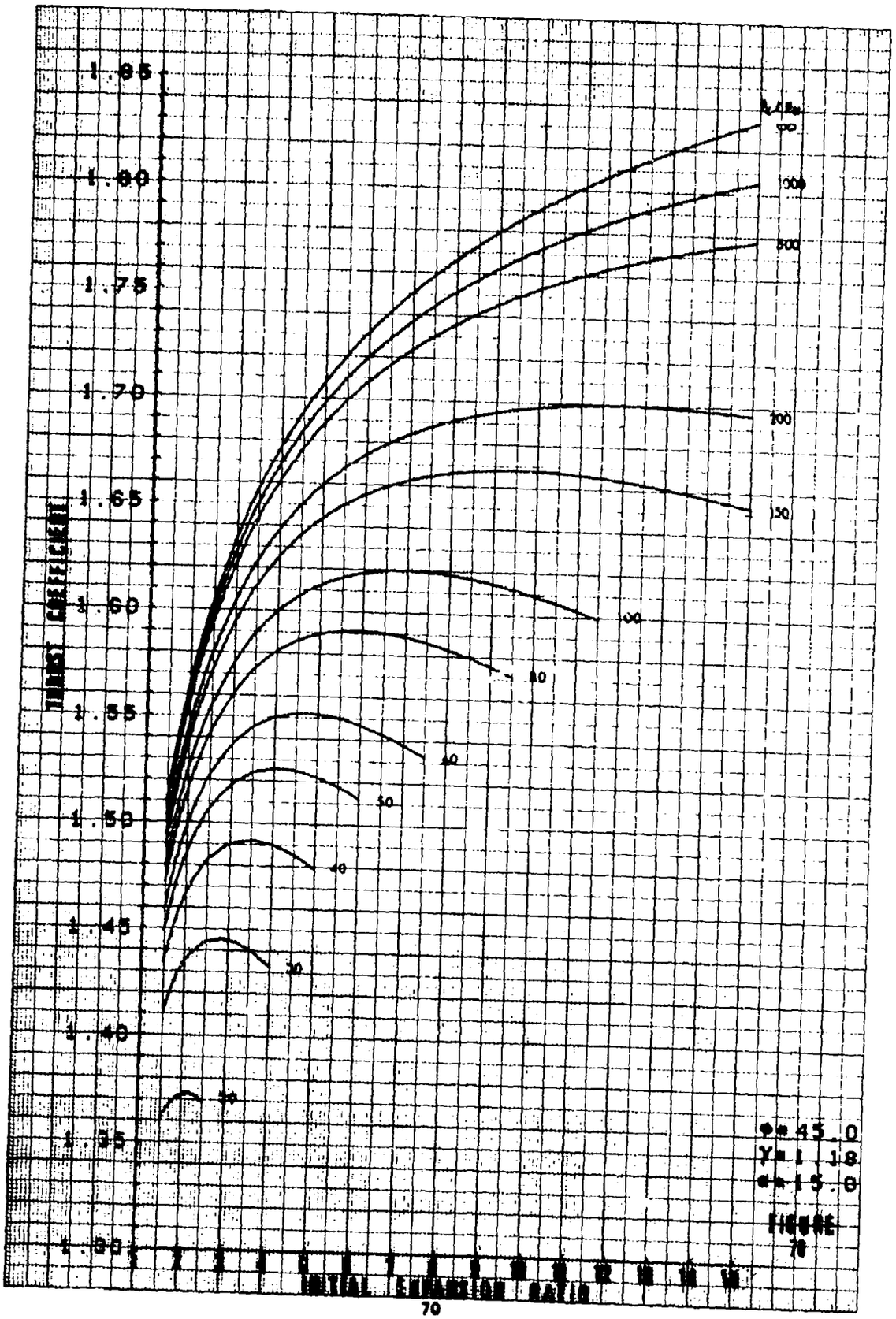

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
300
150
100
80
60
50
40
30
20
φ=45.0
γ=1.18
α=15.0

FIGURE 70

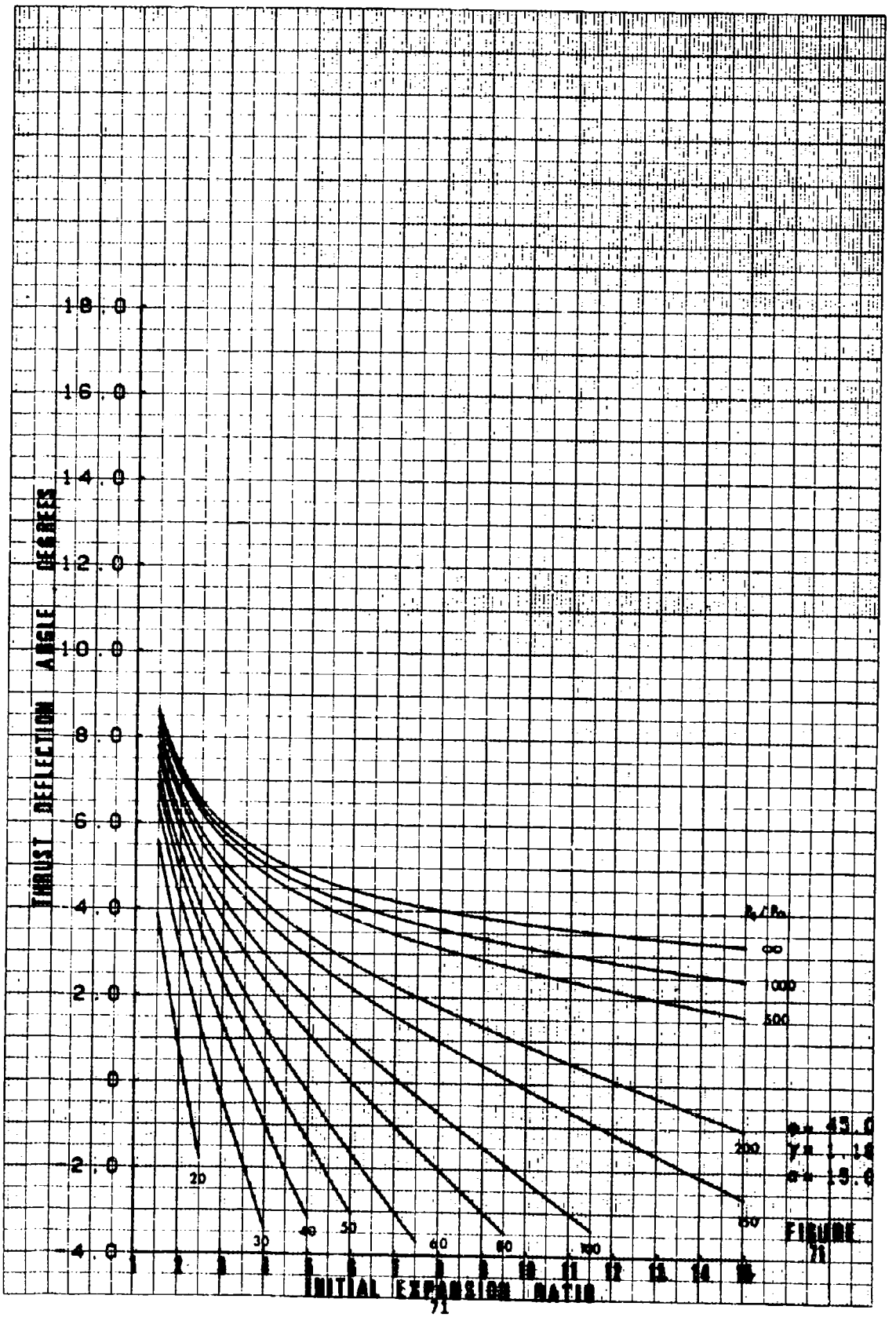
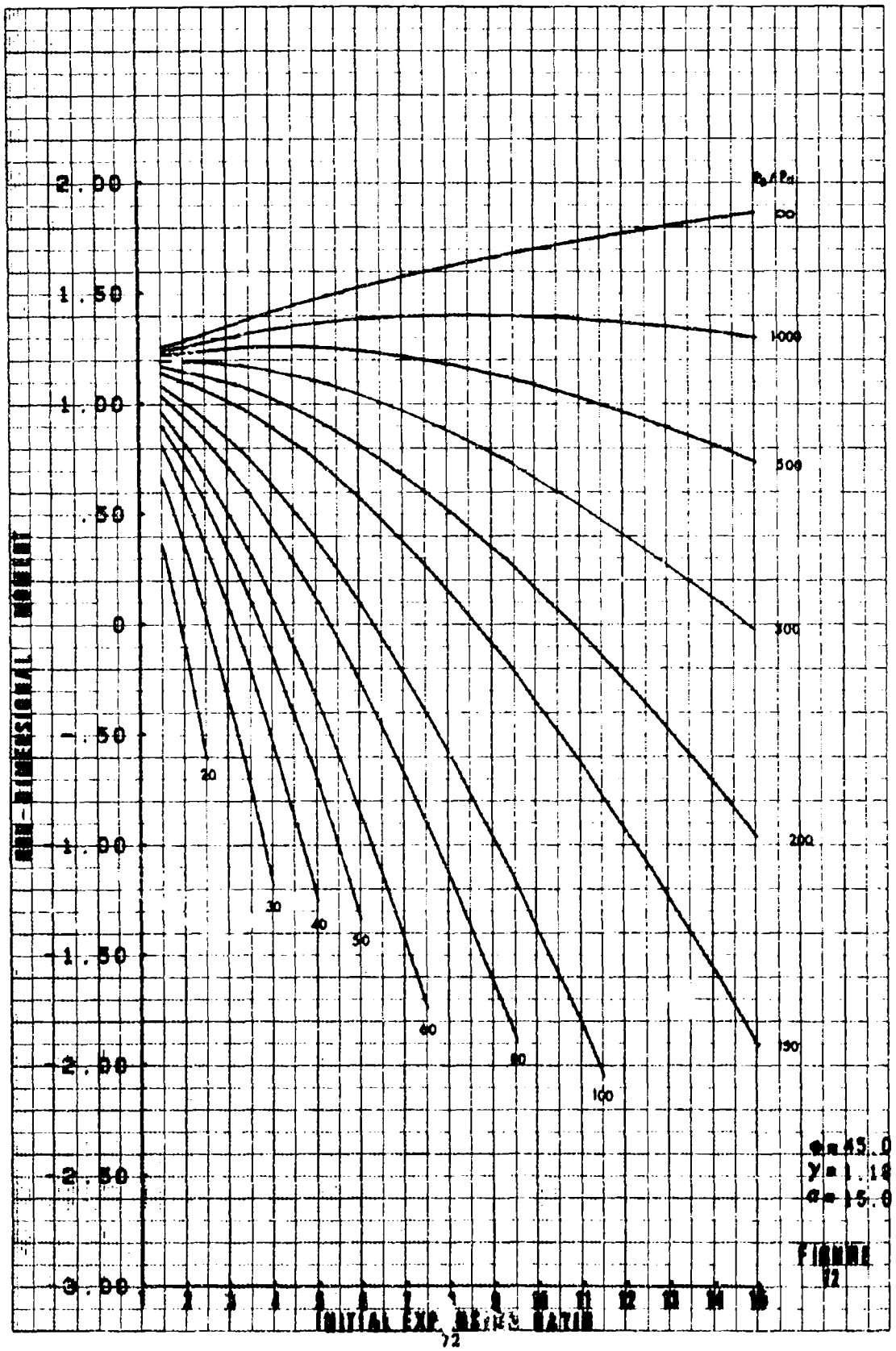

THRUST DEFLECTION ANGLE DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_a/P_o
∞
1000
500
200
100
80
60
50
40
30
20

FIGURE 71



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXP. MSING RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_0/P_a
∞
1000
500
300
200
150
20
30
40
50
60
80
100
φ = 45.0
γ = 1.18
α = 15.0

FIGURE 72

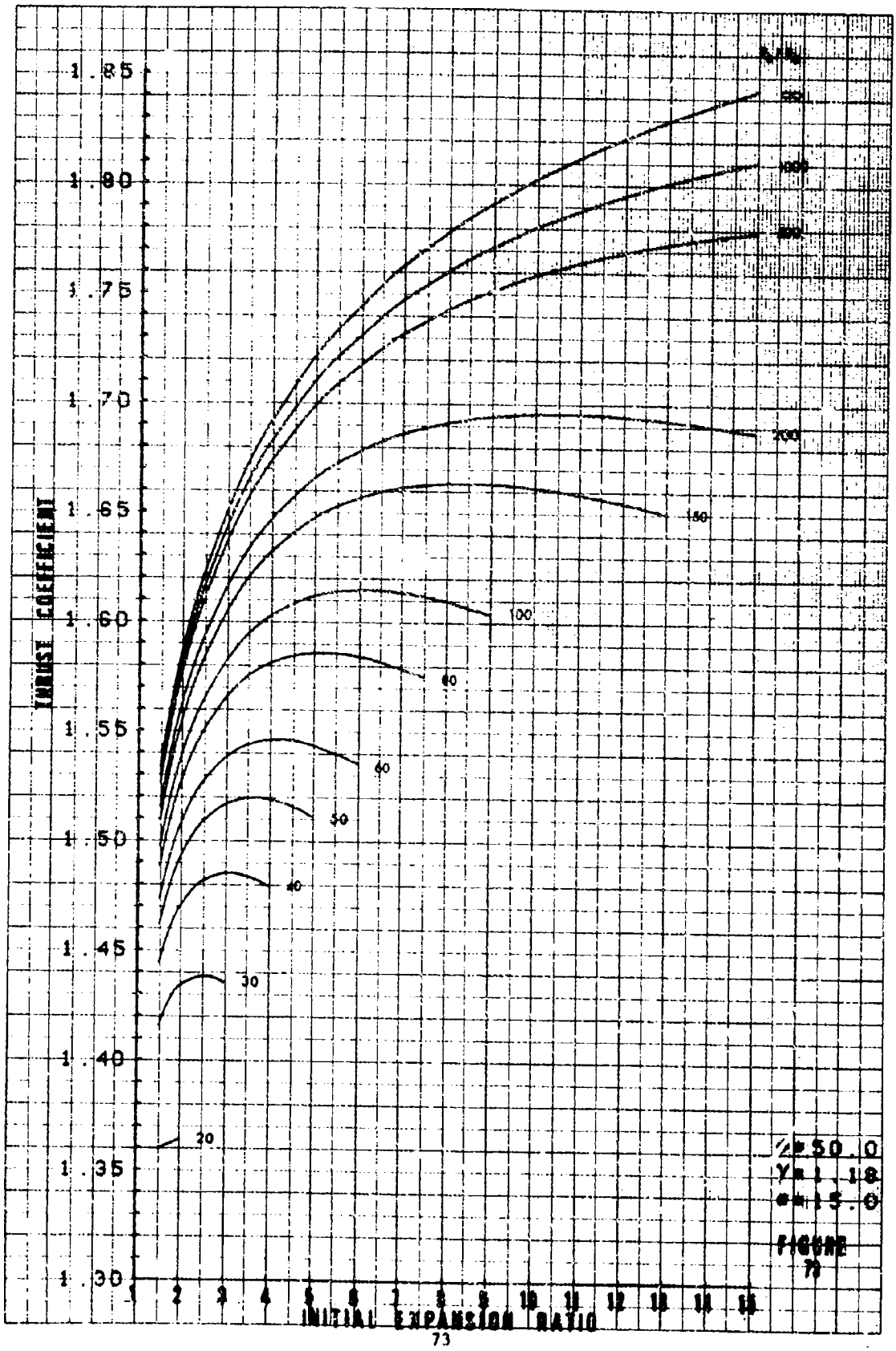
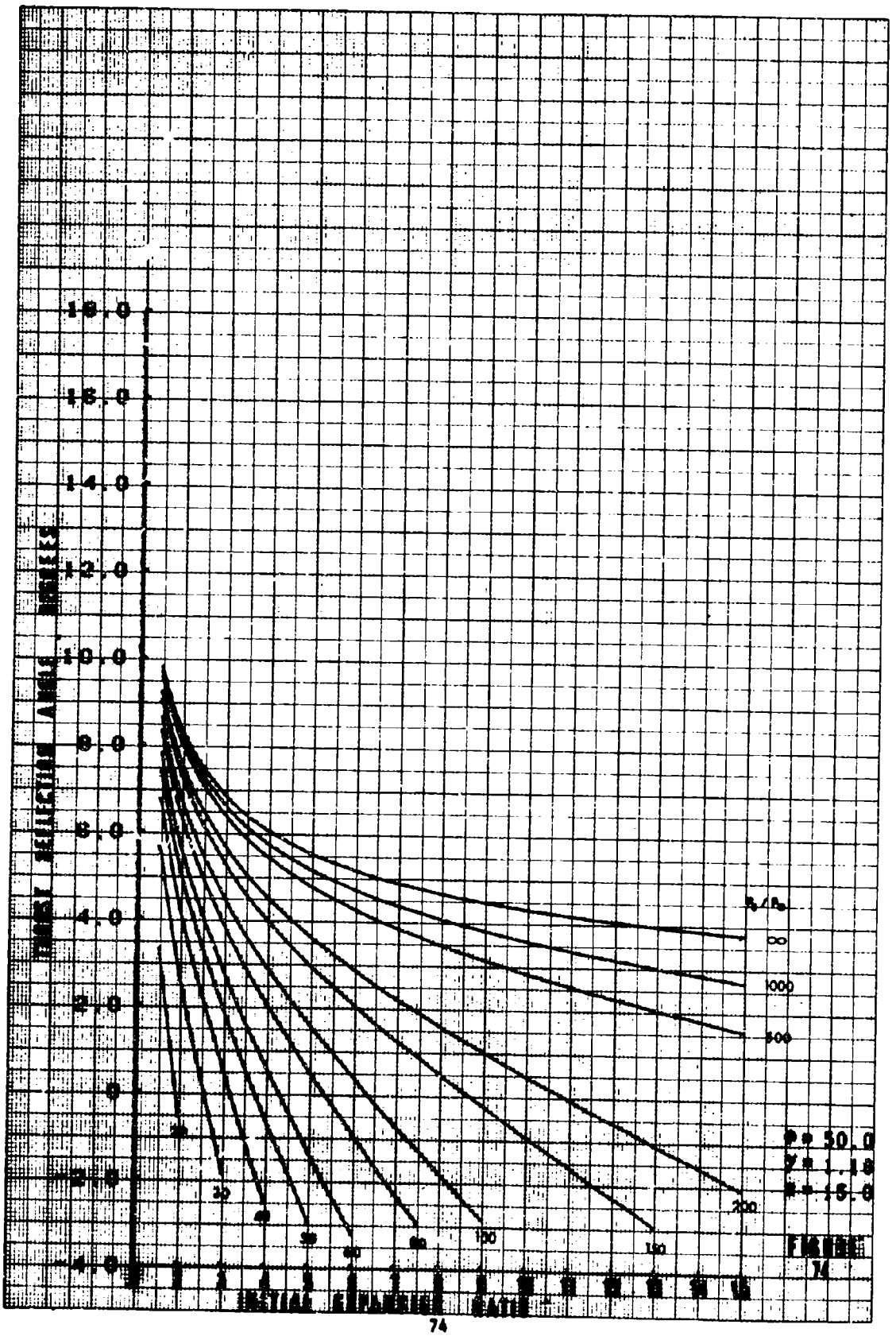

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
200
150
100
80
60
50
40
30
20
Z=50.0
Y=1.18
θ=15.0

FIGURE 73



18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_0/P_∞
∞
1000
500
200
150
100
80
60
50
40
30
20
P = 50.0
γ = 1.18
R = 15.0

FIGURE 74

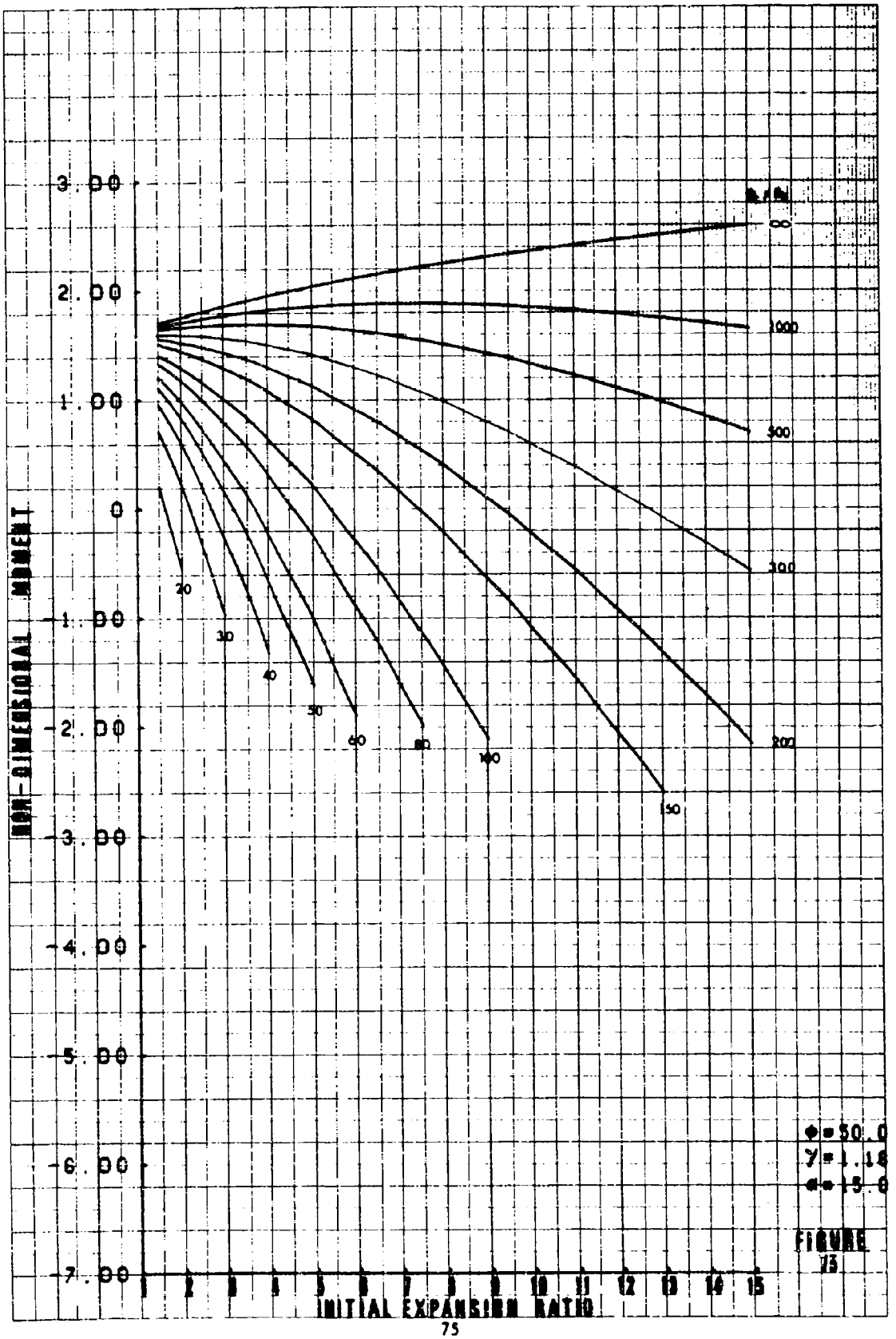
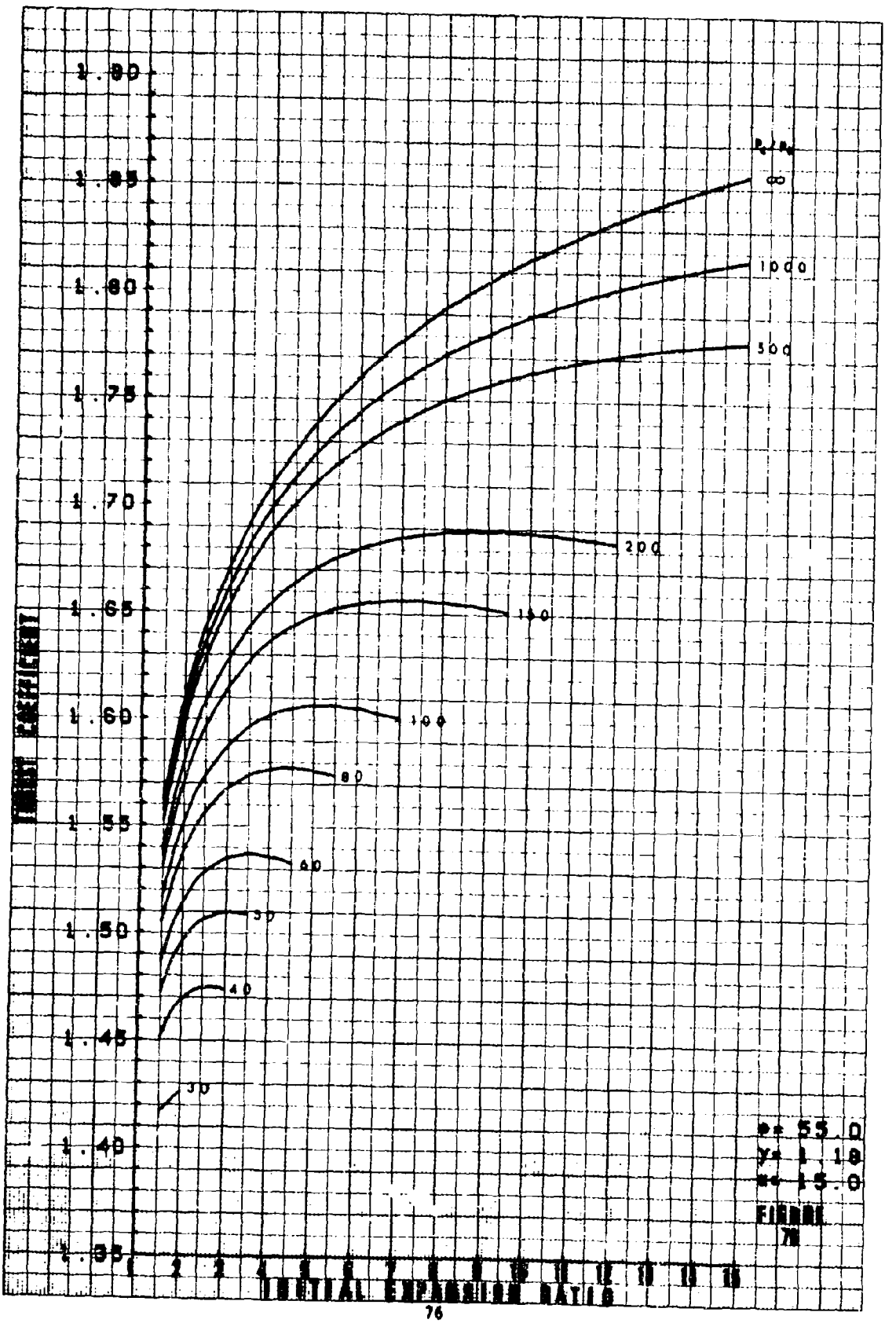

3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ=50.0
γ=1.18
α=15.0

FIGURE 75



1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
∞
1000
500
200
150
100
80
60
50
40
30
e= 55.0
y= 1.18
x= 15.0
FIGURE
76
INITIAL EXPANSION RATIO

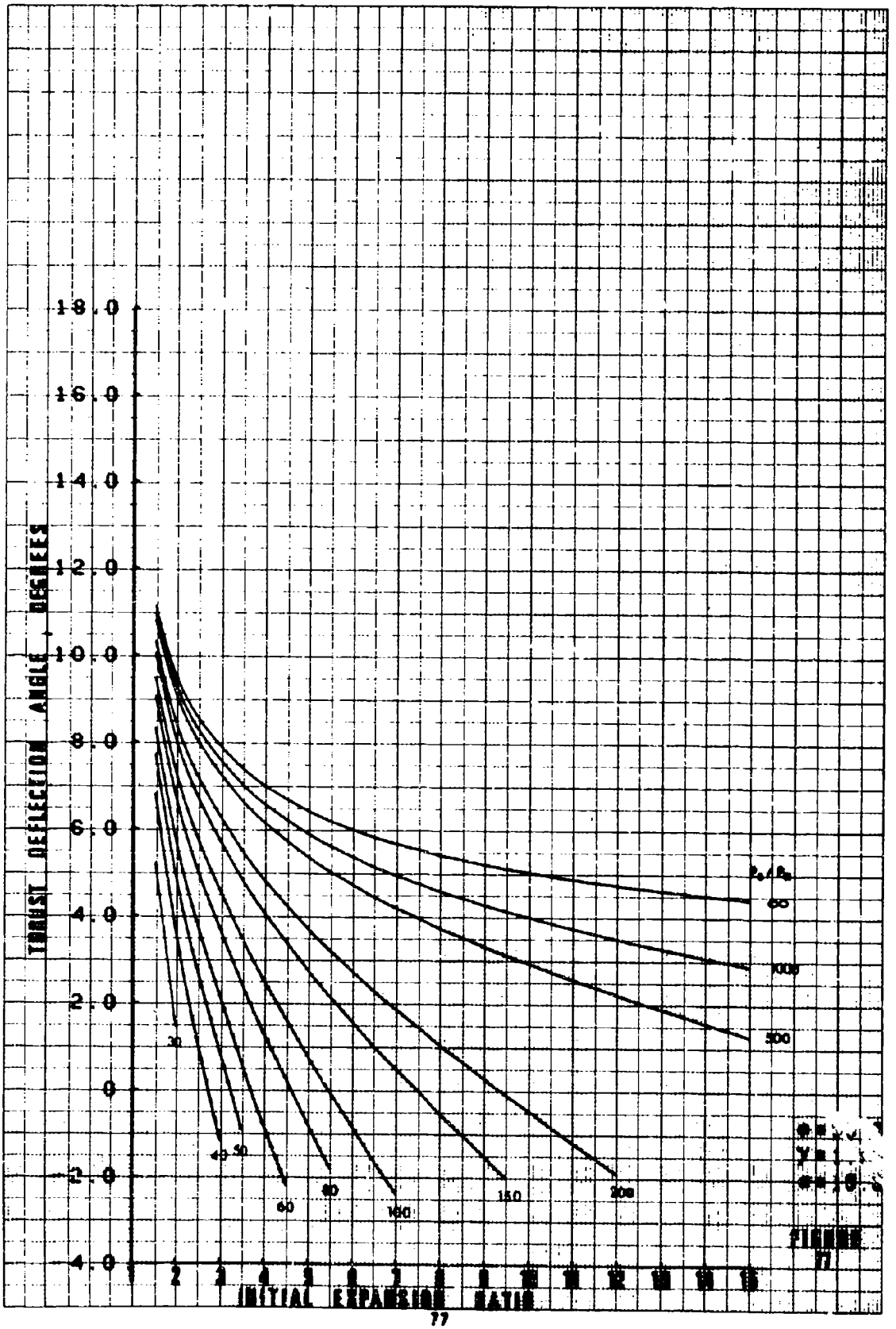

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_o/P_a
60
100
500
30
40
50
60
80
100
150
200

FIGURE 77

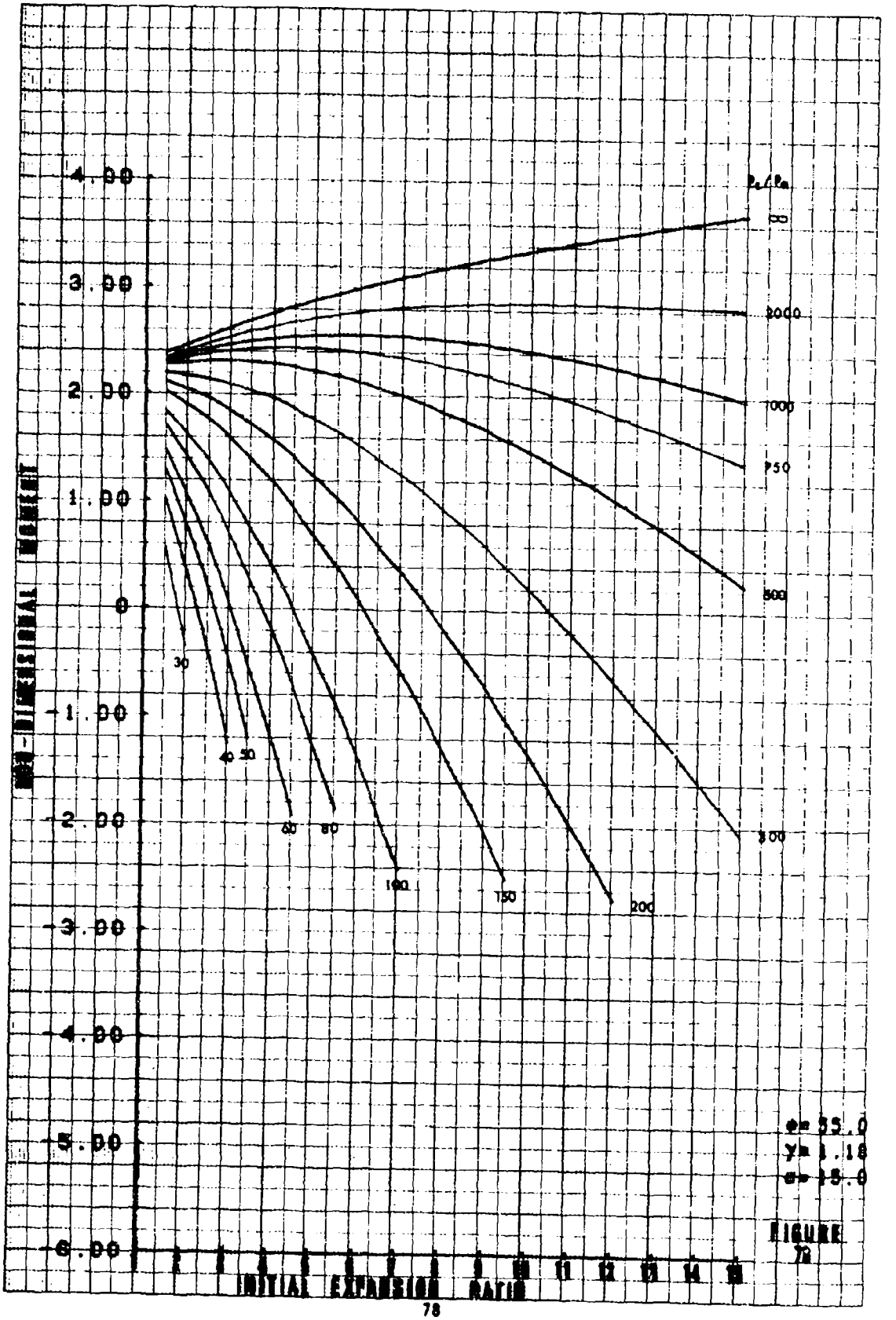
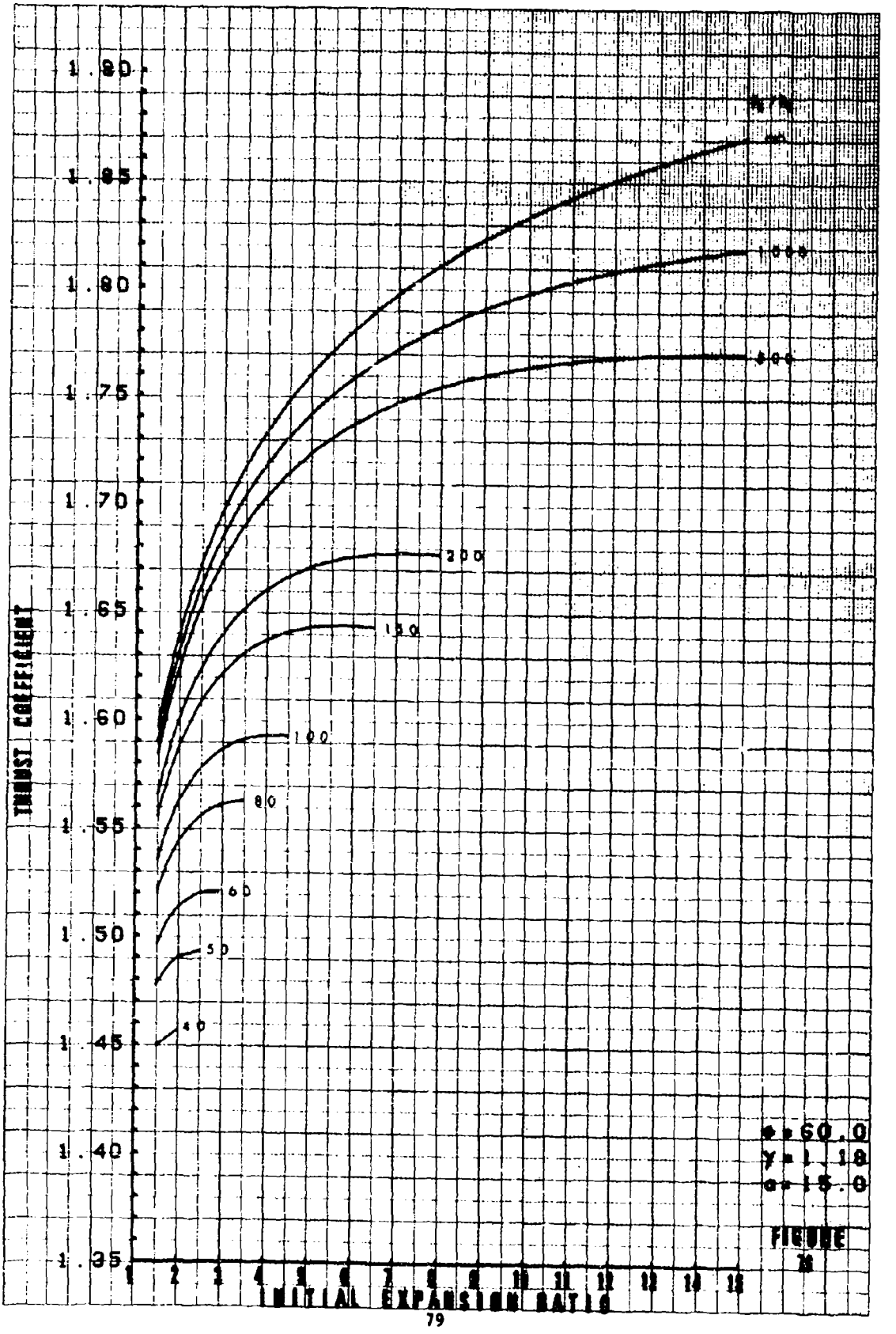

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
3000
1000
750
500
300
200
150
100
80
60
50
40
30
φ= 55.0
γ= 1.18
θ= 15.0

FIGURE 72



1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
THRUST COEFFICIENT
1000
500
200
150
100
80
60
50
40
φ = 60.0
γ = 1.18
α = 15.0
FIGURE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

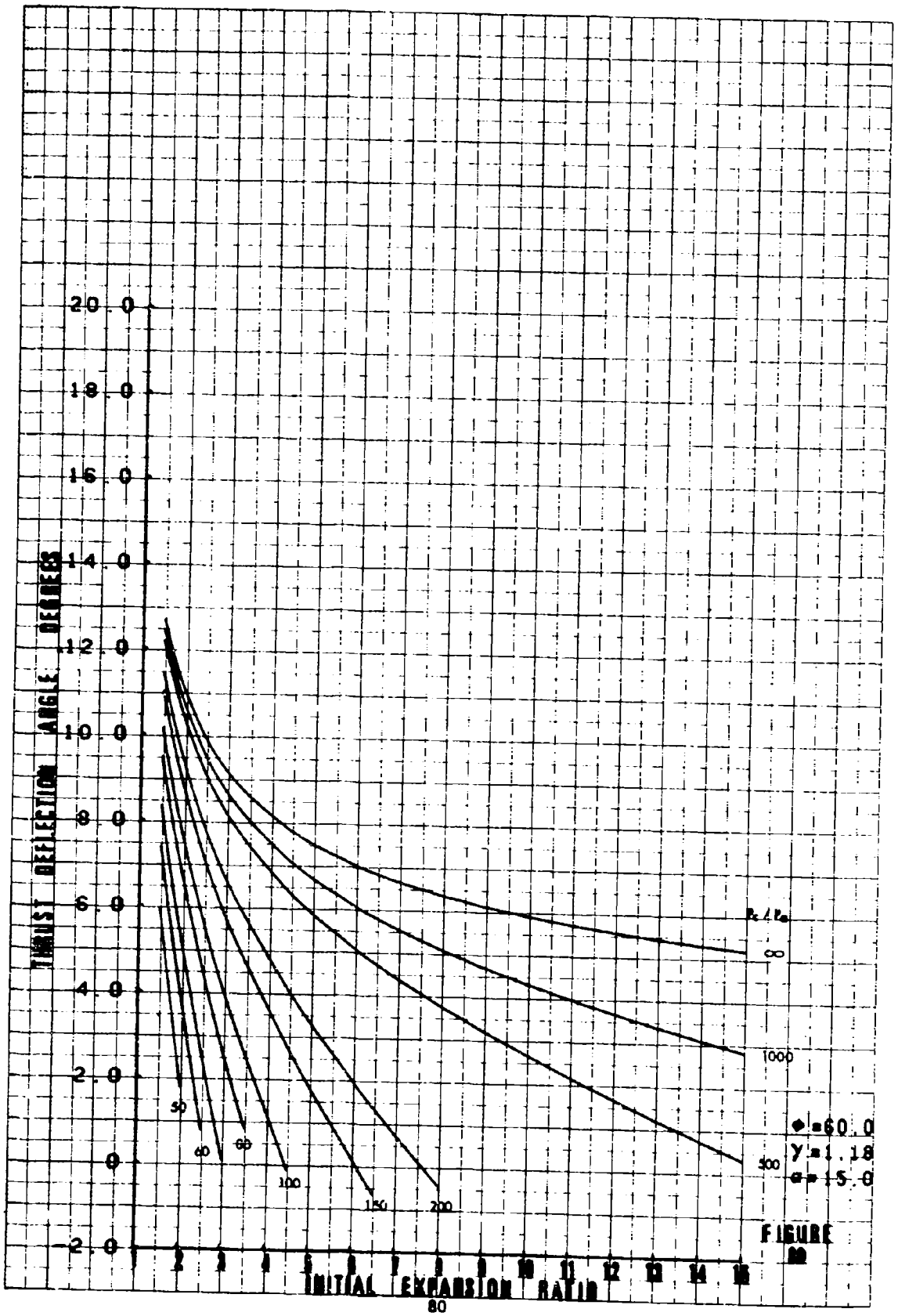

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
ϕ=60.0
γ=1.18
α=15.0

FIGURE 80

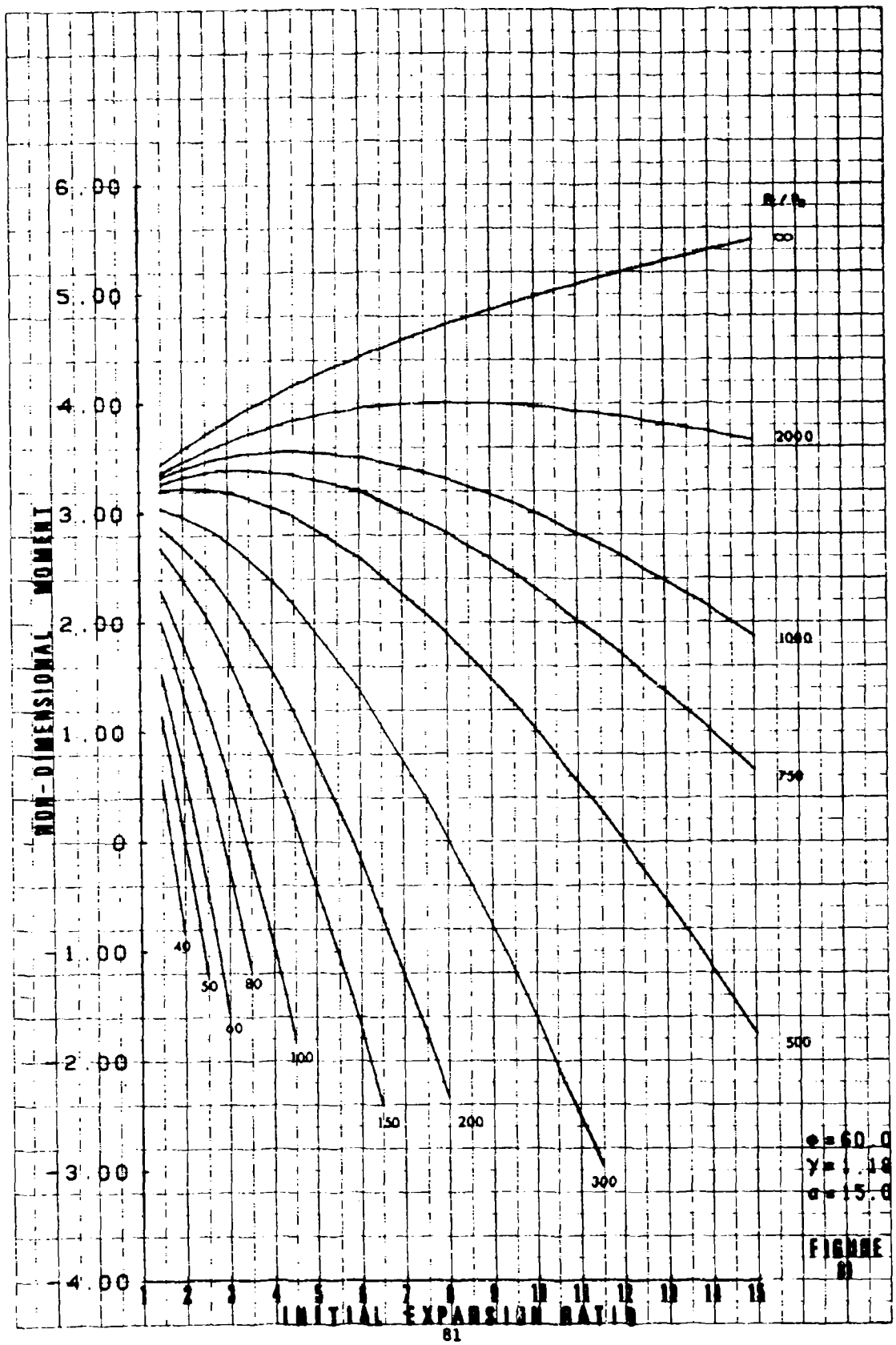

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R/Ro
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
φ = 60.0
γ = 1.19
α = 15.0

FIGURE 8

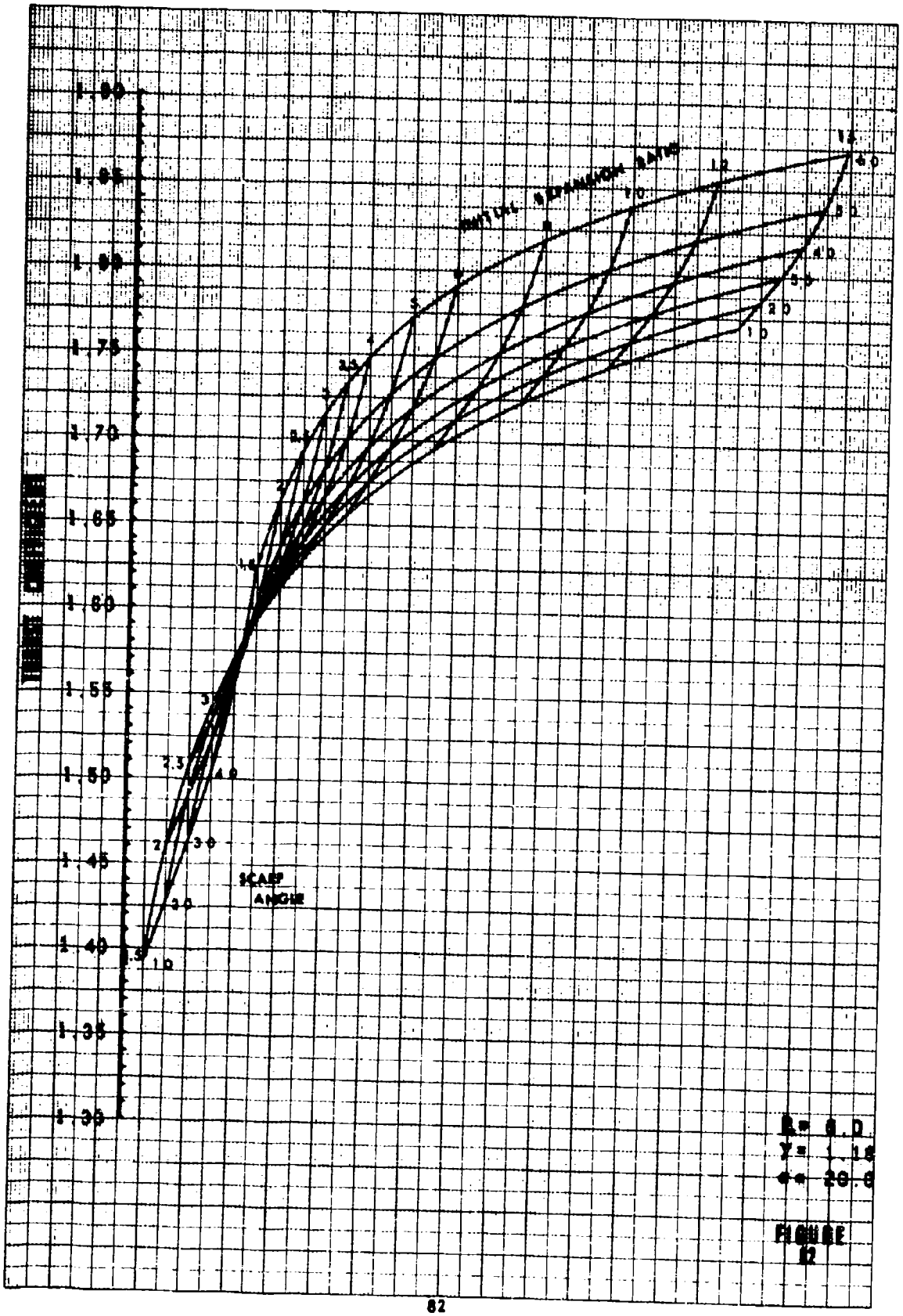

1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
R= 6.0
γ= 1.18
α= 20.0

FIGURE 82

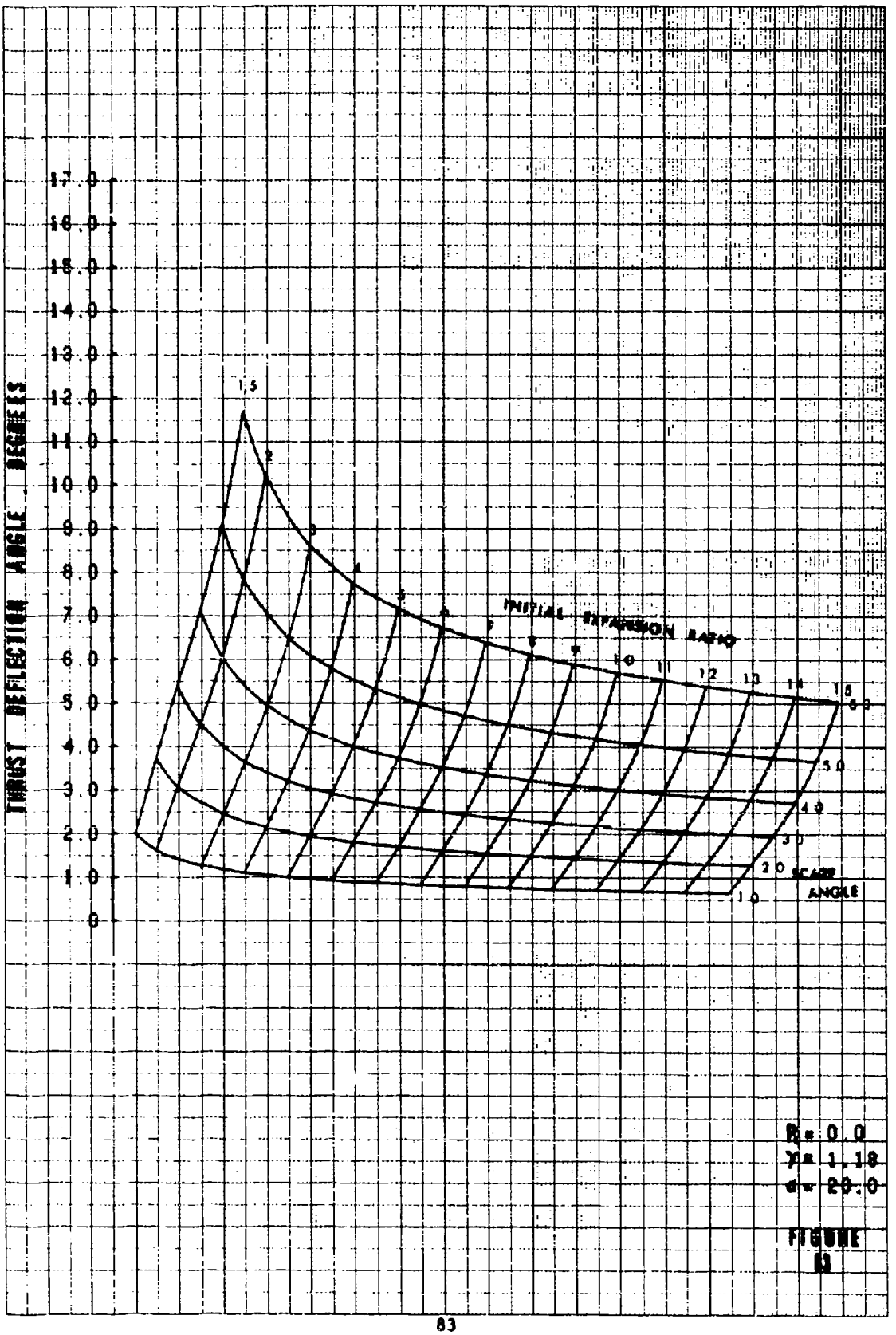

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
6.0
5.0
4.0
3.0
2.0
1.0
SCARF ANGLE
R = 0.0
γ = 1.18
α = 20.0

FIGURE 8

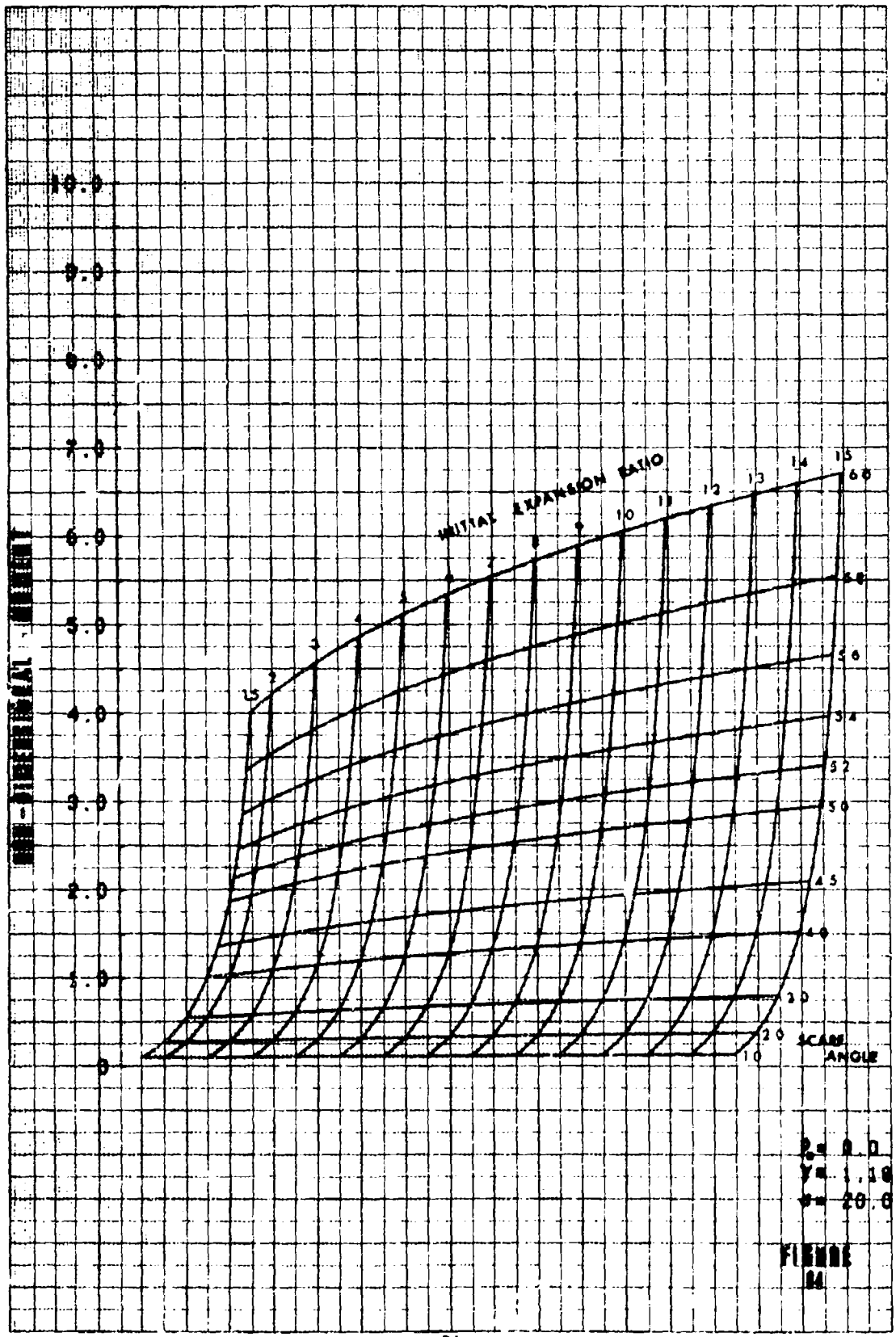

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P_o = 0.0
γ = 1.10
ω = 20.0

FIGURE 84

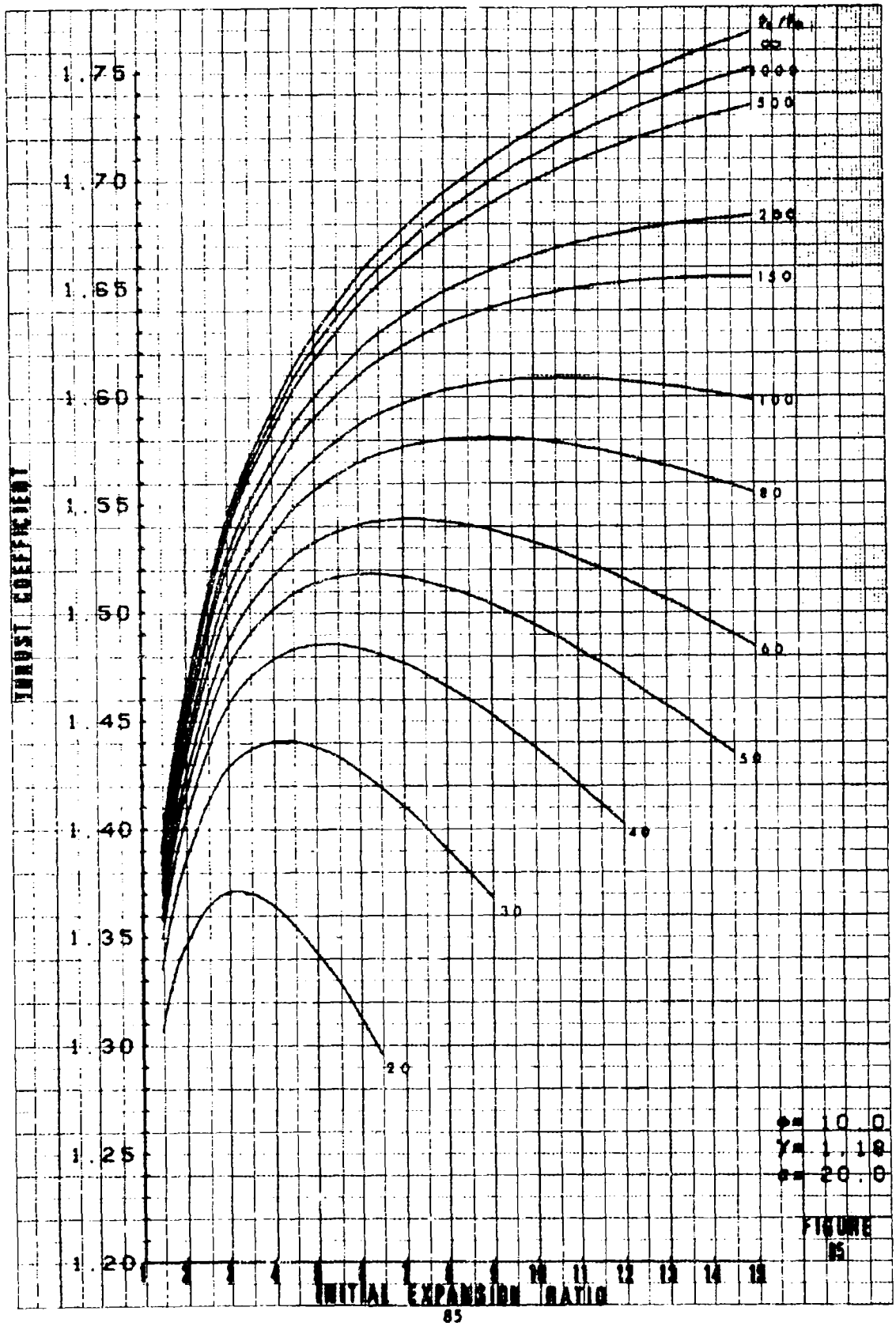
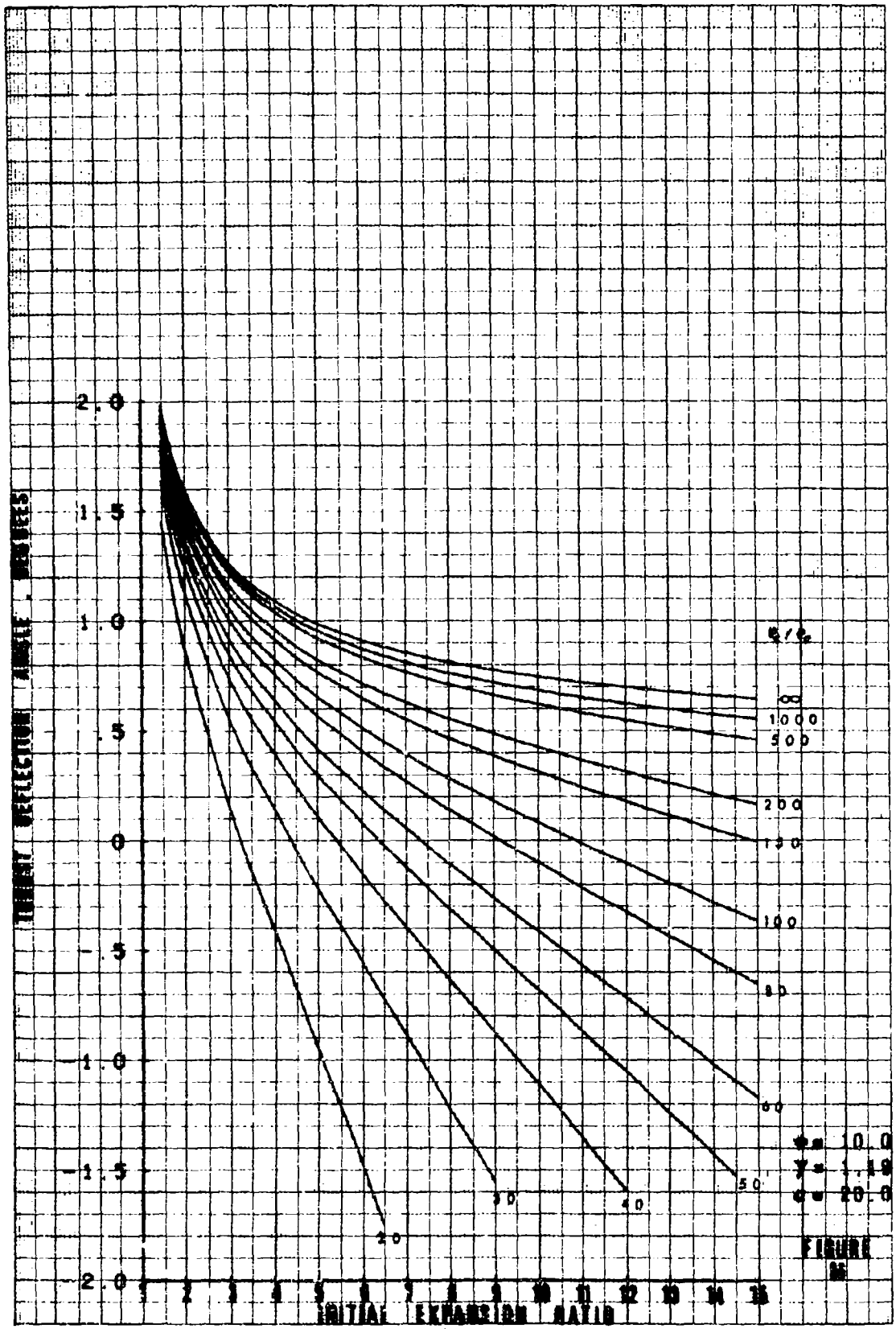

THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.18
θ= 20.0

FIGURE 85



2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
e_i/e_o
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.19
α = 20.0

FIGURE 36

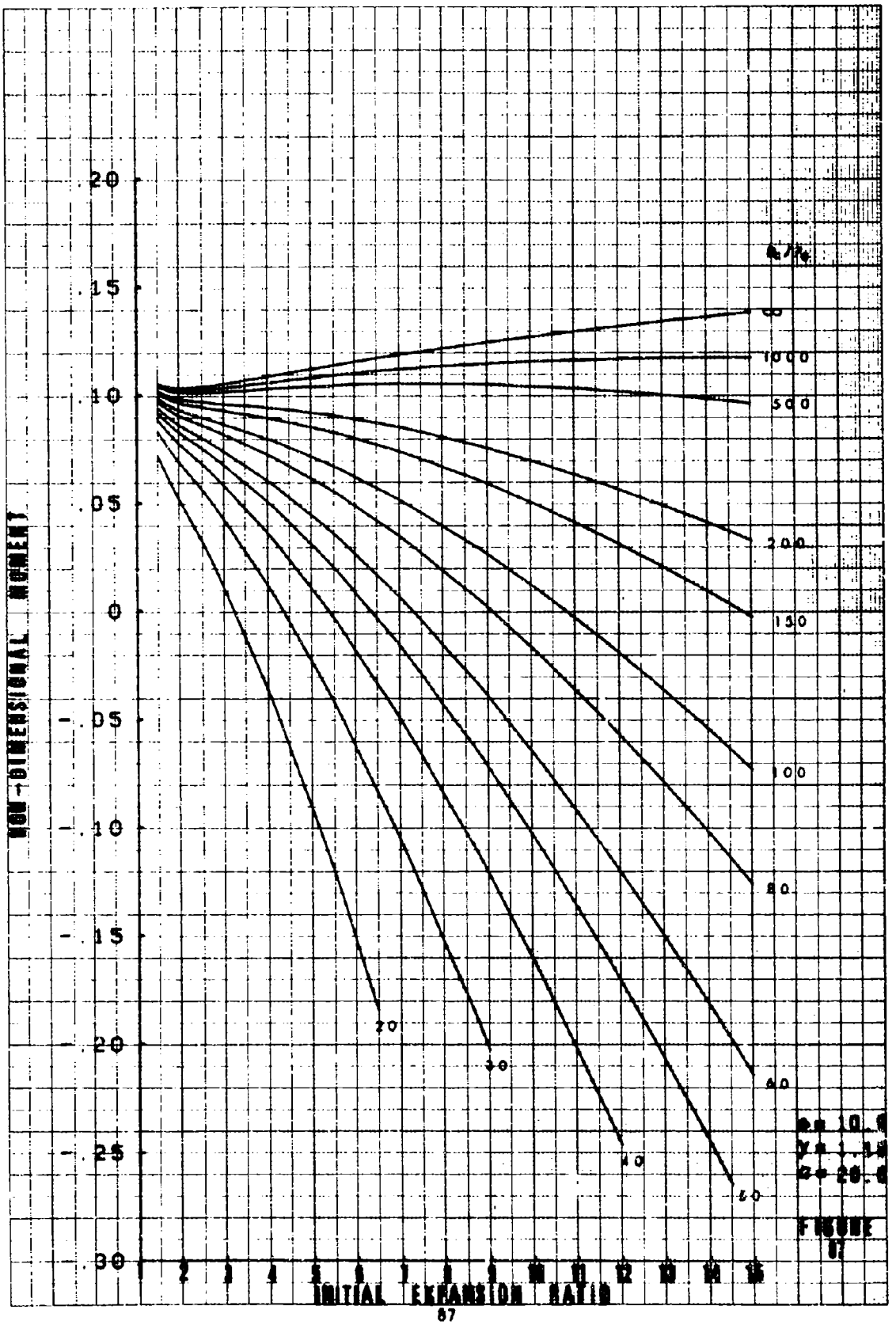
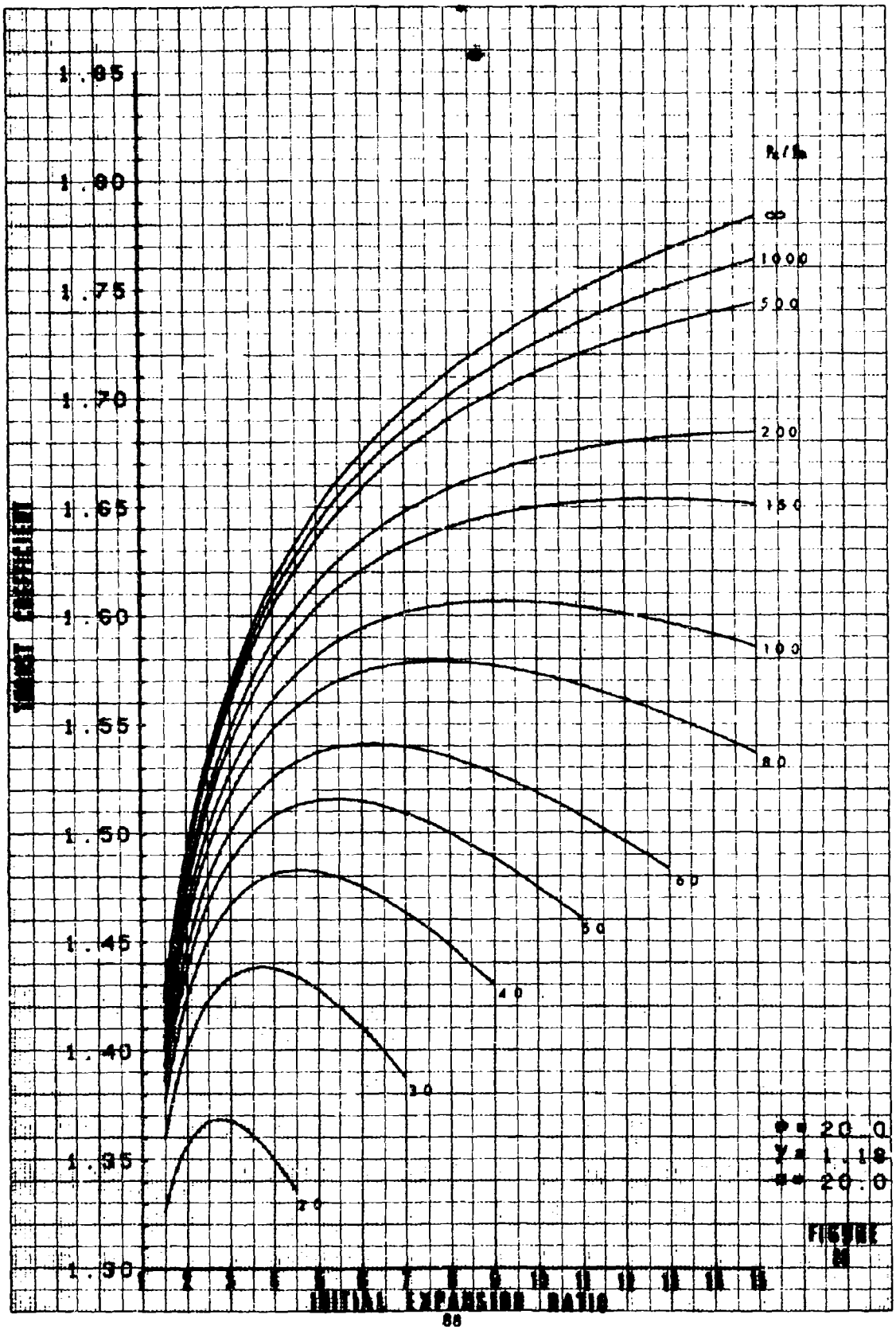

NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
40
30
20

FIGURE 87



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
TRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
Y = 1.18

FIGURE

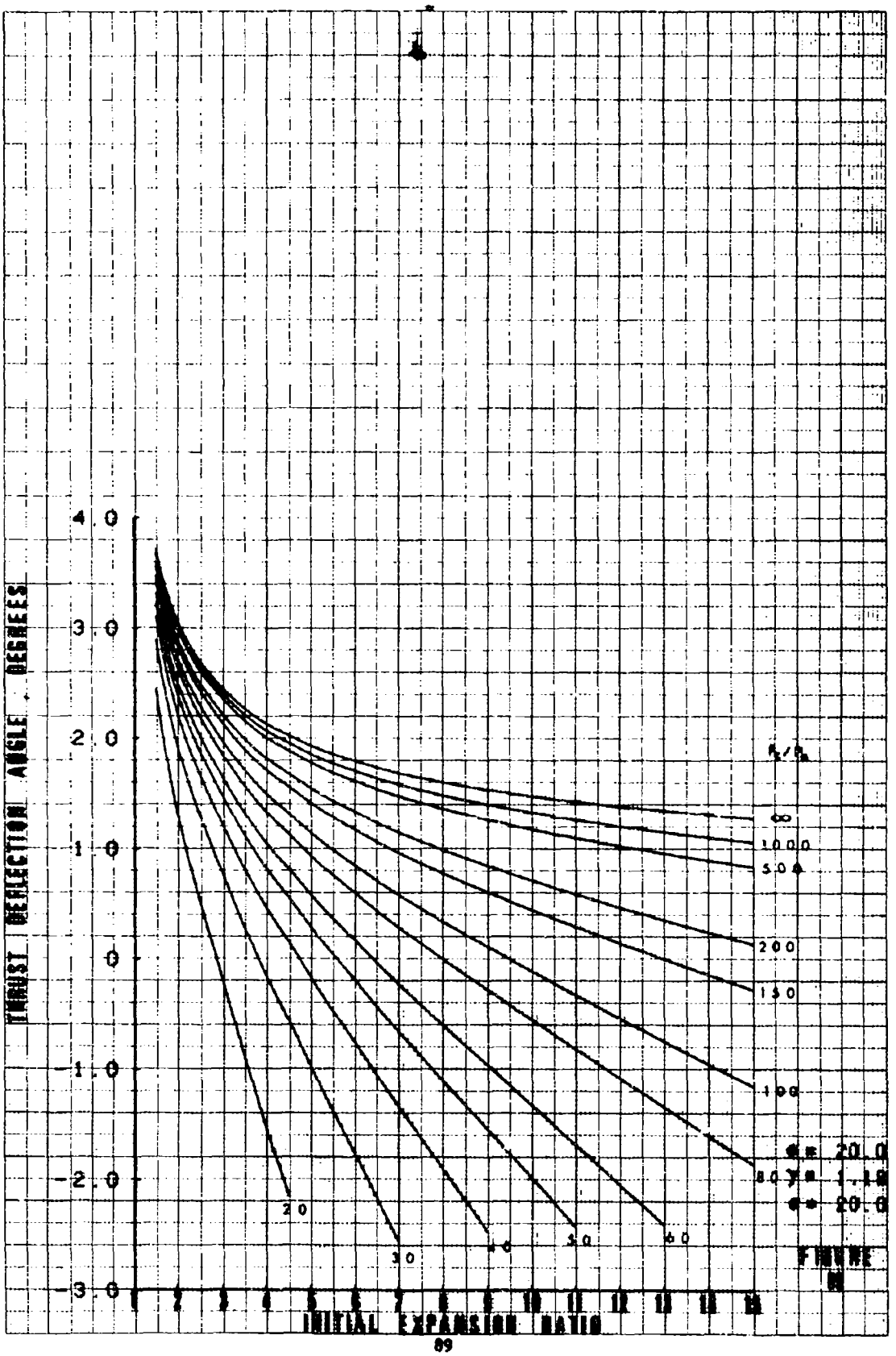

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
α = 20.0
γ = 1.18
α = 20.0

FIGURE 11

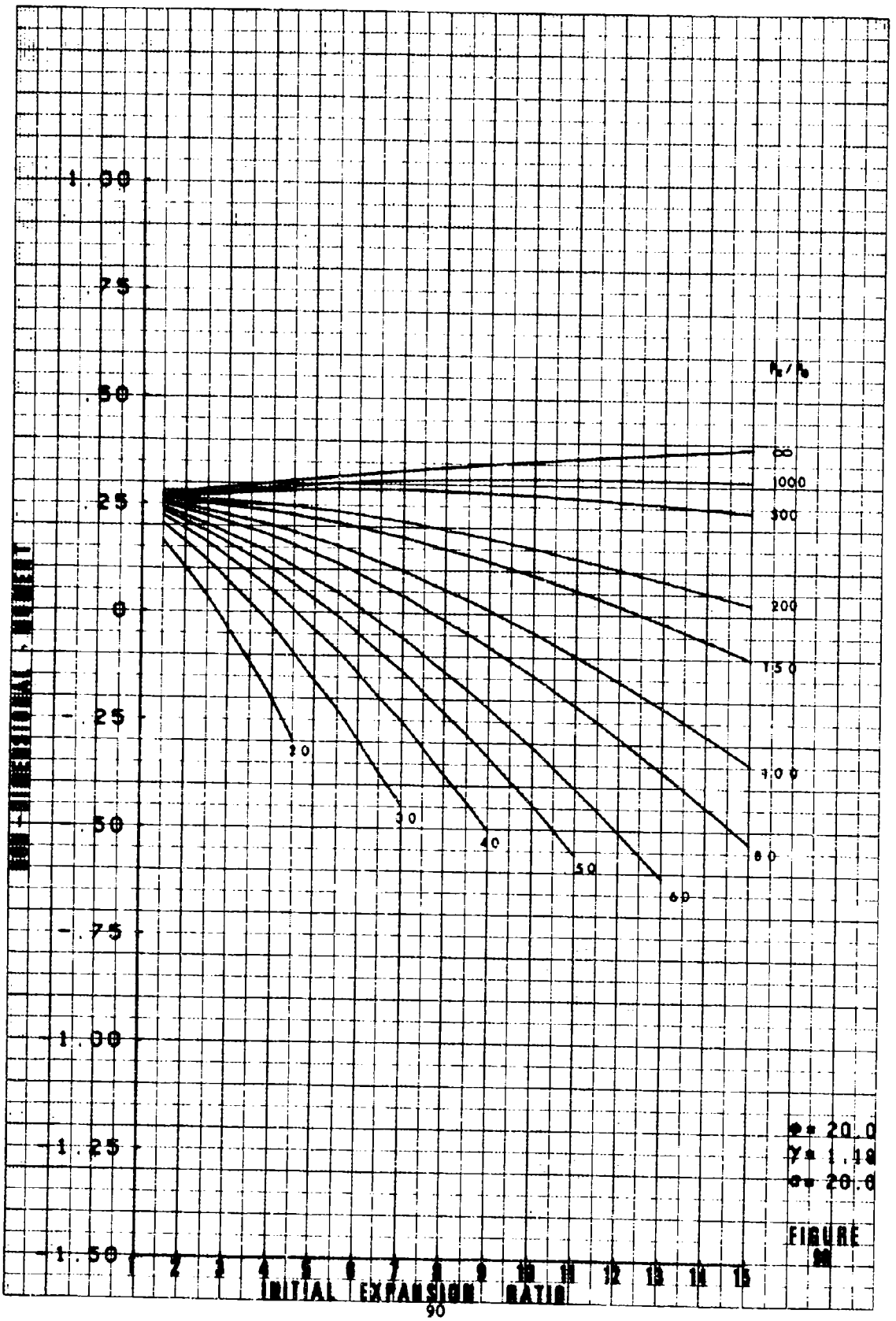

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R_2/R_0
∞
1000
300
200
150
100
80
60
50
40
30
20
φ= 20.0
γ= 1.18
σ= 20.0

FIGURE 28

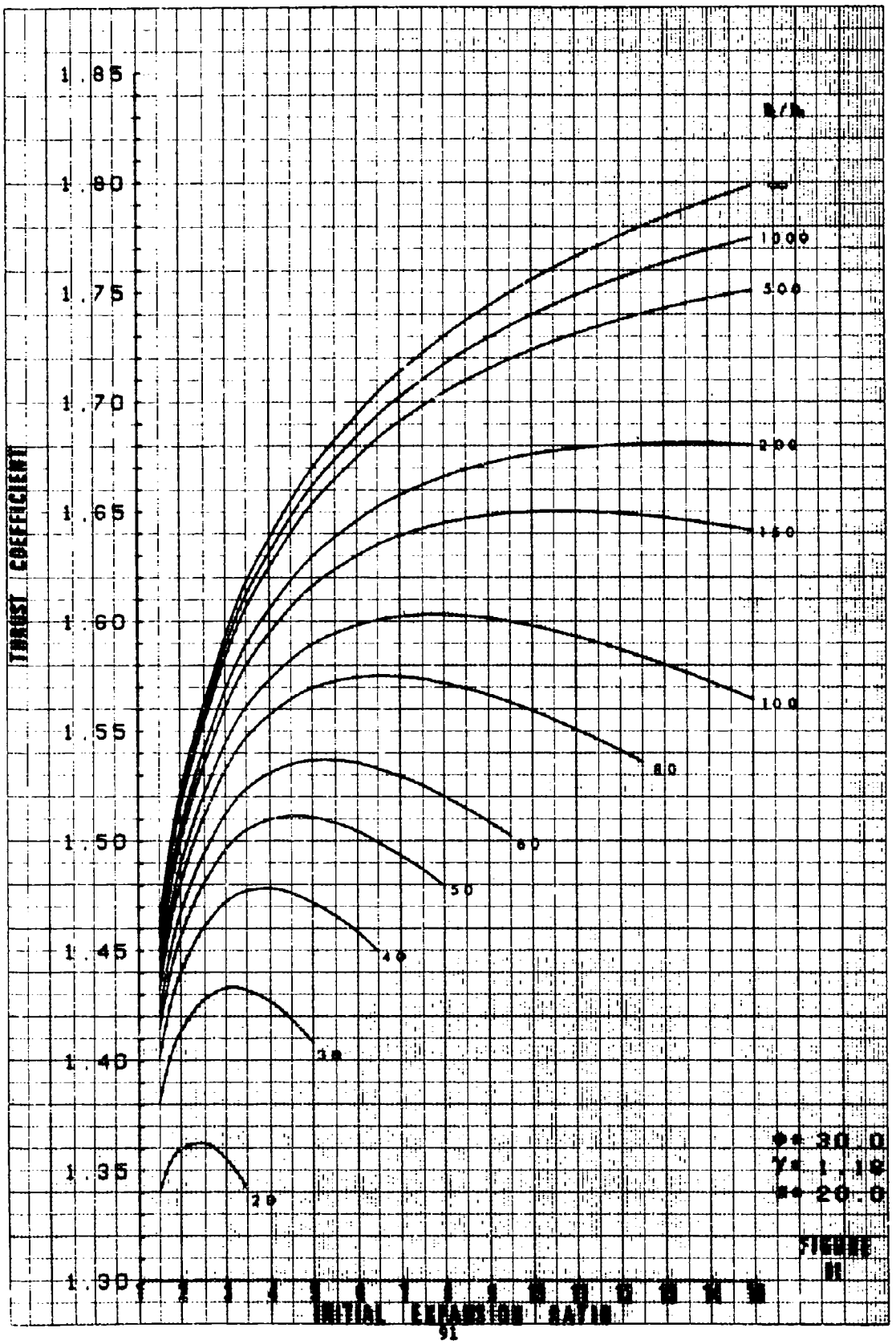

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO

FIGURE 11

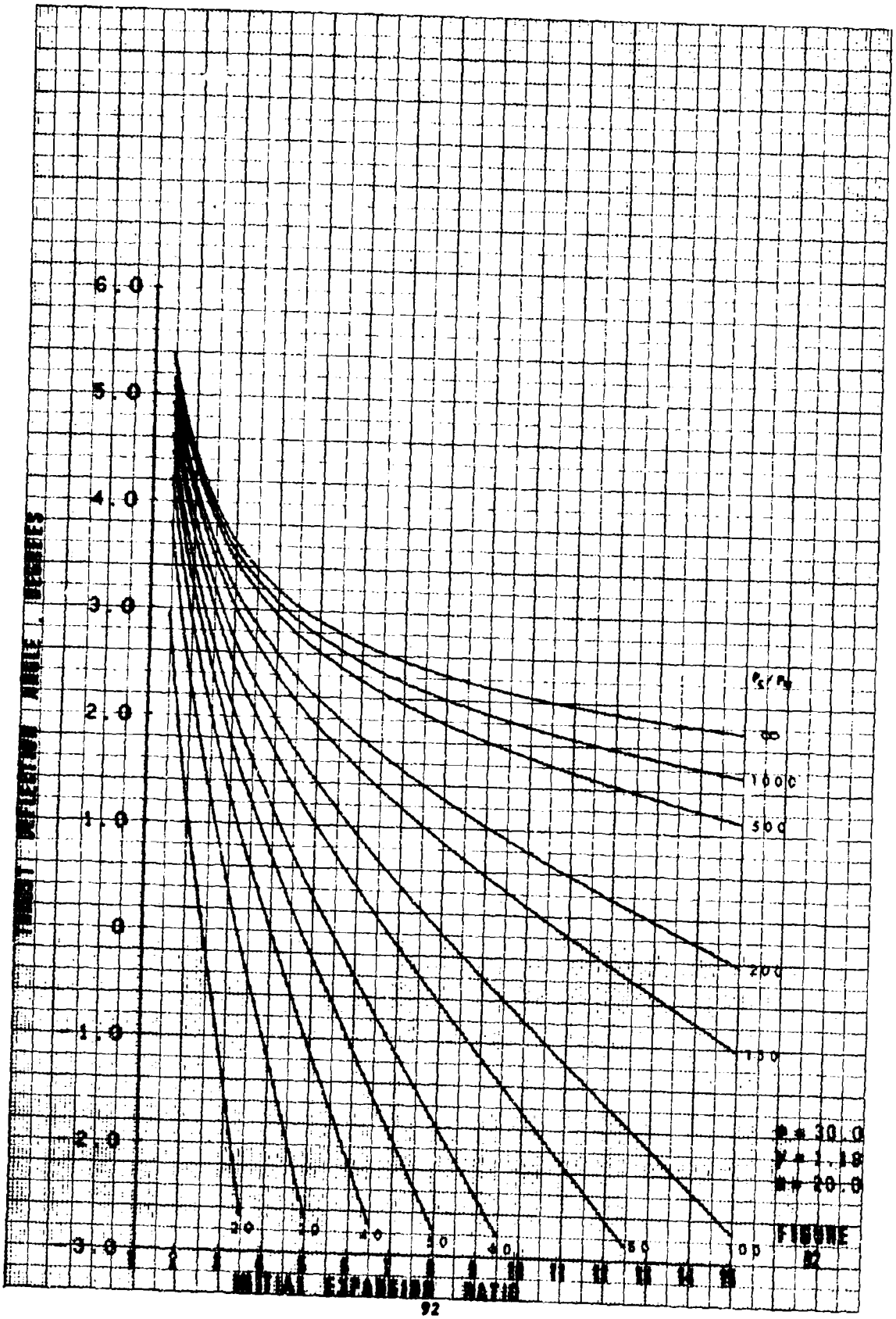
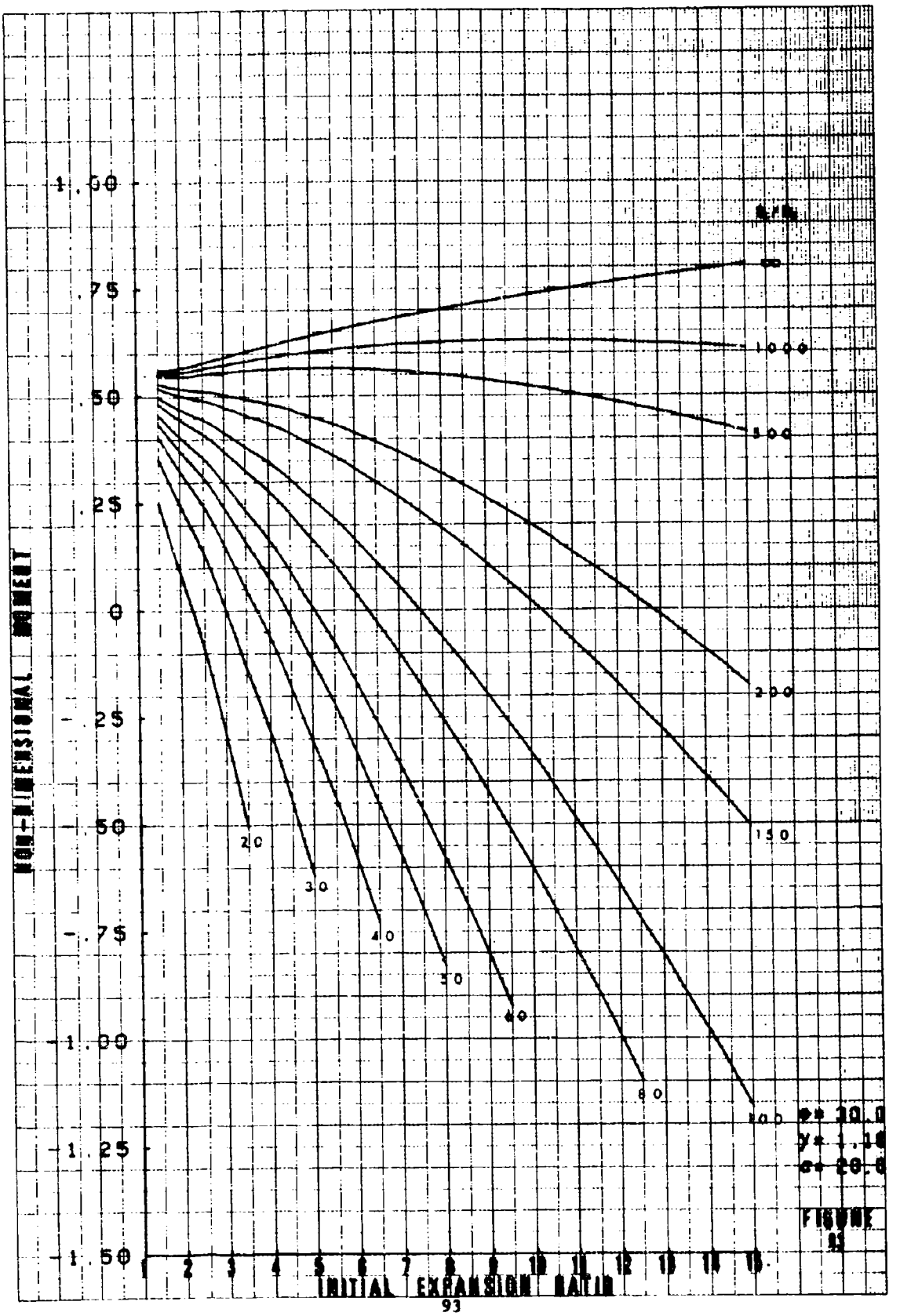
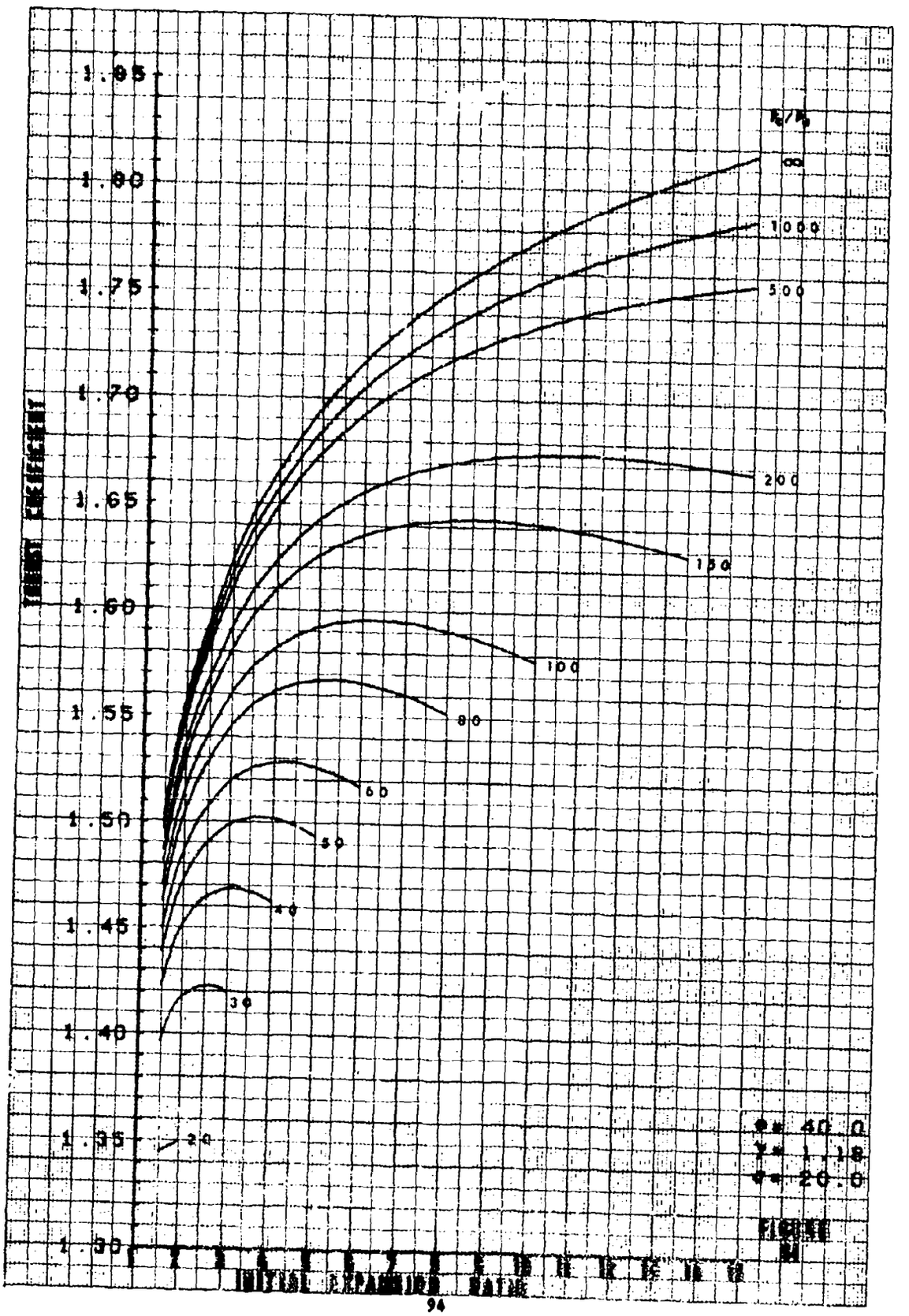

6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
∞
1000
500
200
150
100
50
40
30
20
10
INITIAL EXPANSION RATIO

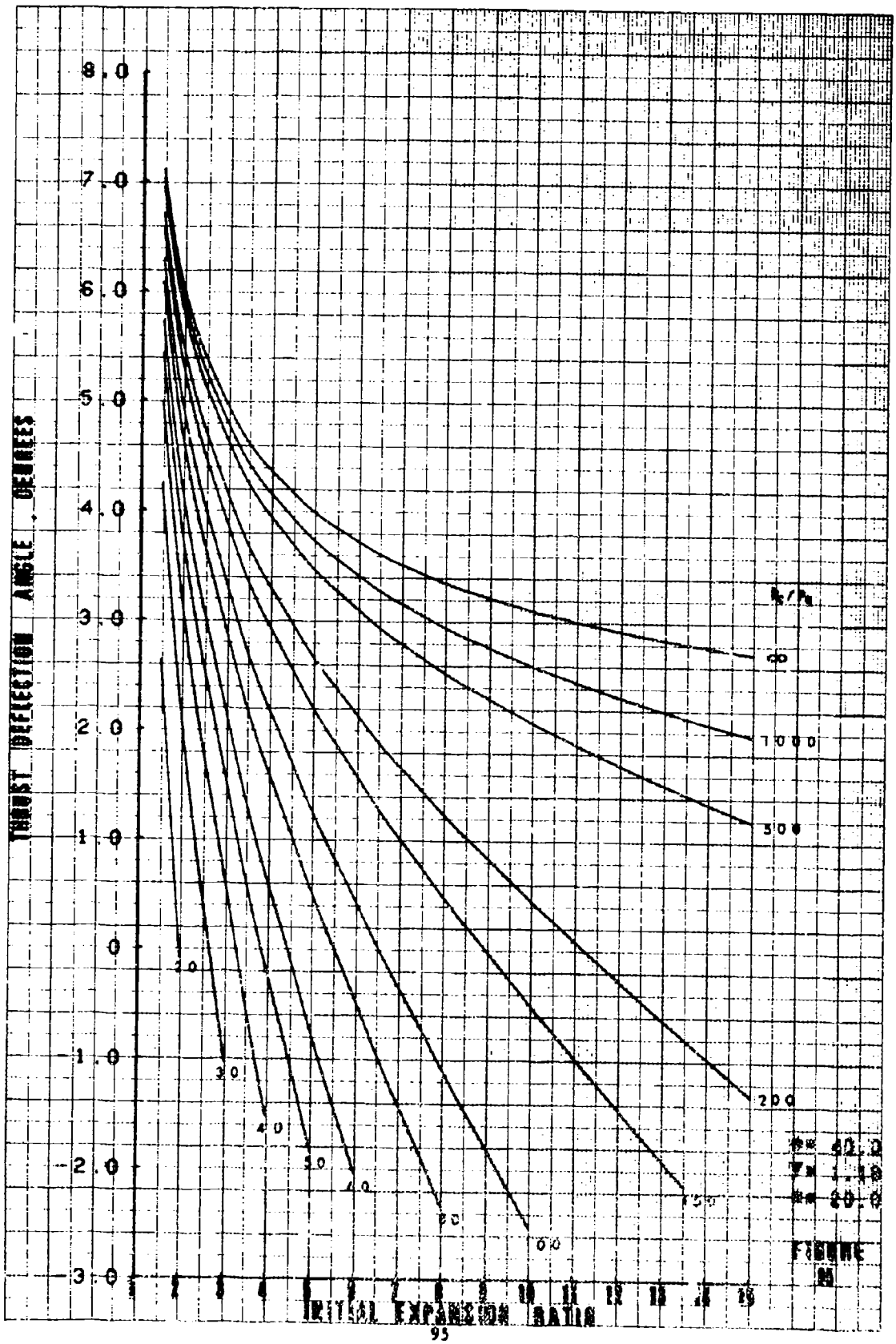
FIGURE 82


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE 11

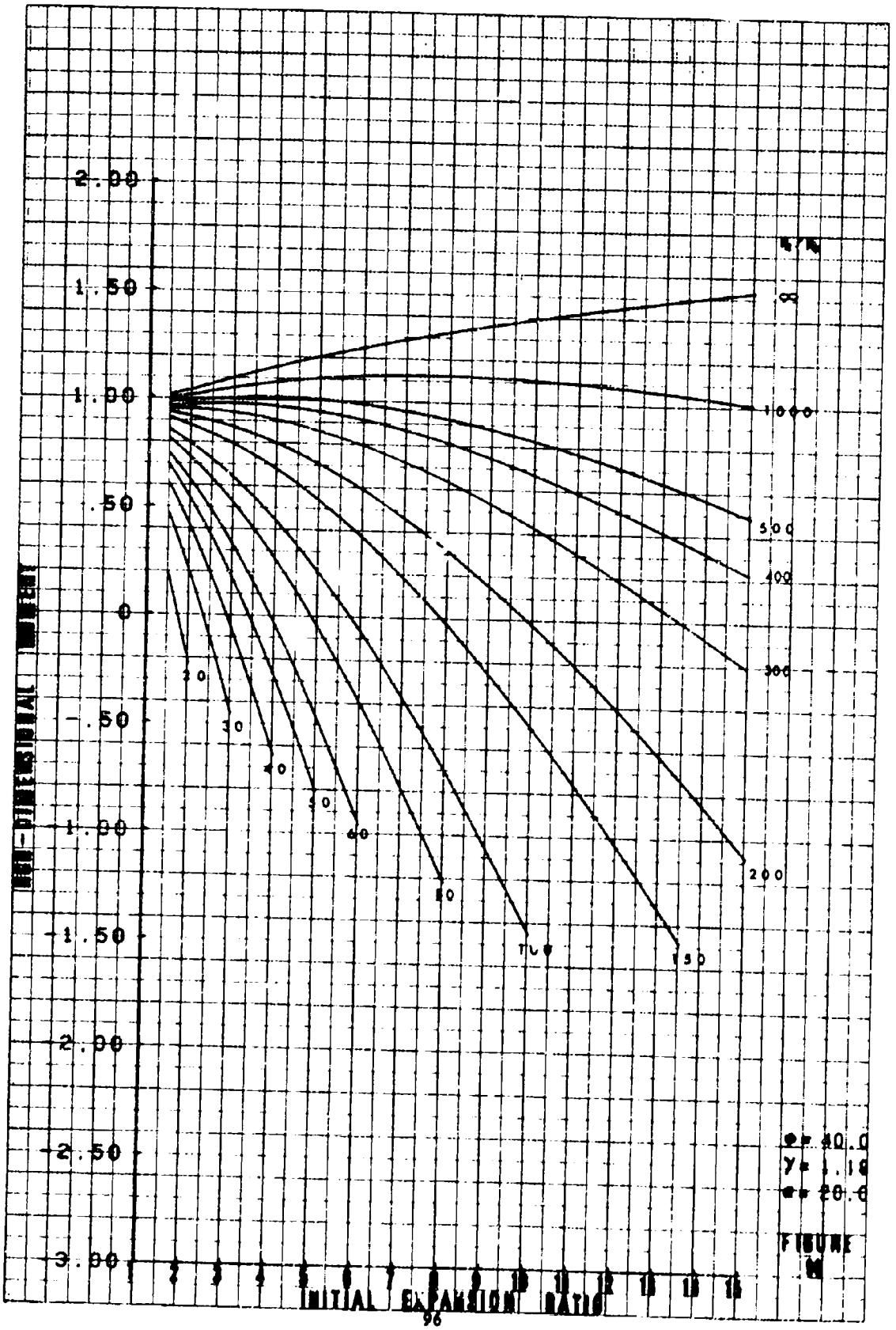


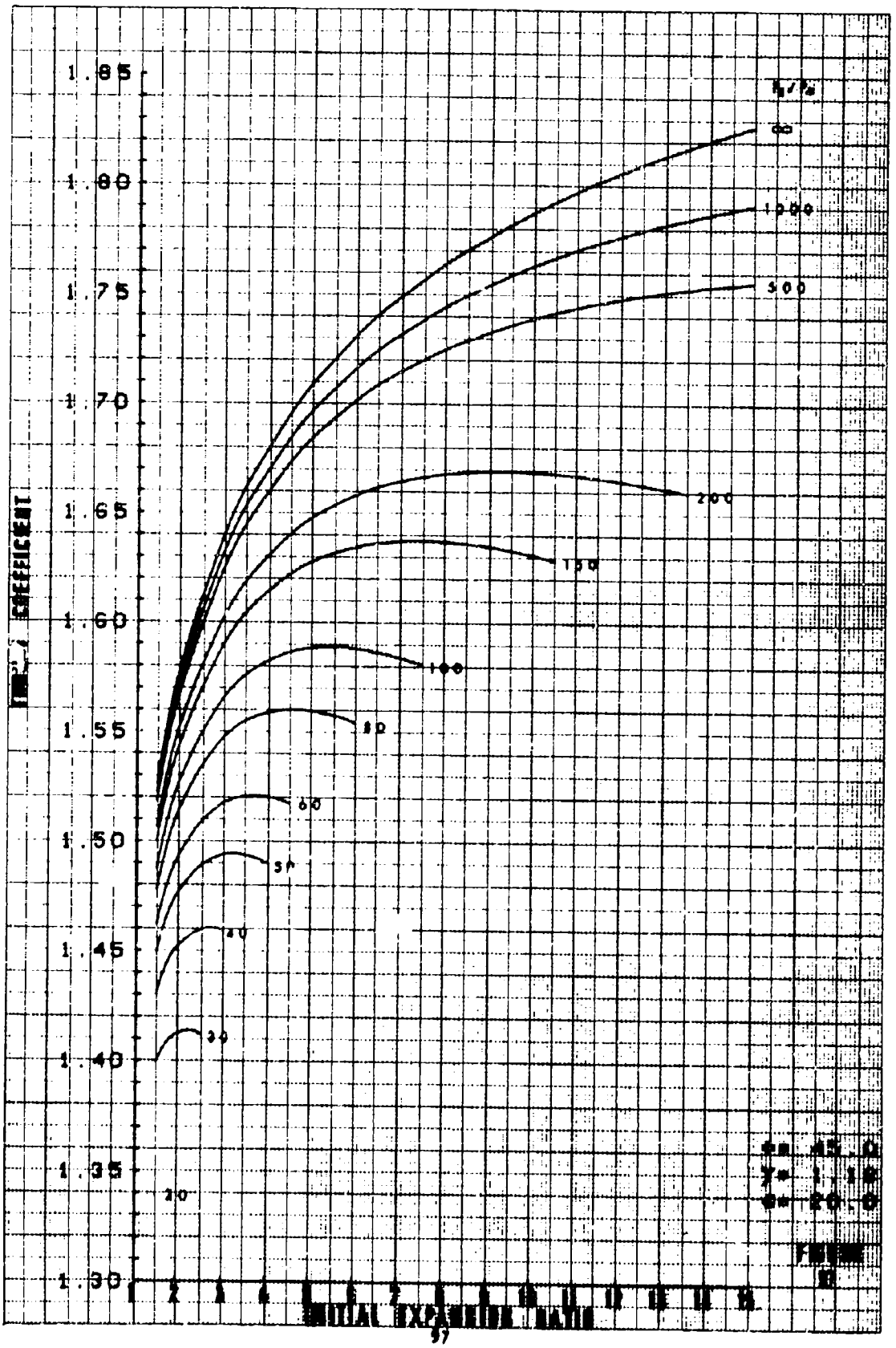
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 40.0
γ= 1.18
σ= 20.0

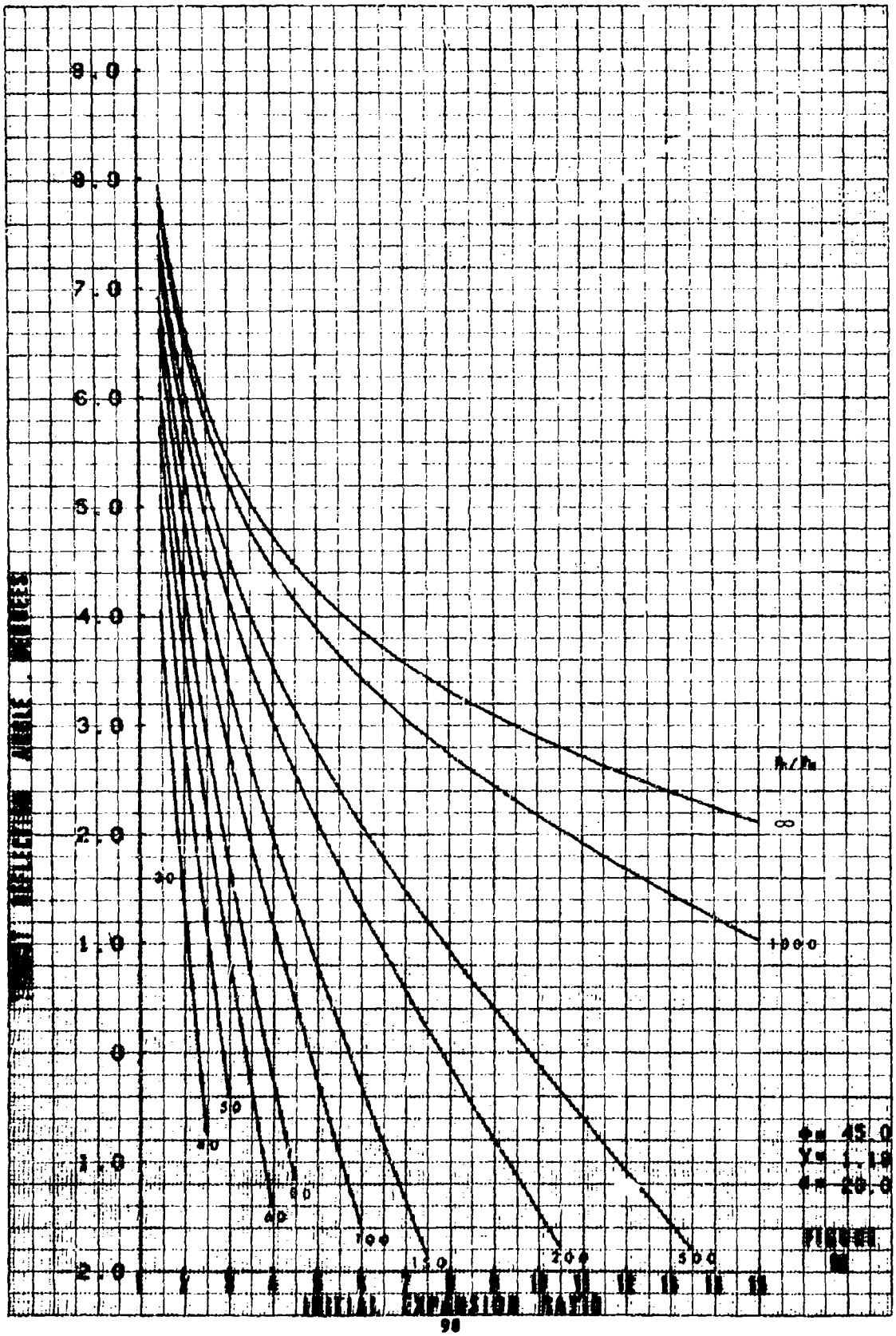
FIGURE 94


THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
40
30
20

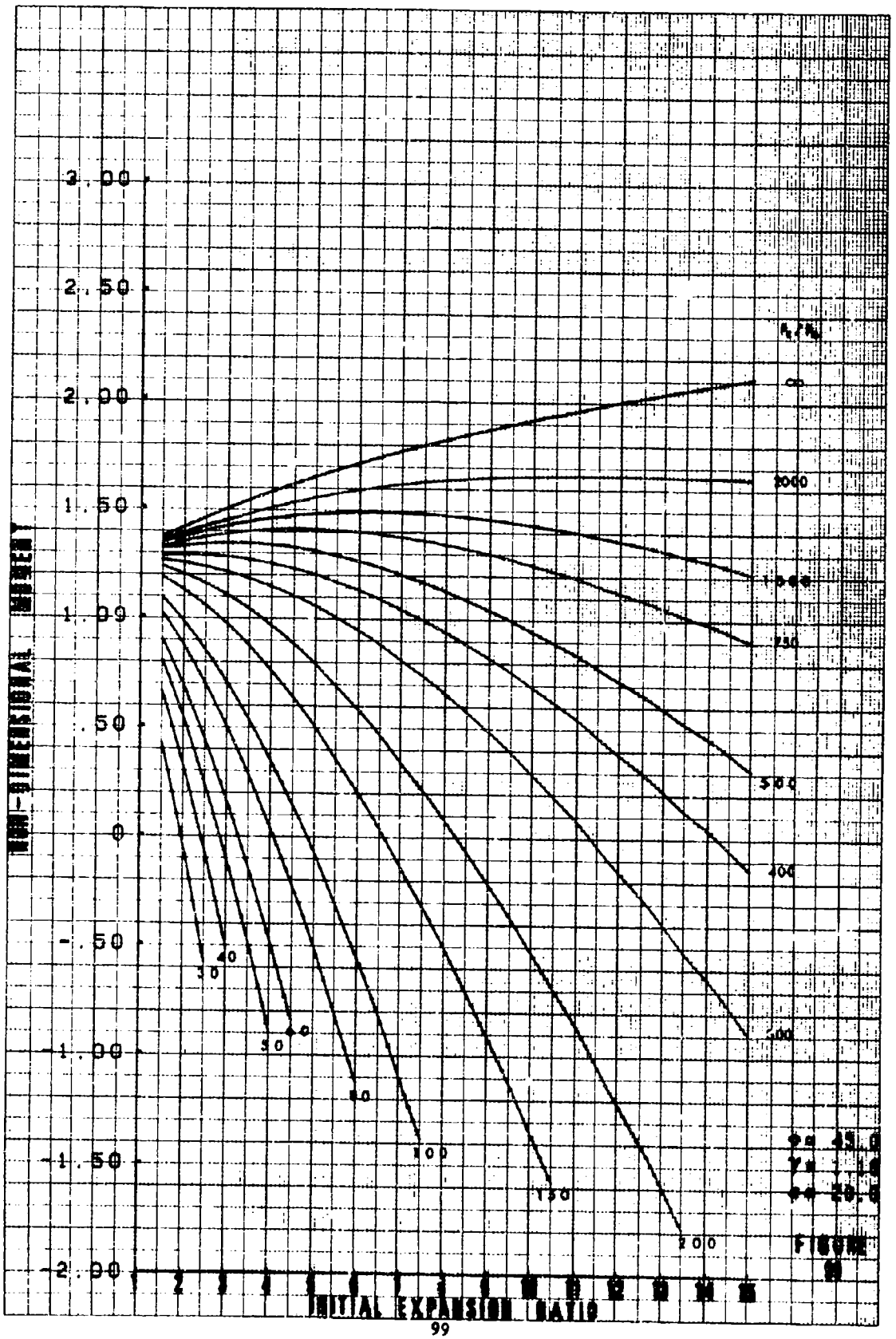
FIGURE


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1000
500
400
300
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
COEFFICIENT
∞
1000
500
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO



9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
30
40
50
60
80
100
150
200
500
1000
∞
INITIAL EXPANSION RATIO



3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40
30

FIGURE

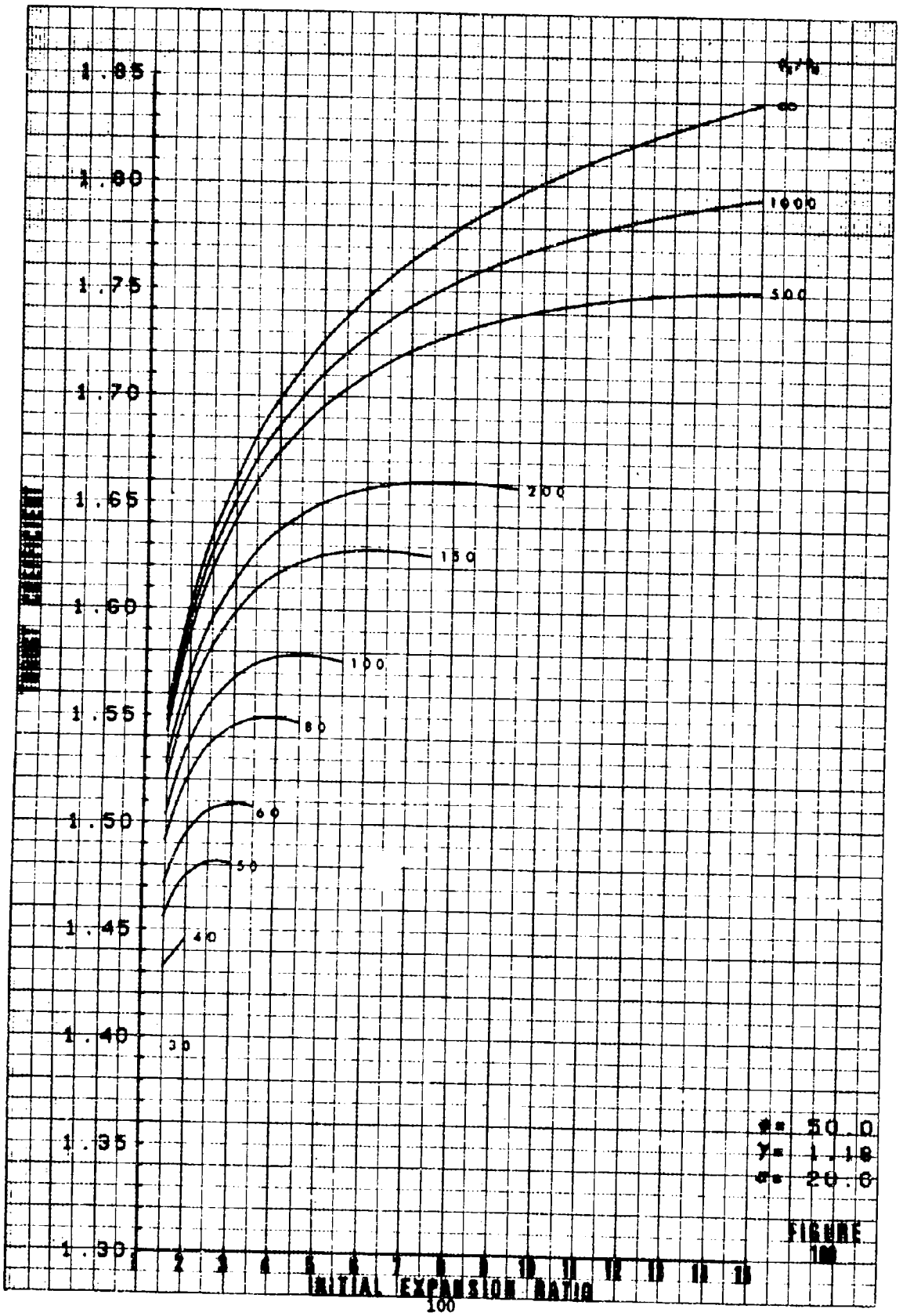

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
φ= 50.0
γ= 1.18
σ= 20.0

FIGURE 100

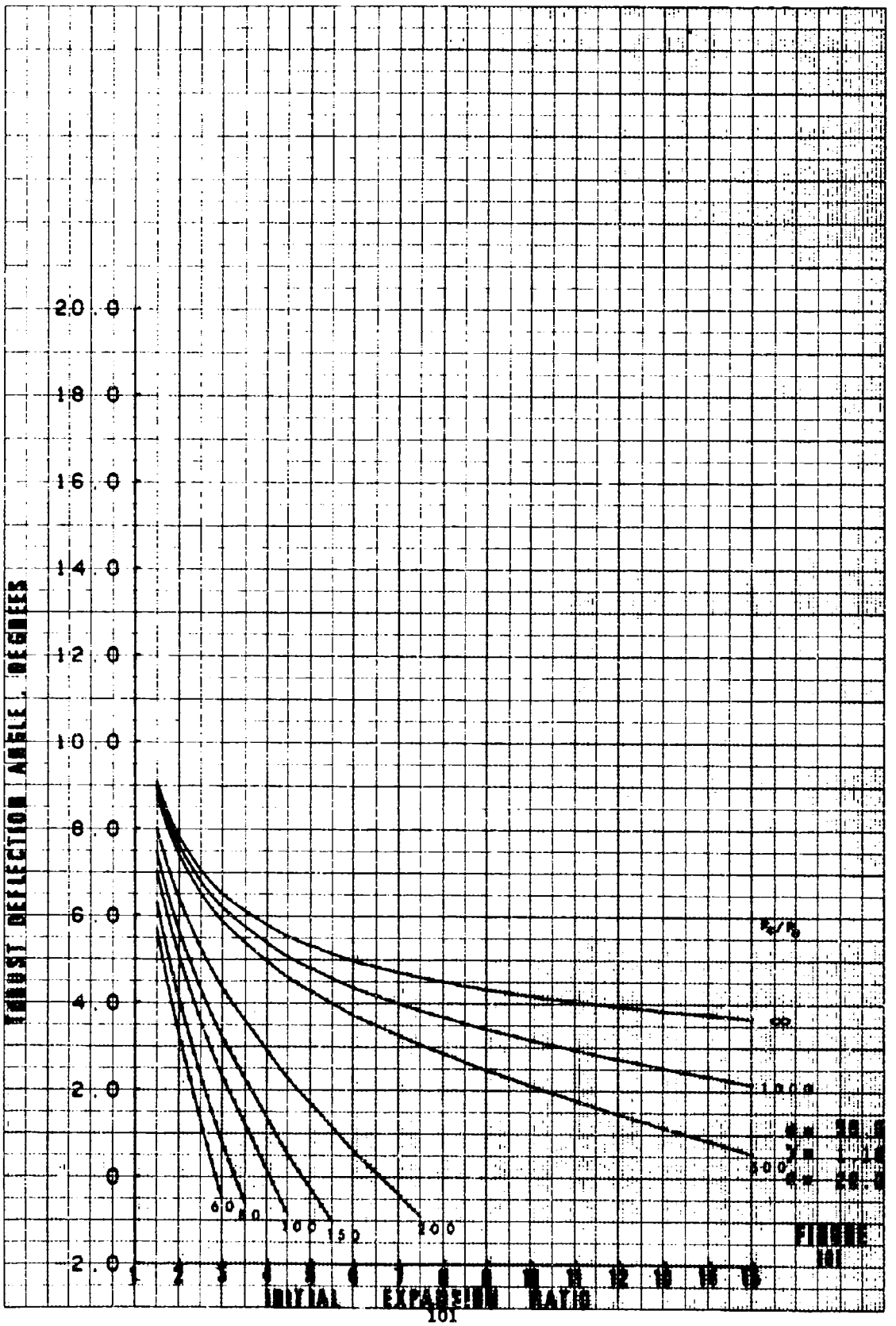

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
60
80
100
150
200
∞
1000
500

FIGURE 101

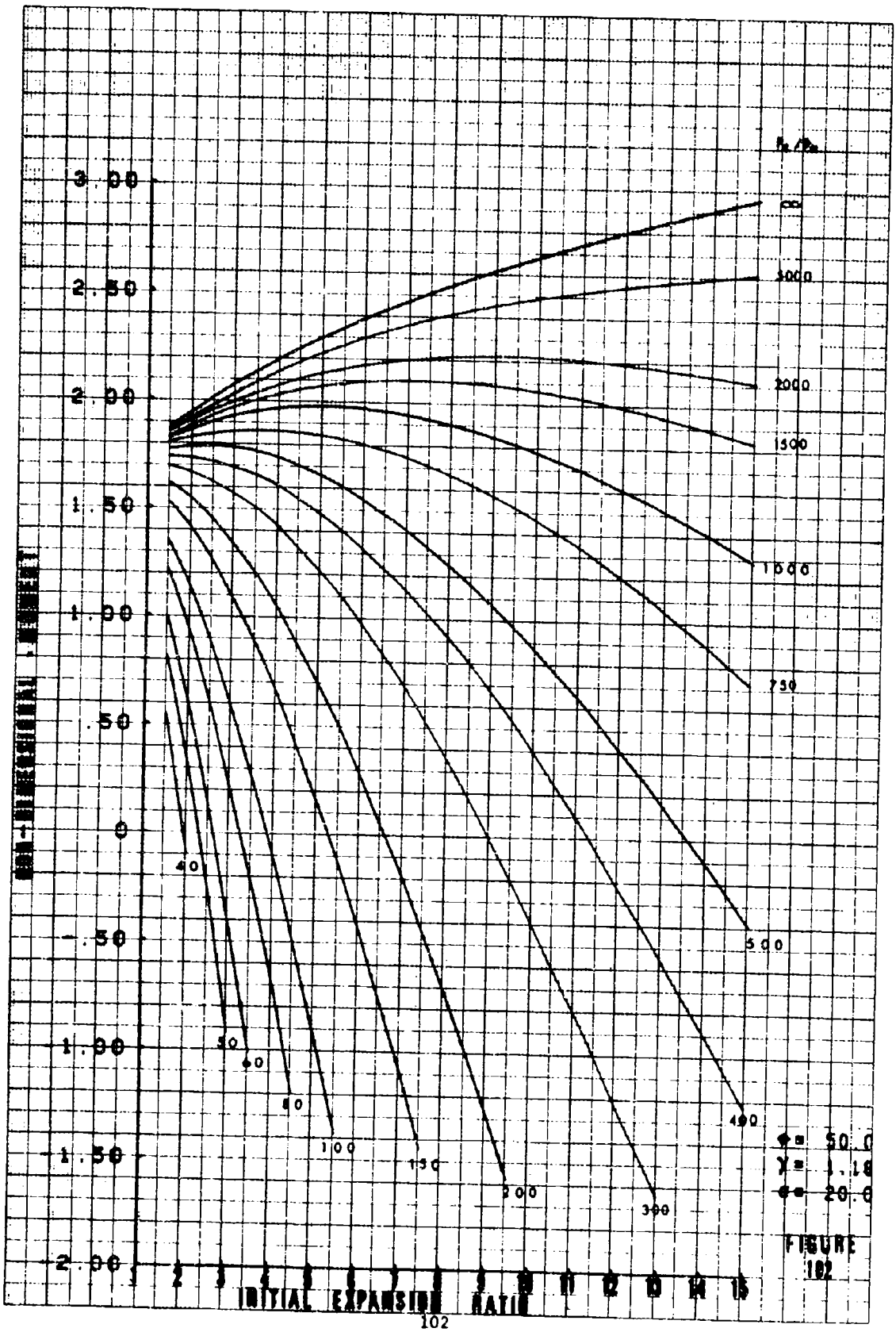

3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
3000
2000
1500
1000
750
500
400
300
200
150
100
80
60
50
40

FIGURE 102

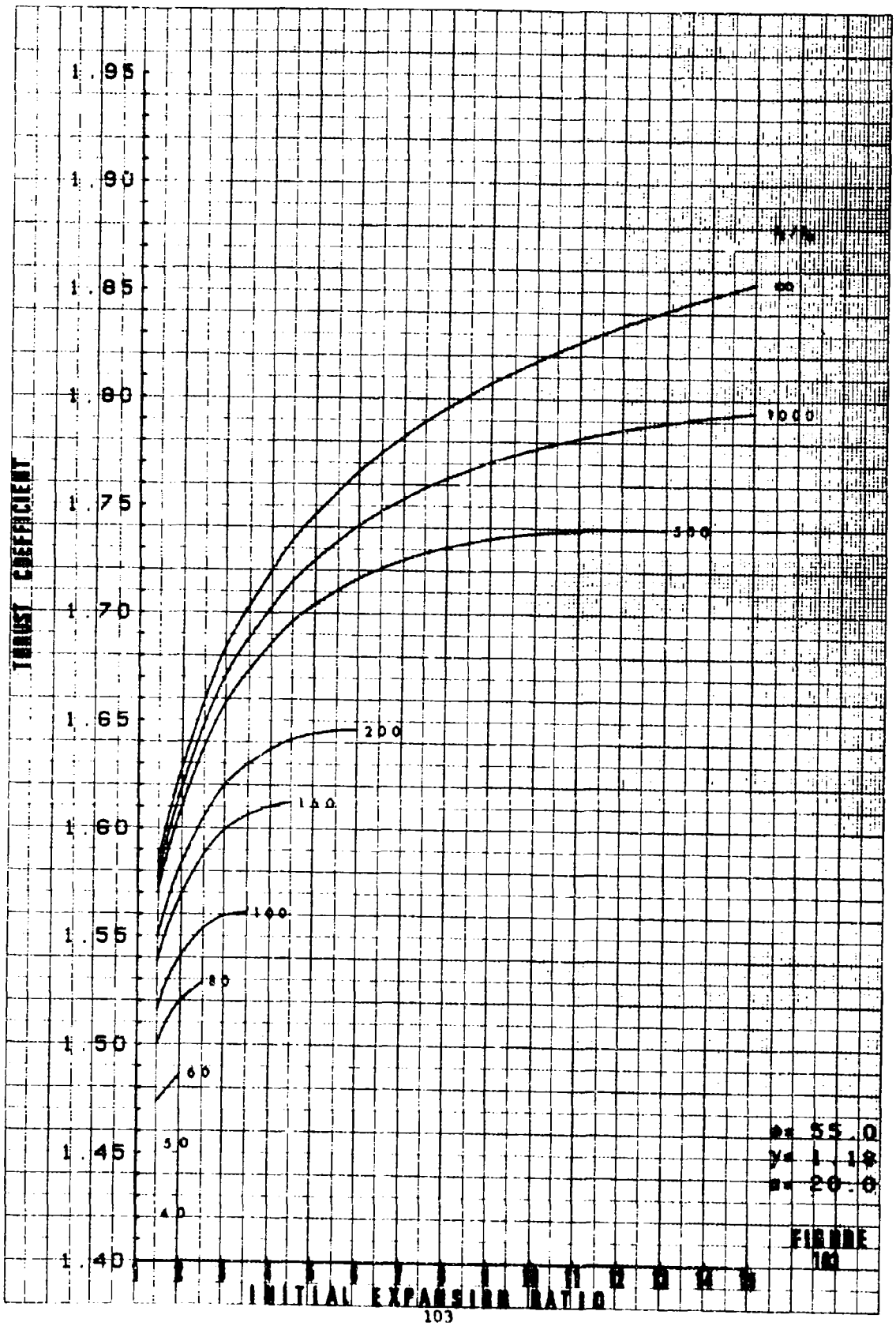

THRUST COEFFICIENT
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
φ= 55.0
γ= 1.10
α= 20.0

FIGURE 10

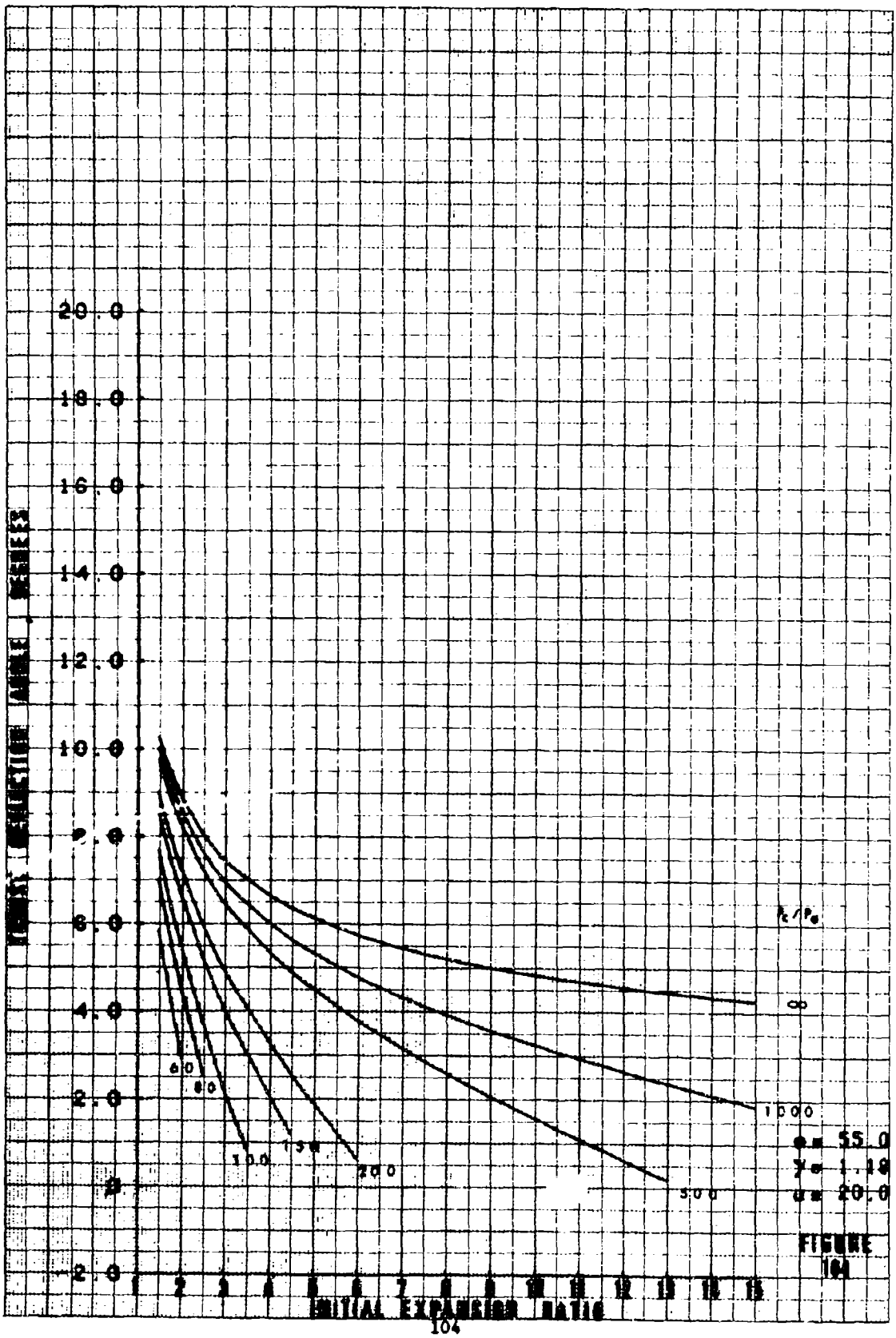
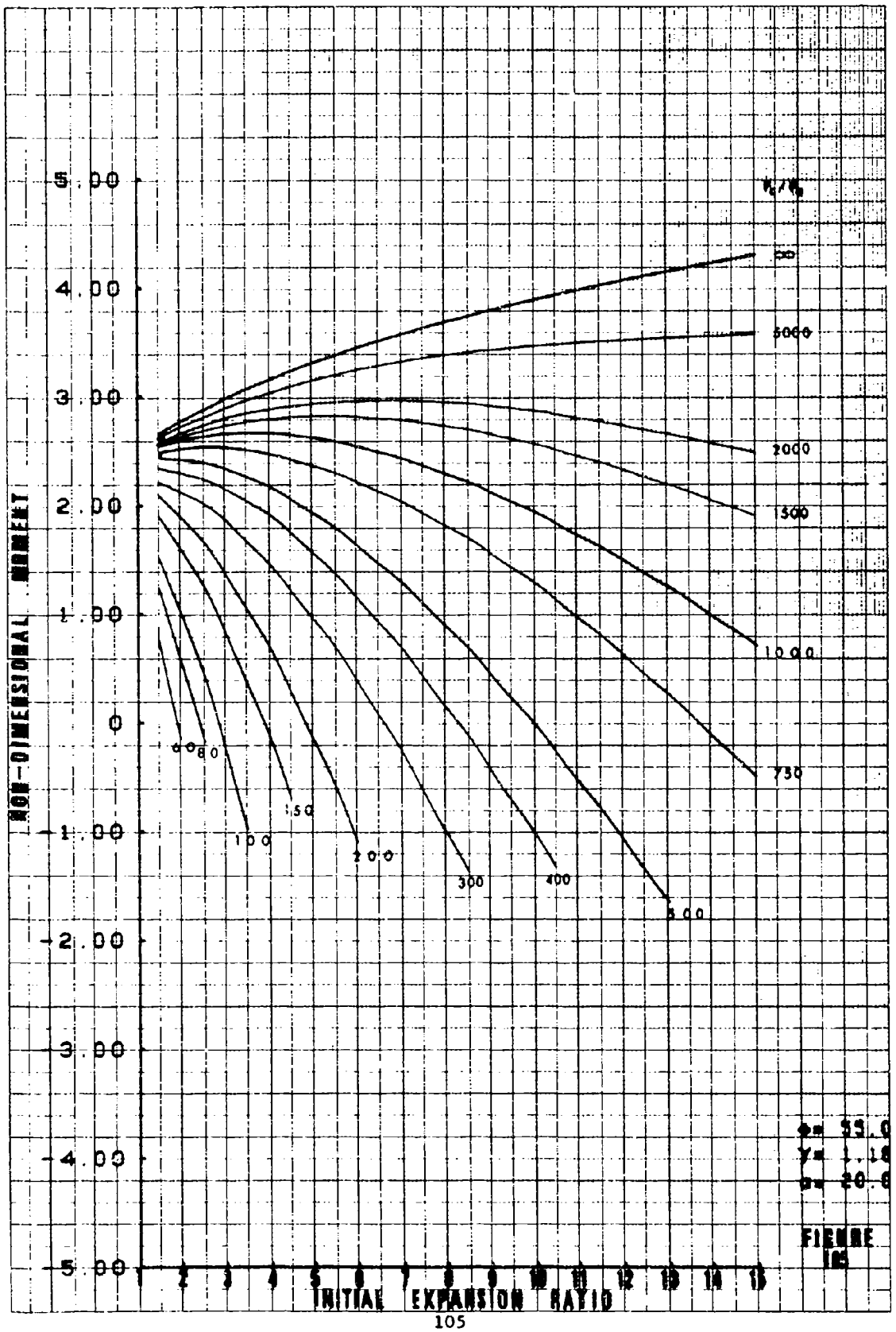
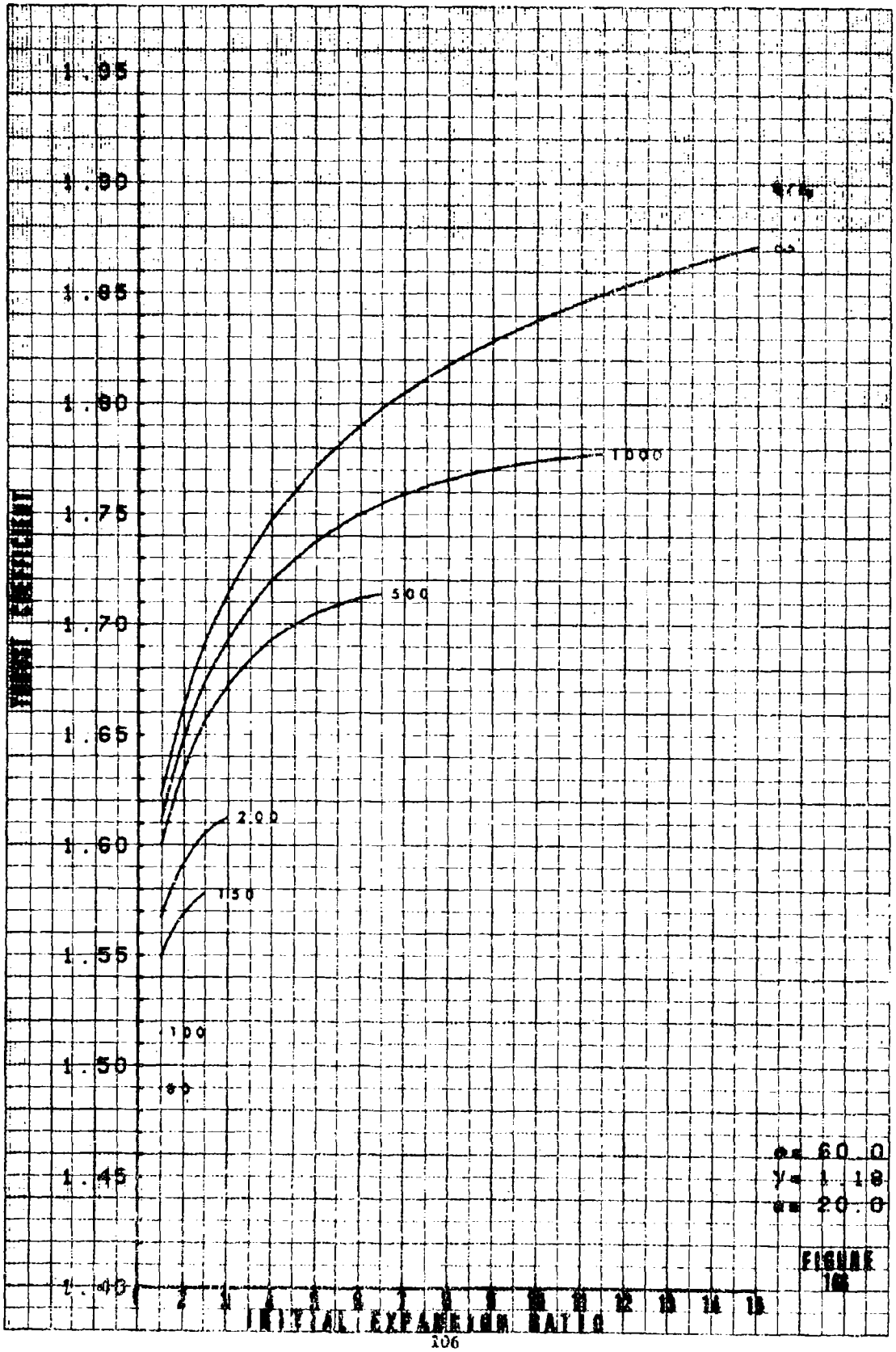
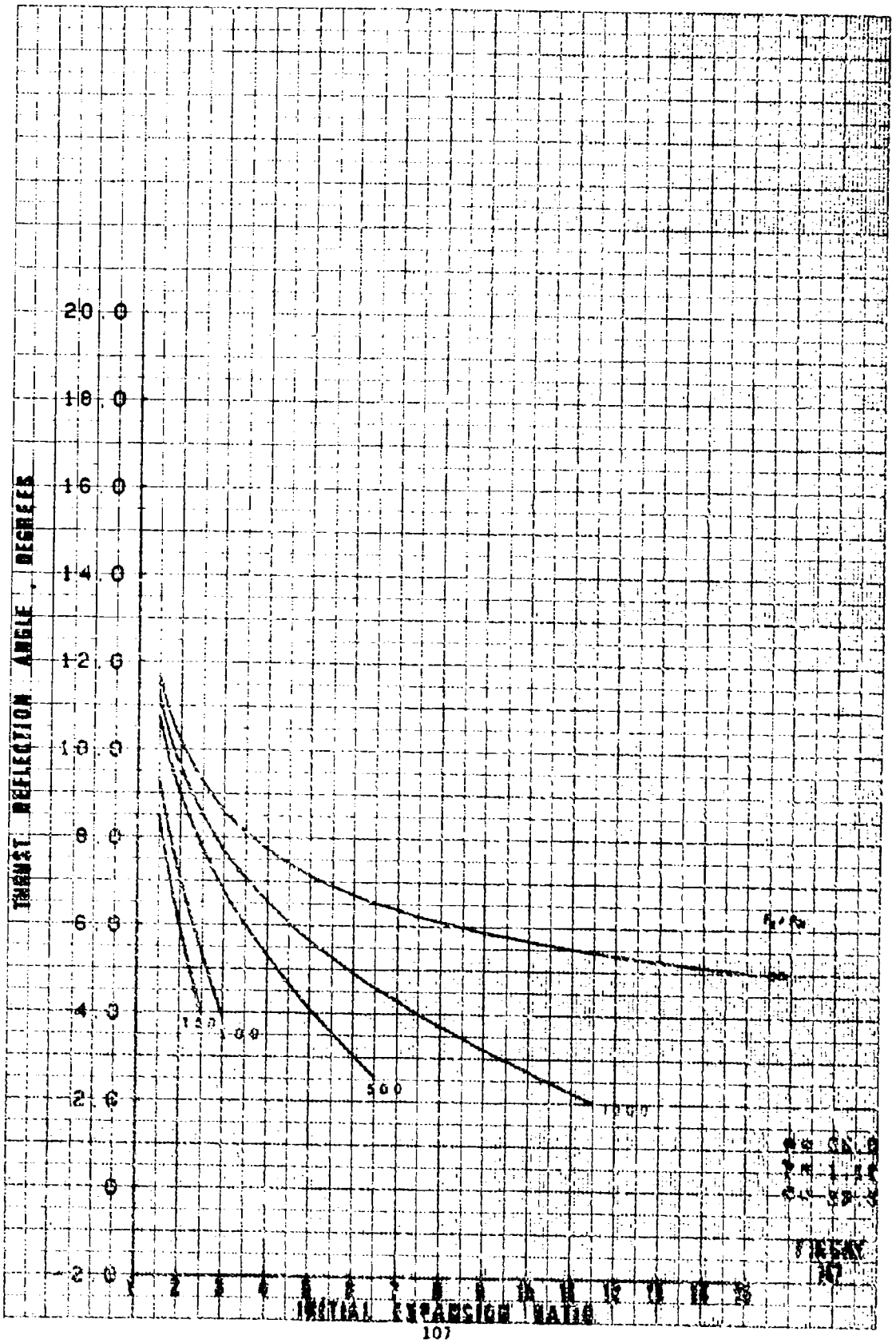
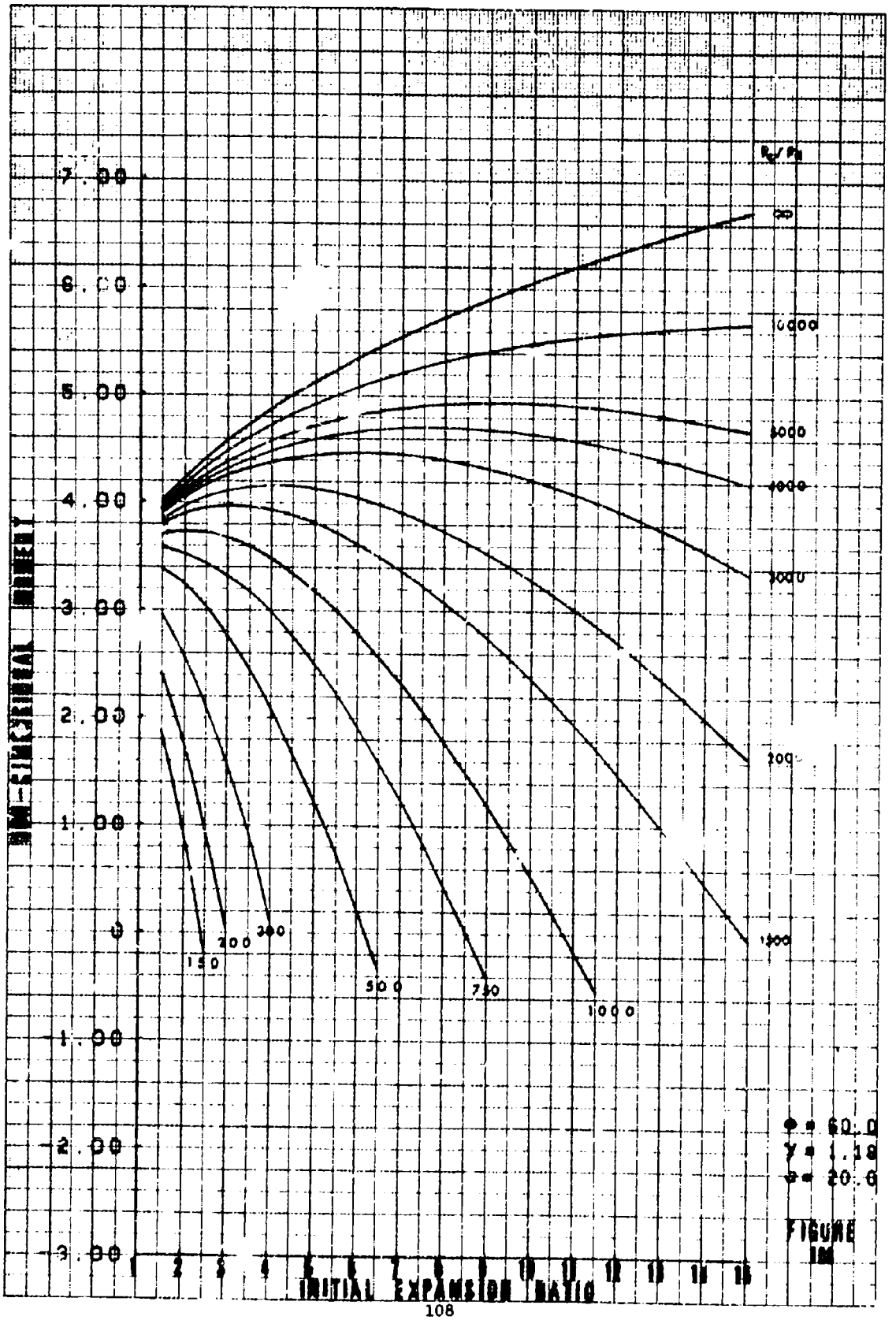

20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
e = 55.0
γ = 1.18
α = 20.0

FIGURE 104

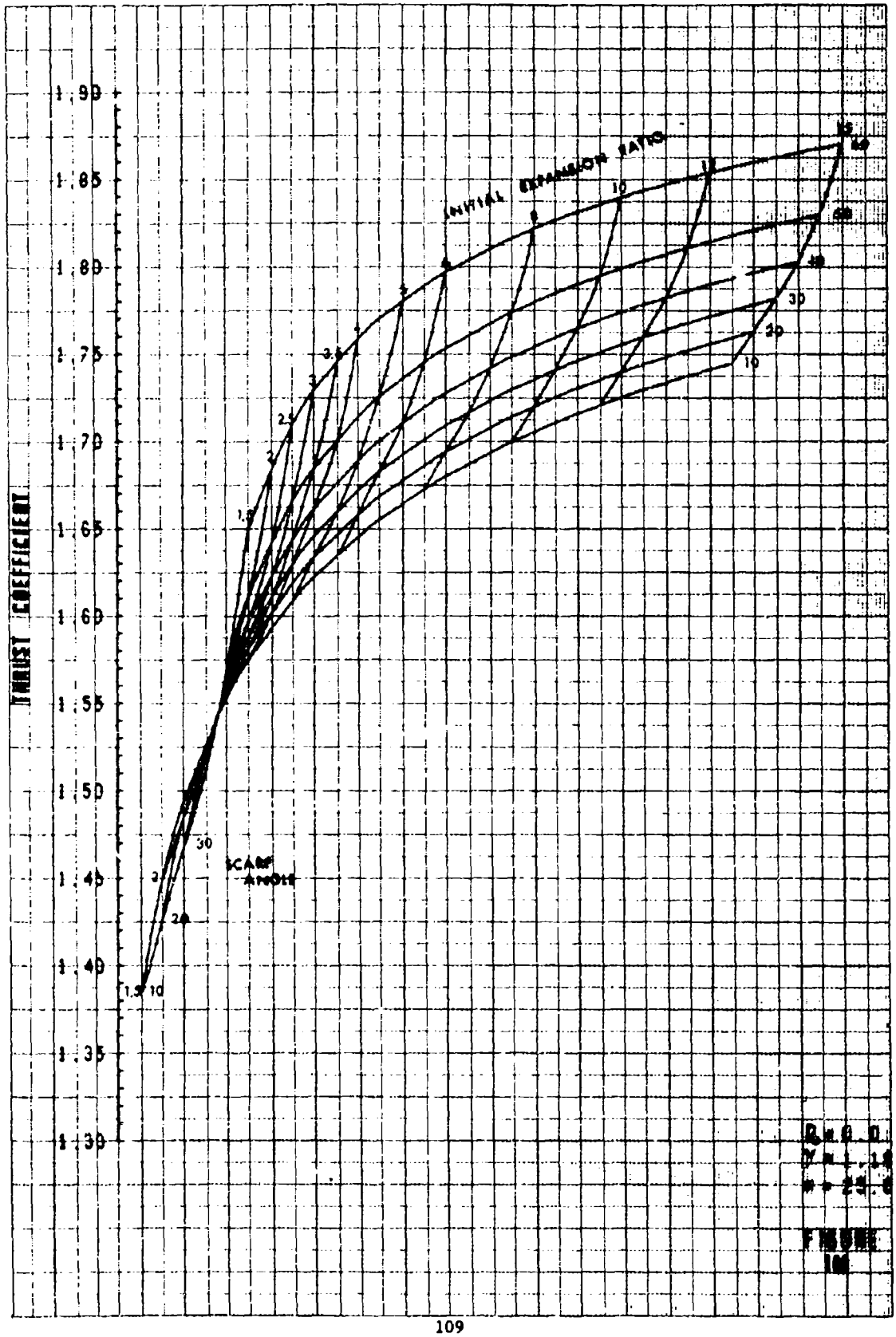

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
5000
2000
1500
1000
750
500
400
300
200
150
100
80
60
FIGURE 16

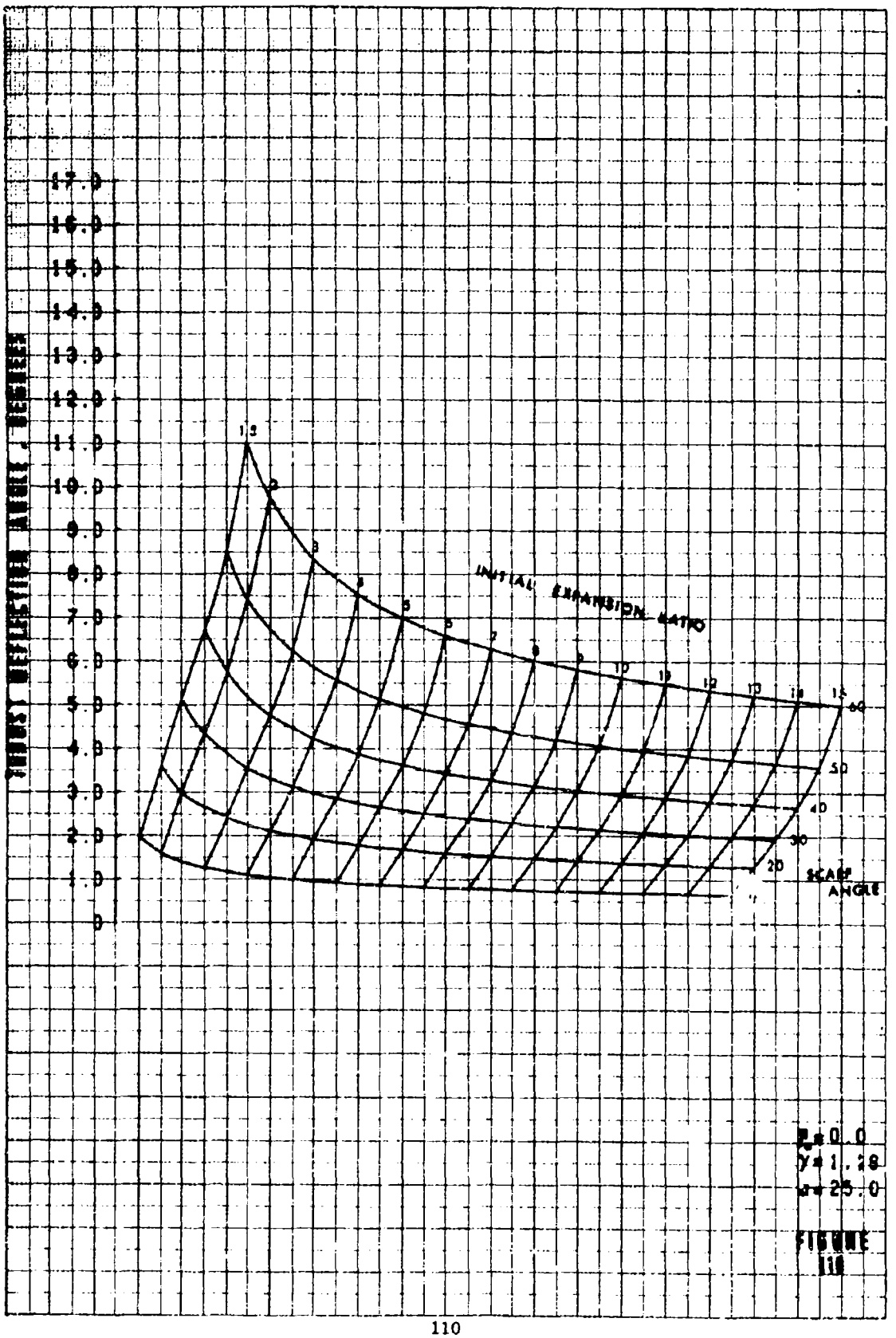

1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
THRUST COEFFICIENT
1000
500
200
150
100
80
INITIAL EXPANSION RATIO
α= 60.0
γ= 1.18
α= 20.0
FIGURE
106


THRUST REFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
150
100
500
1000
INITIAL EXPANSION RATIO



7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
φ = 60.0
γ = 1.18
α = 20.6
FIGURE


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE 16



17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
60
50
40
30
20
SCARF ANGLE

FIGURE 110

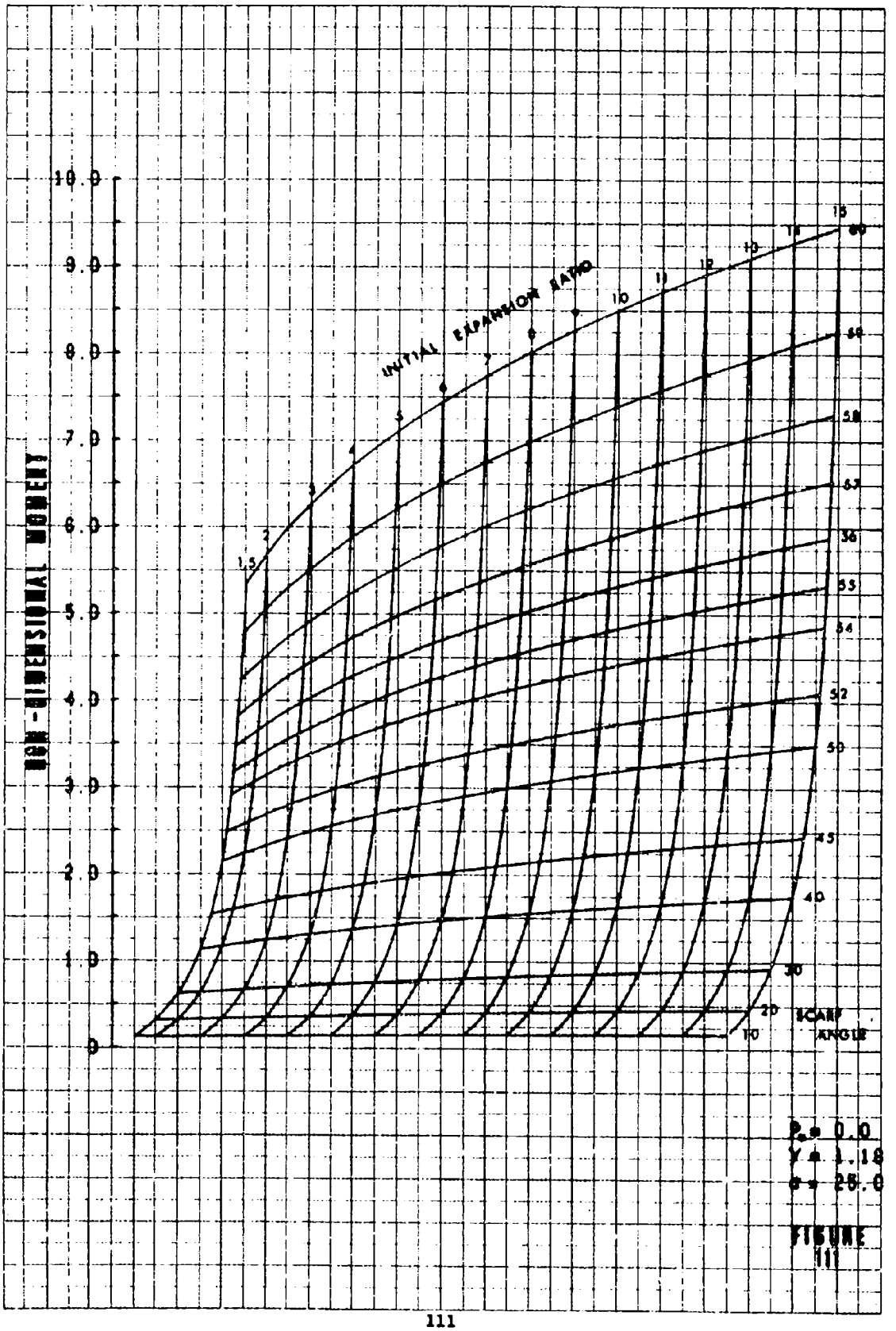

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
SCARF ANGLE
P_o = 0.0
γ = 1.18
σ = 25.0

FIGURE 111

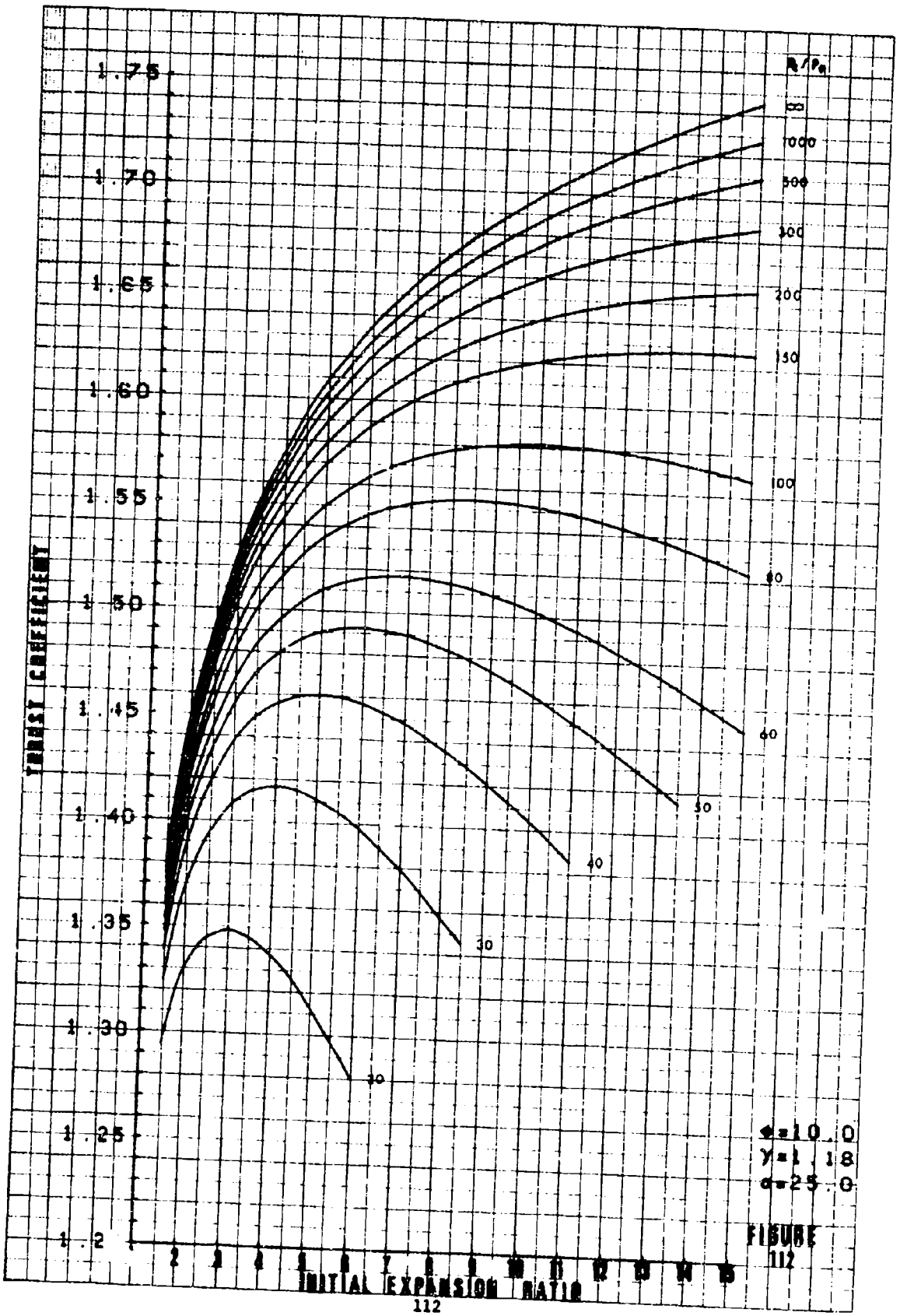

THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.2
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ε=10.0
γ=1.18
α=25.0

FIGURE 112

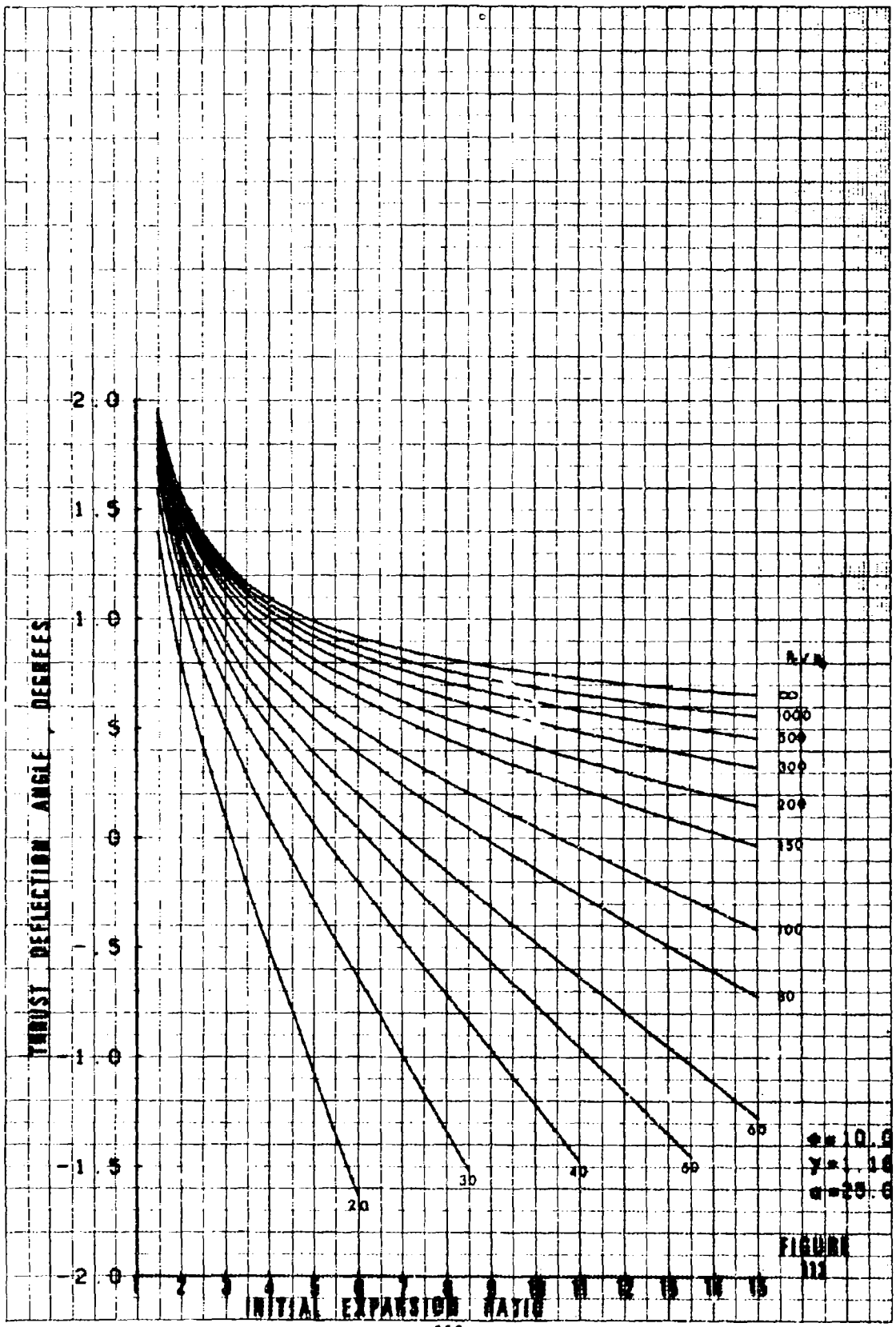
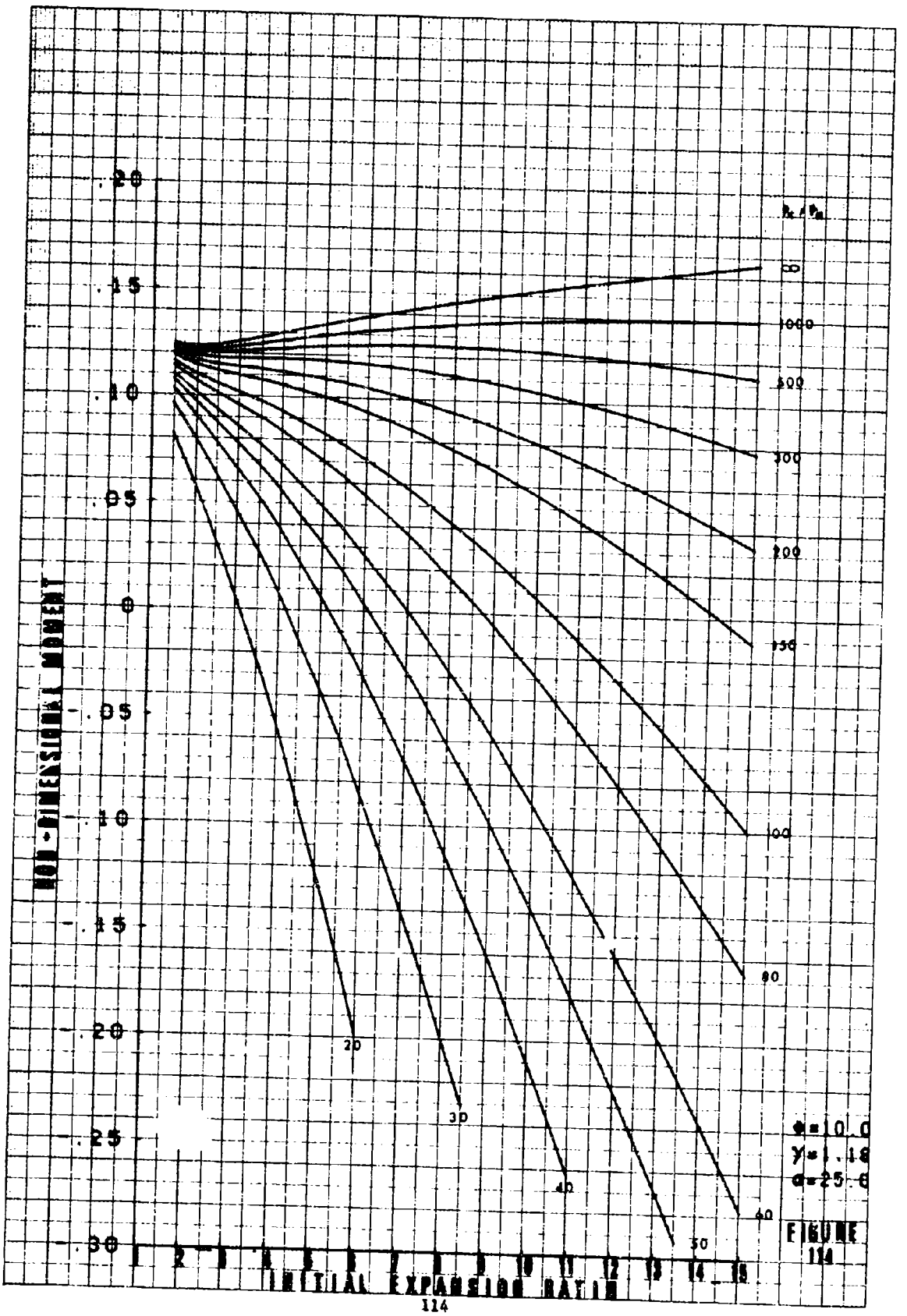

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
300
500
1000
∞

FIGURE 113


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
300
500
1000
∞
γ=1.18
FIGURE
114

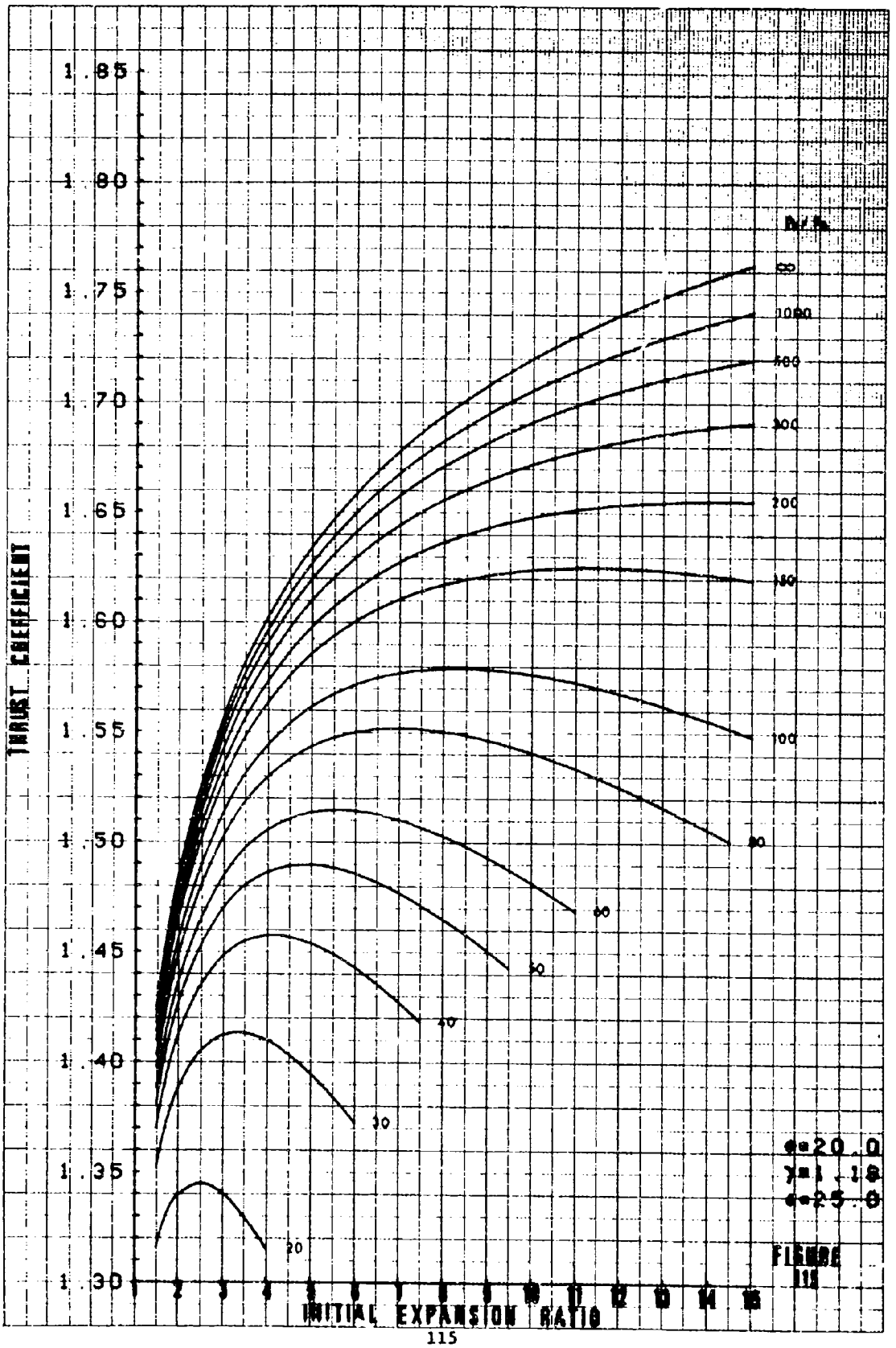

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.18
ε=25.0

FIGURE 115

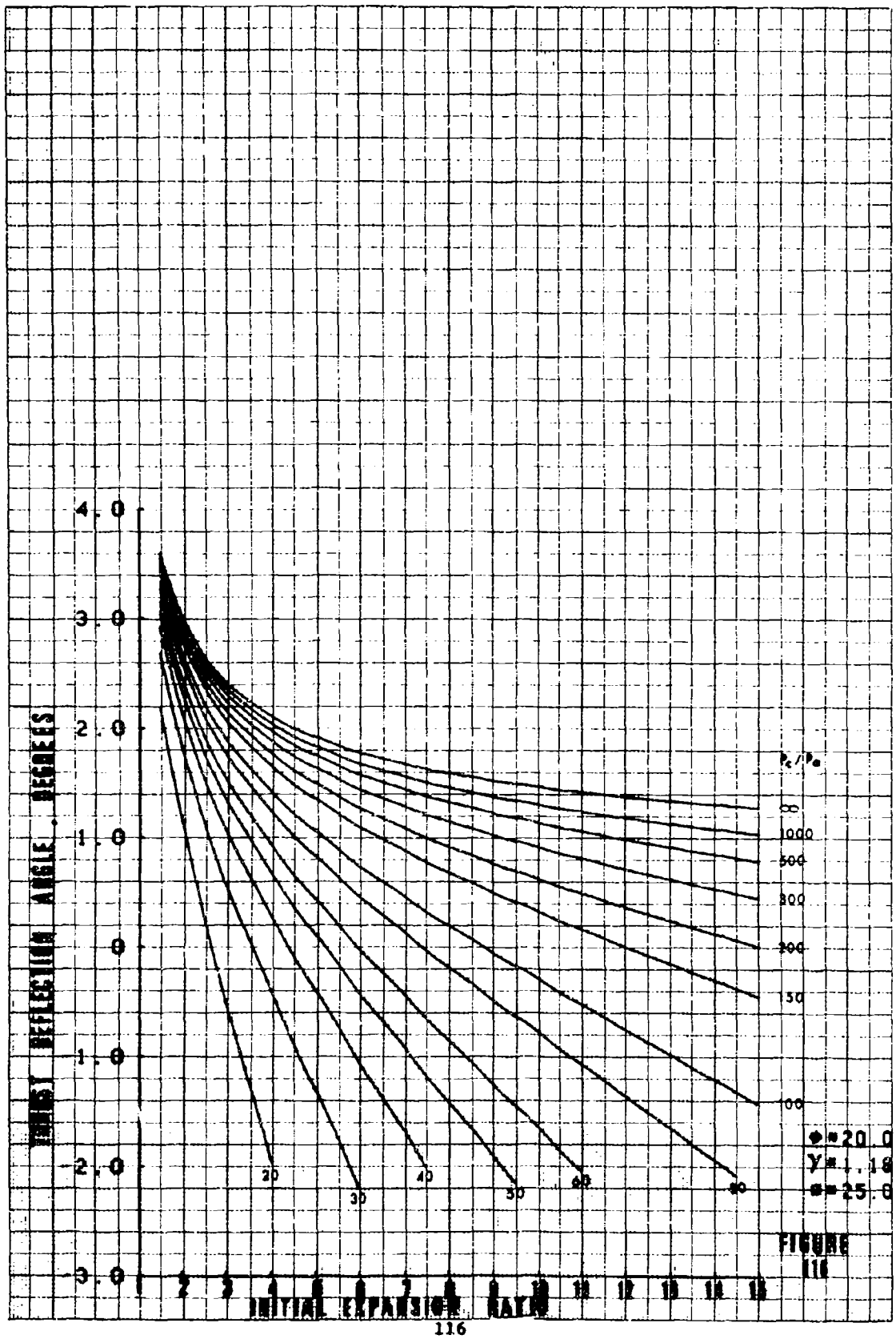

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
1.0
2.0
3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
20
30
40
50
60
80
φ=20.0
γ=1.18
θ=25.0

FIGURE 116

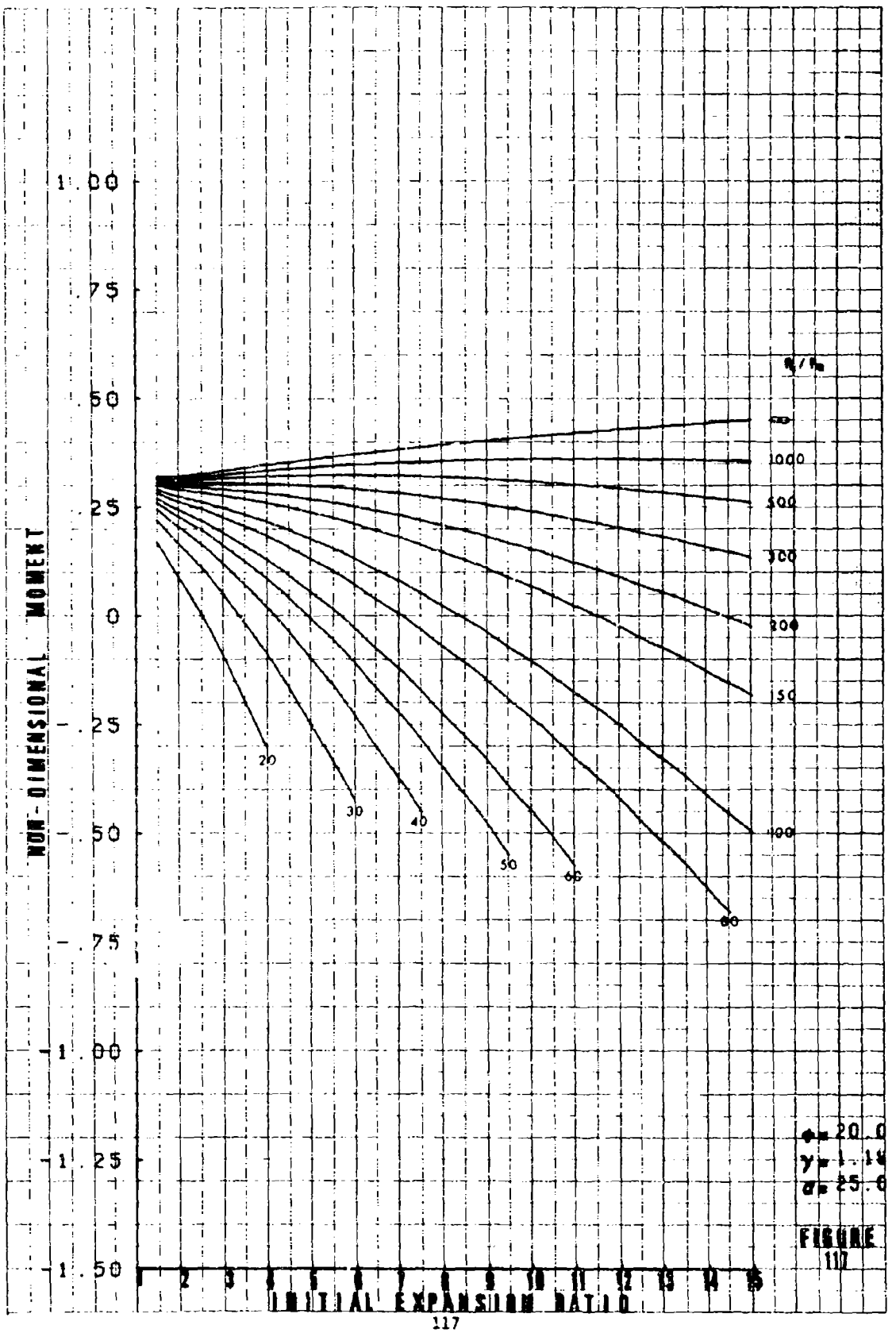
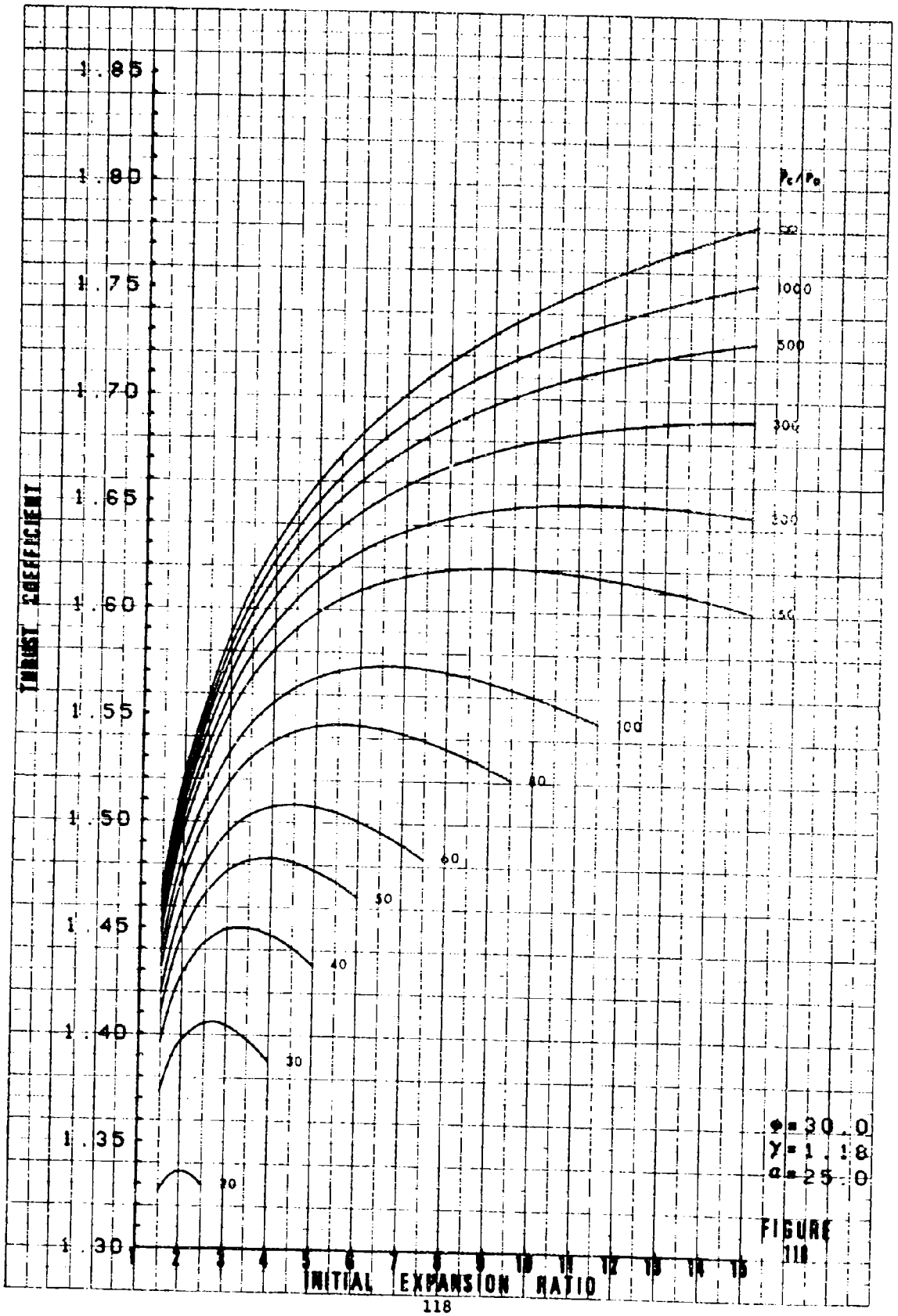
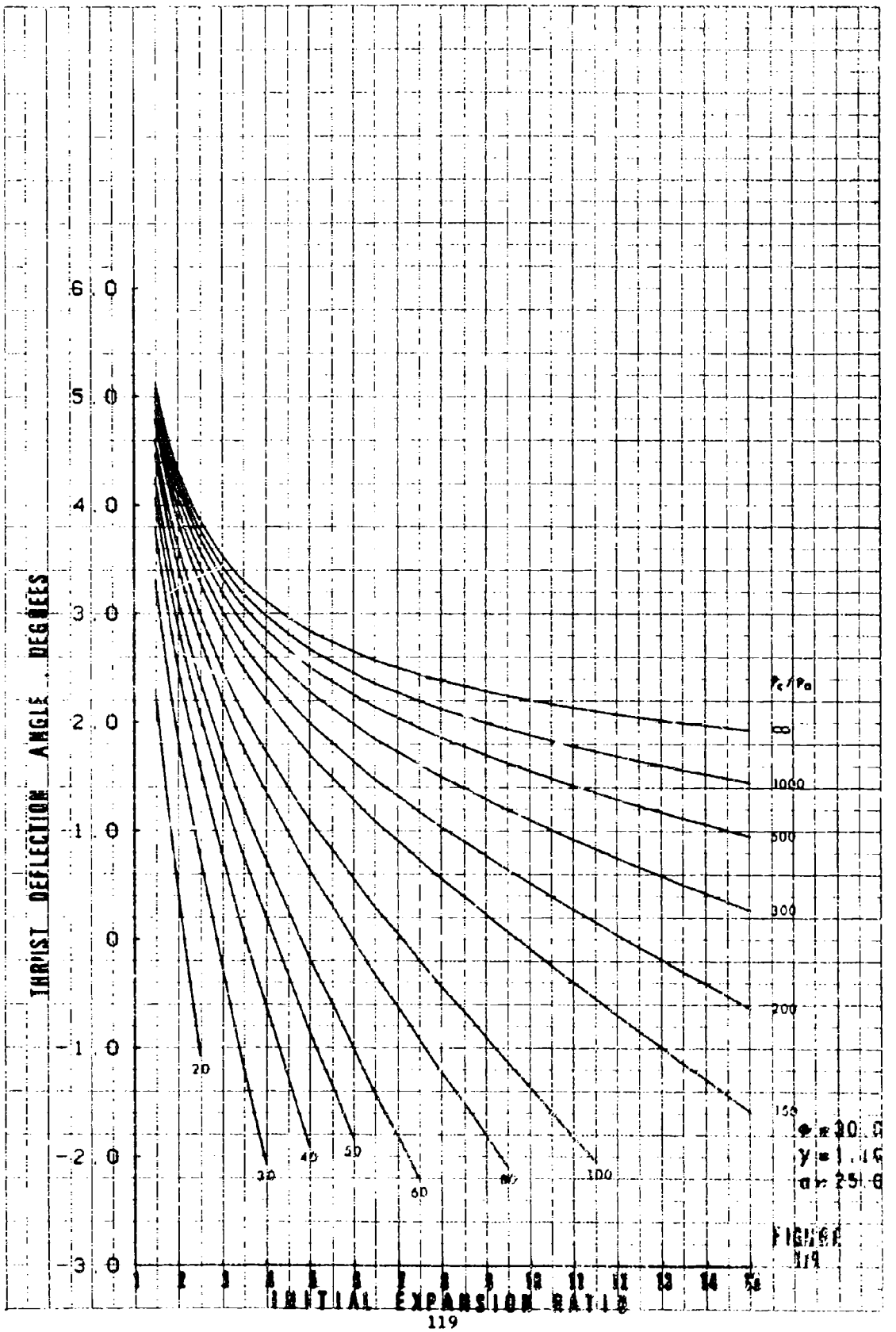

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.18
σ = 25.0

FIGURE 117



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.18
α = 25.0

FIGURE 118


THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
20
30
40
50
60
100
FIGURE 119

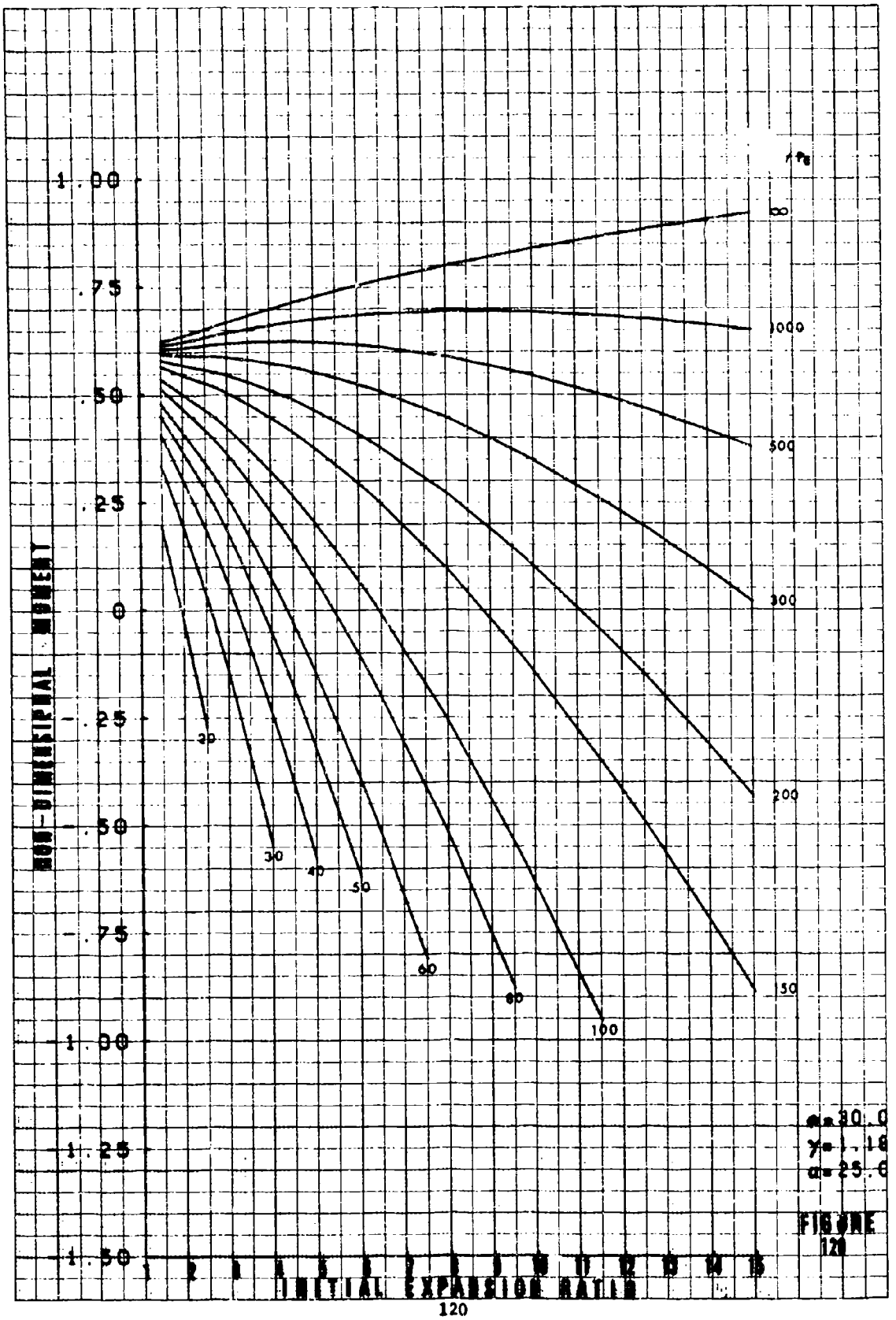

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
r/r_0
∞
1000
500
300
200
150
20
30
40
50
60
80
100
α=30.0
γ=1.18
a=25.6

FIGURE 120

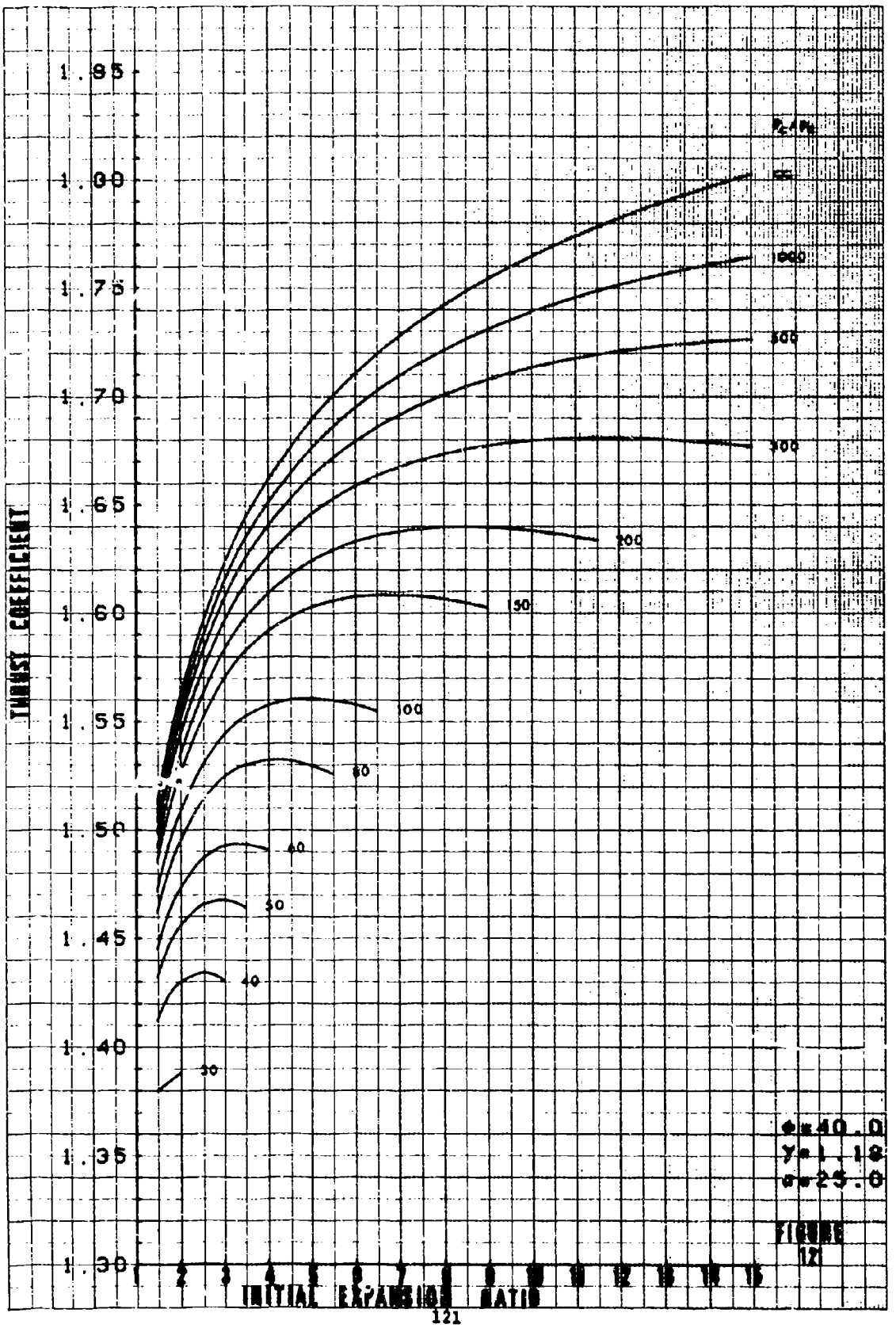
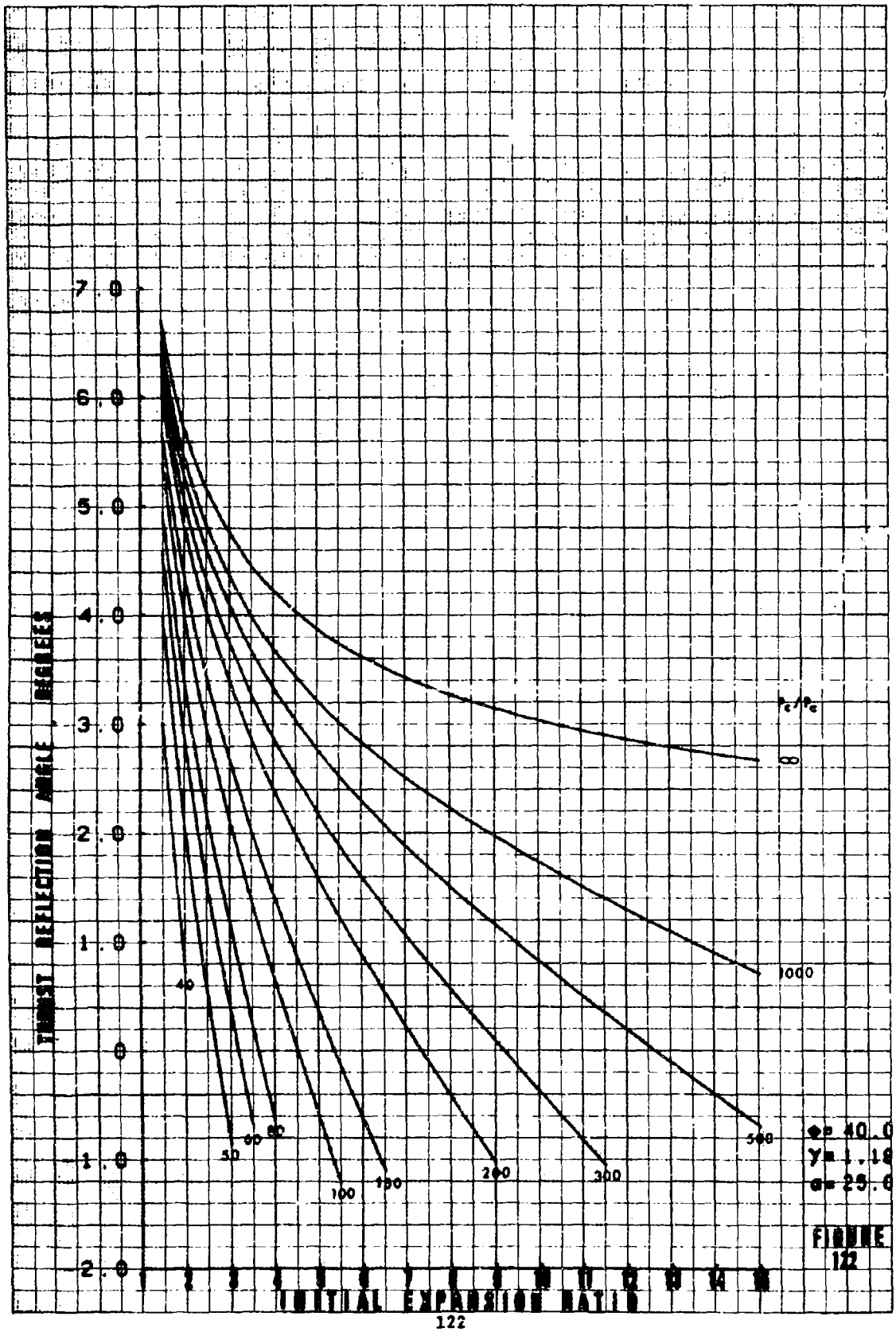

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
300
200
150
100
80
60
50
40
30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 12 13 14 15
φ=40.0
γ=1.18
α=25.0

FIGURE 12



7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
THRUST REFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
300
200
150
100
80
60
50
40
Φ= 40.0
γ= 1.18
α= 25.0

FIGURE 122

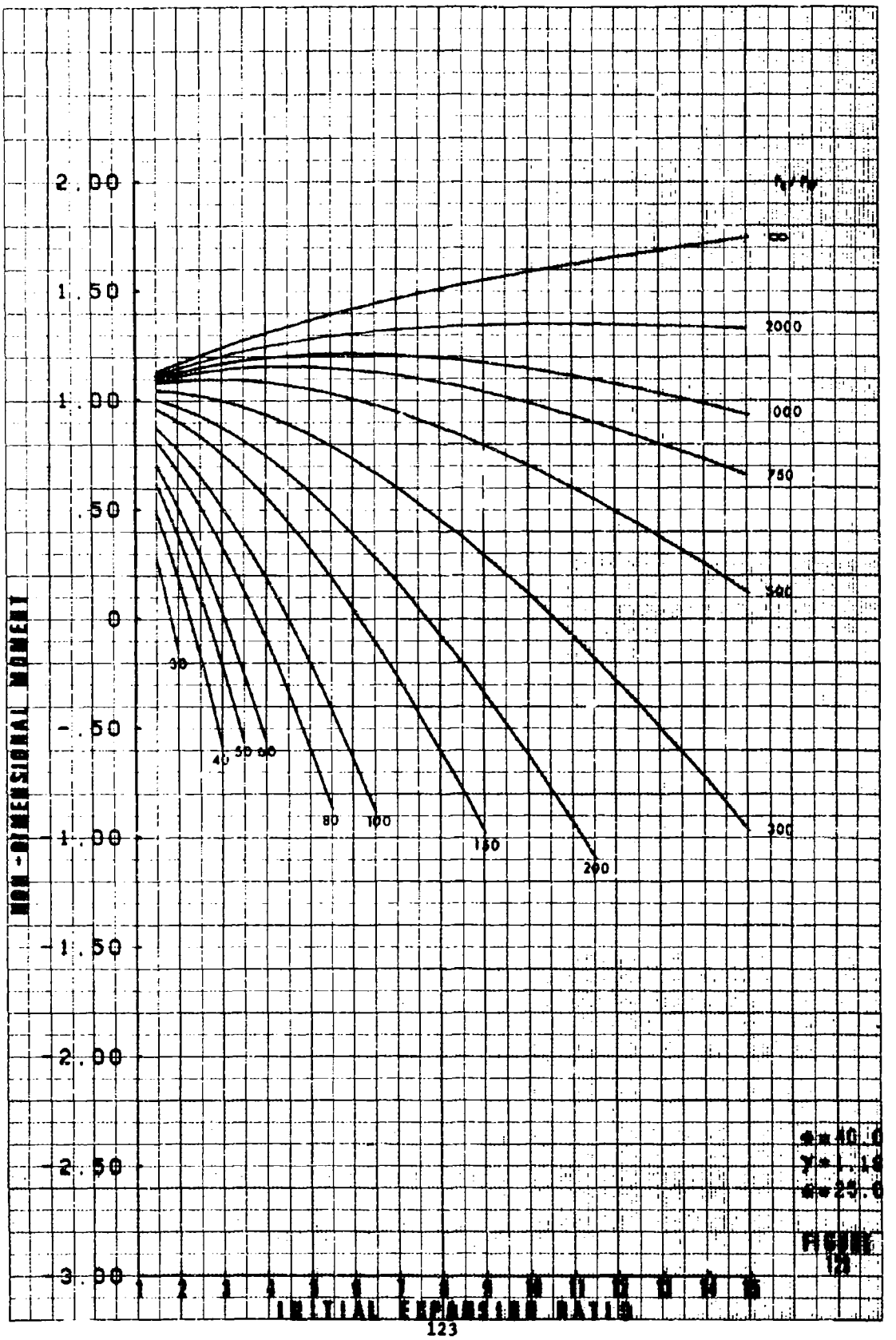

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
∞
2000
1000
750
500
300
30
40
50
60
80
100
150
200

FIGURE 13

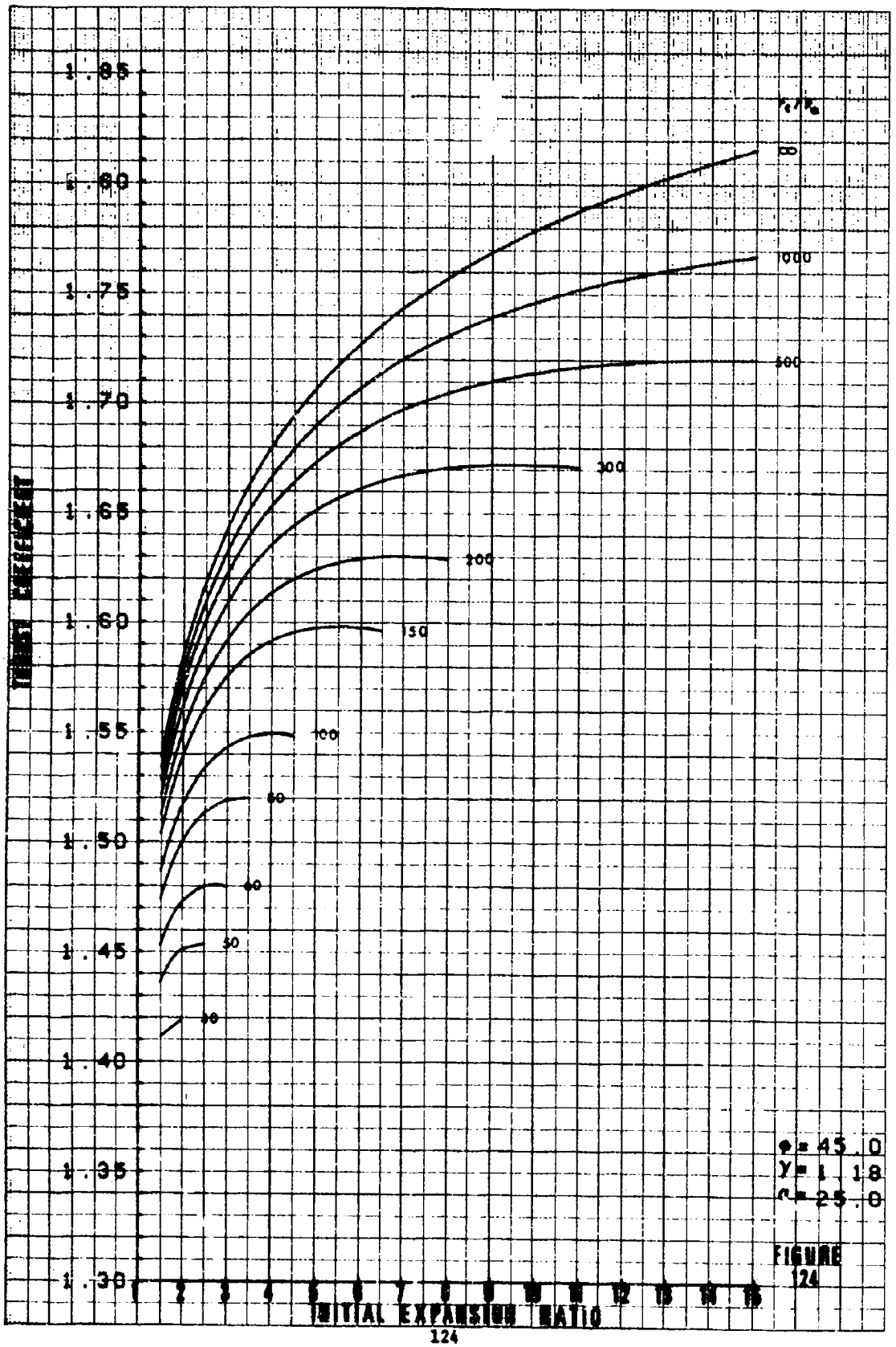

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
r_c/r_a
∞
1000
500
300
200
150
100
60
40
30
20
φ = 45.0
γ = 1.18
c* = 25.0

FIGURE 124

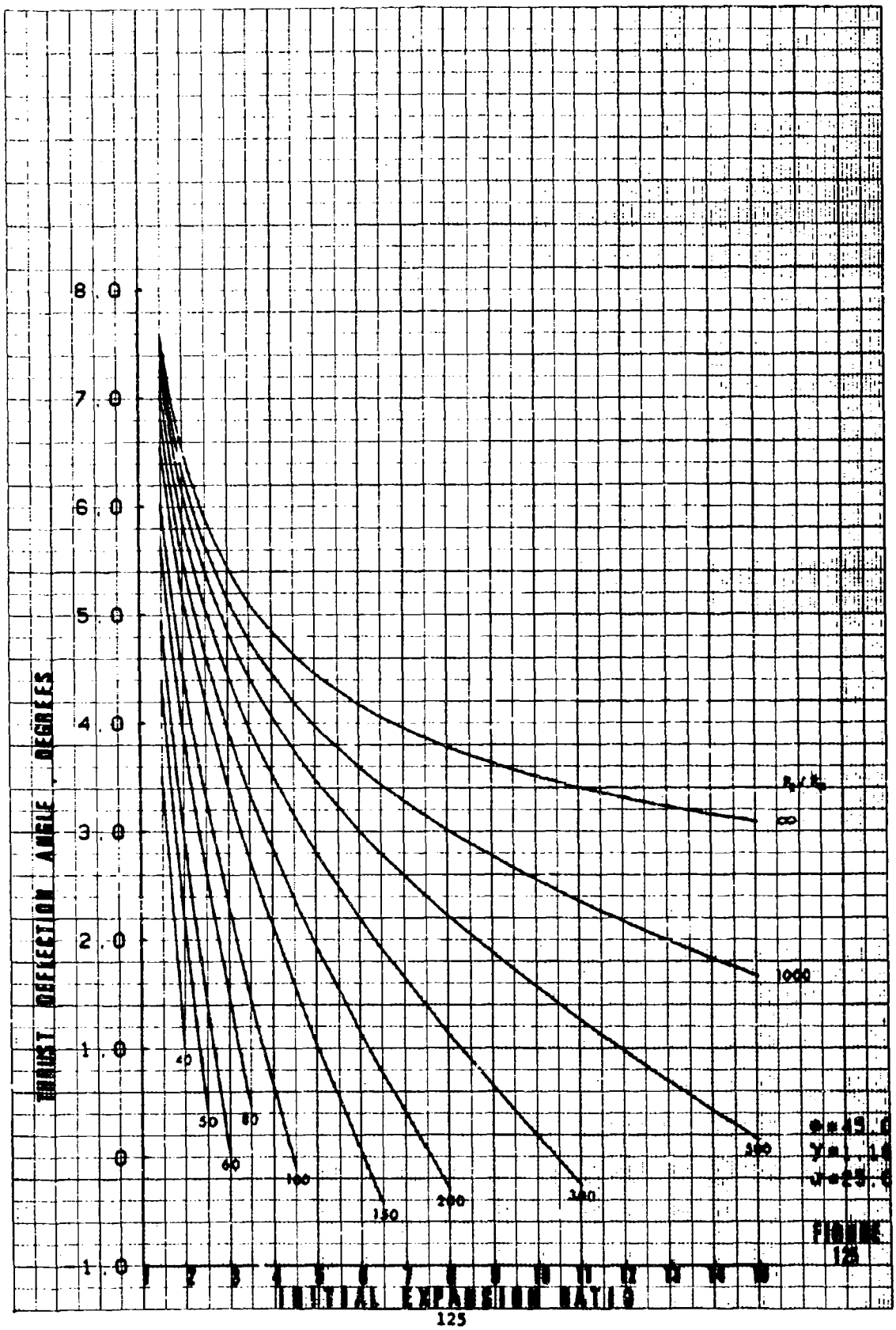

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
40
50
60
80
100
150
200
300
1000
∞

FIGURE 12

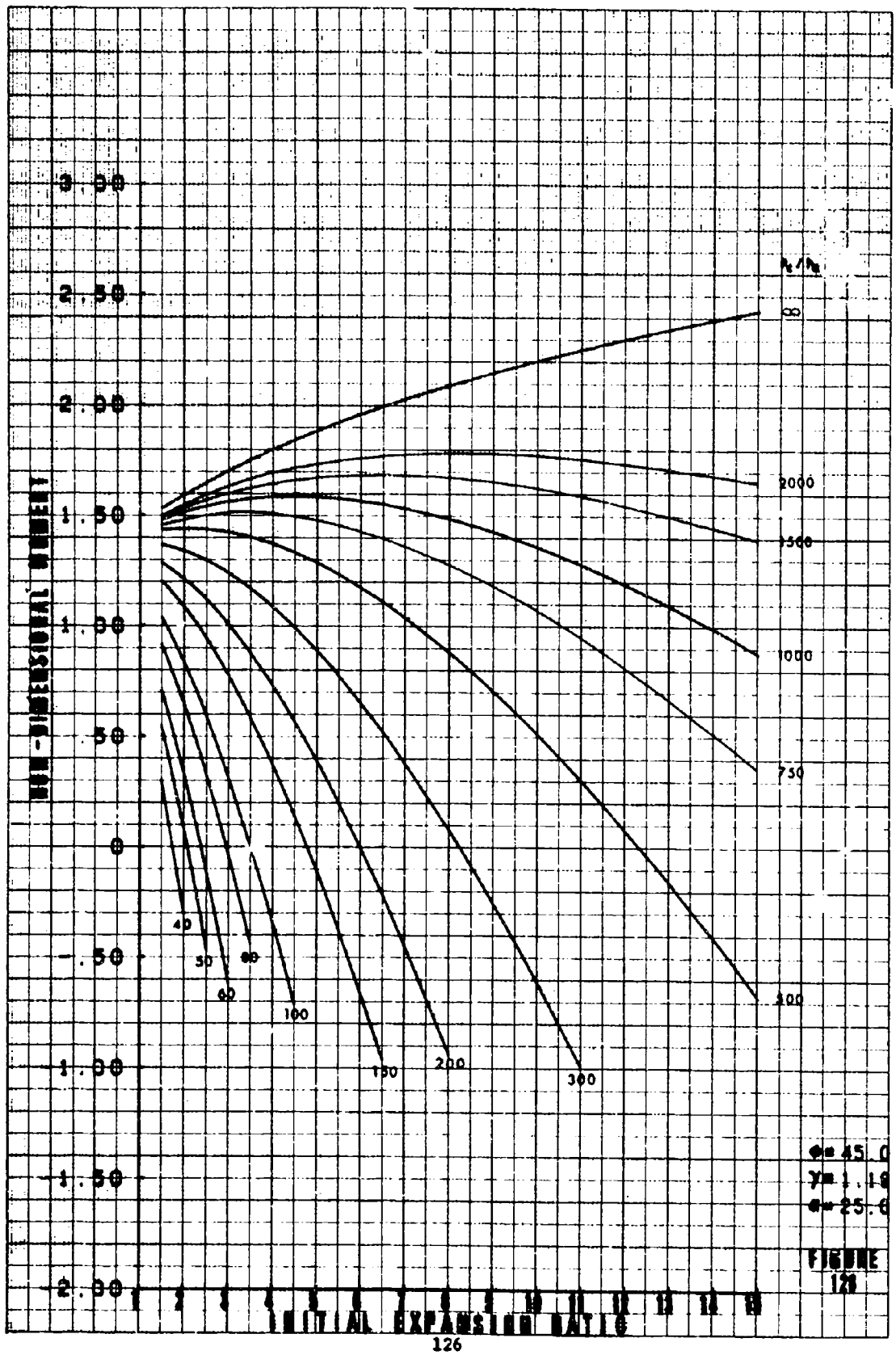

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
h_c/h_n
∞
2000
1500
1000
750
500
40
50
60
80
100
150
200
300
Φ= 45.0
γ= 1.18
θ= 25.0

FIGURE 129

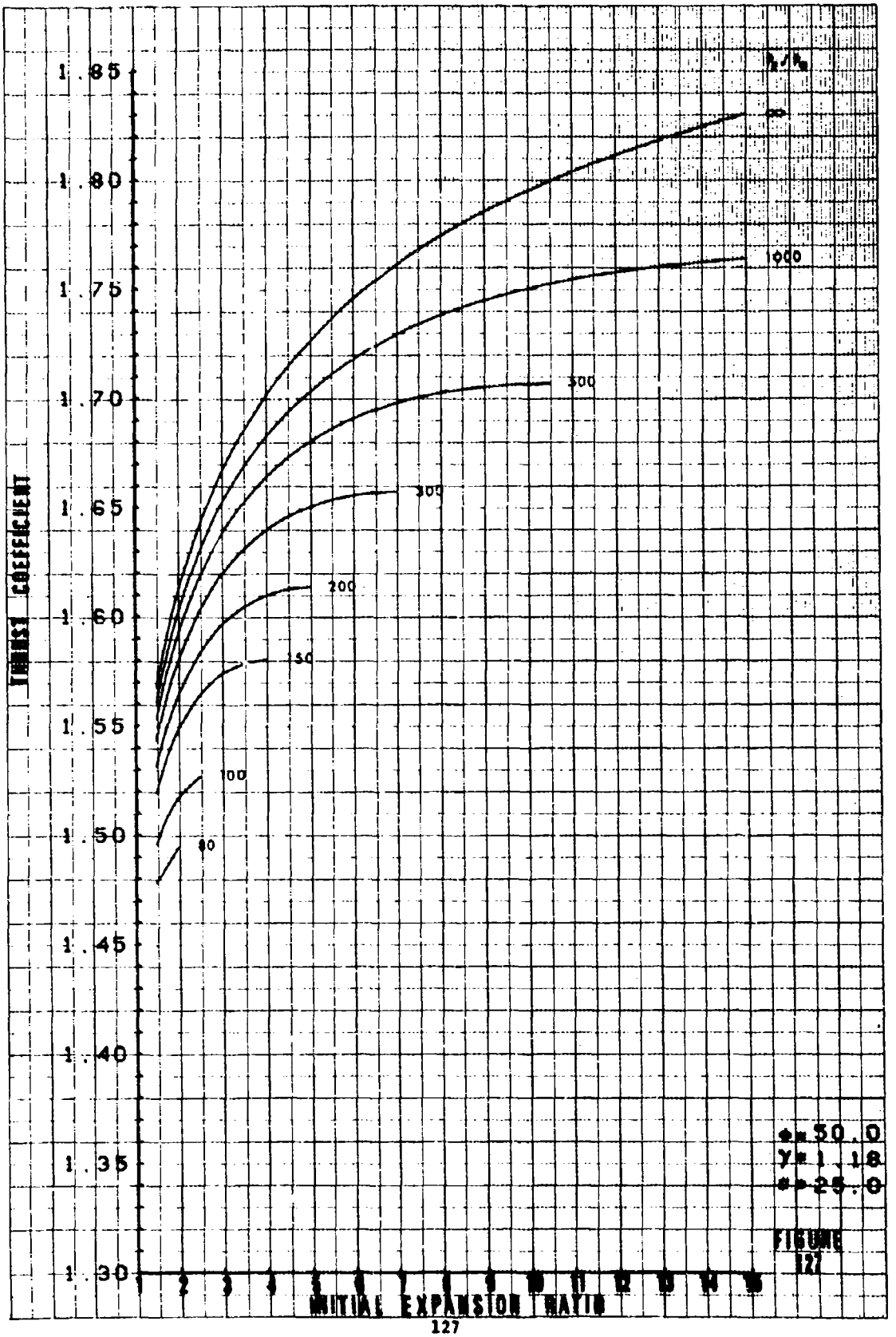
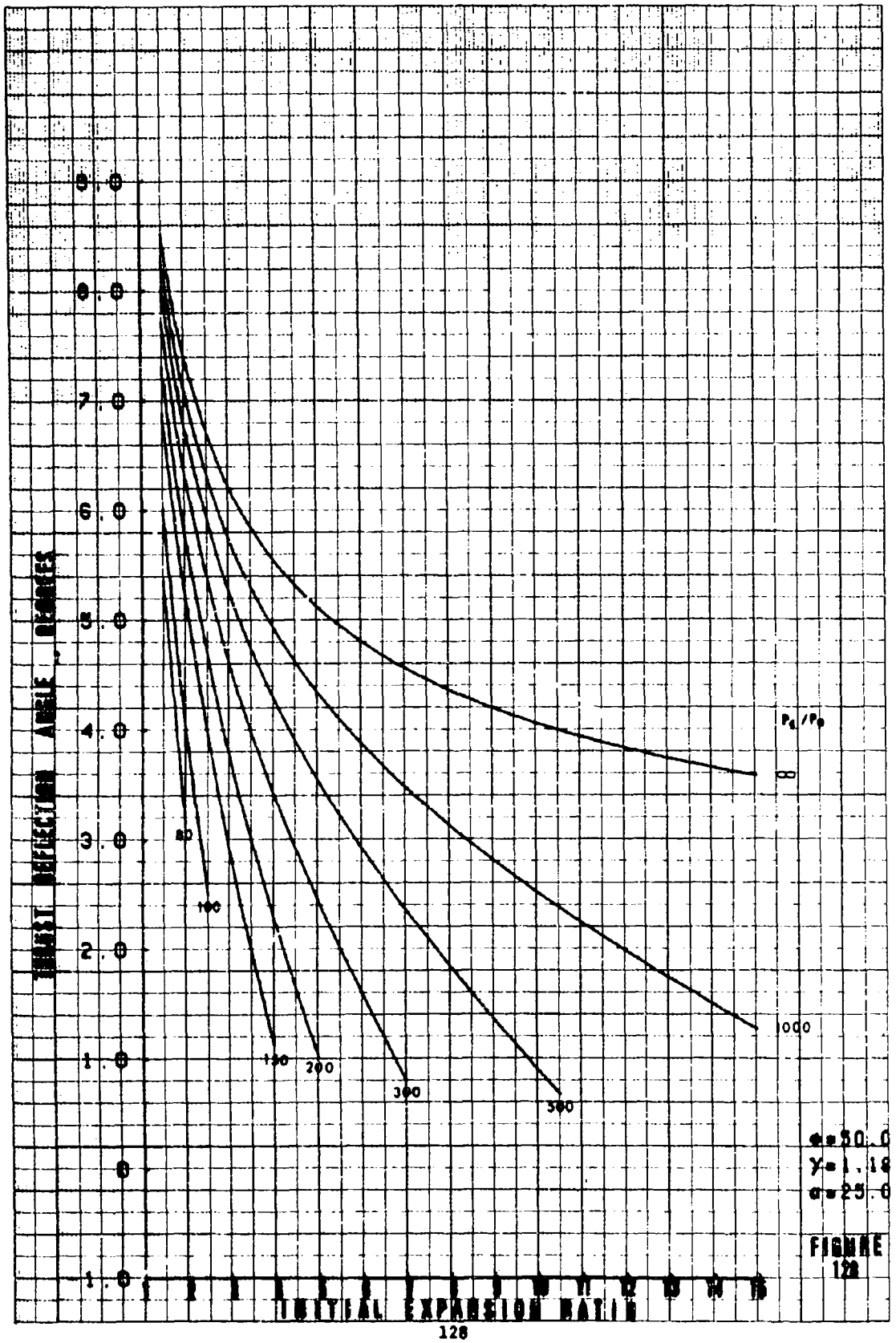

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
φ=50.0
γ=1.18
θ=25.0

FIGURE 127



THRUST DEFLECTION ANGLE, DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
P_d/P_0
∞
1000
80
100
150
200
300
500
φ=50.0
γ=1.18
α=25.0

FIGURE 128

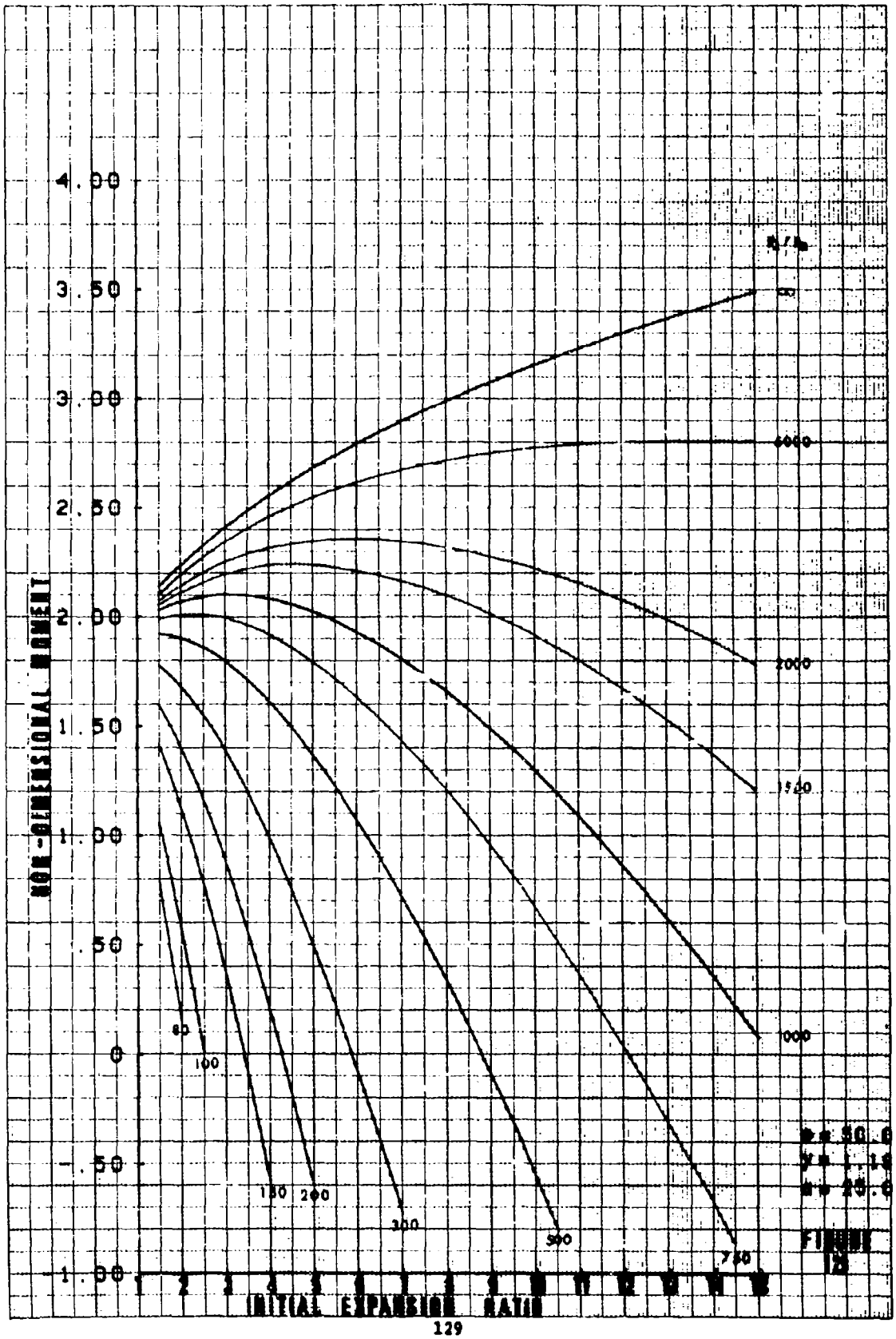
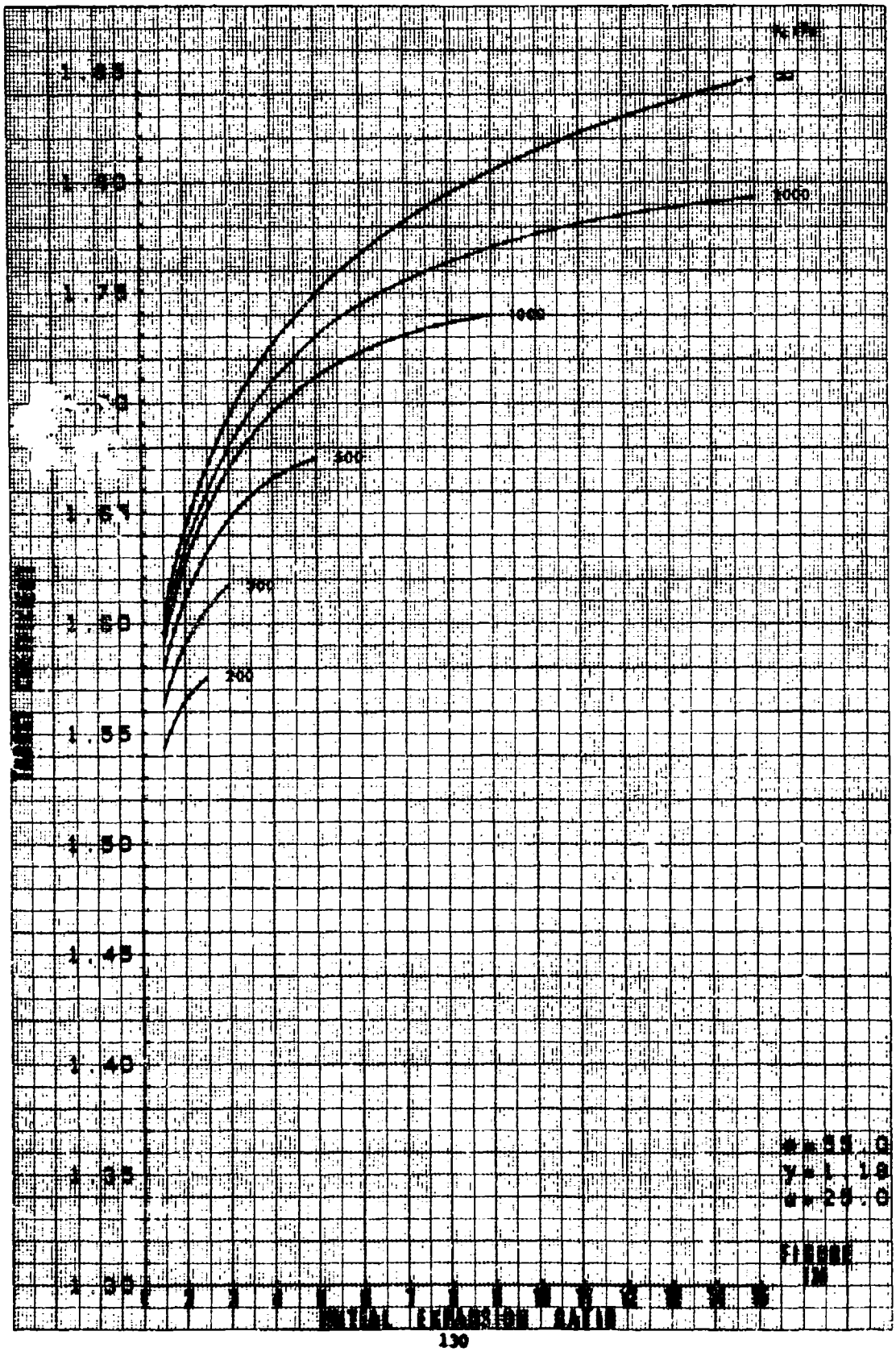
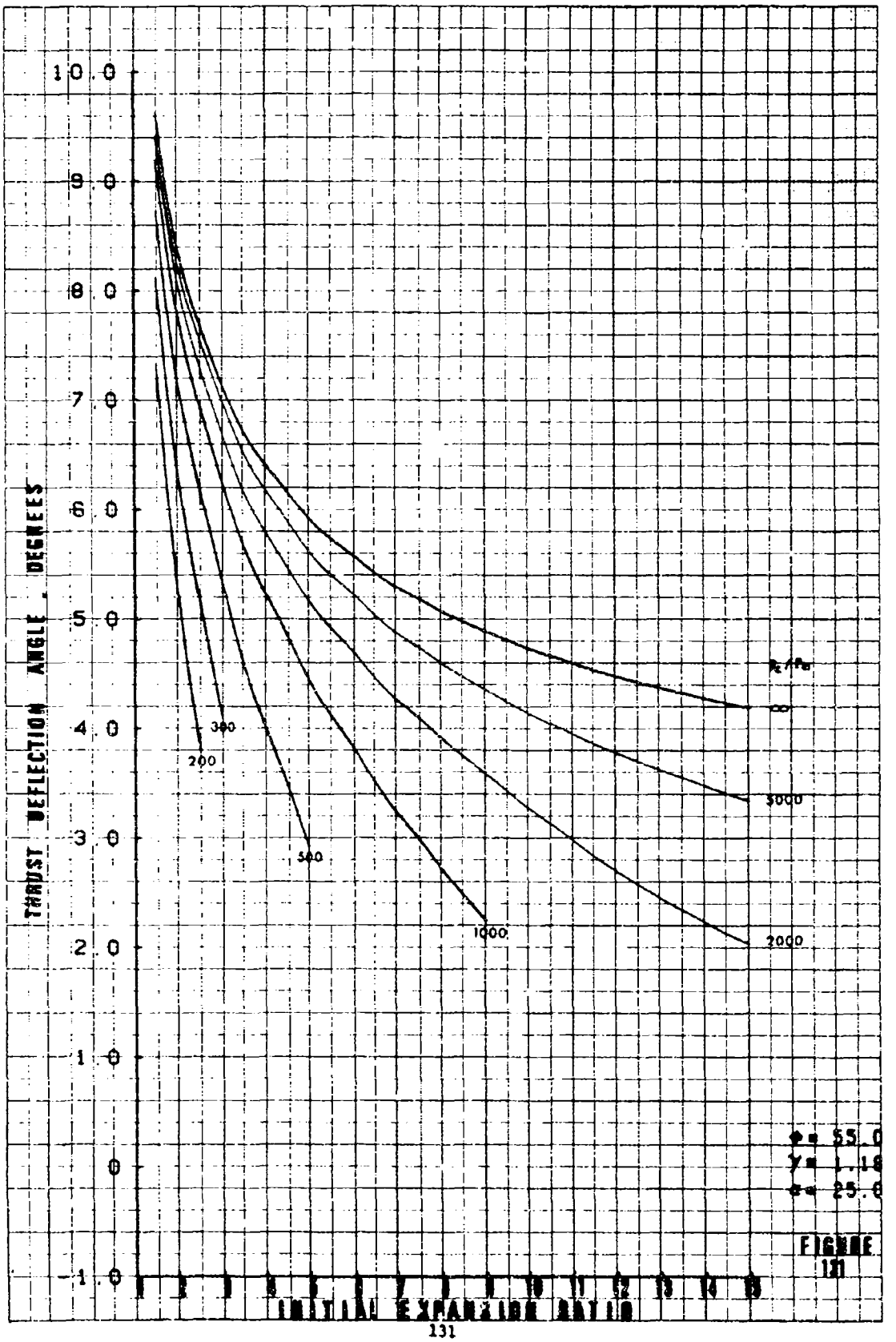

4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
6000
2000
1500
1000
80
100
150
200
300
500
750

FIGURE 16

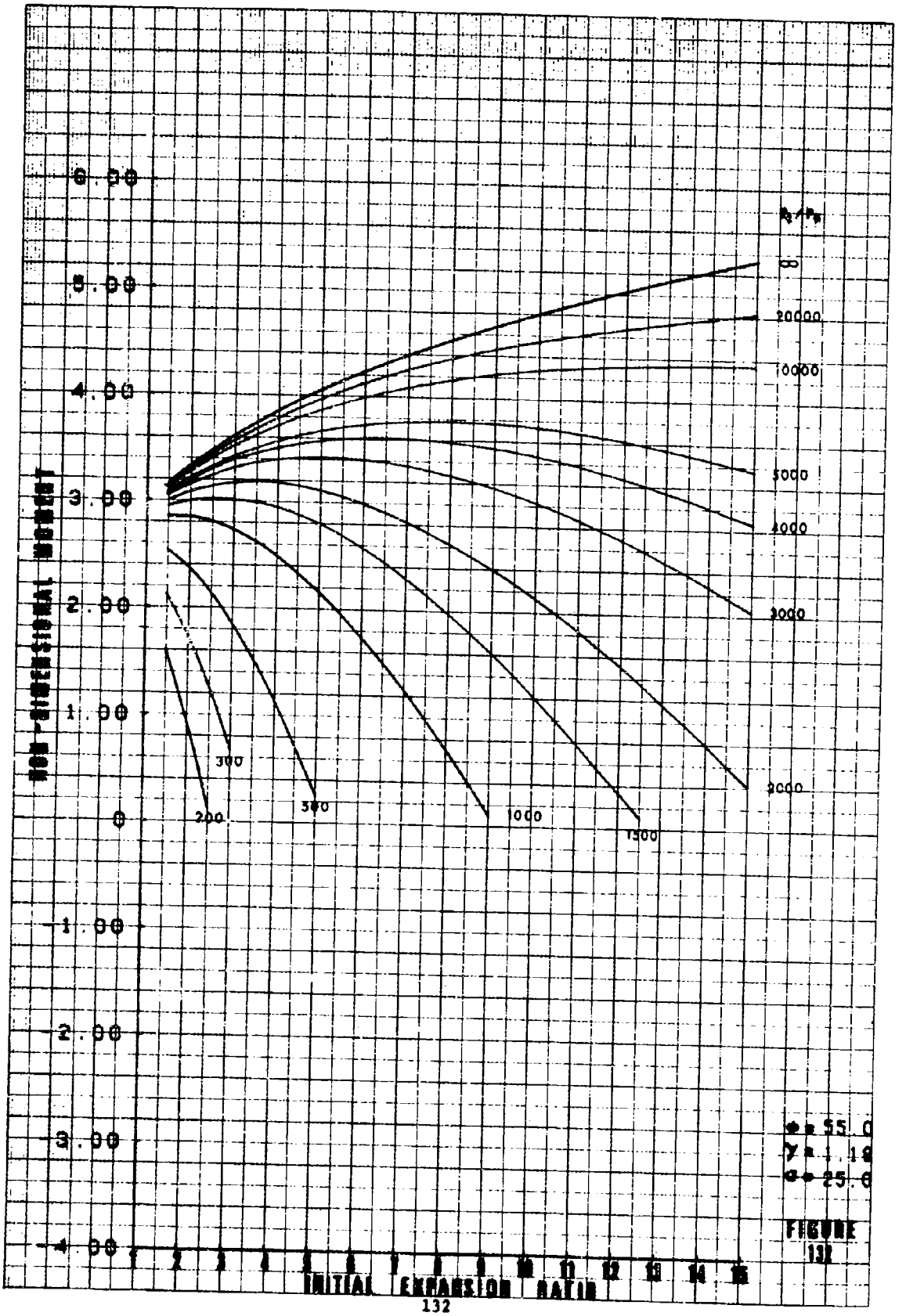


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
2000
1000
500
300
200
y=1.18
FIGURE



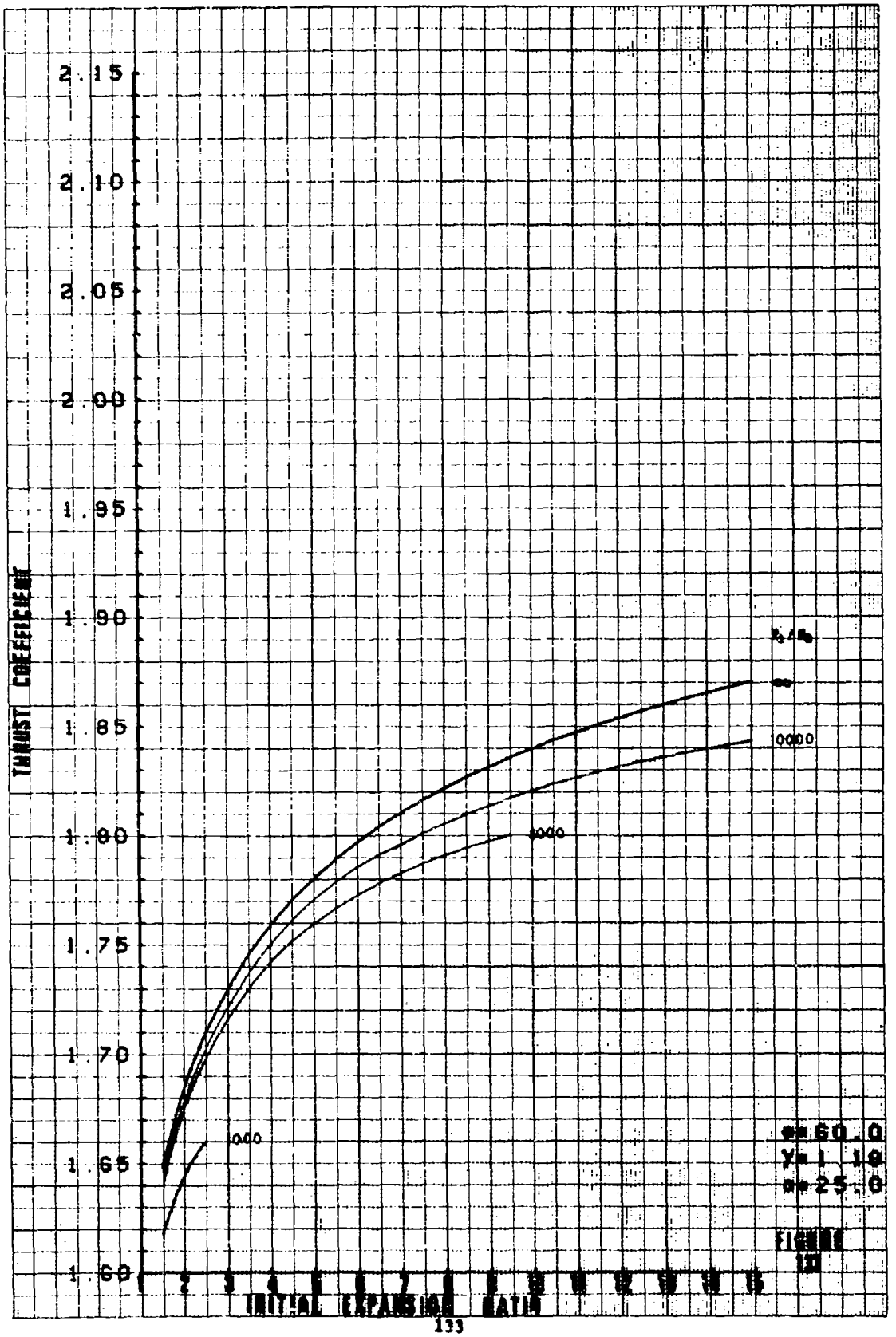
THRUST DEFLECTION ANGLE, DEGREES
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
200
300
500
1000
2000
5000
∞

FIGURE 131



6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
NON-DIMENSIONAL MOMENT
P_2/P_1
∞
20000
10000
5000
4000
3000
2000
1500
1000
500
300
200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 132



2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
0000
∞

FIGURE 10

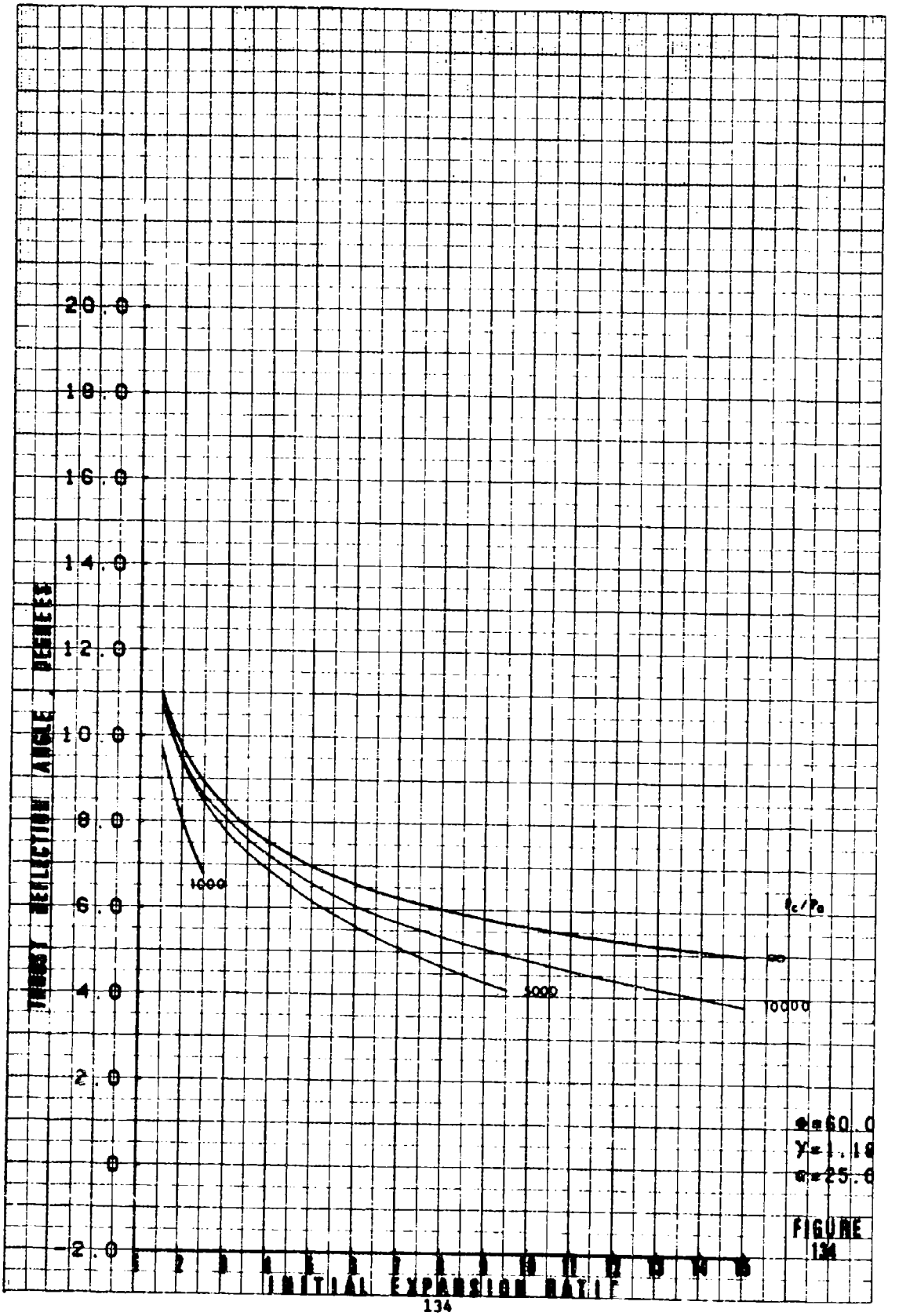

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1000
5000
10000
p_c/p_a
∞
INITIAL EXPANSION RATIO

FIGURE 134

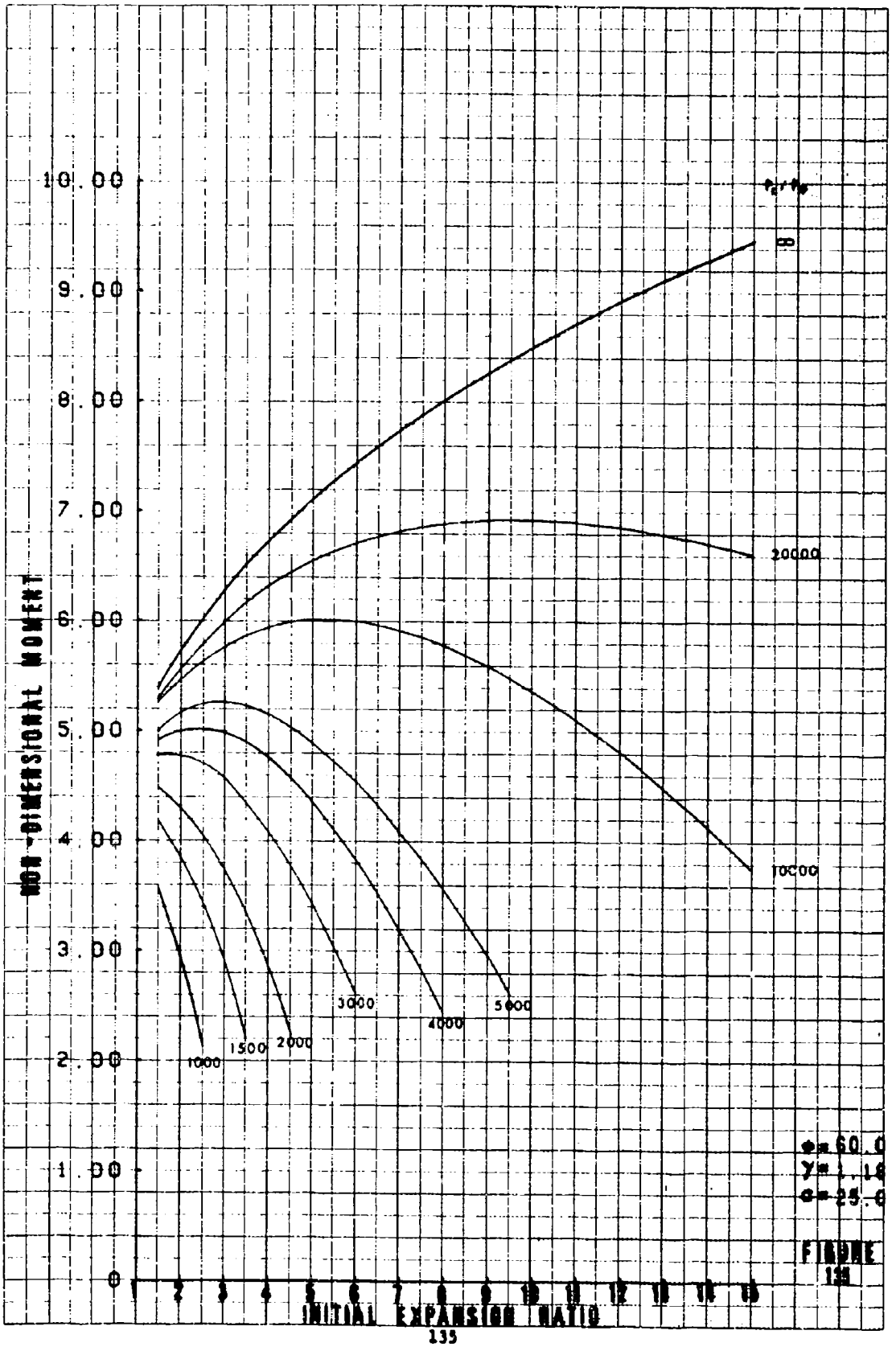

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
20000
10000
5000
4000
3000
2000
1500
1000
φ=60.0
γ=1.16
α=25.0

FIGURE 139

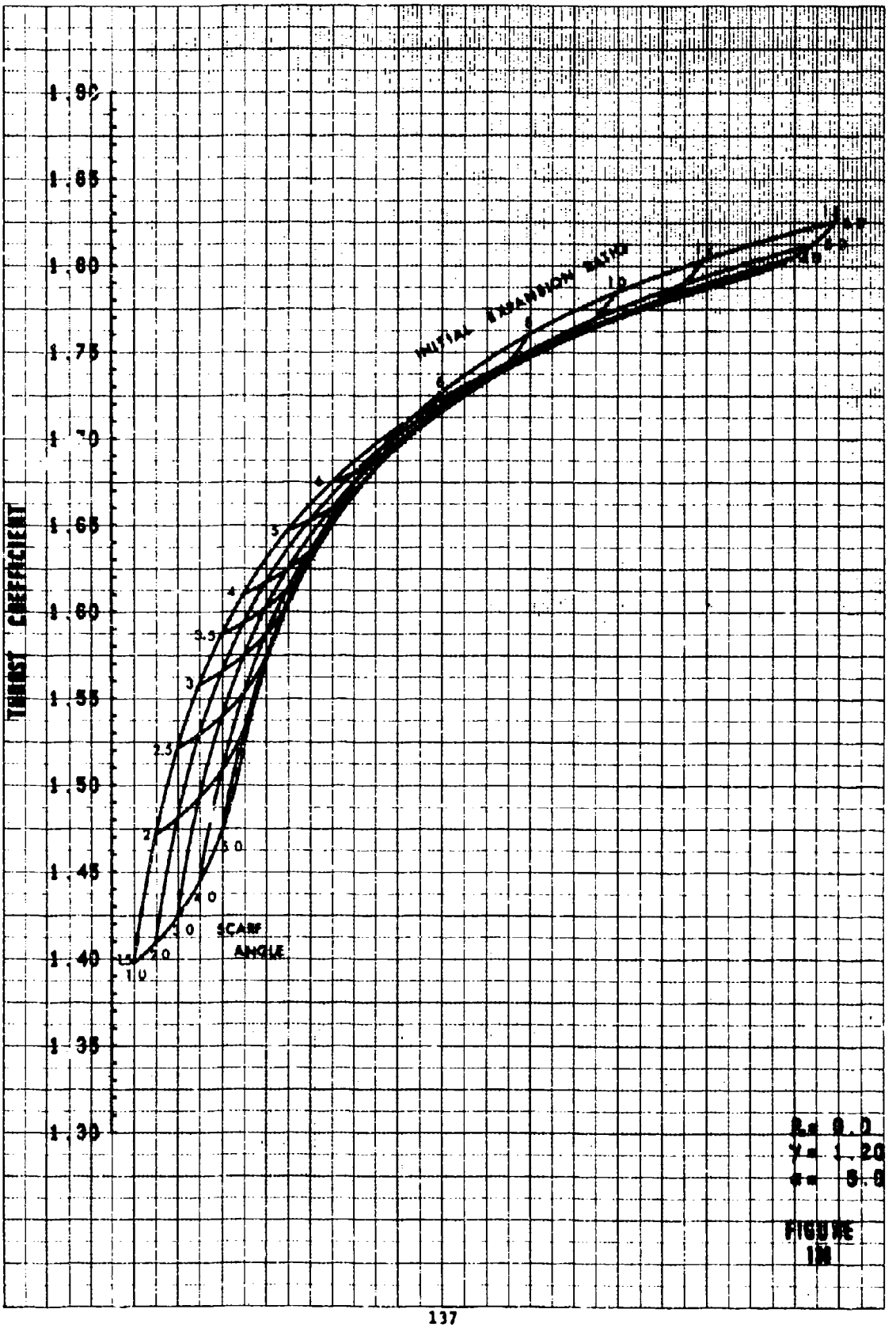
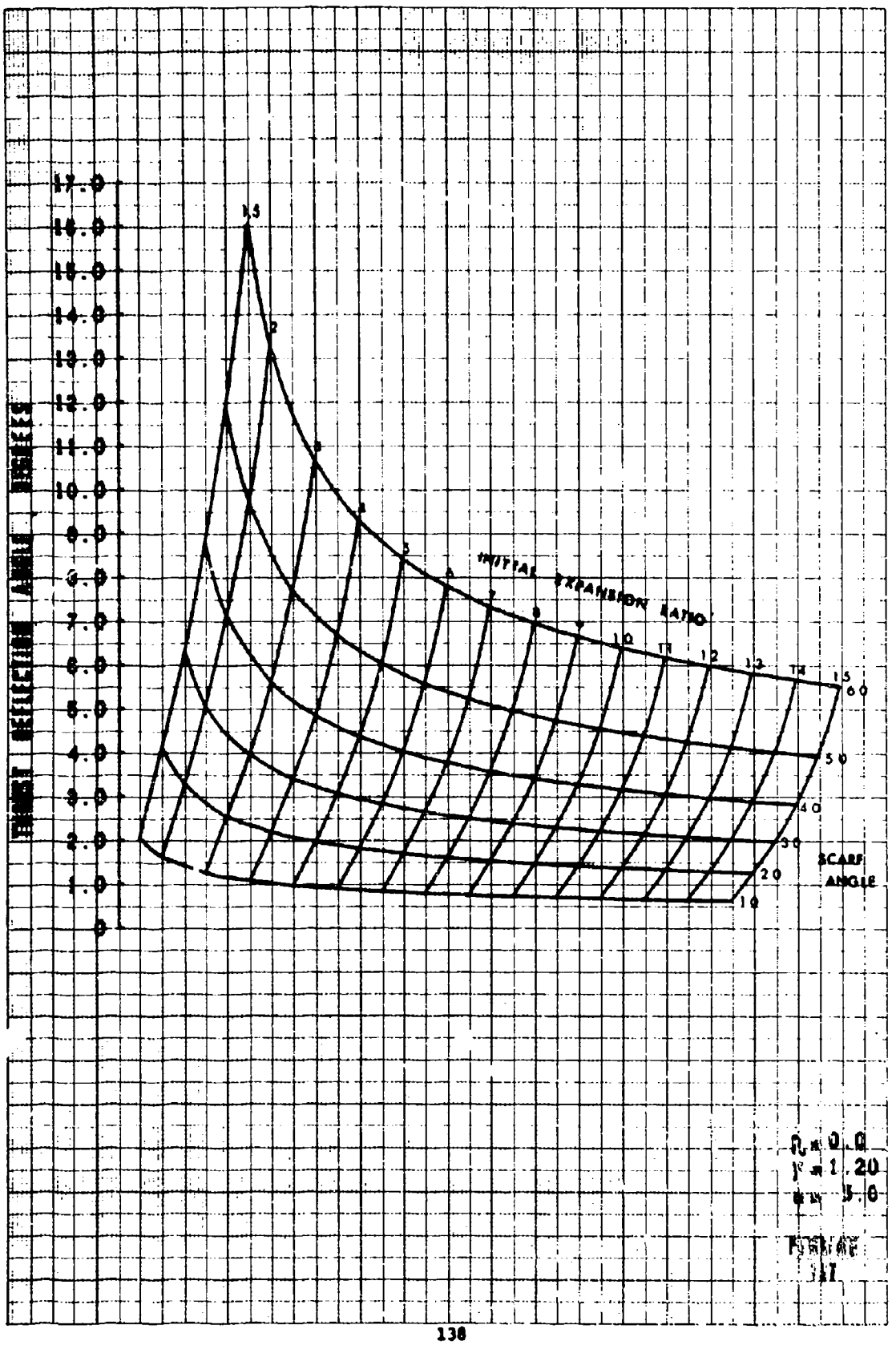

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
R = 0.0
γ = 1.20
α = 5.0

FIGURE 1M



17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE

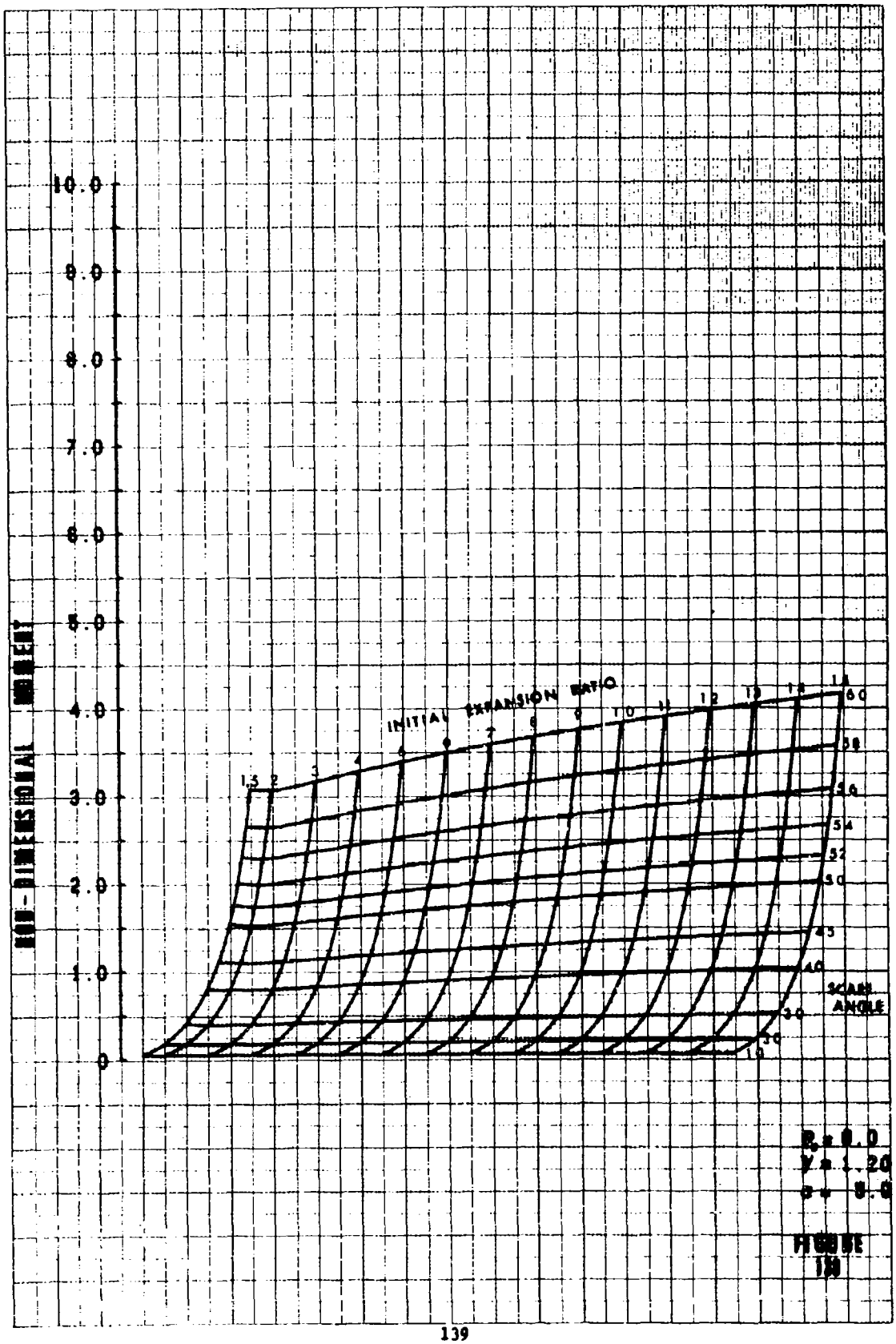
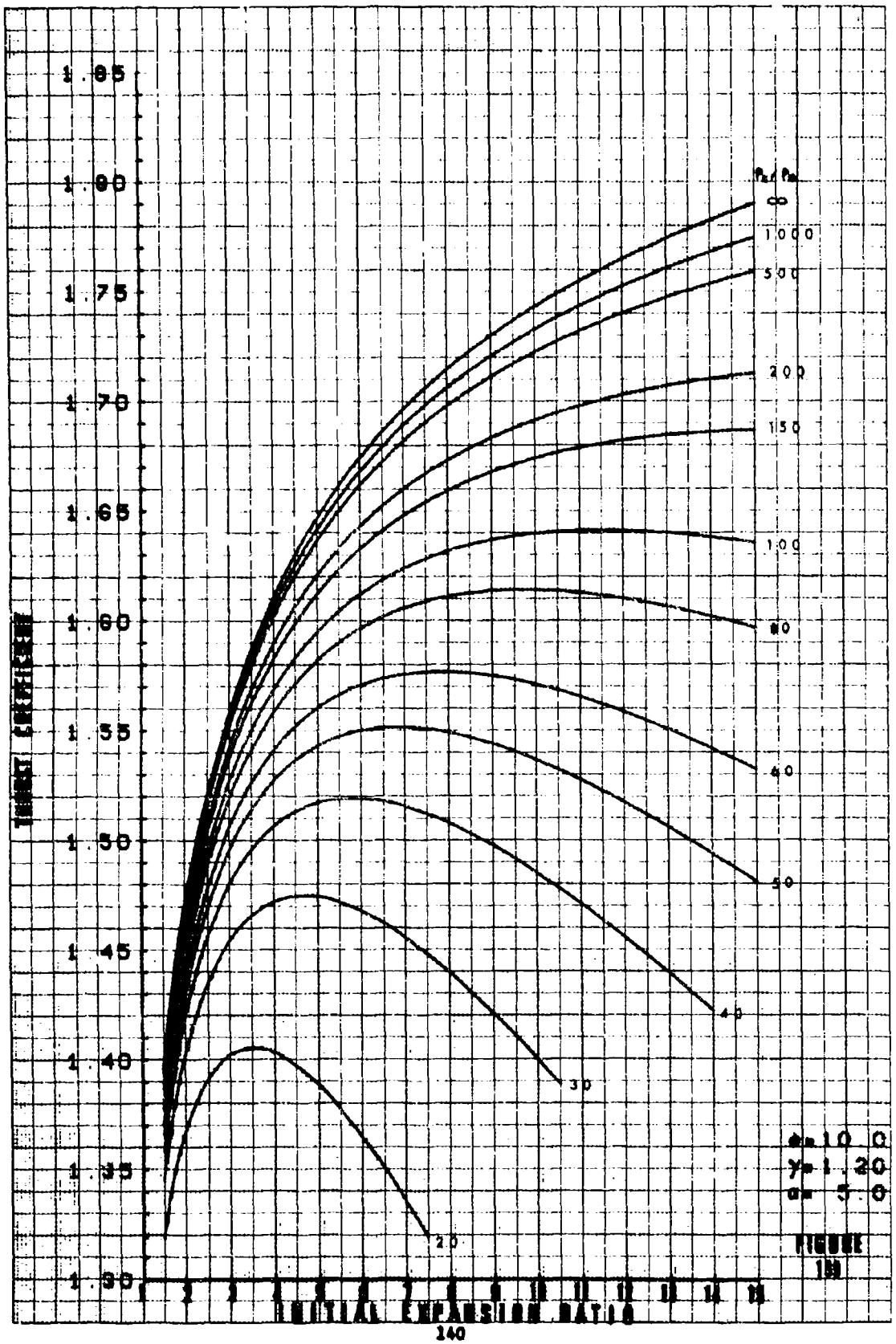
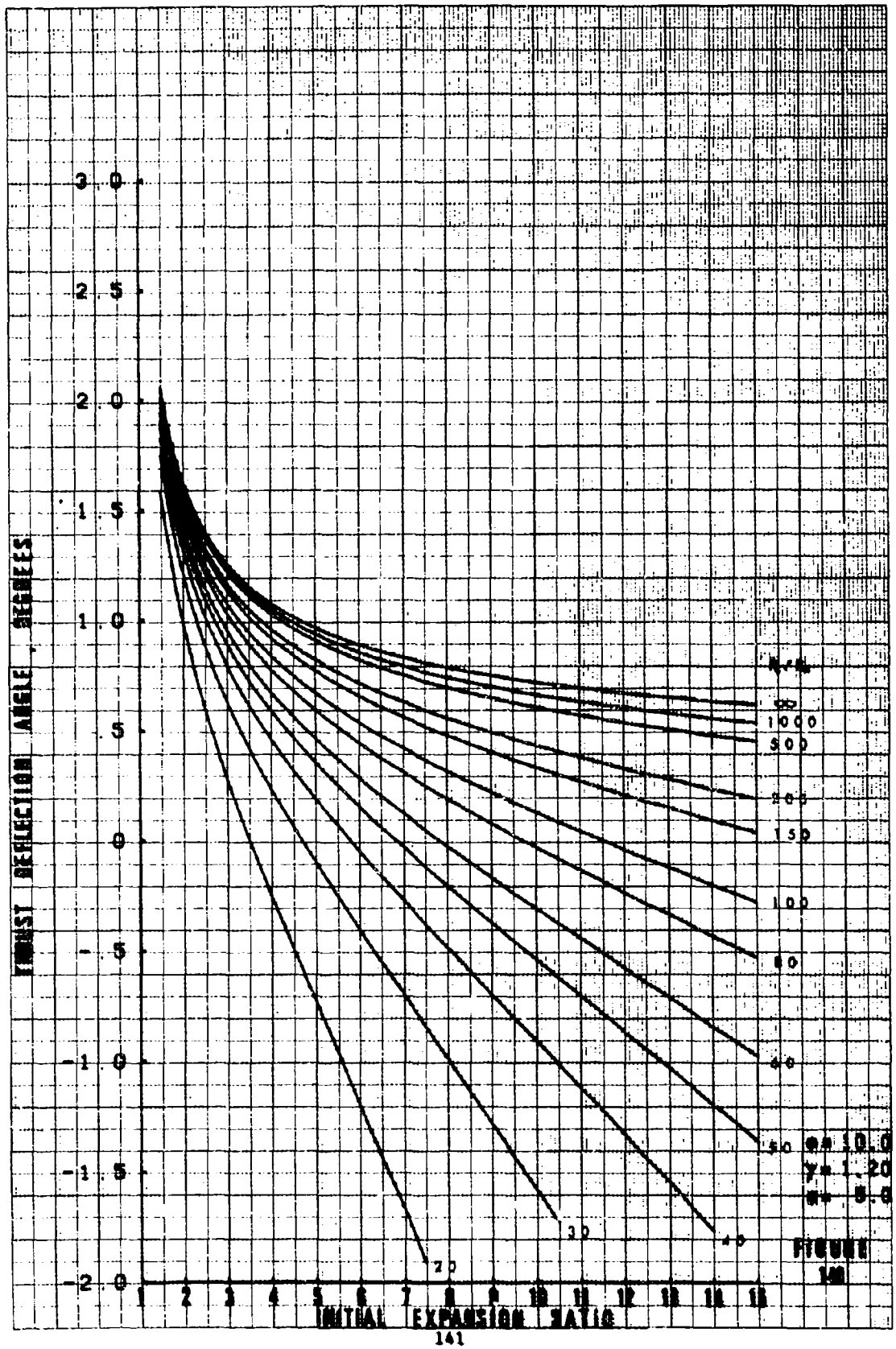

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P_o = 0.0
γ = 1.20
σ = 5.0

FIGURE 139



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=10.0
γ=1.20
α= 5.0

FIGURE 1[illegible]



THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
e= 10.0
γ= 1.20
α= 5.0

FIGURE 140

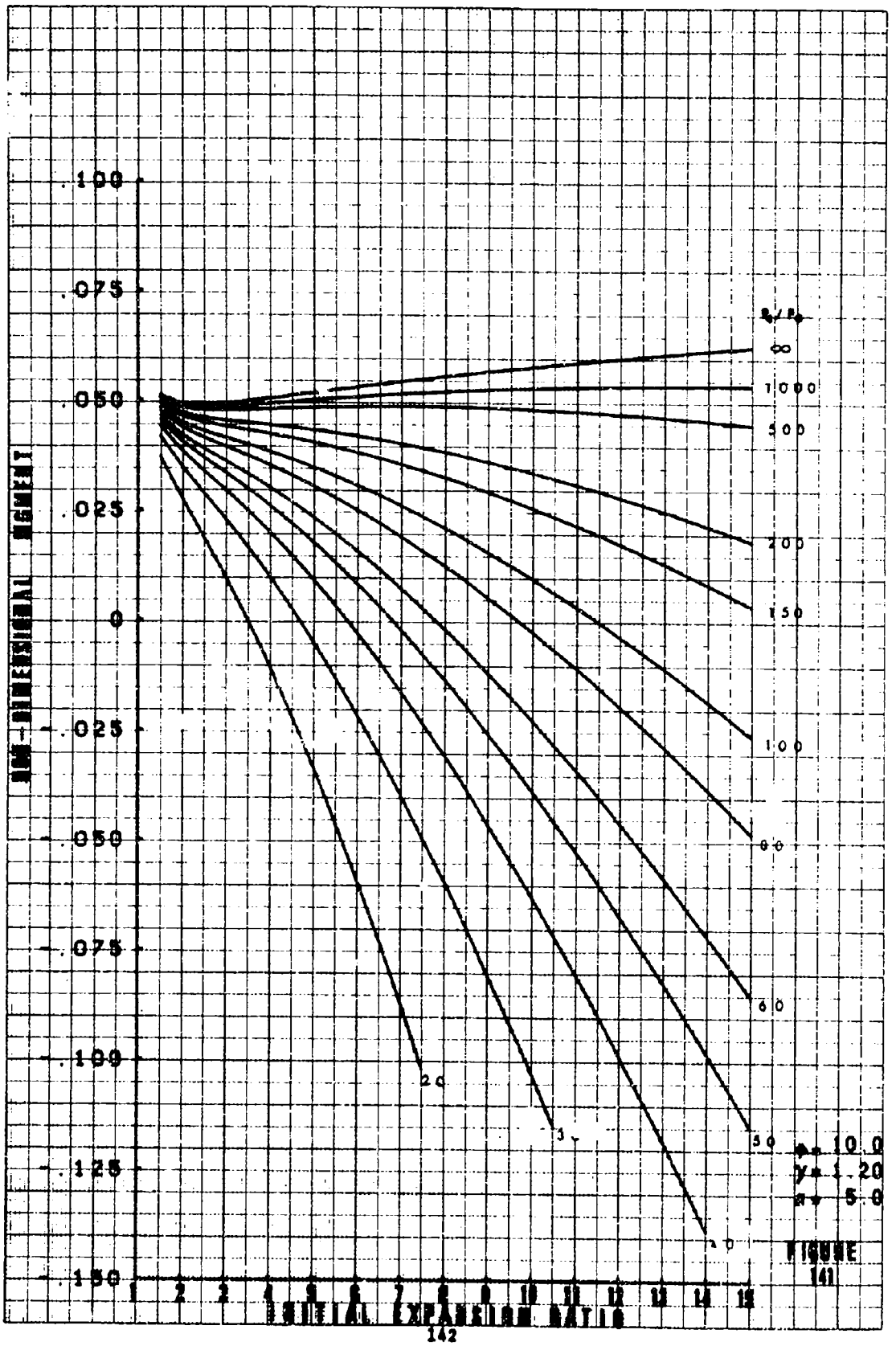

.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
20
10
φ = 10.0
γ = 1.20
n = 5.0

FIGURE 141

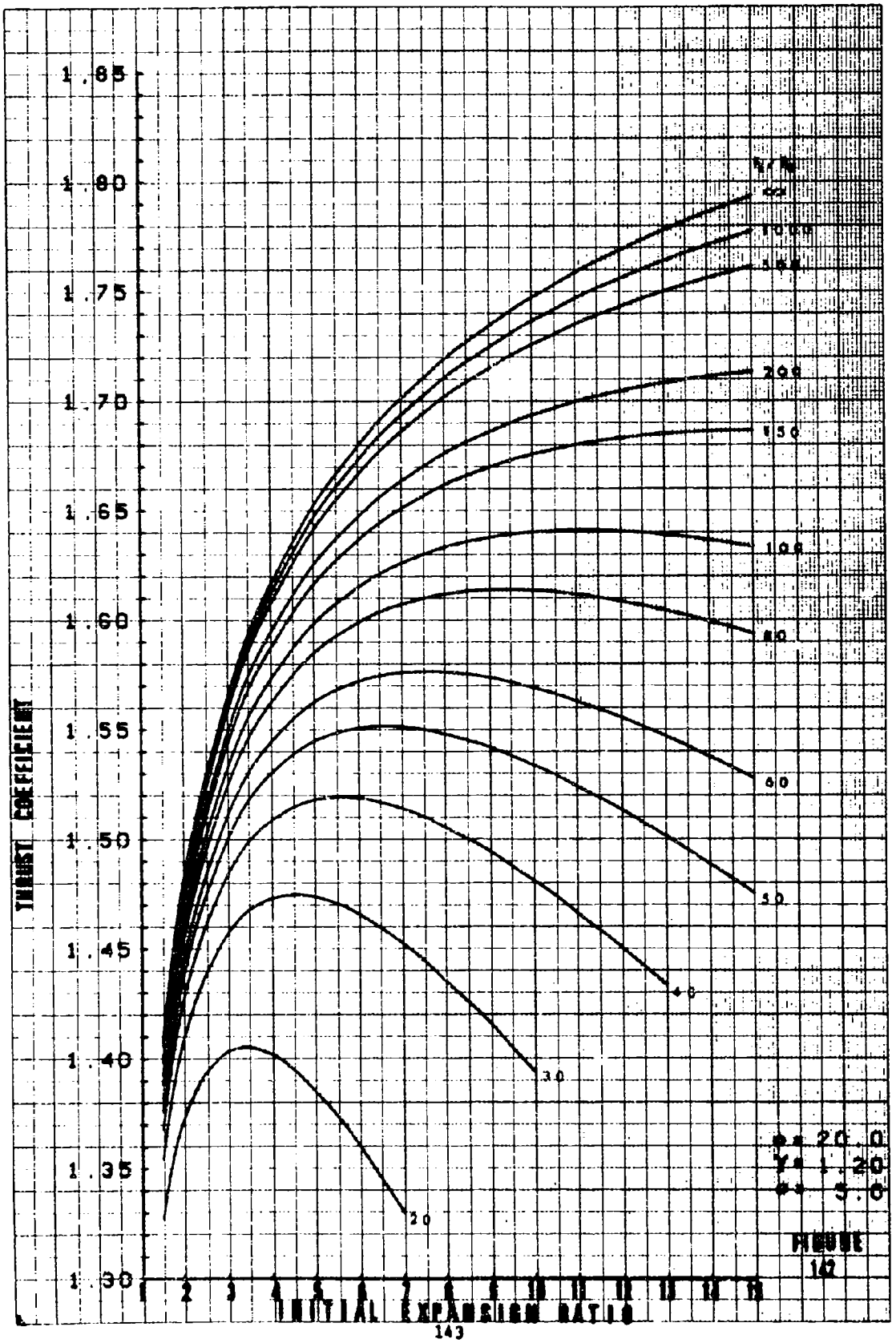

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 20.0
γ= 1.20
φ= 5.0

FIGURE 142

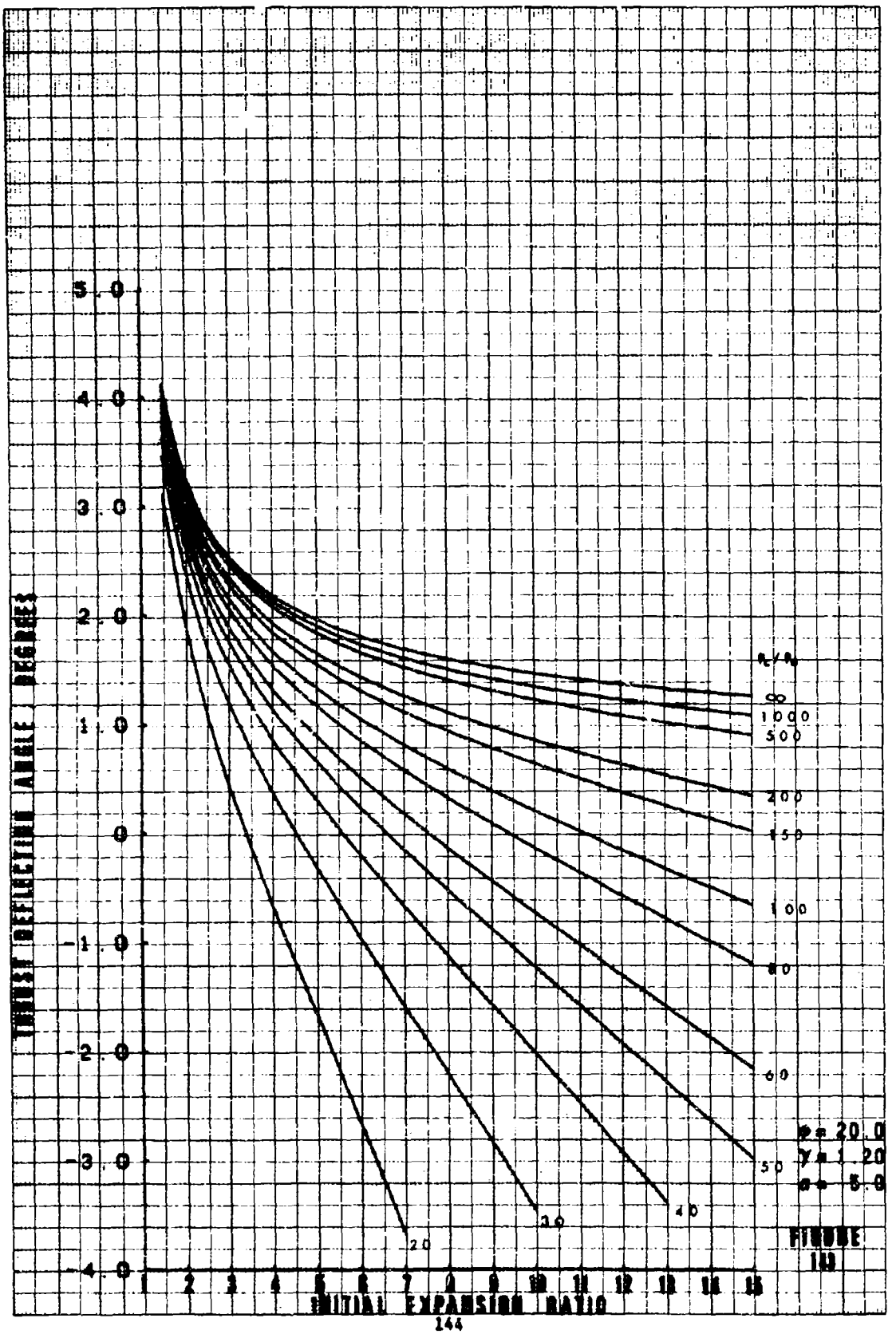

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R_c/R_t
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
α = 5.0

FIGURE 143

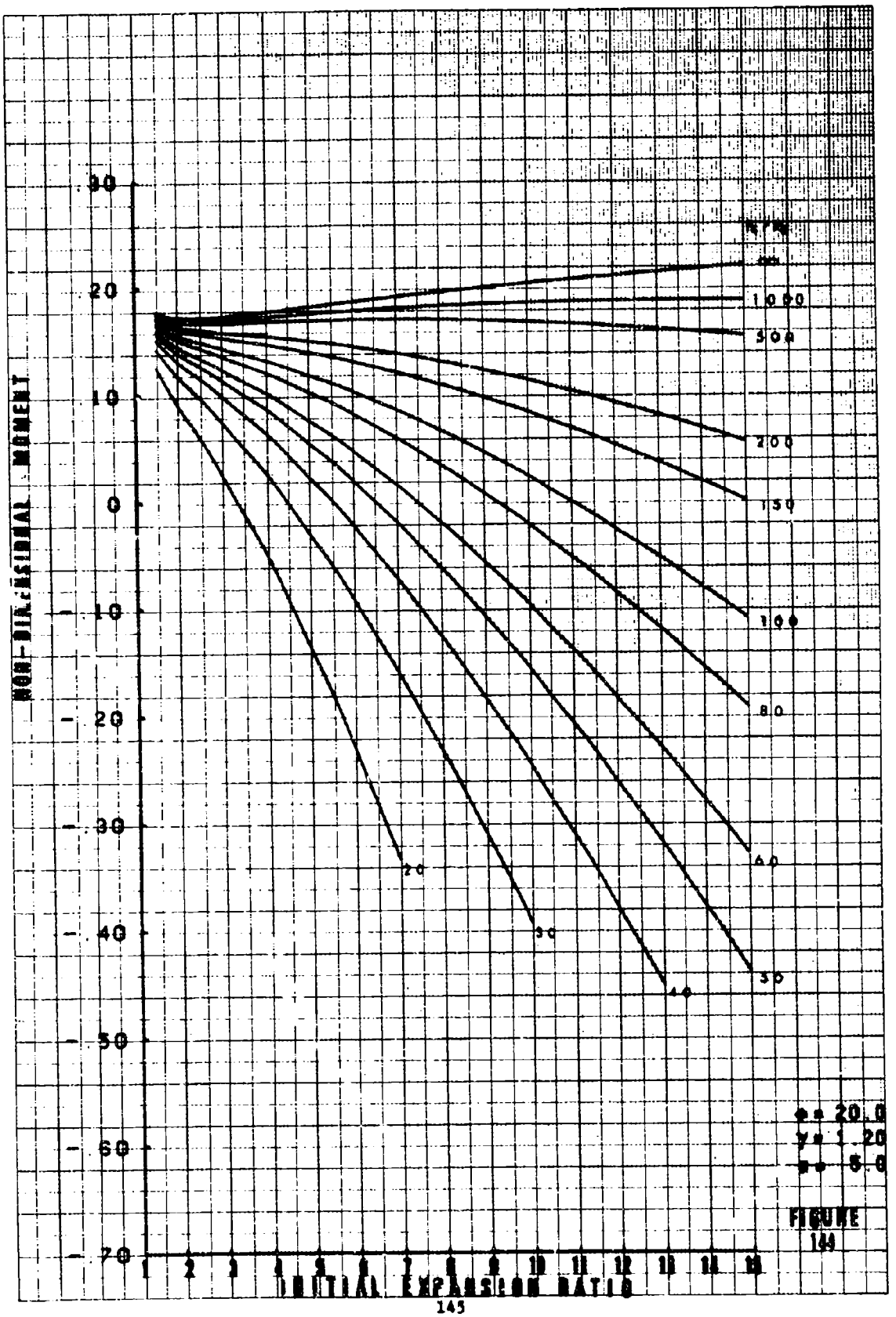
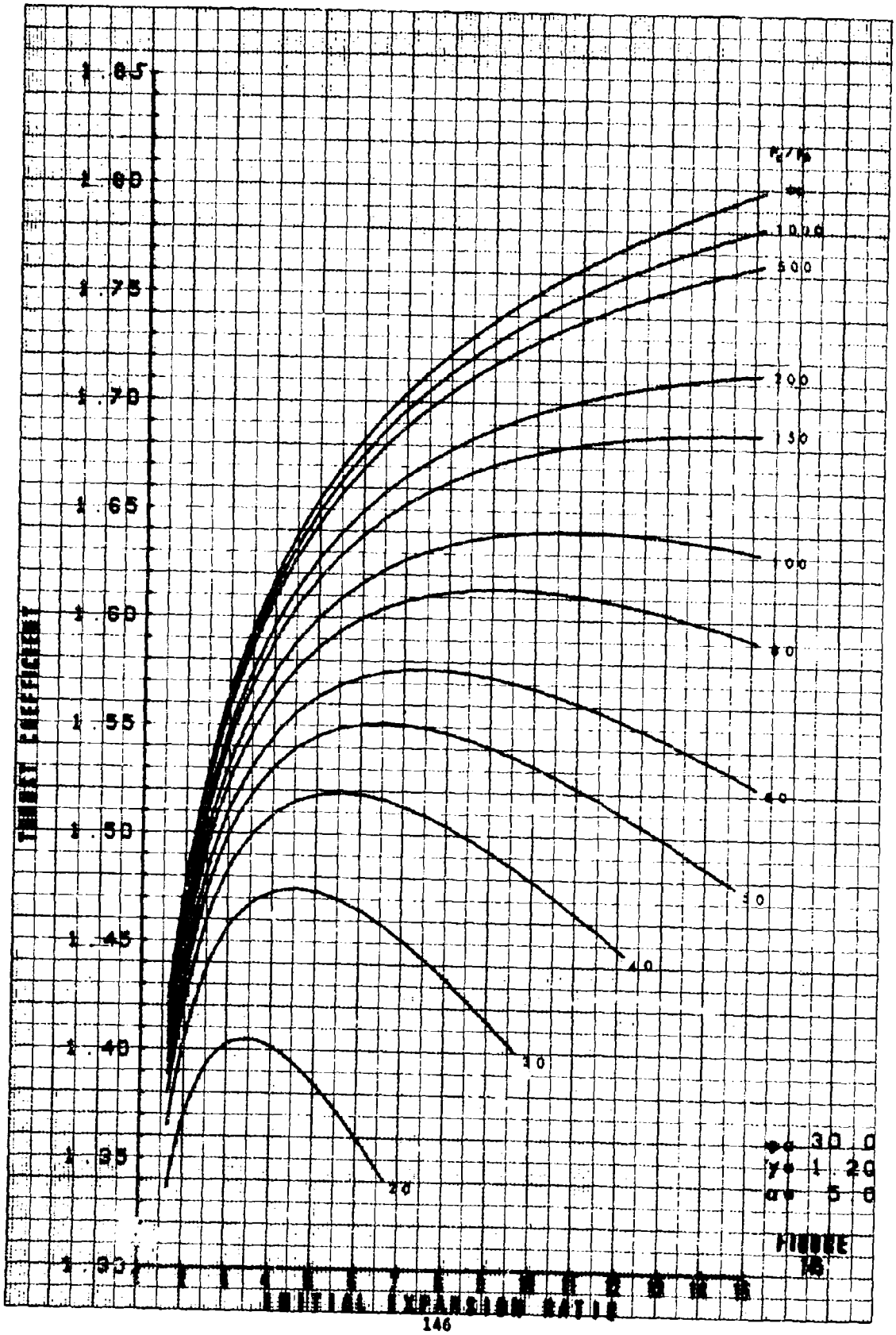

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1000
500
200
150
100
80
60
50
40
30
20
= 20.0
= 1.20
= 5.0

FIGURE 144



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
30.0
1.20
5.0

FIGURE 16

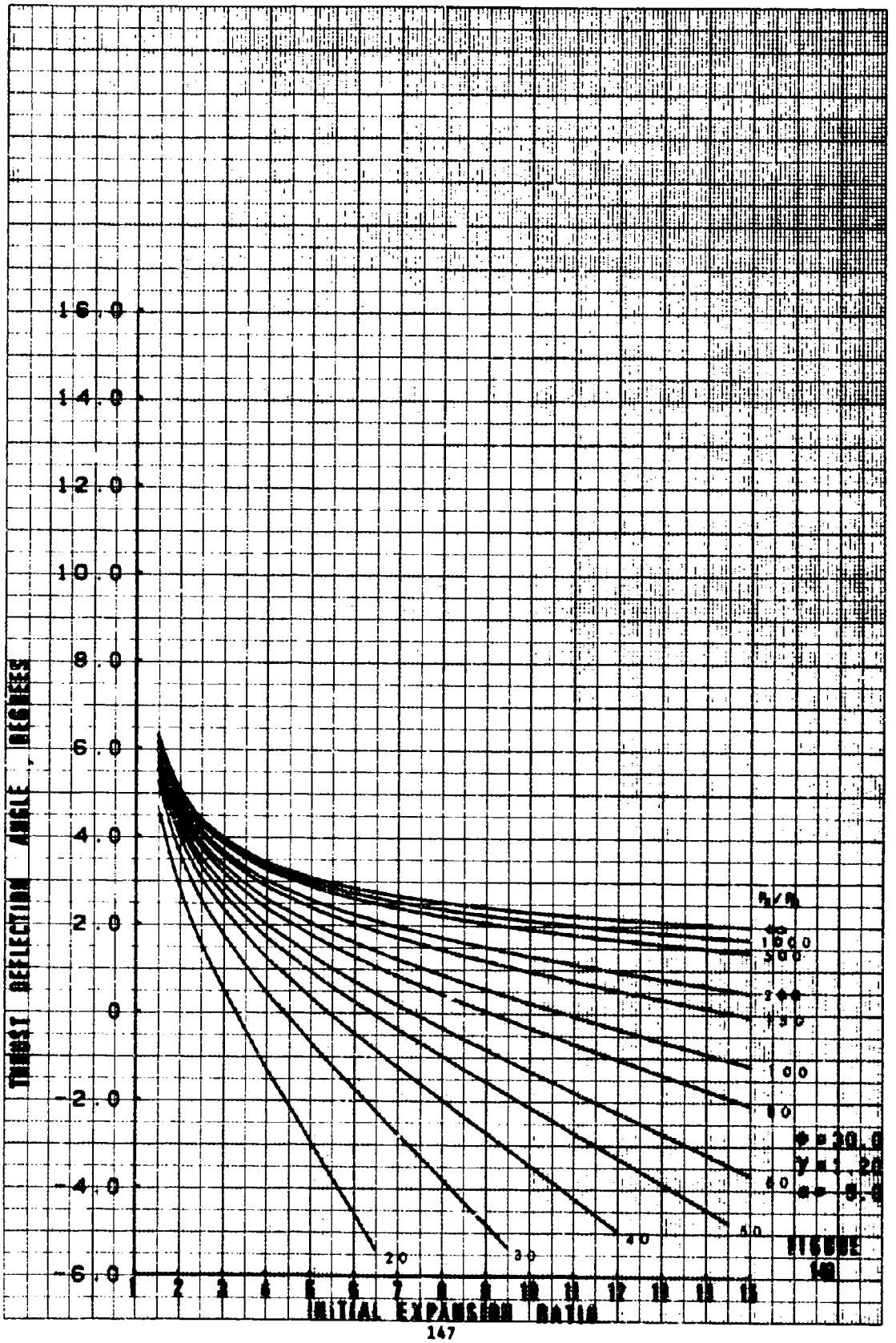

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 10

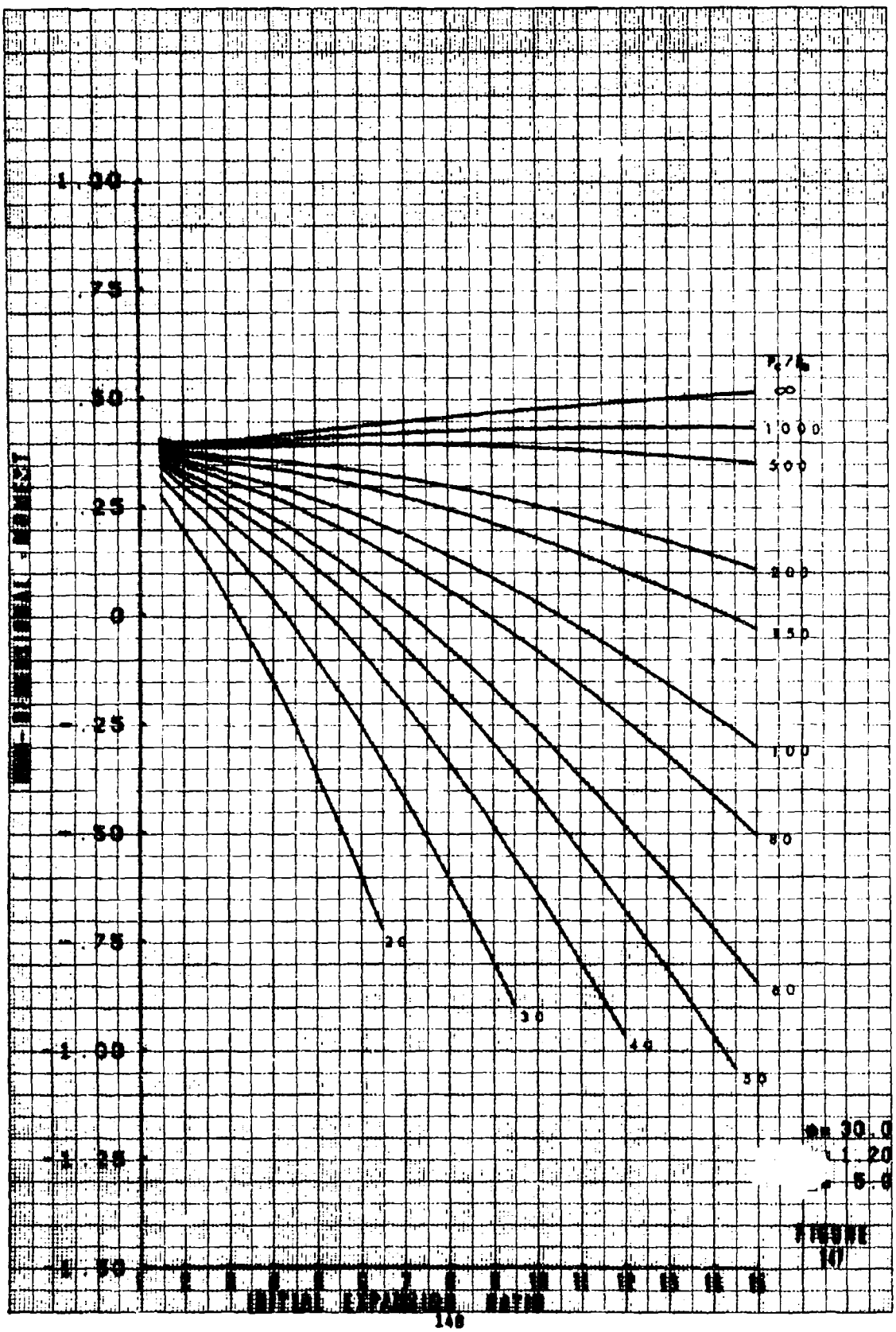
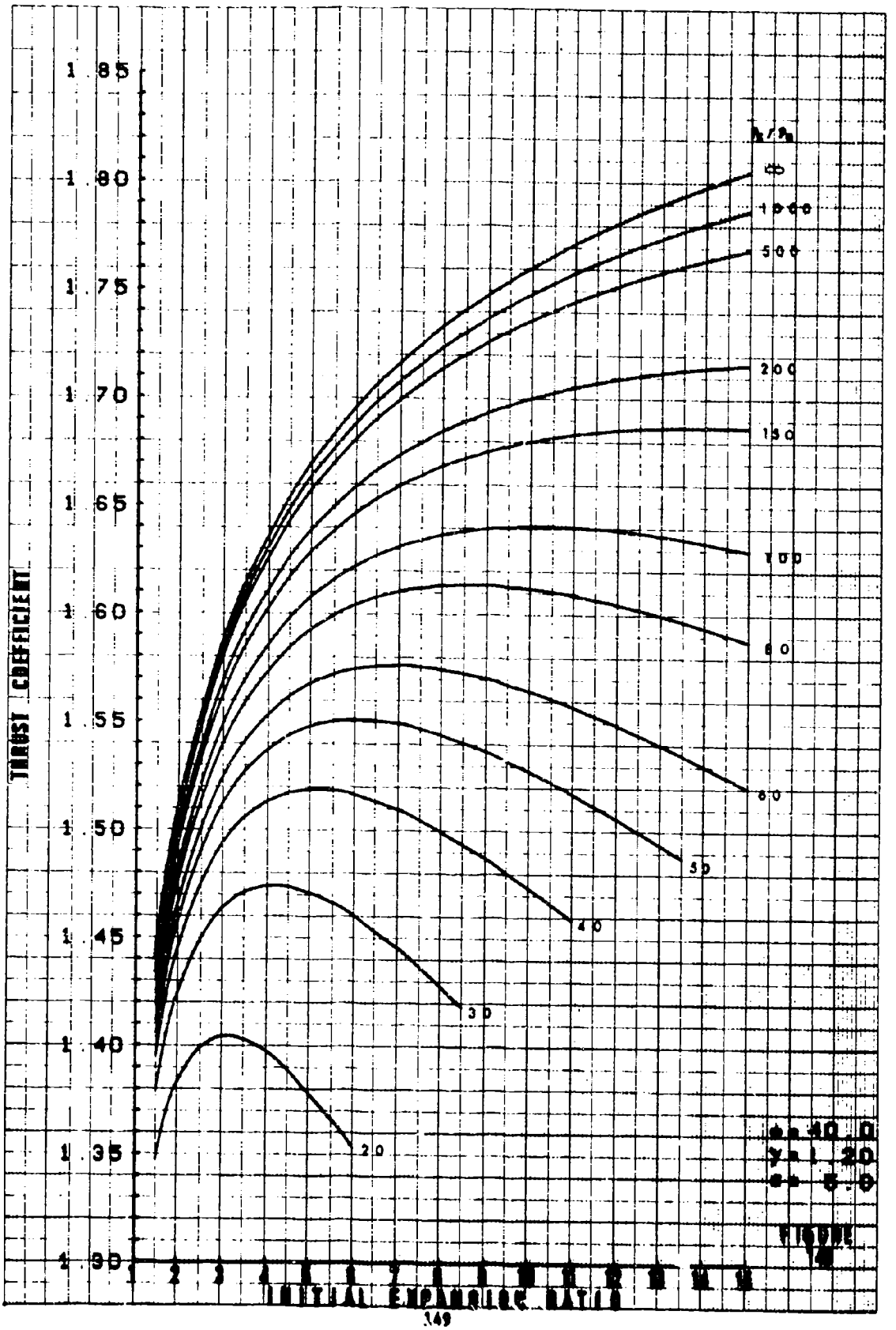
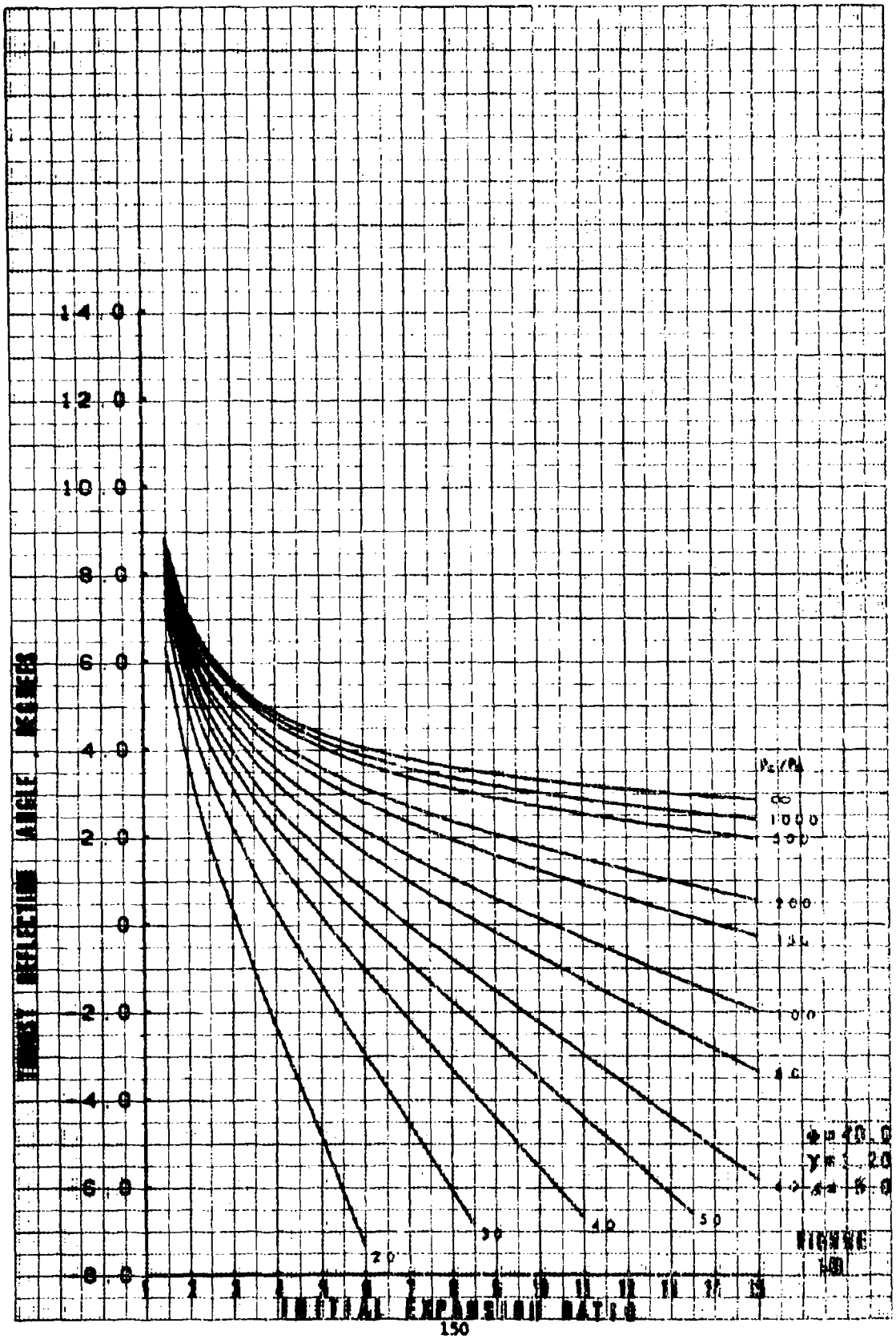

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
30.0
1.20
5.0

FIGURE 10


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
FIGURE


14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
THRUST REFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
20
30
40
50
∞
1000
500
200
100
40
FIGURE

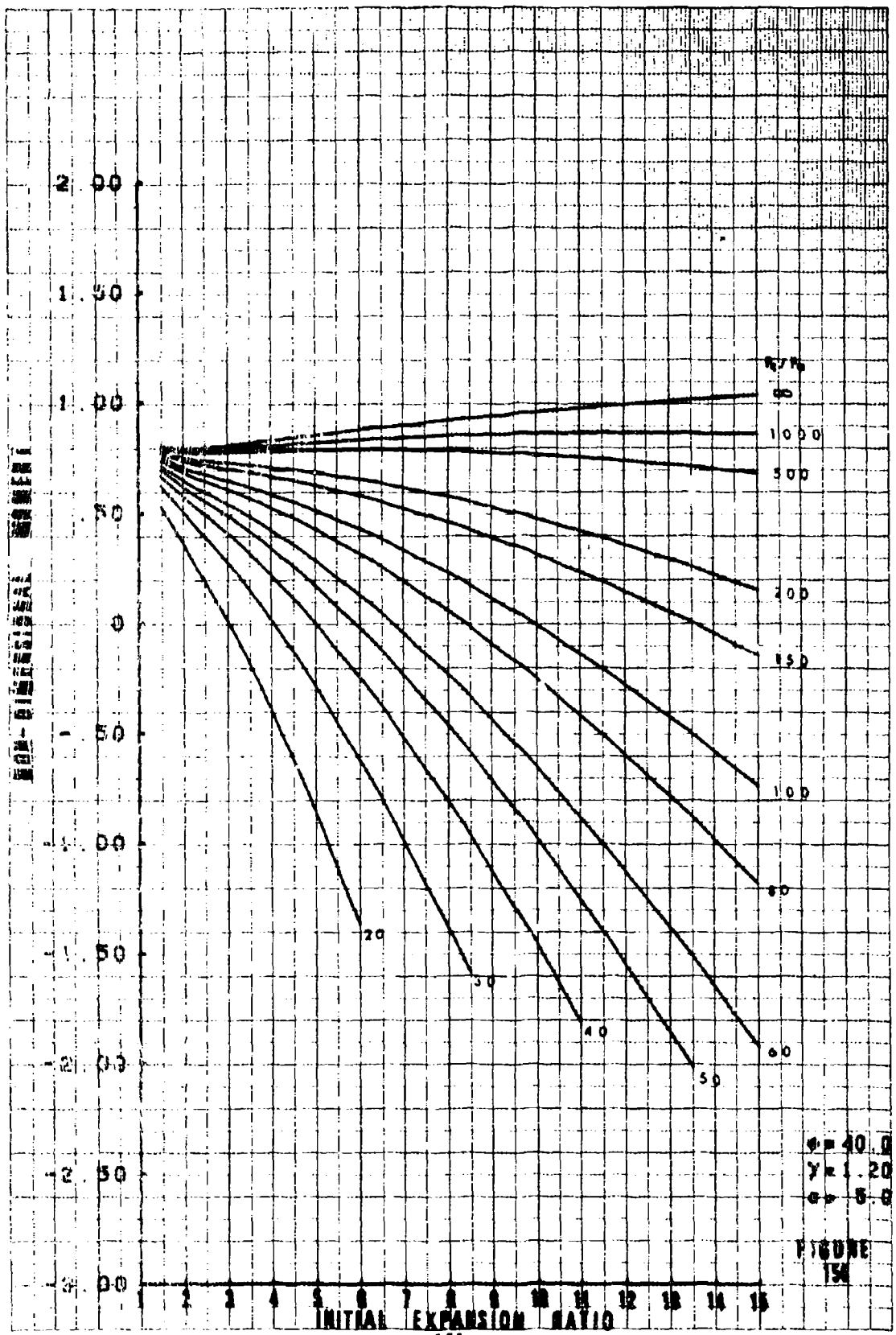

NON-DIMENSIONAL
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.20
σ = 5.0

FIGURE 154

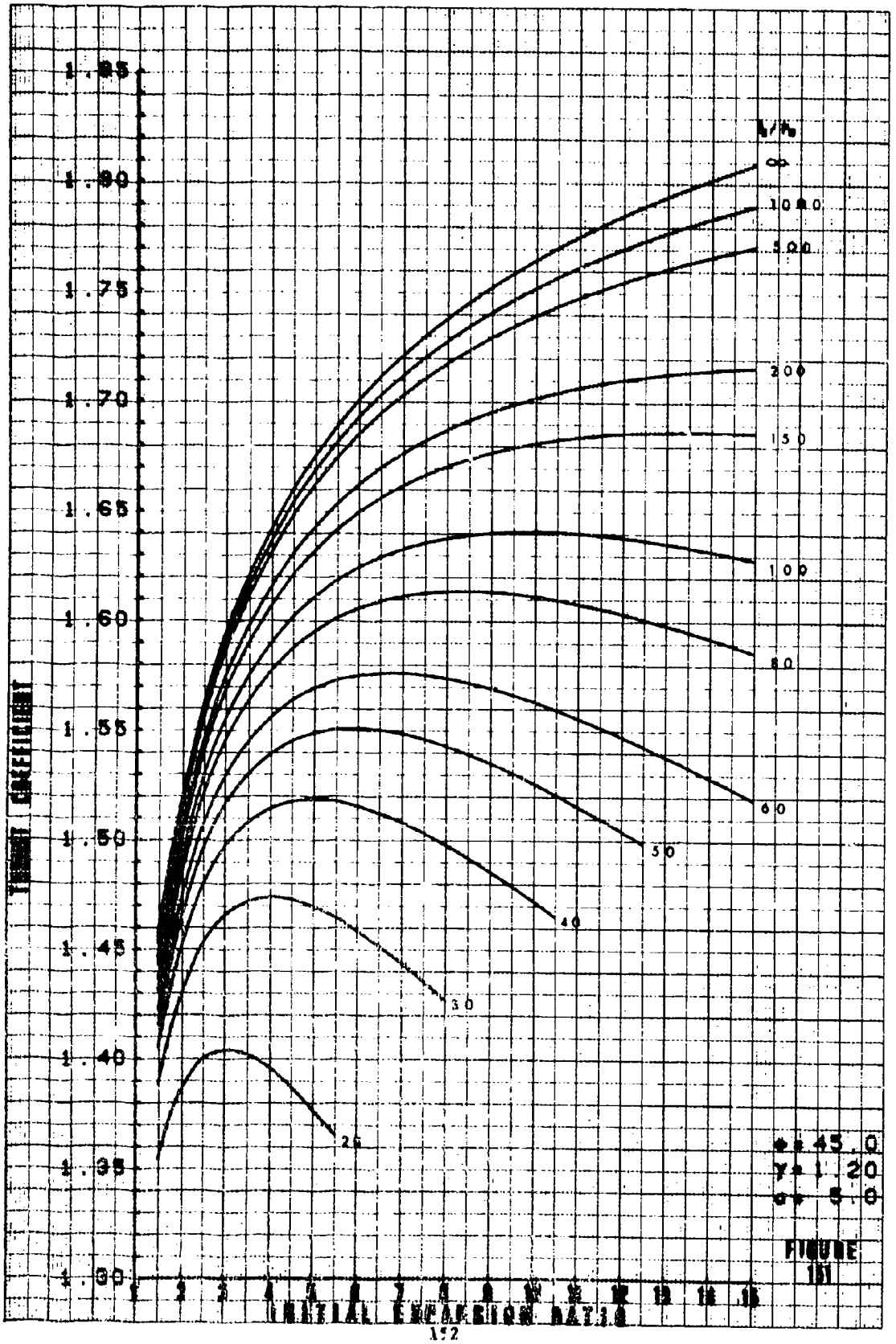
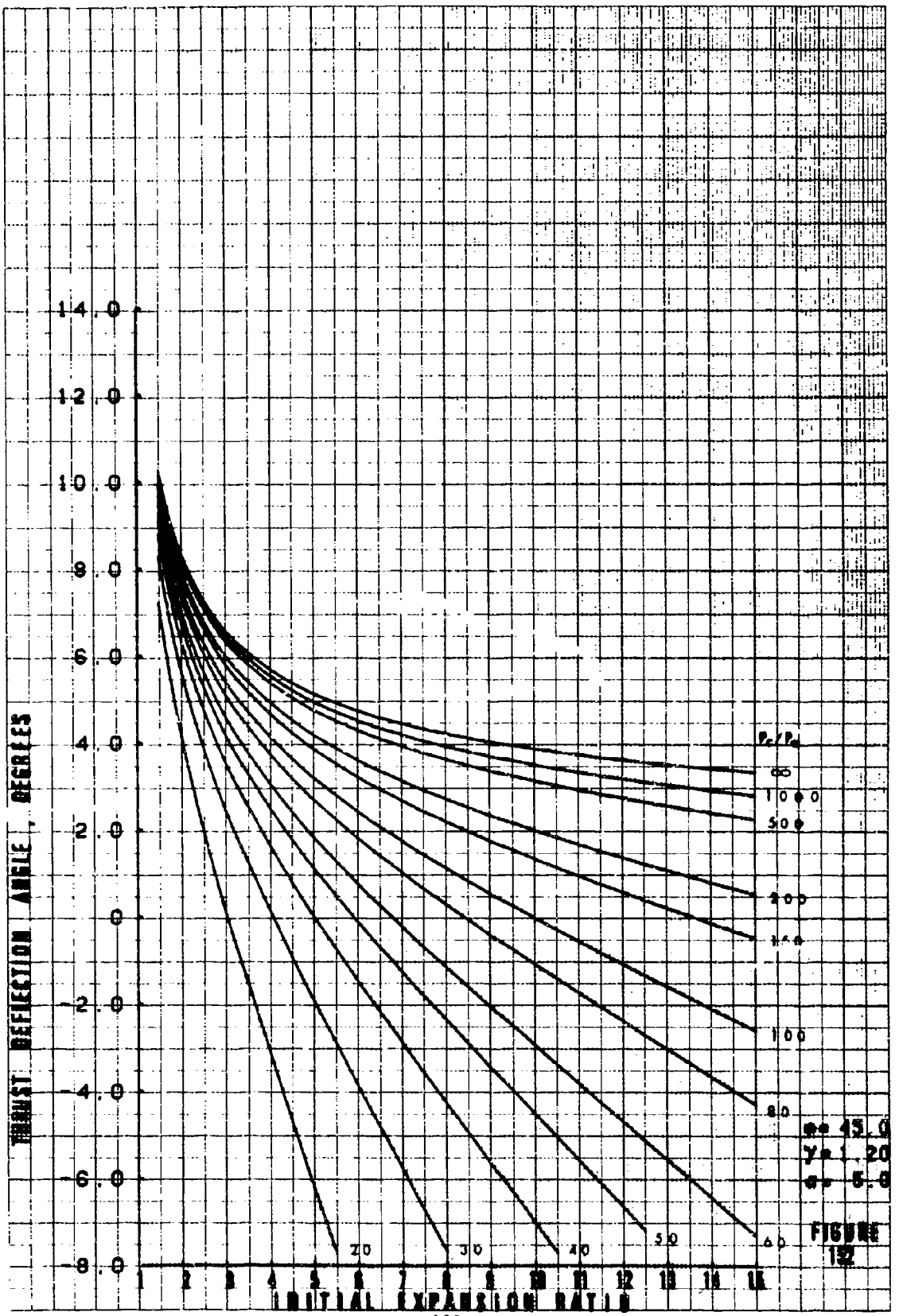
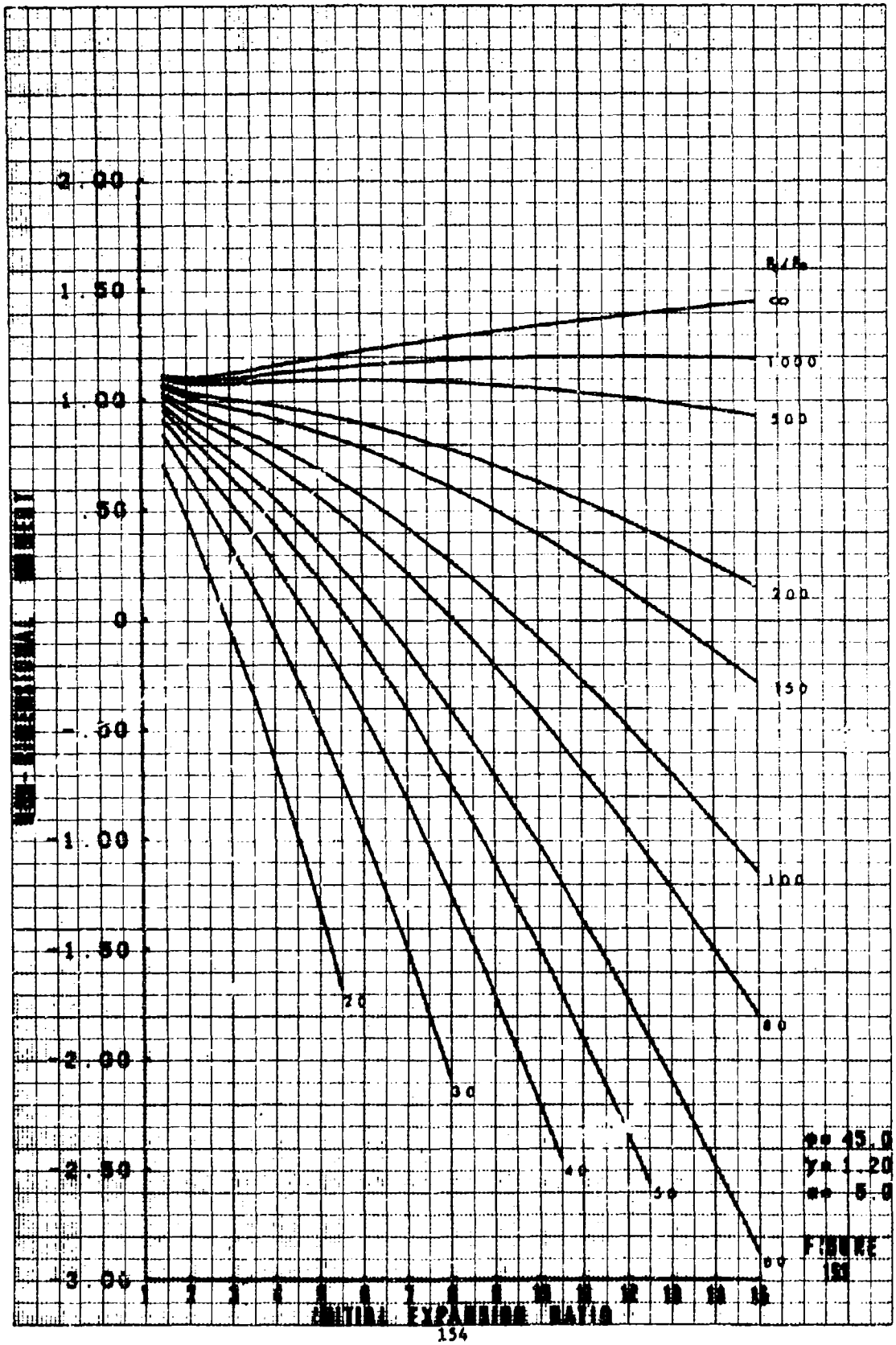

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
h/h_0
∞
1000
500
200
150
100
80
60
50
40
30
25
ϕ = 45.0
γ = 1.20
σ = 5.0

FIGURE 151



14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
100
80
60
50
40
30
20
φ= 45.0
γ= 1.20
α= 5.0

FIGURE 152


2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 45.0
γ= 1.20
α= 5.0
FIGURE
INITIAL EXPANSION RATIO

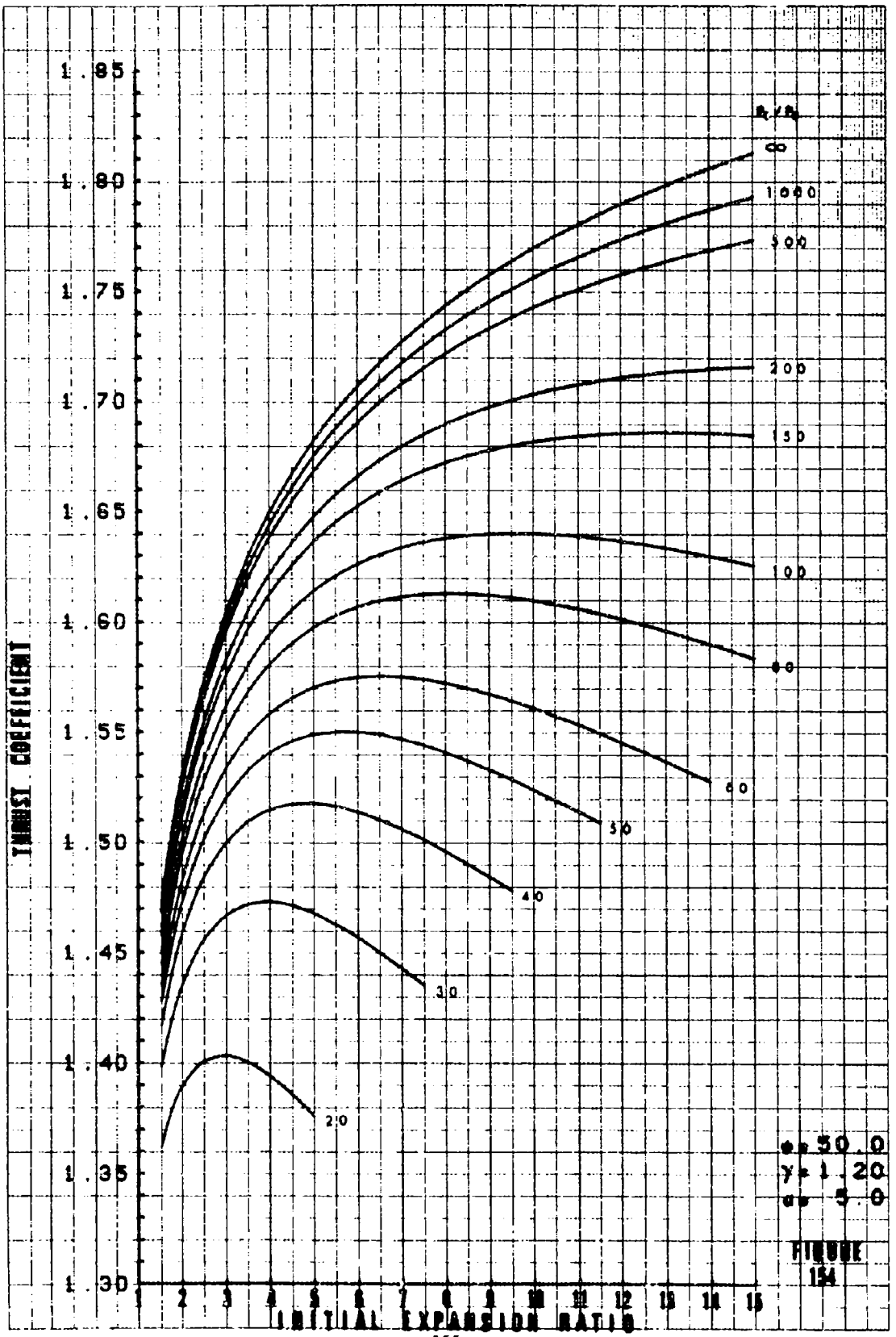

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.20
α = 5.0

FIGURE 154

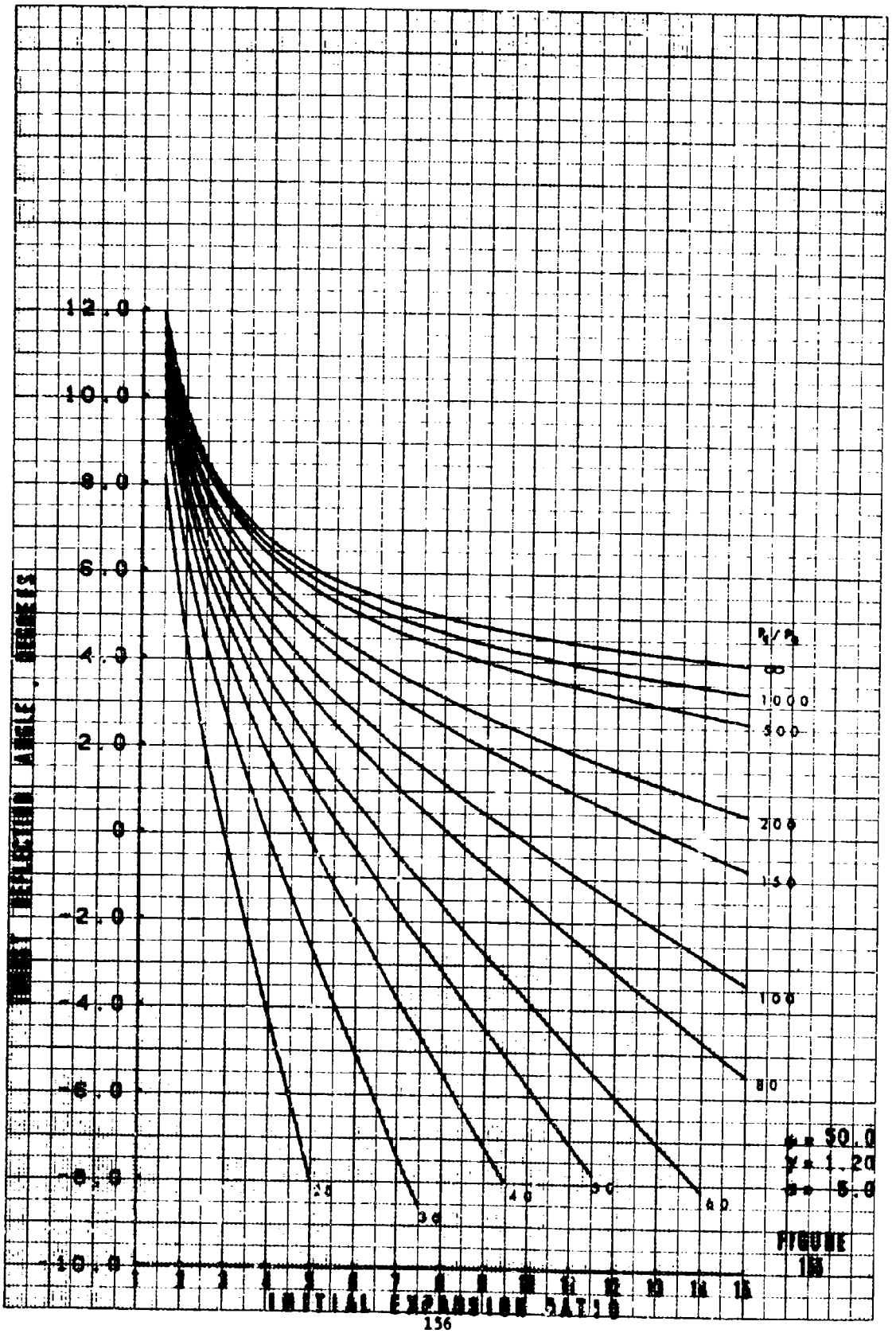

12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
-10.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_1/P_2
∞
1000
500
200
150
100
80
60
40
30
20
ϕ = 50.0
γ = 1.20
θ = 5.0

FIGURE 15

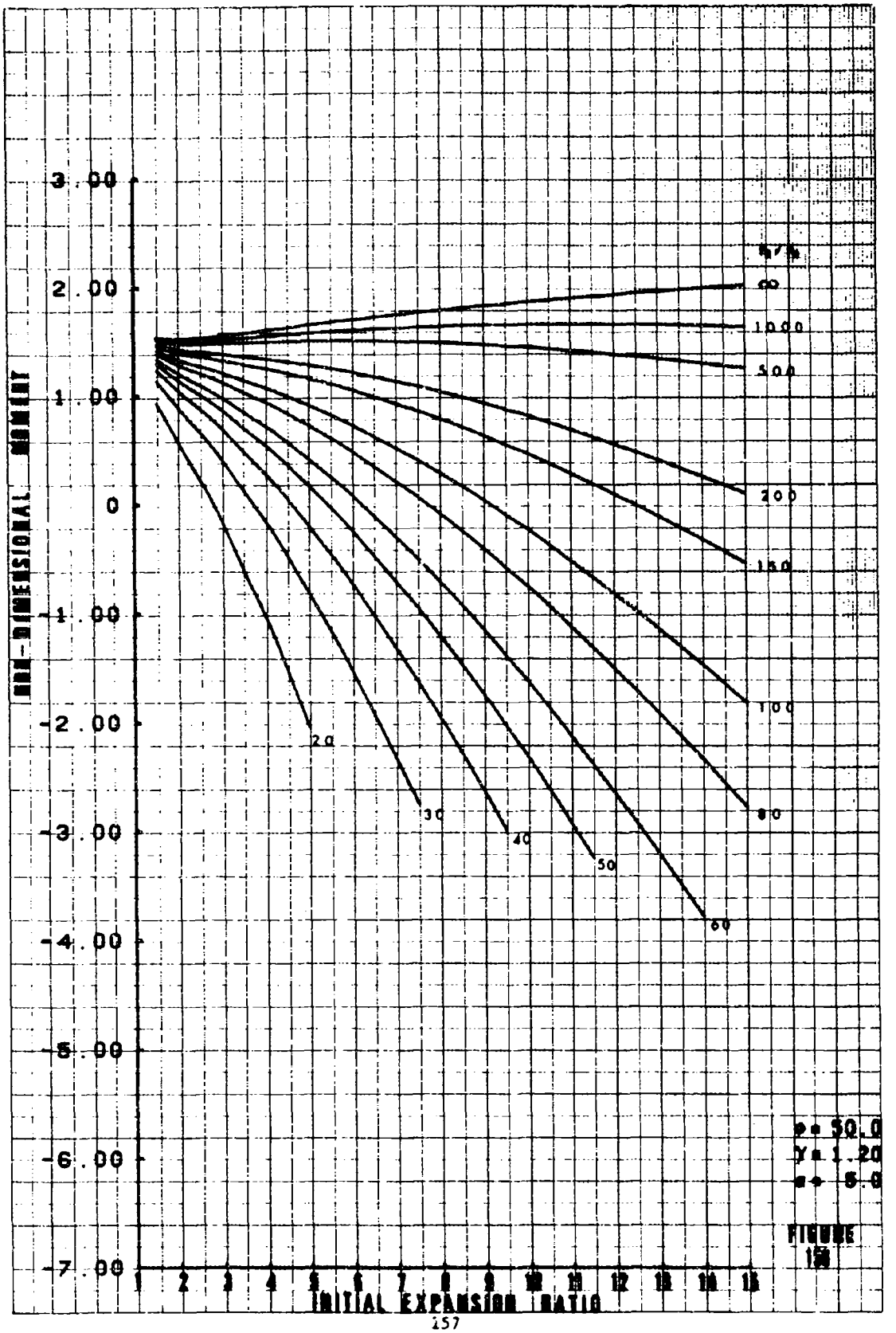
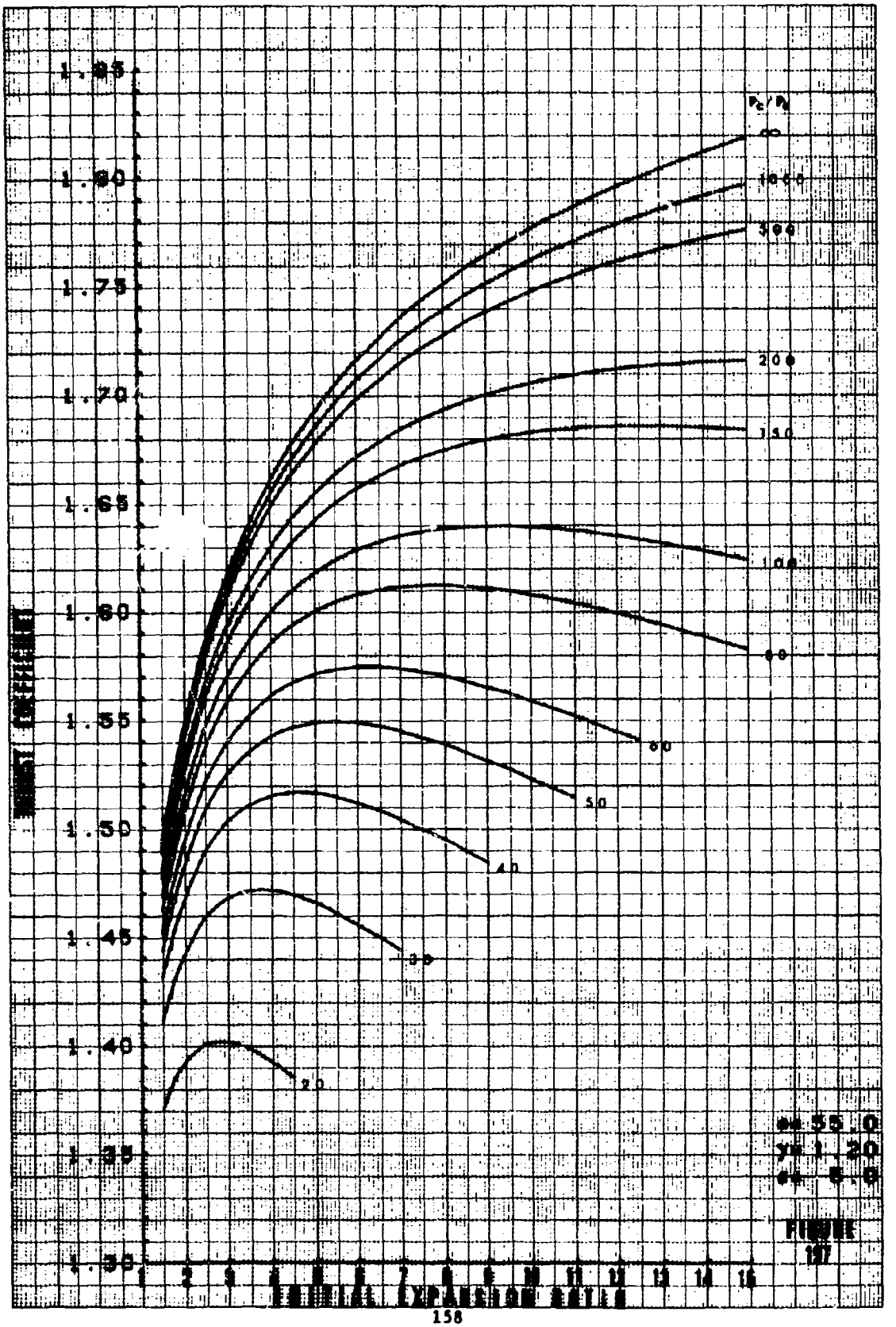

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
20
30
40
50
60
φ= 50.0
γ= 1.20
ε= 5.0

FIGURE 15



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 197

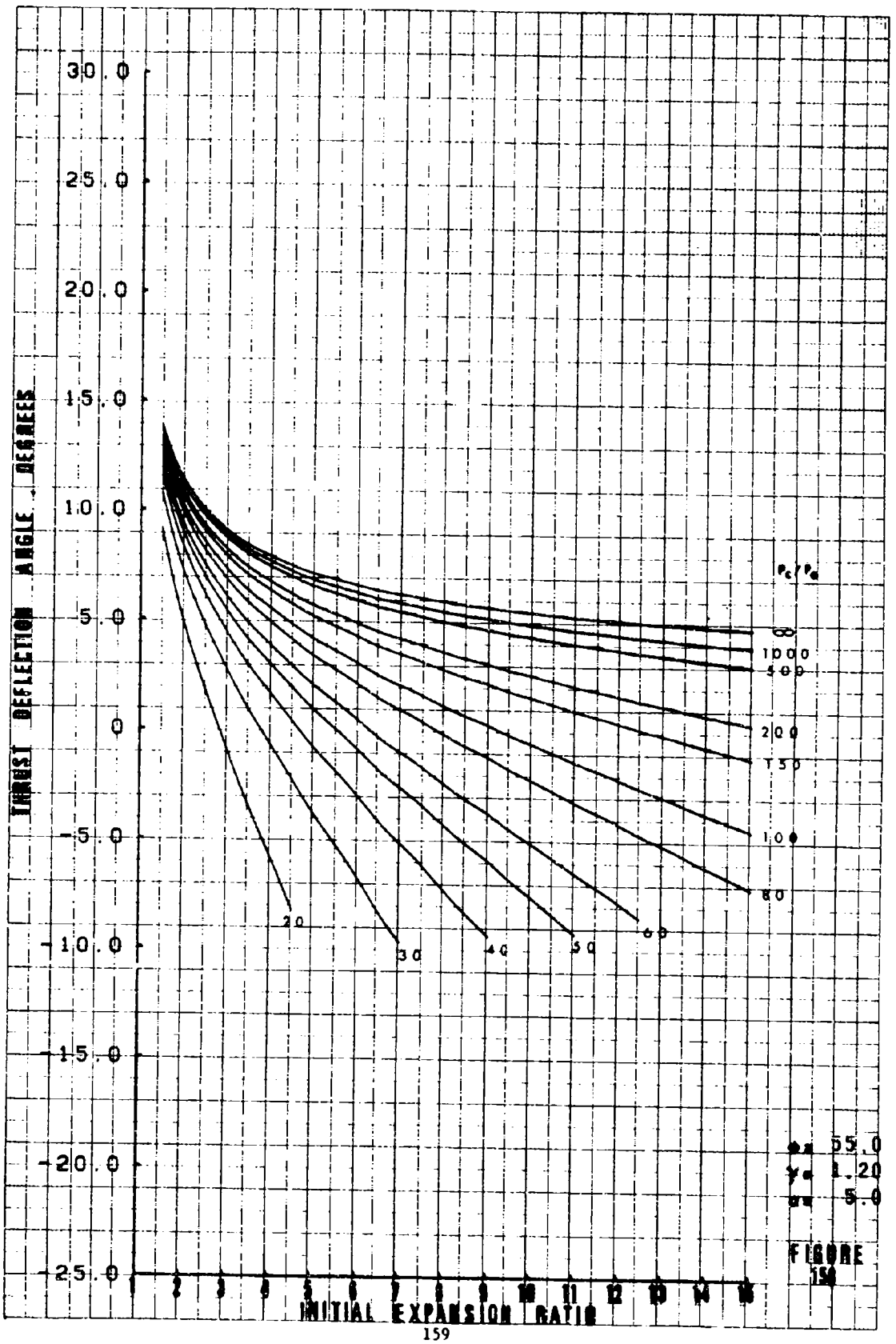

THRUST DEFLECTION ANGLE, DEGREES
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ_a 55.0
γ_a 1.20
α_a 5.0

FIGURE 15

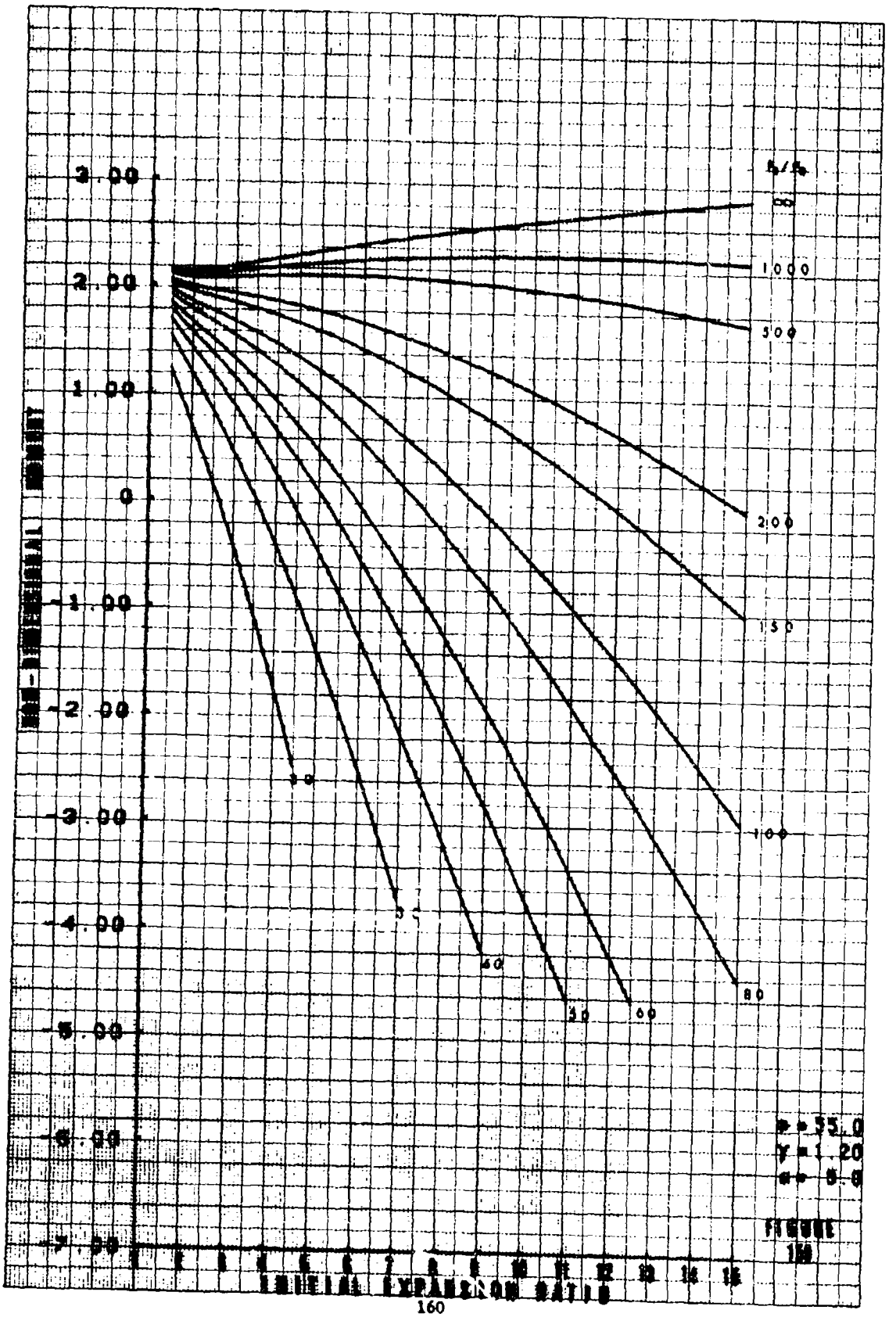

3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1000
500
200
150
100
80
60
50
40
30
INITIAL EXPANSION RATIO

FIGURE 150

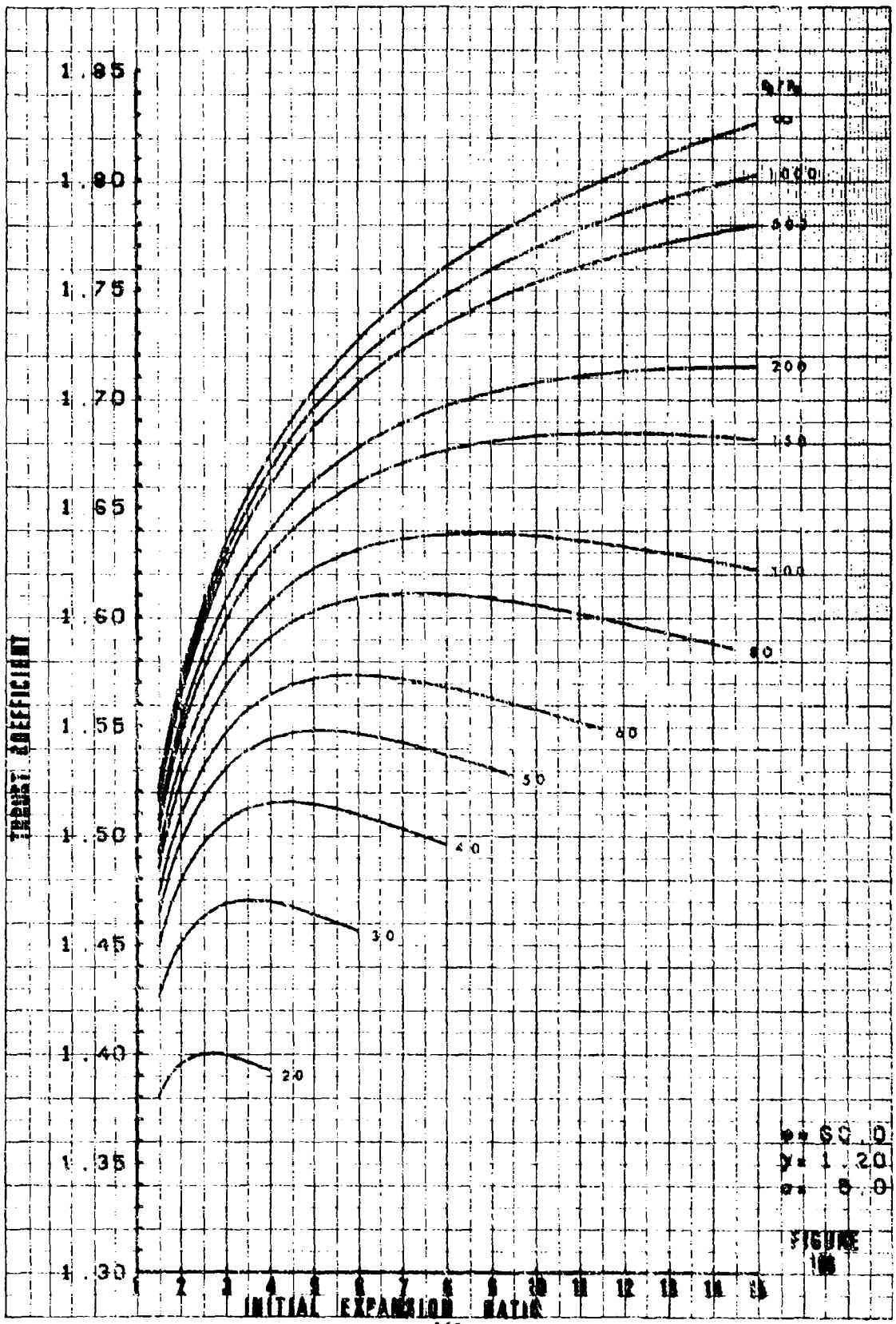

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 60.0
γ = 1.20
= 5.0

FIGURE 16

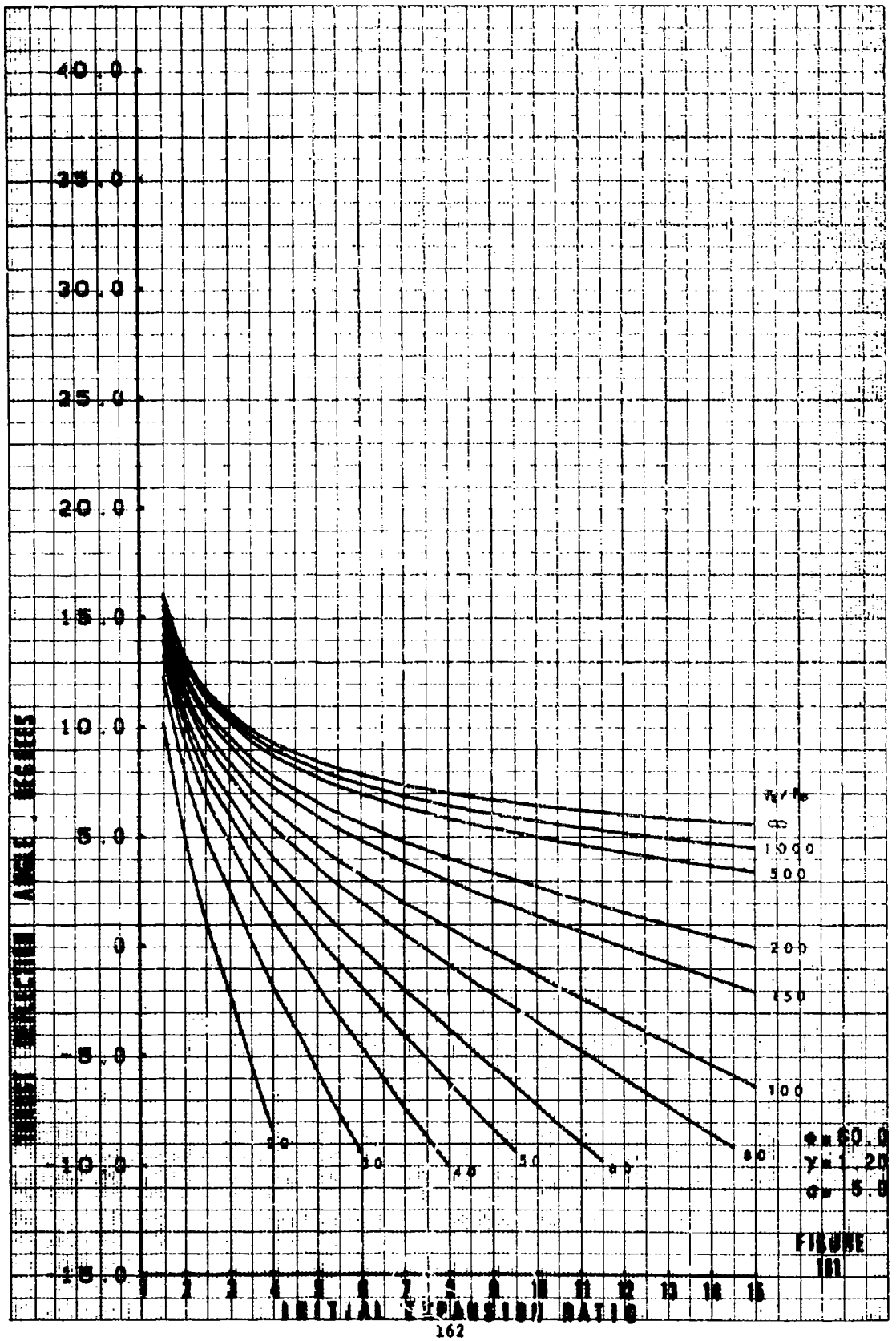

40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.20
σ = 5.0

FIGURE 161

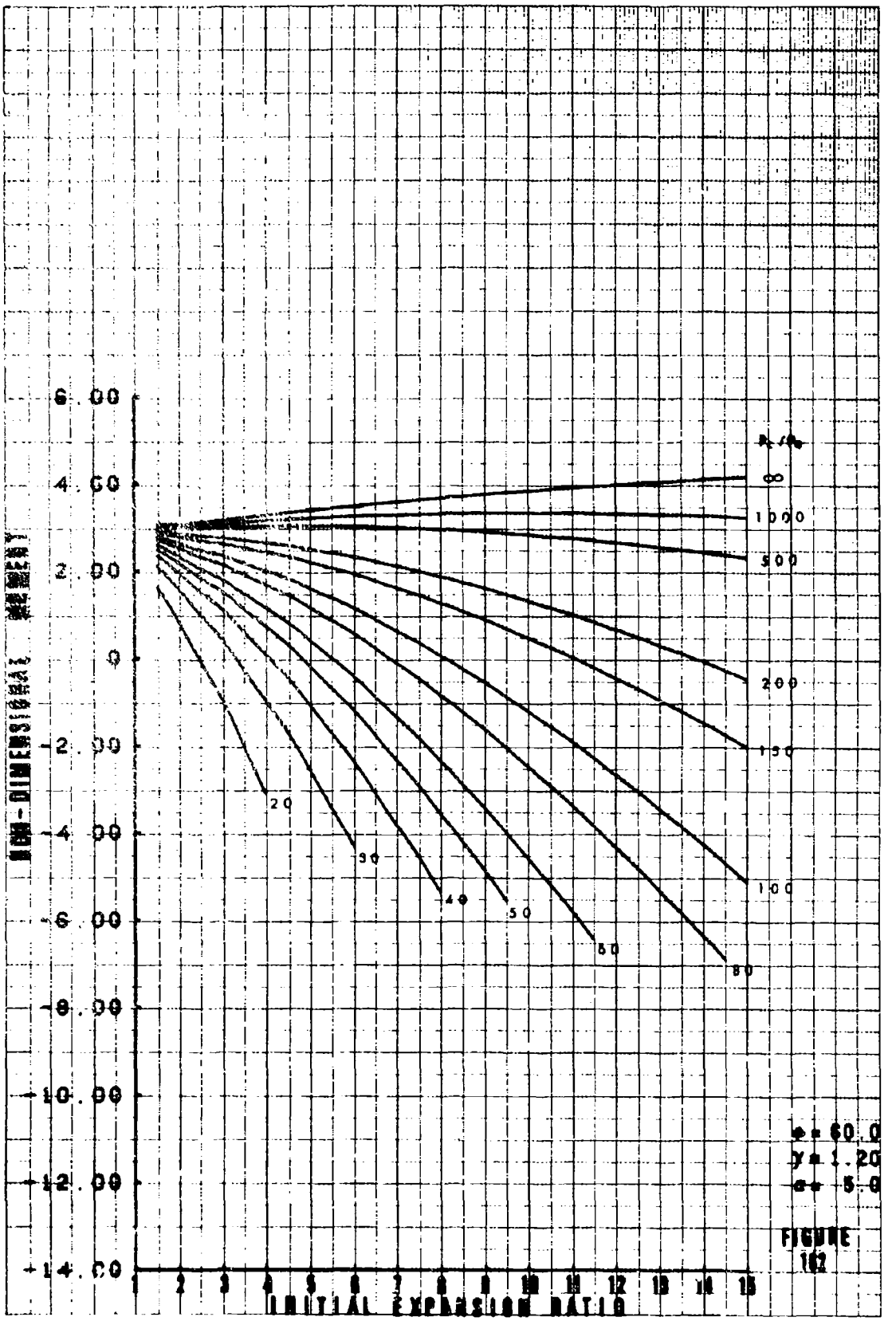
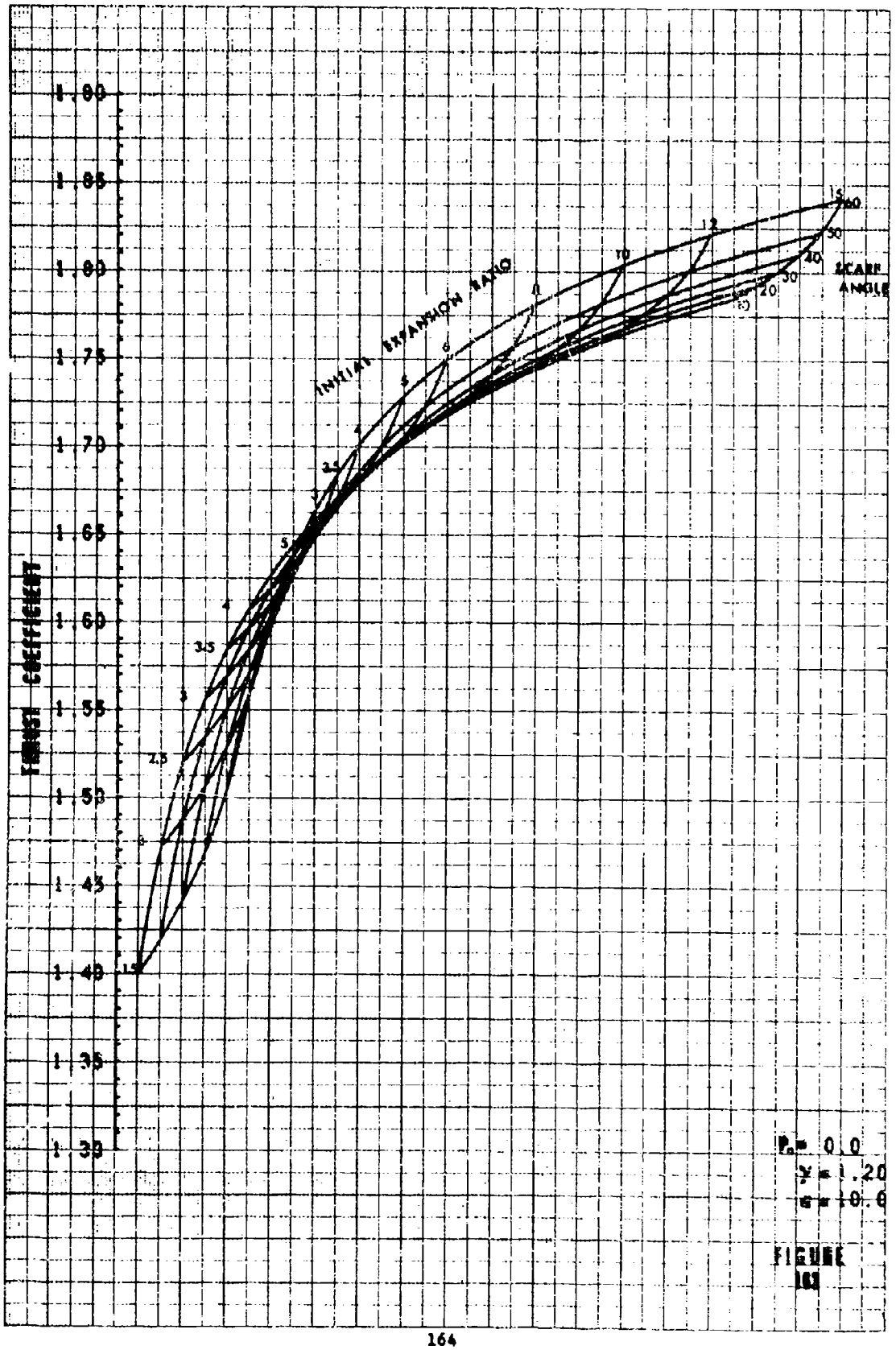

NON-DIMENSIONAL EFFICIENCY
6.00
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.20
α = 5.0

FIGURE 162



1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
SCARF ANGLE
P_o = 0.0
γ = 1.20
ϵ = 10.0

FIGURE 163

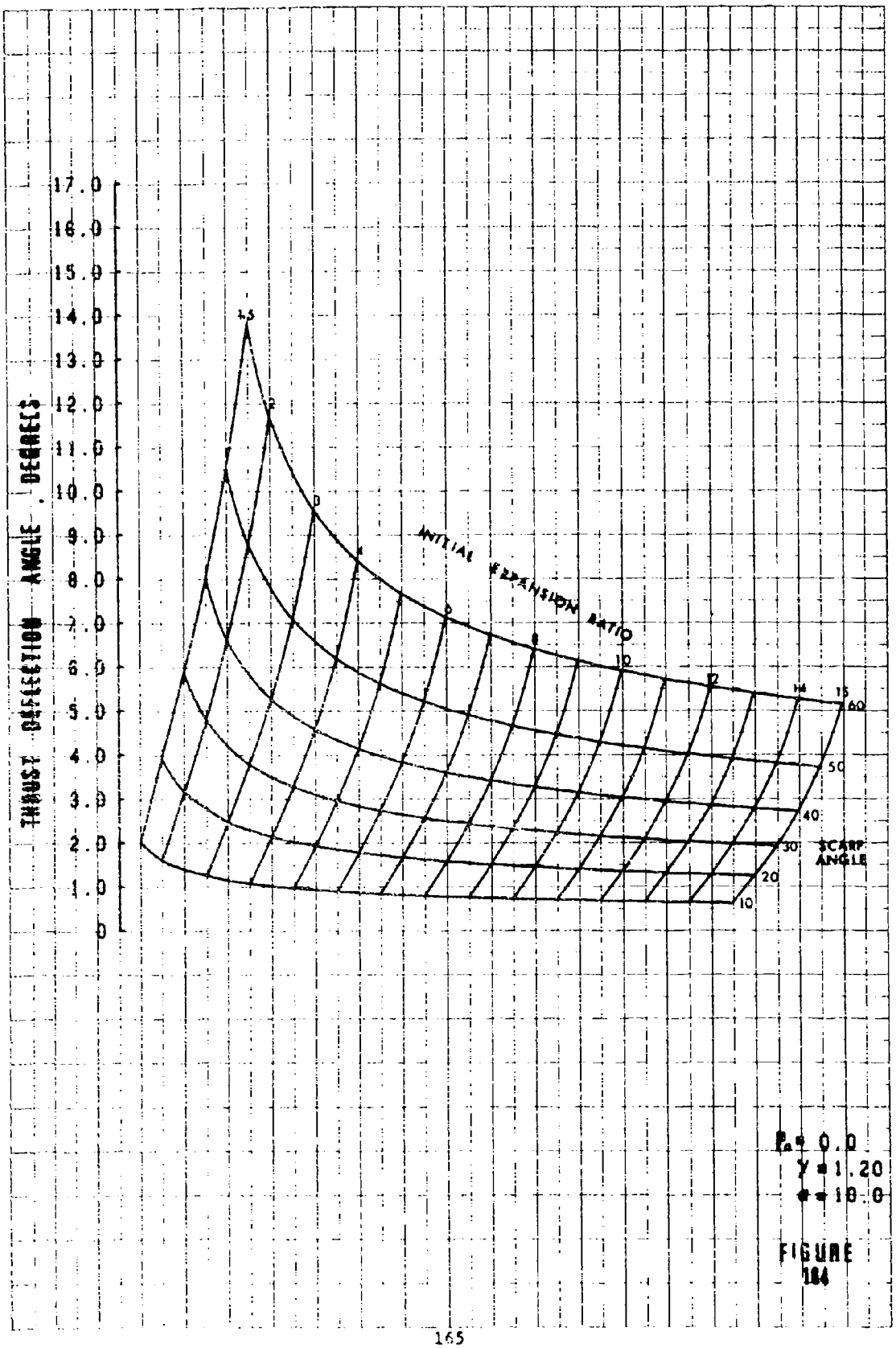

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
10
20
30
40
50
60
P_A = 0.0
γ = 1.20
θ = 10.0

FIGURE 184

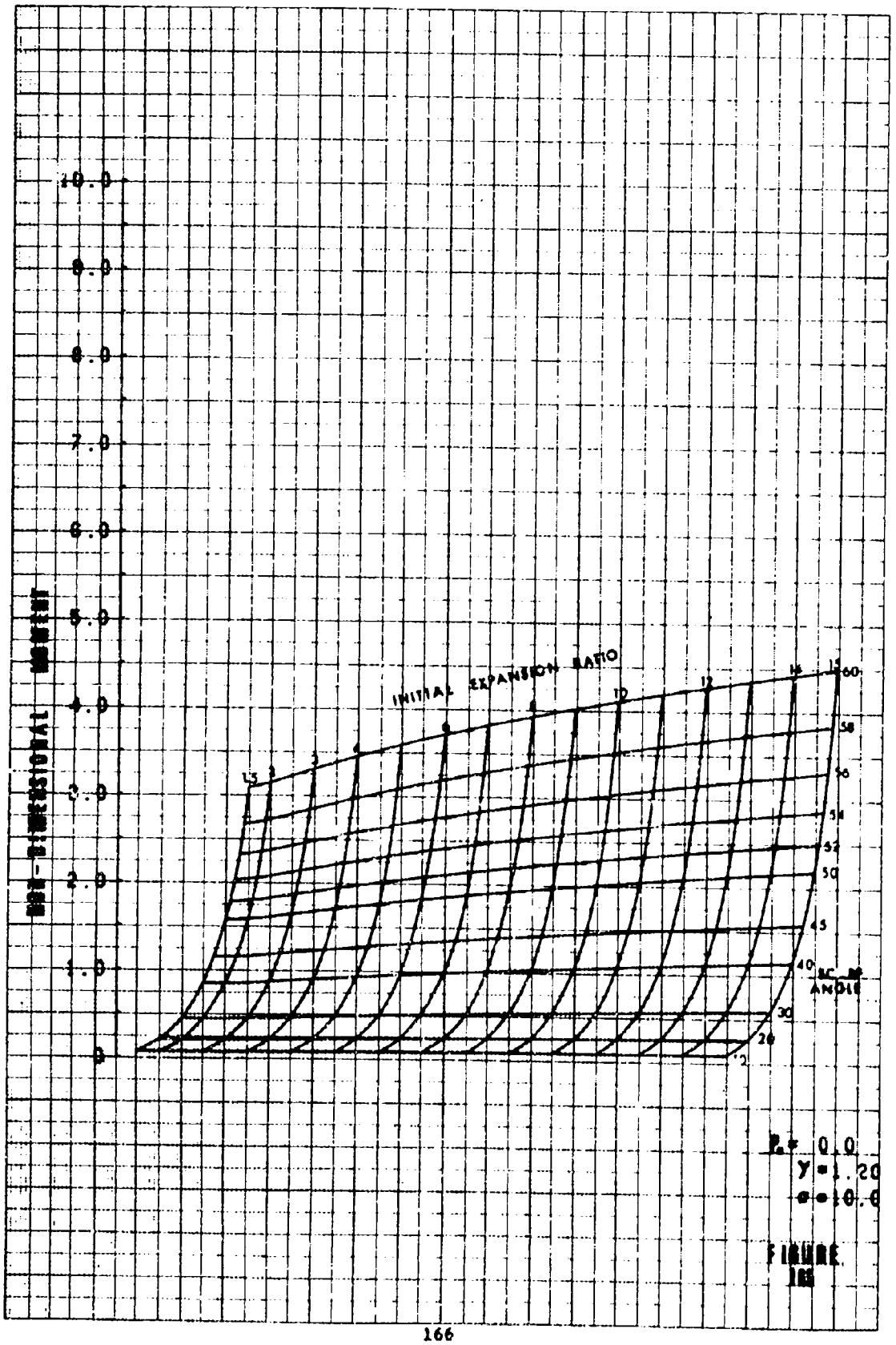
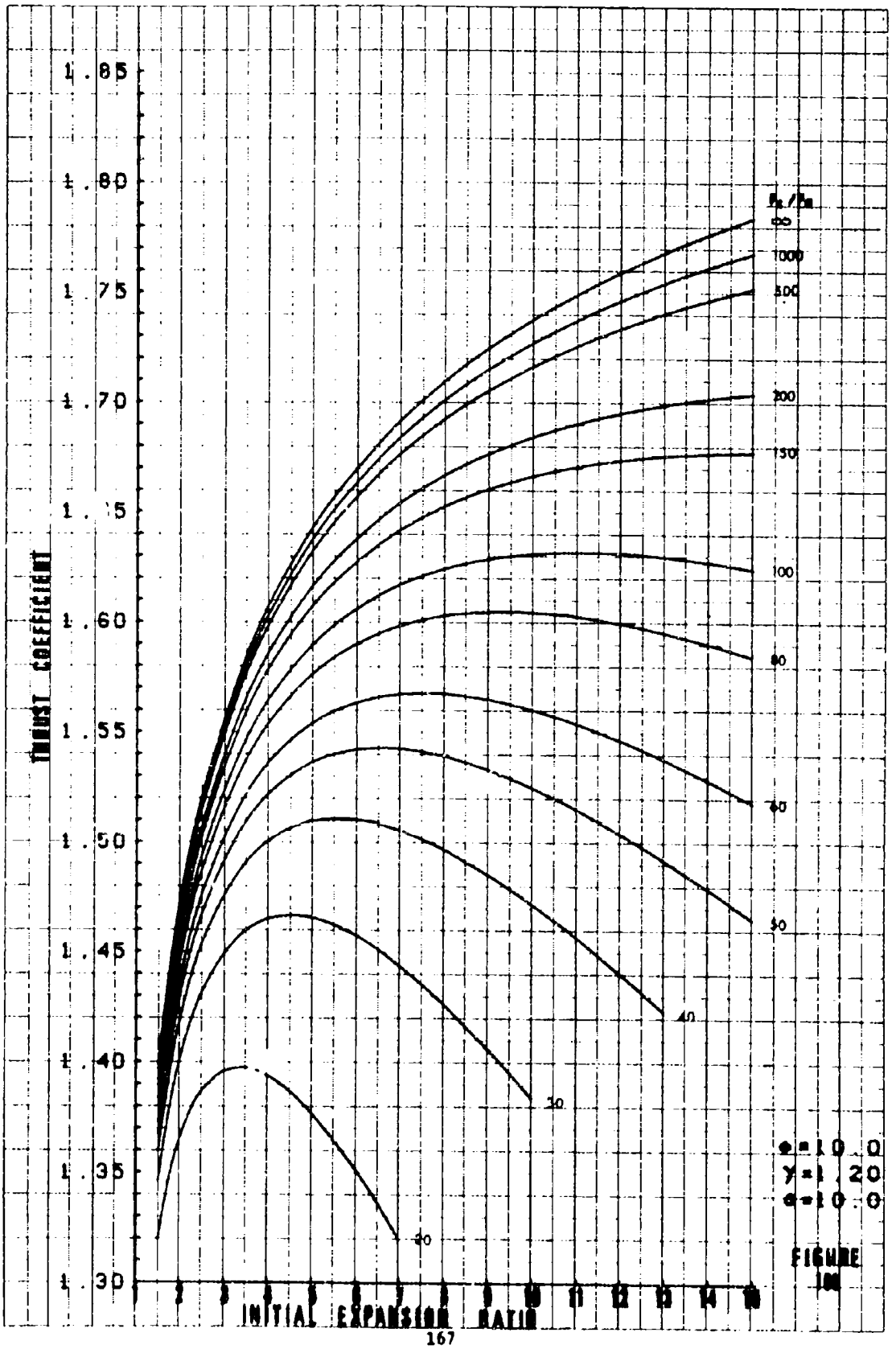

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
60
58
56
54
52
50
45
40
30
20
ANGLE
P = 0.0
γ = 1.20
σ = 10.0

FIGURE 166


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ=1.20
FIGURE 10

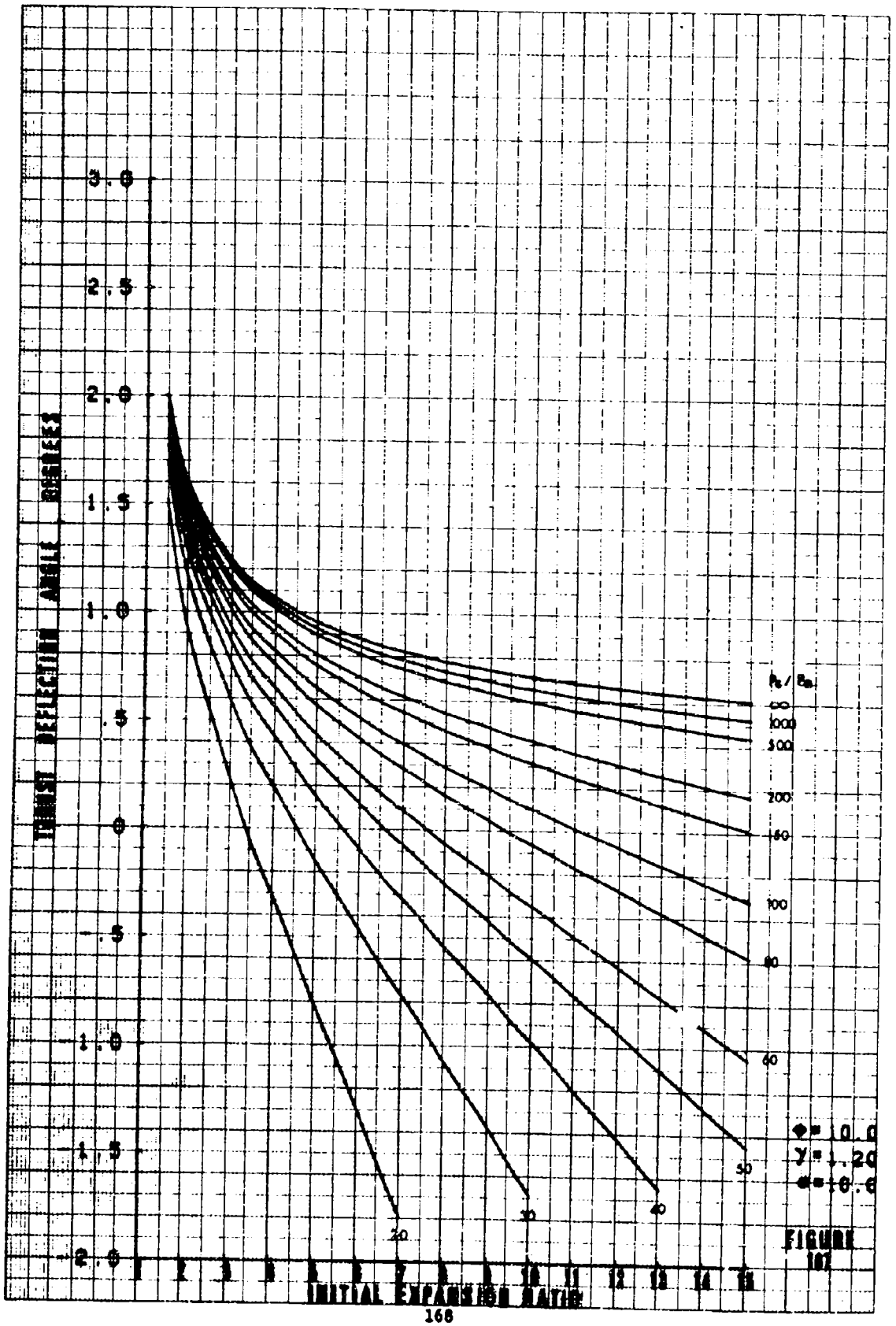
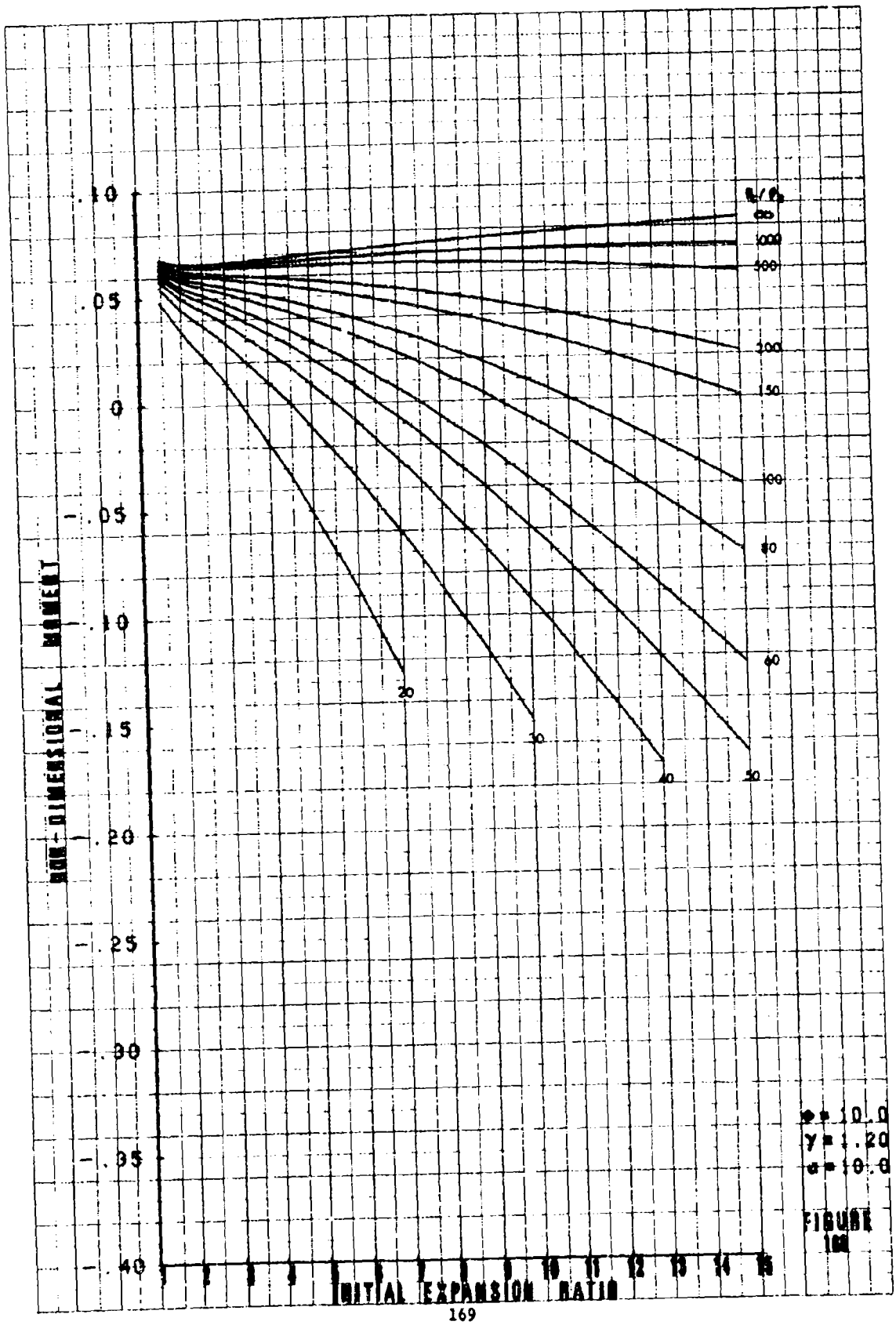

THRUST DEFLECTION ANGLE DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.20
θ = 0.6

FIGURE 107



NON-DIMENSIONAL MOMENT
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ρ_c/ρ_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.20
α = 10.0

FIGURE 16[illegible]

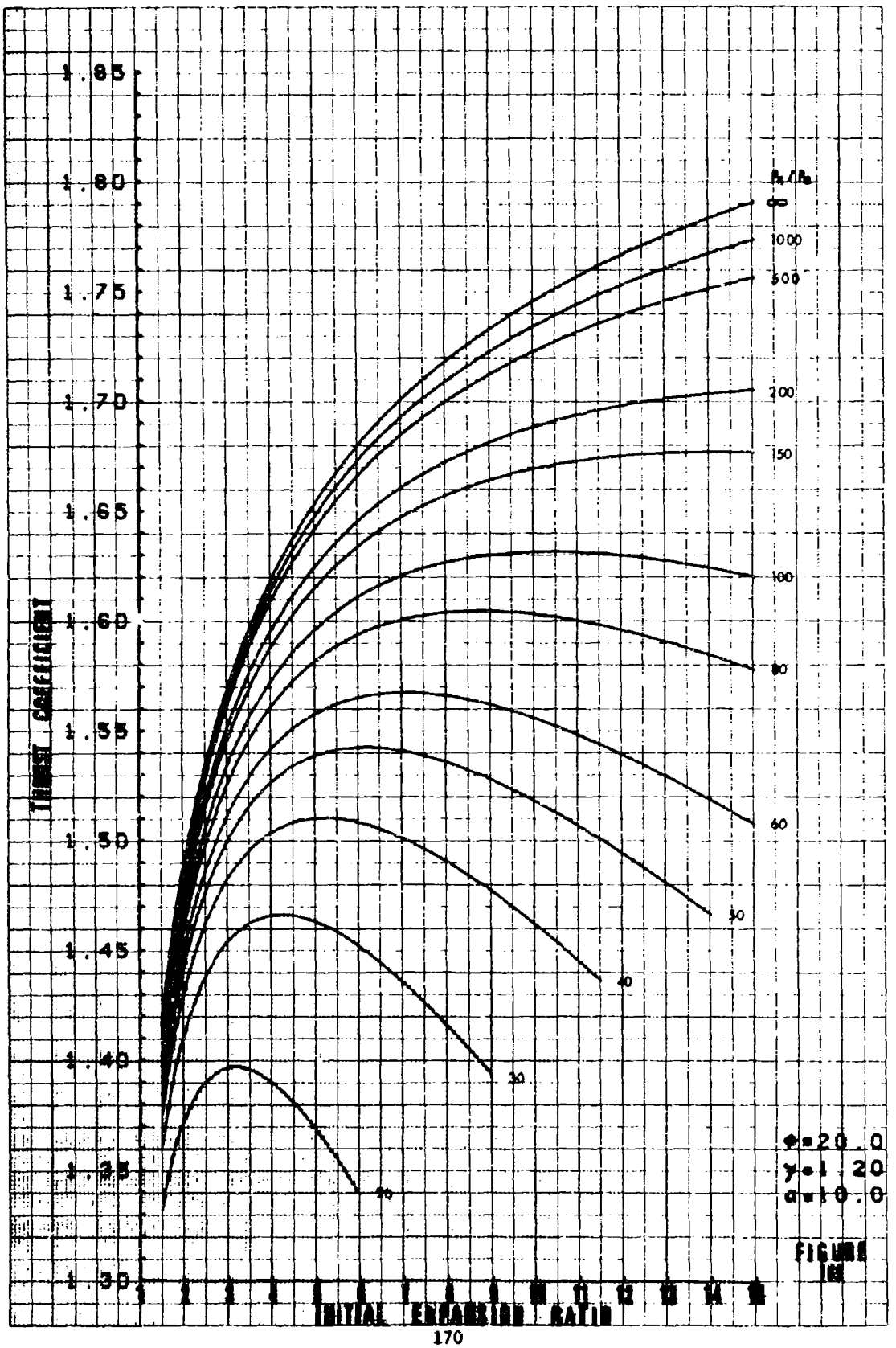

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
12
13
14
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.20
α=10.0

FIGURE 16

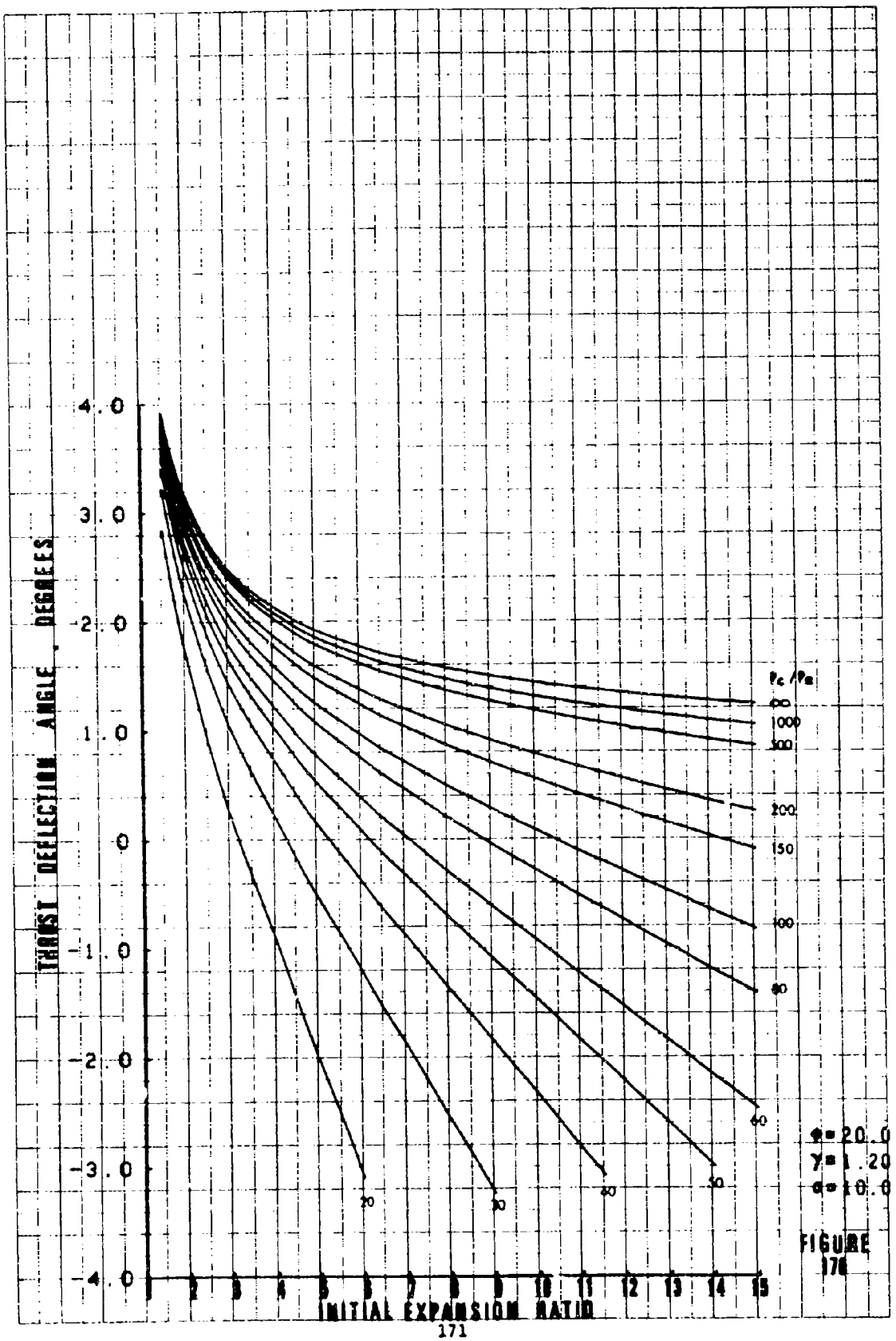
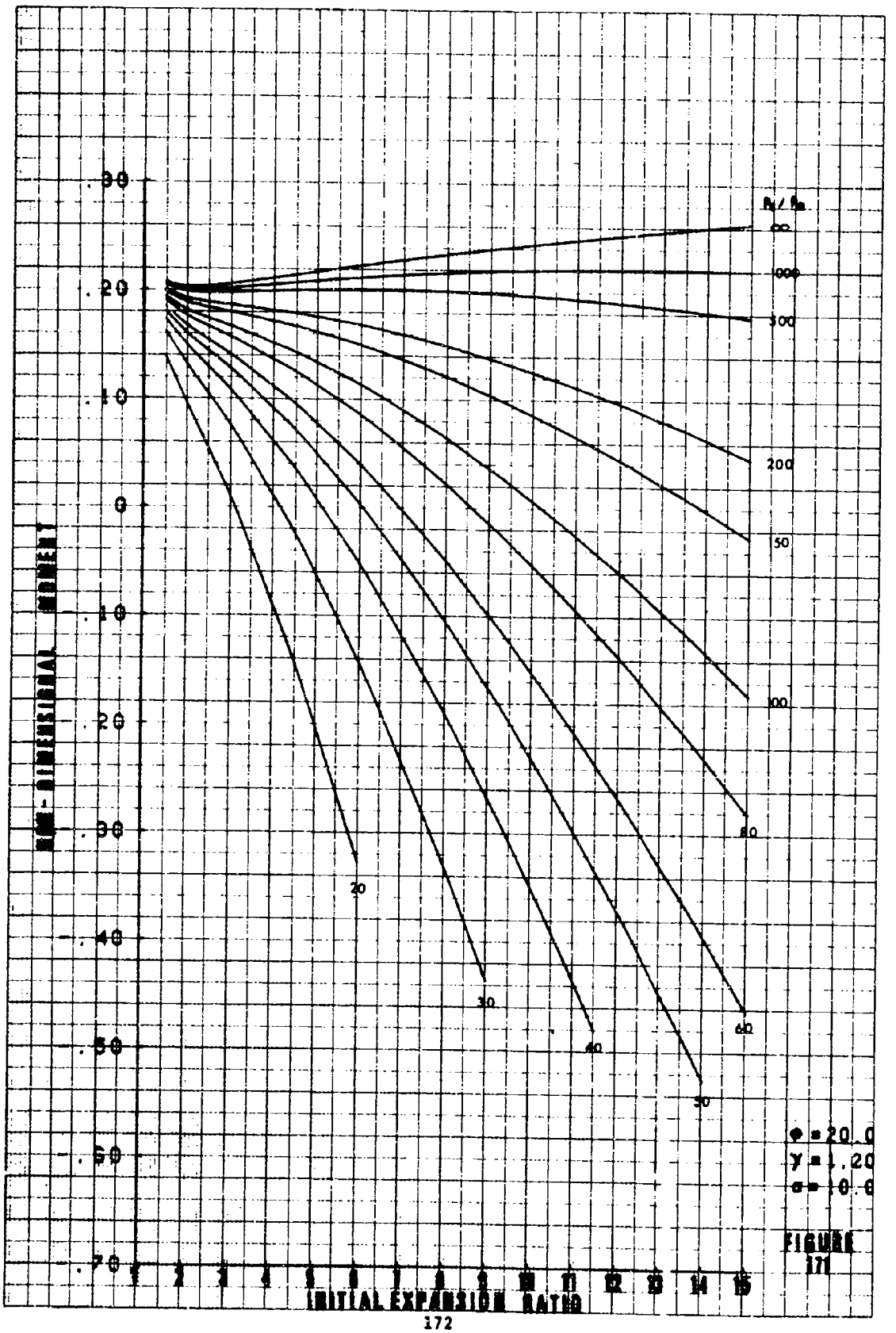

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
Pc/Pa
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 20.0
γ= 1.20
α= 10.0

FIGURE 176



.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
300
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
σ = 10.0

FIGURE 171

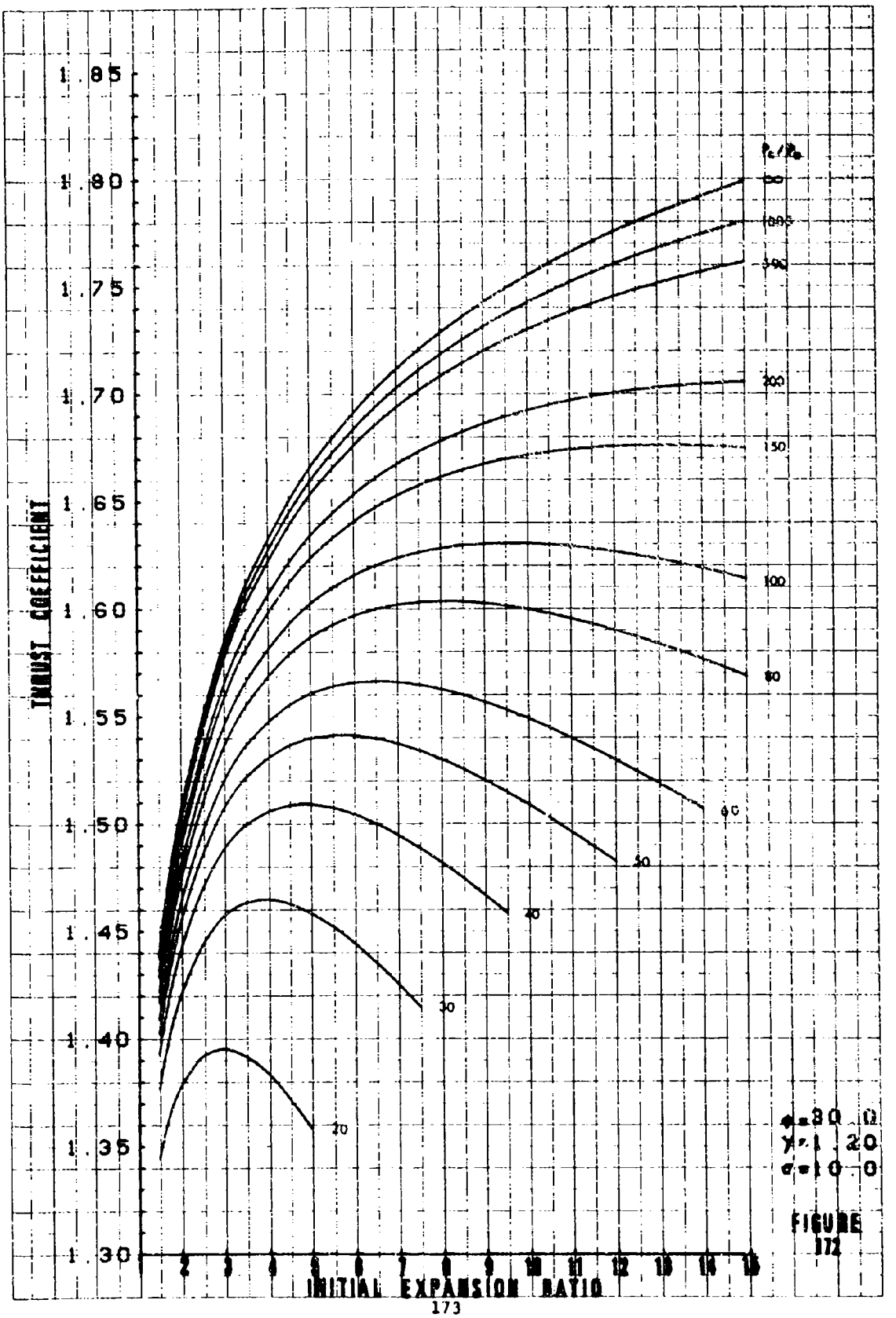

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=80.0
γ=1.20
σ=10.0

FIGURE 172

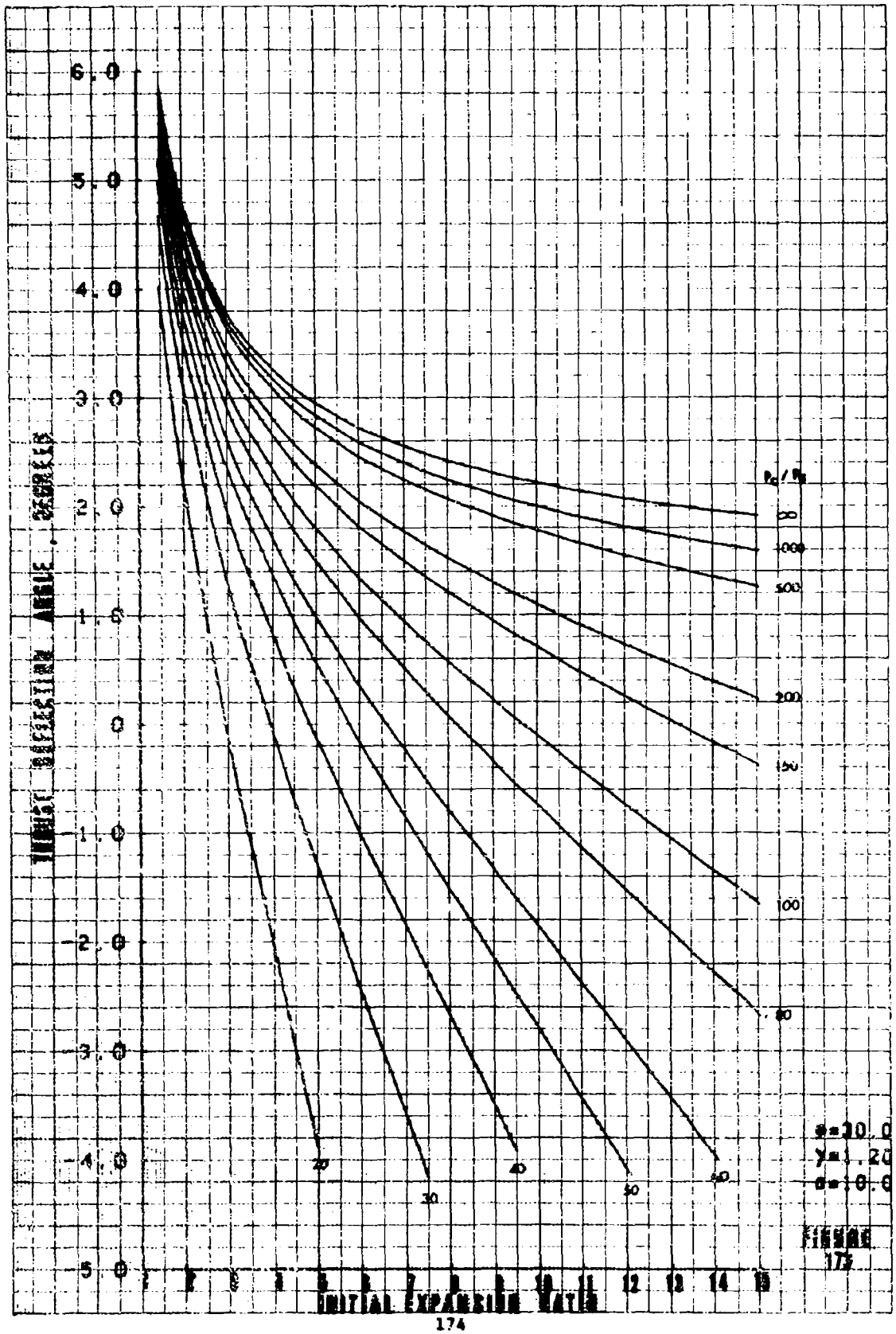

6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
THRUST DEFLECTION ANGLE, DEGREES
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO

FIGURE 173

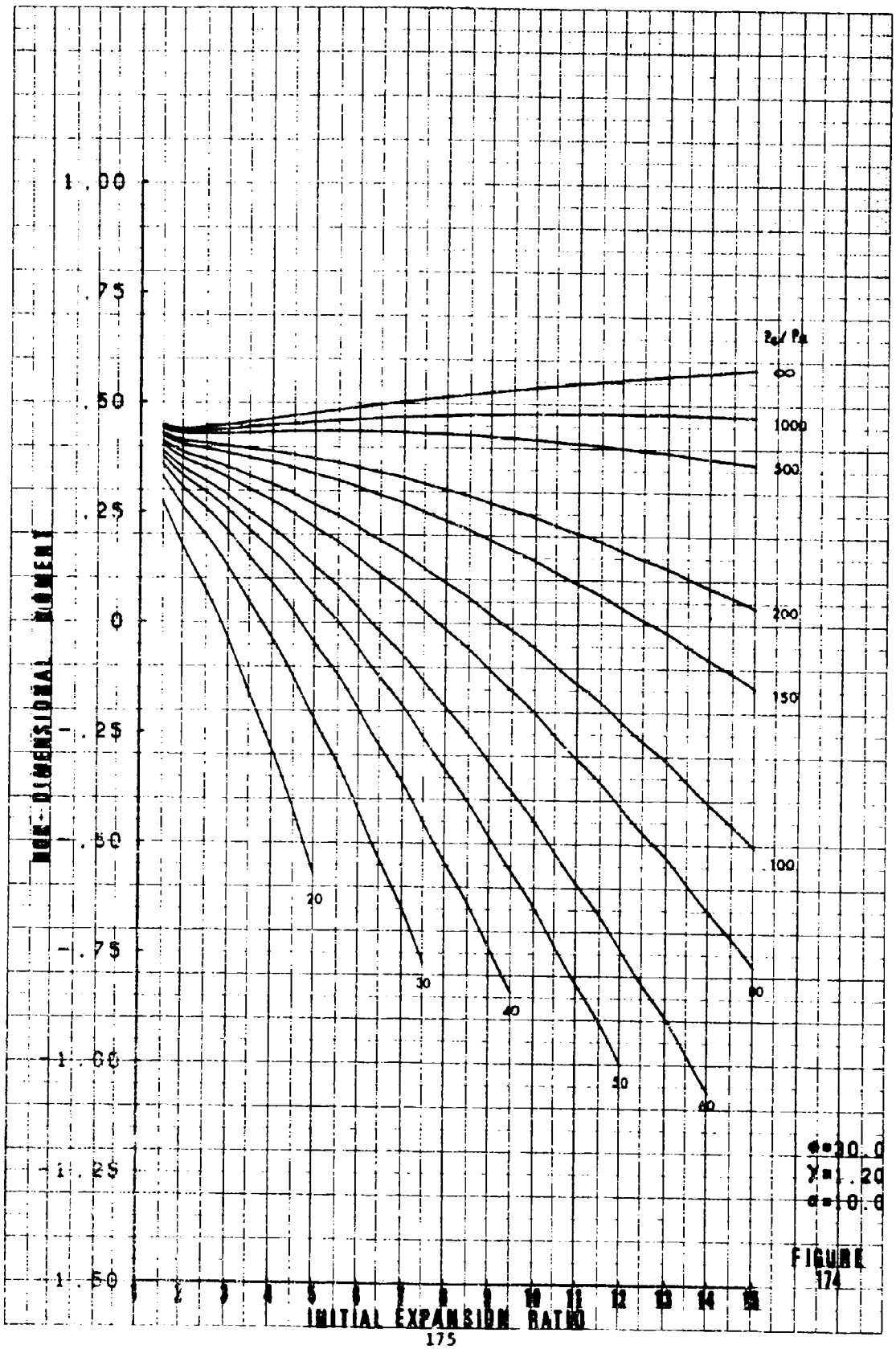

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
20
30
40
50
60
φ=30.0
γ=1.20
α=0.0

FIGURE 174

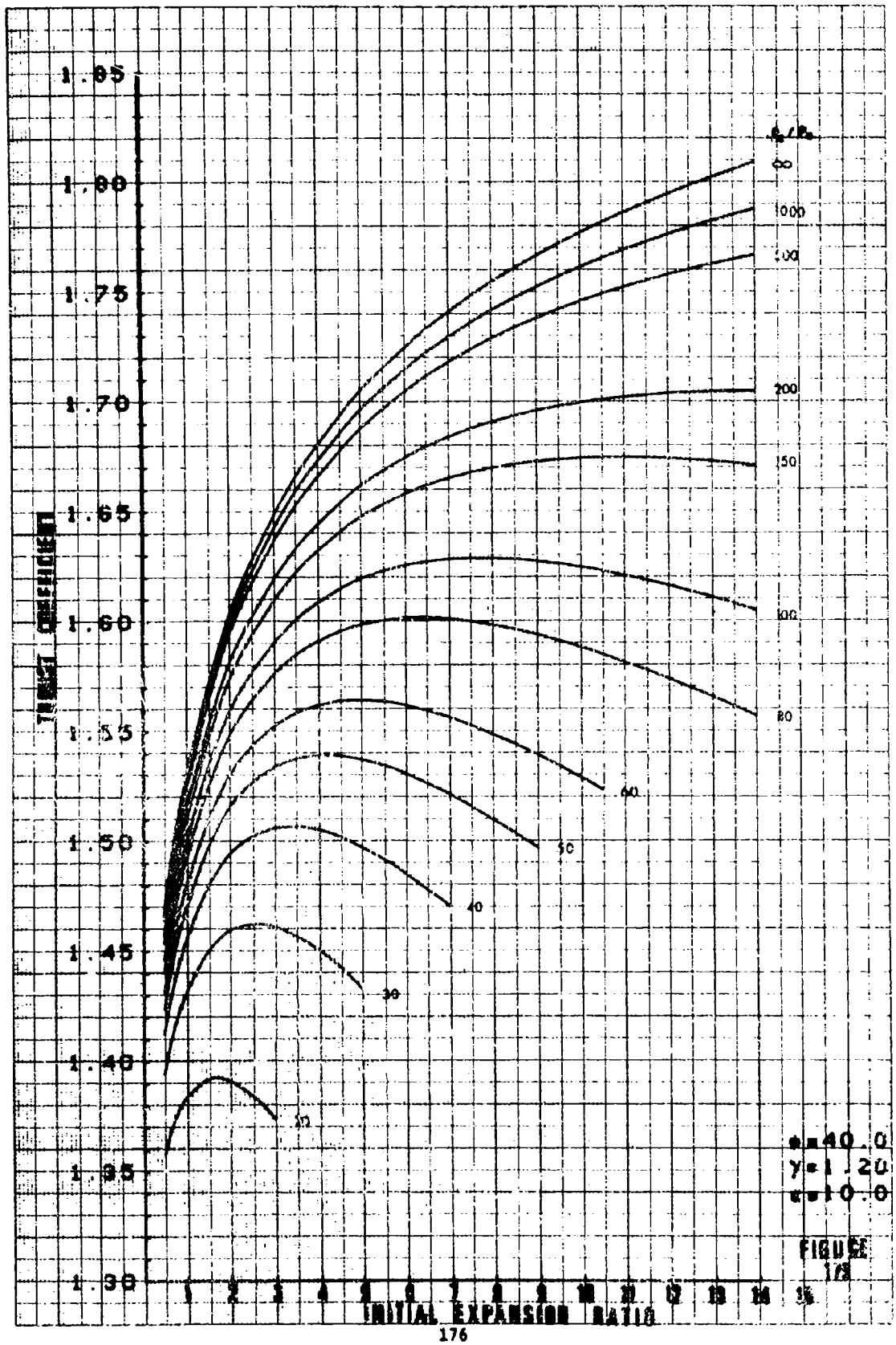

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ=1.20
ε=10.0

FIGURE 178

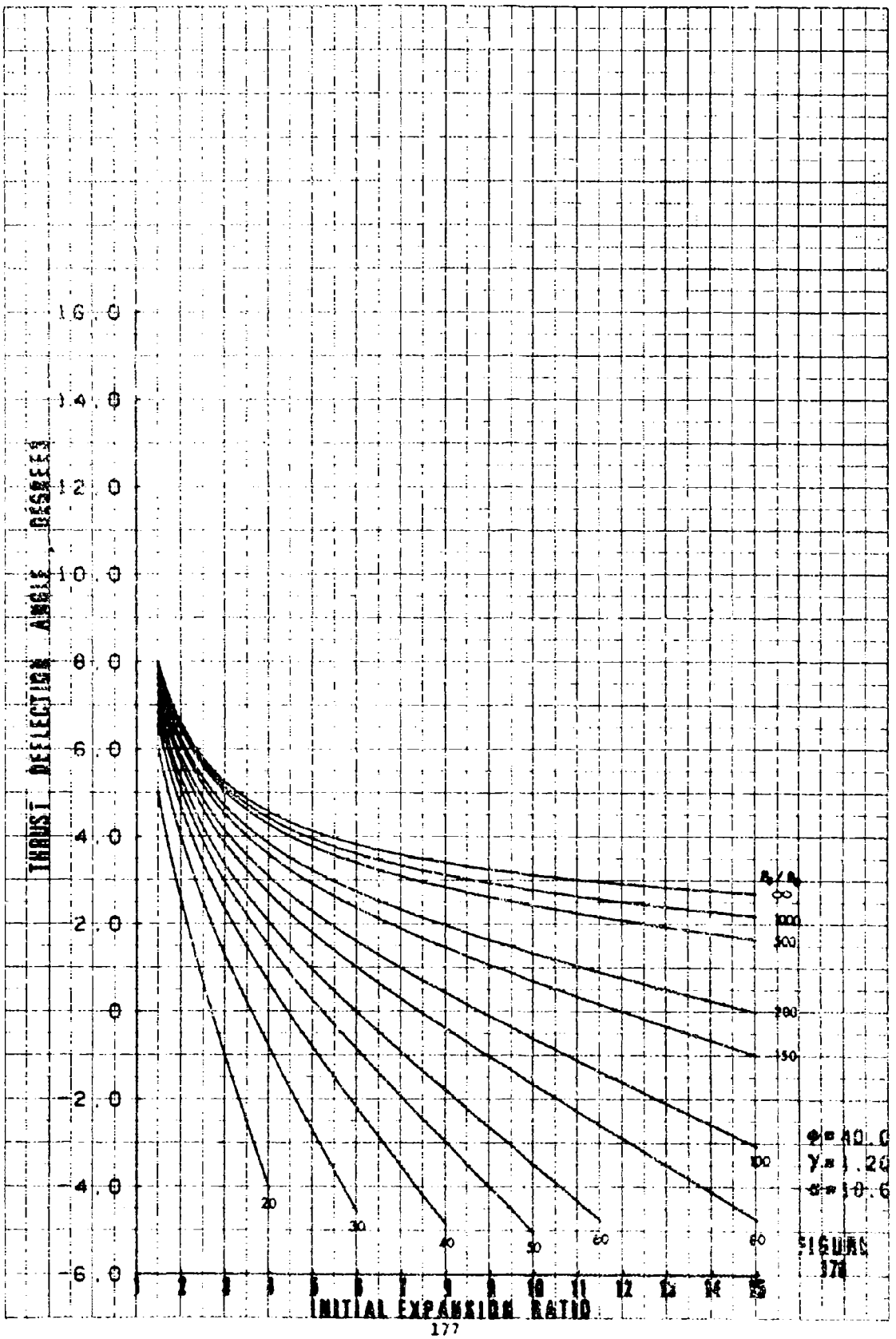

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R_0/R_0
∞
1000
500
200
150
100
60
50
40
30
20
φ = 40.0
γ = 1.20
α = 10.6

FIGURE 178

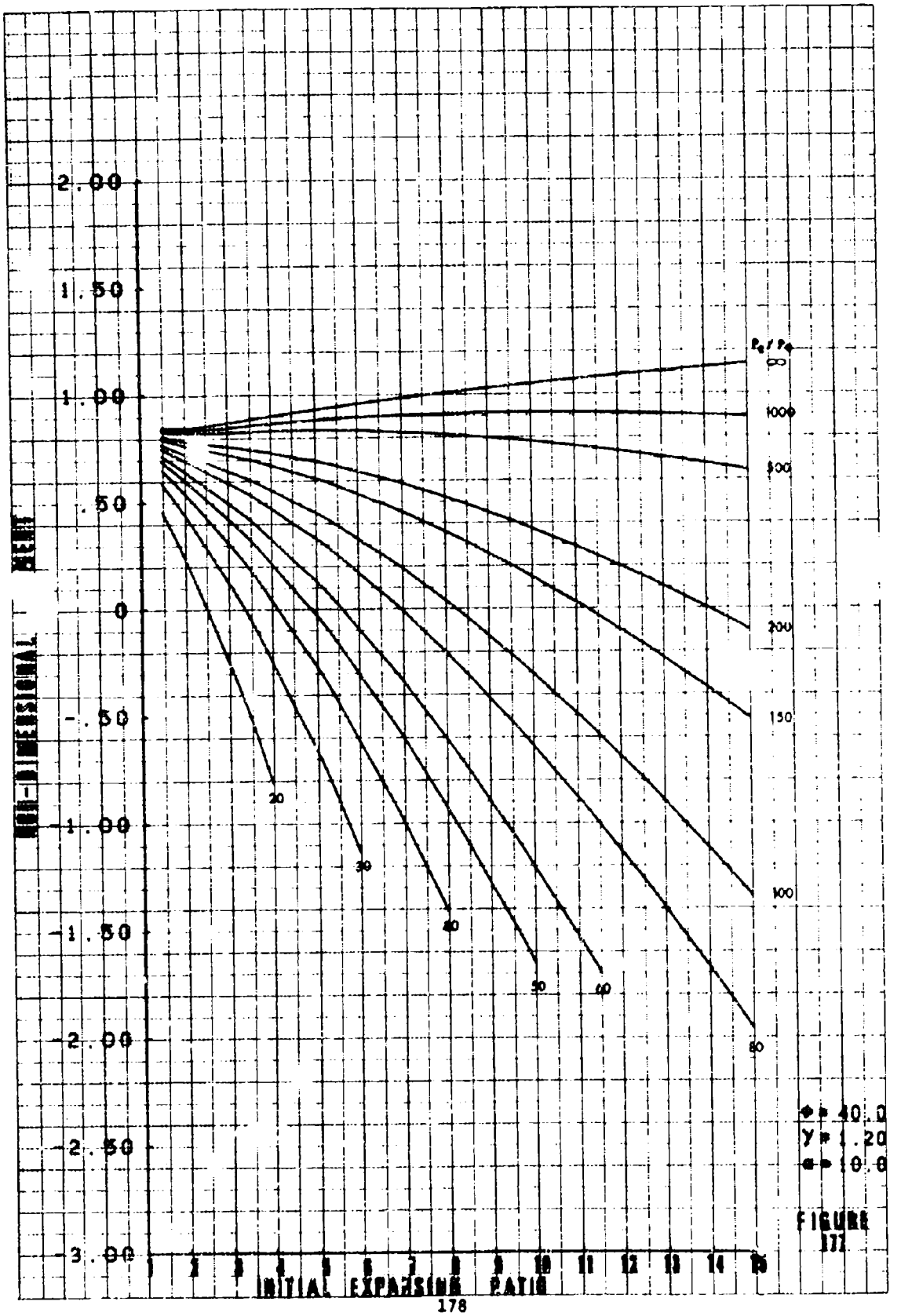

NON-DIMENSIONAL HEAT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_0/P_4
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 40.0
γ = 1.20
α = 10.0

FIGURE 177

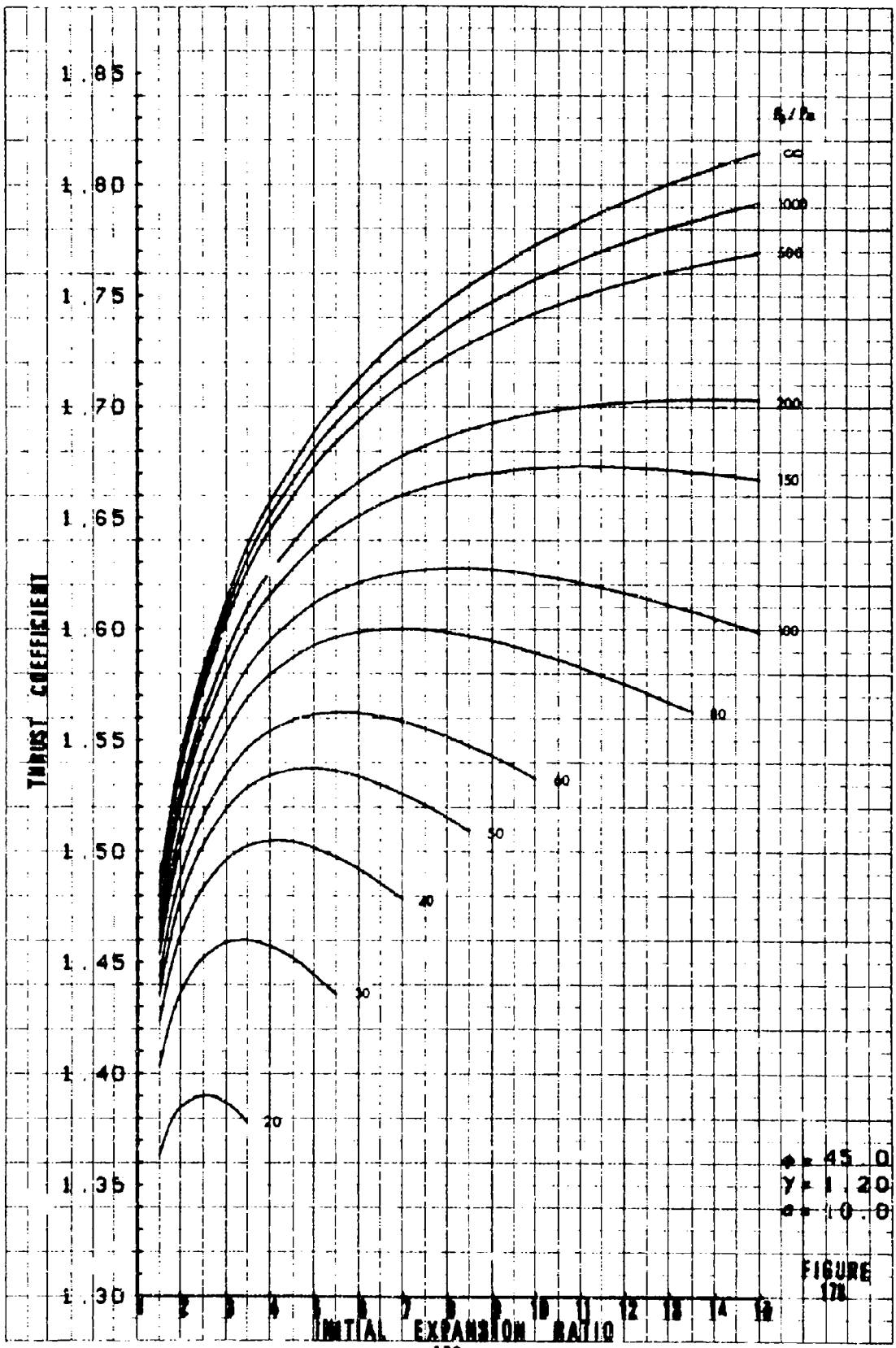

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.20
α = 10.0

FIGURE 178

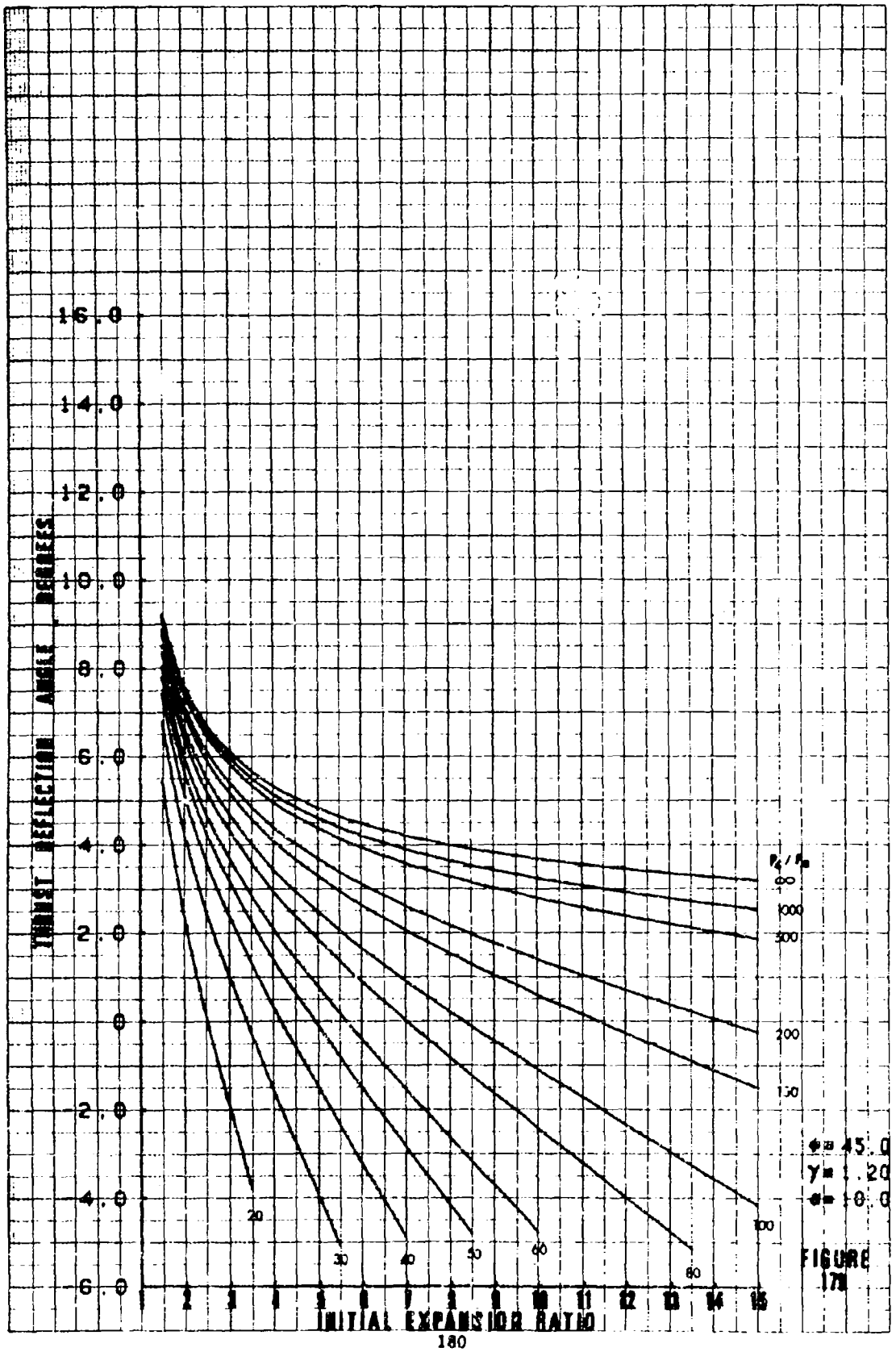

16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
300
1000
∞
φ = 45.0
γ = 1.20
α = 10.0

FIGURE 17B

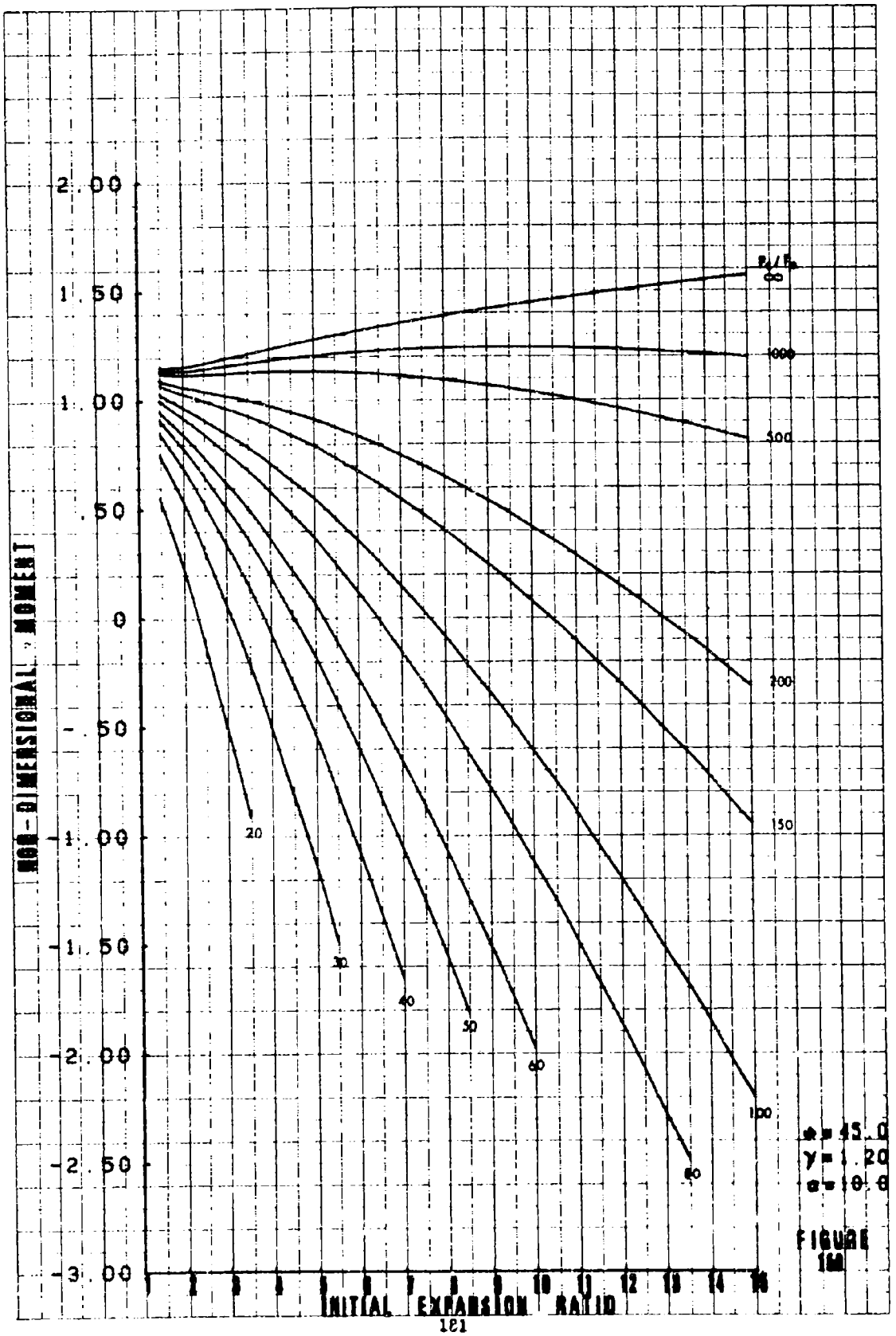

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_i/P_a
∞
1000
500
200
150
100
60
20
30
40
50
60
φ = 45.0
γ = 1.20
α = 10.0

FIGURE 16

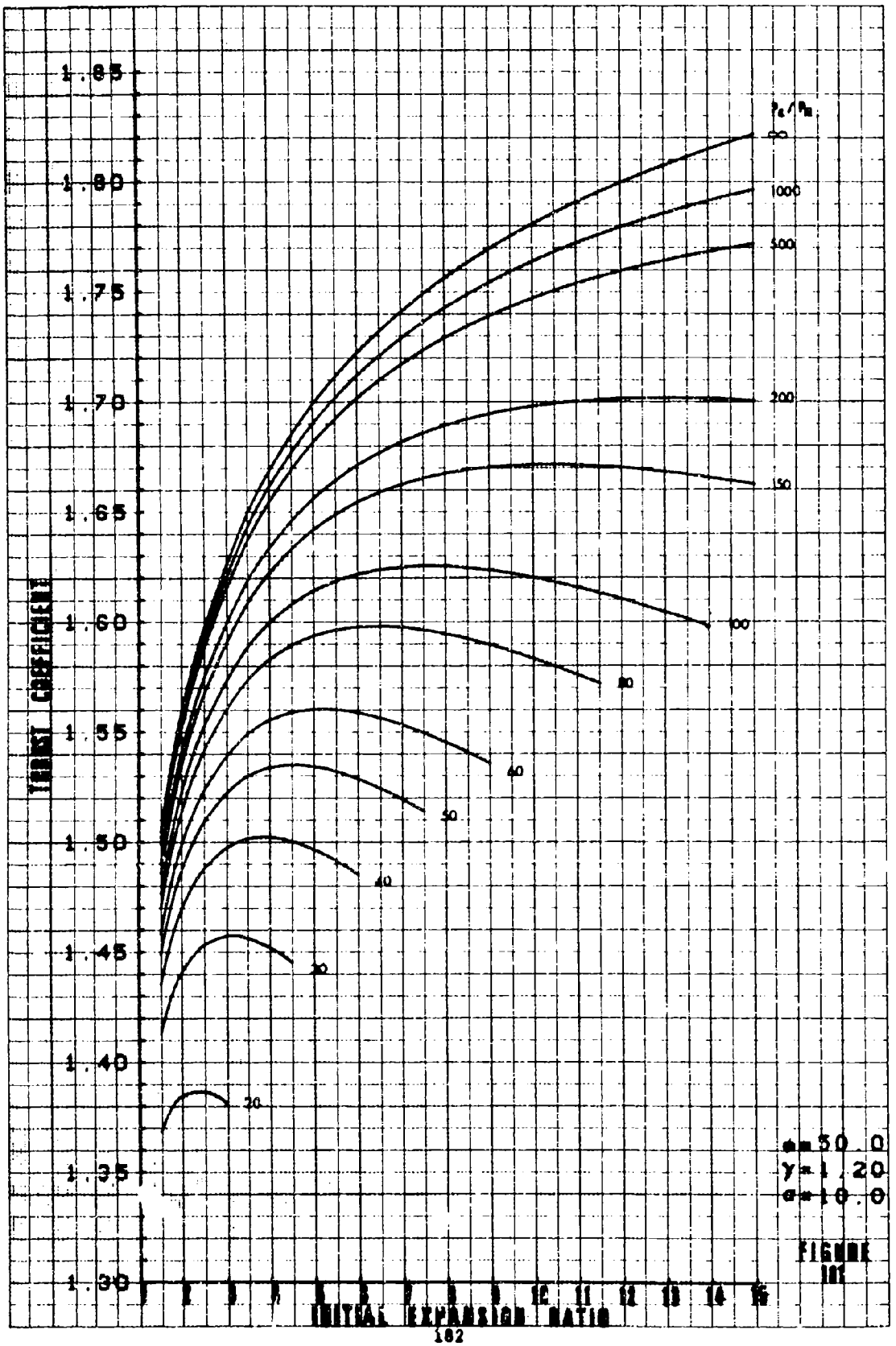

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ=1.20
α=10.0

FIGURE 101

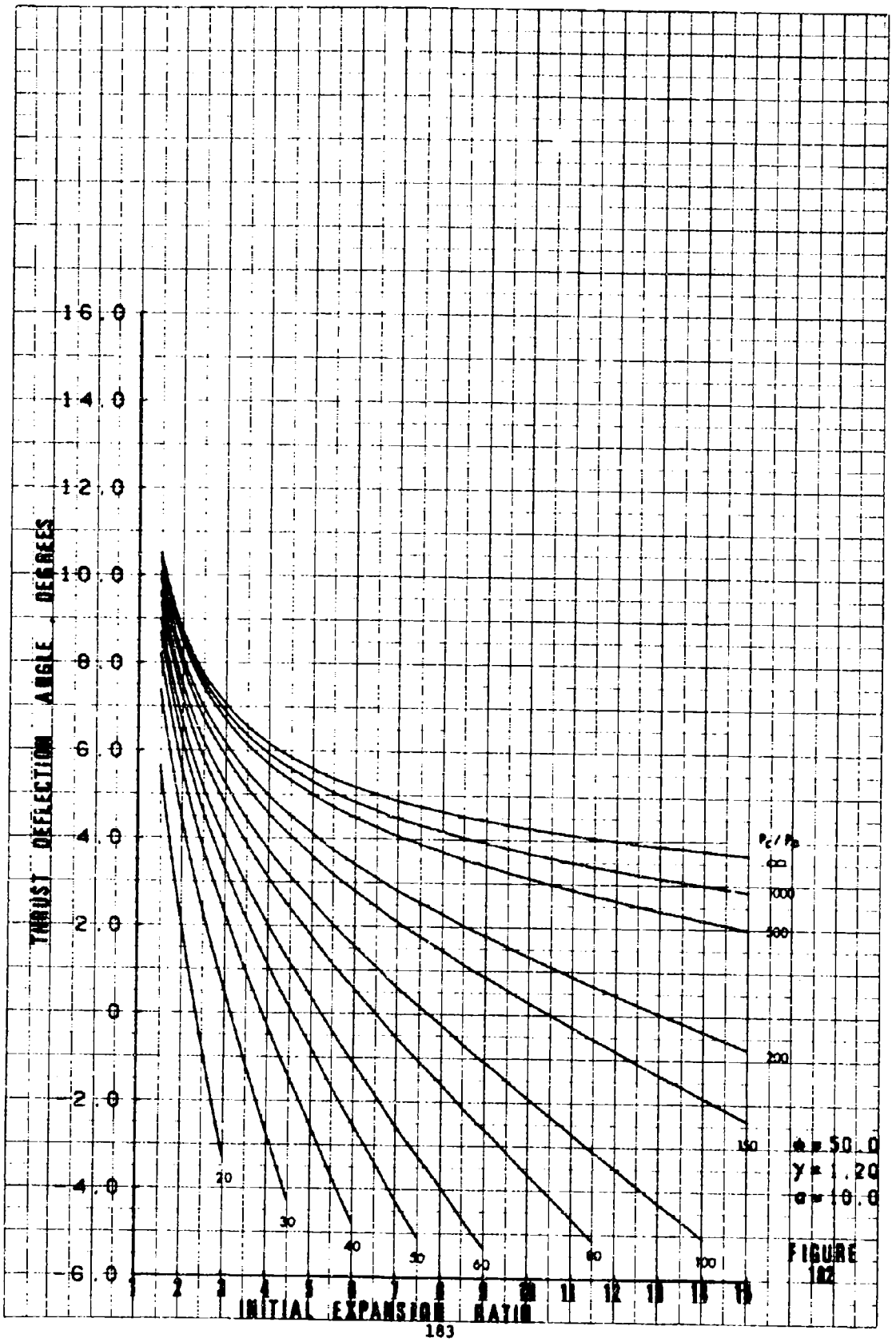

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 50.0
γ = 1.20
α = 10.0

FIGURE 182

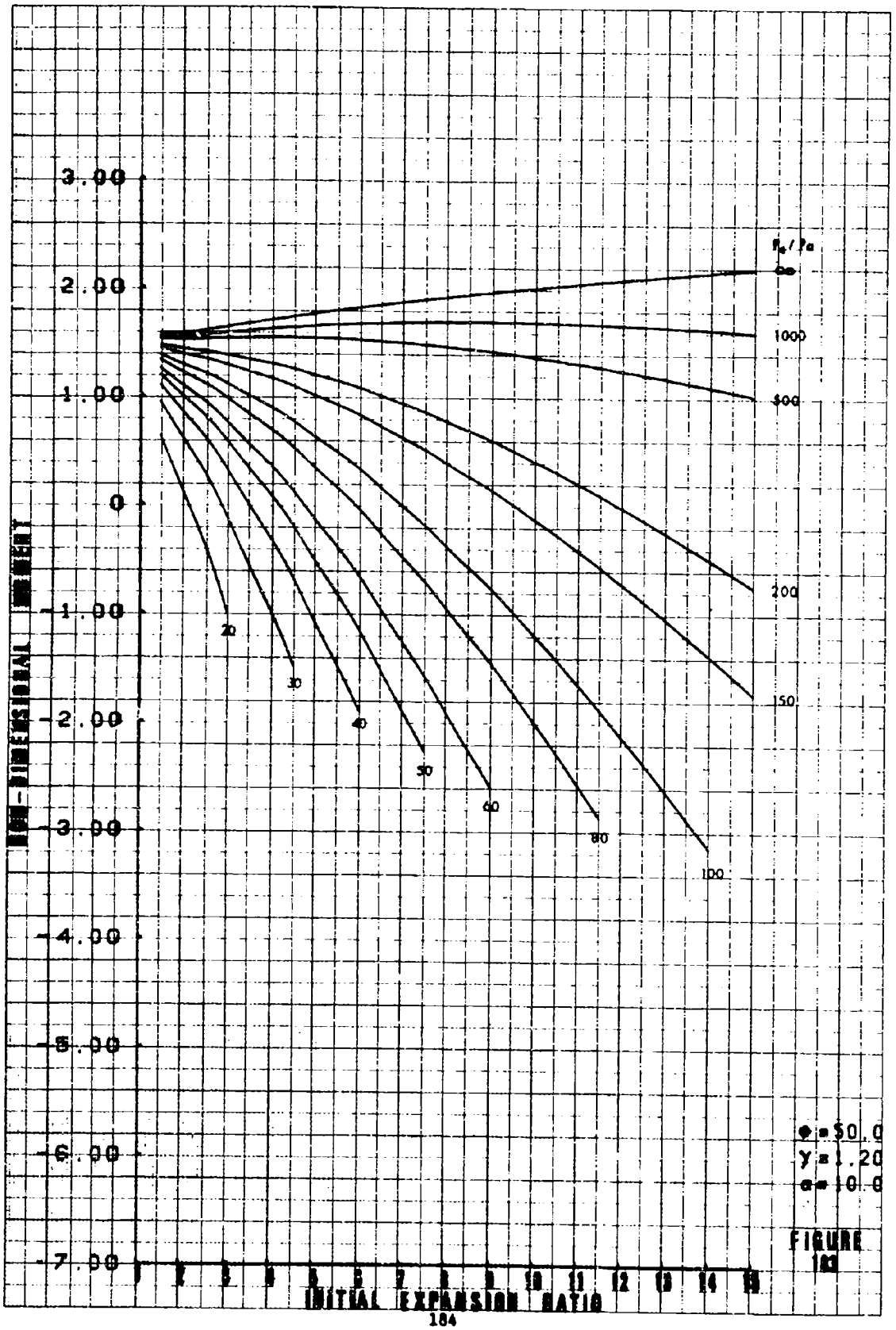

3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_e/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.20
α = 10.0

FIGURE 183

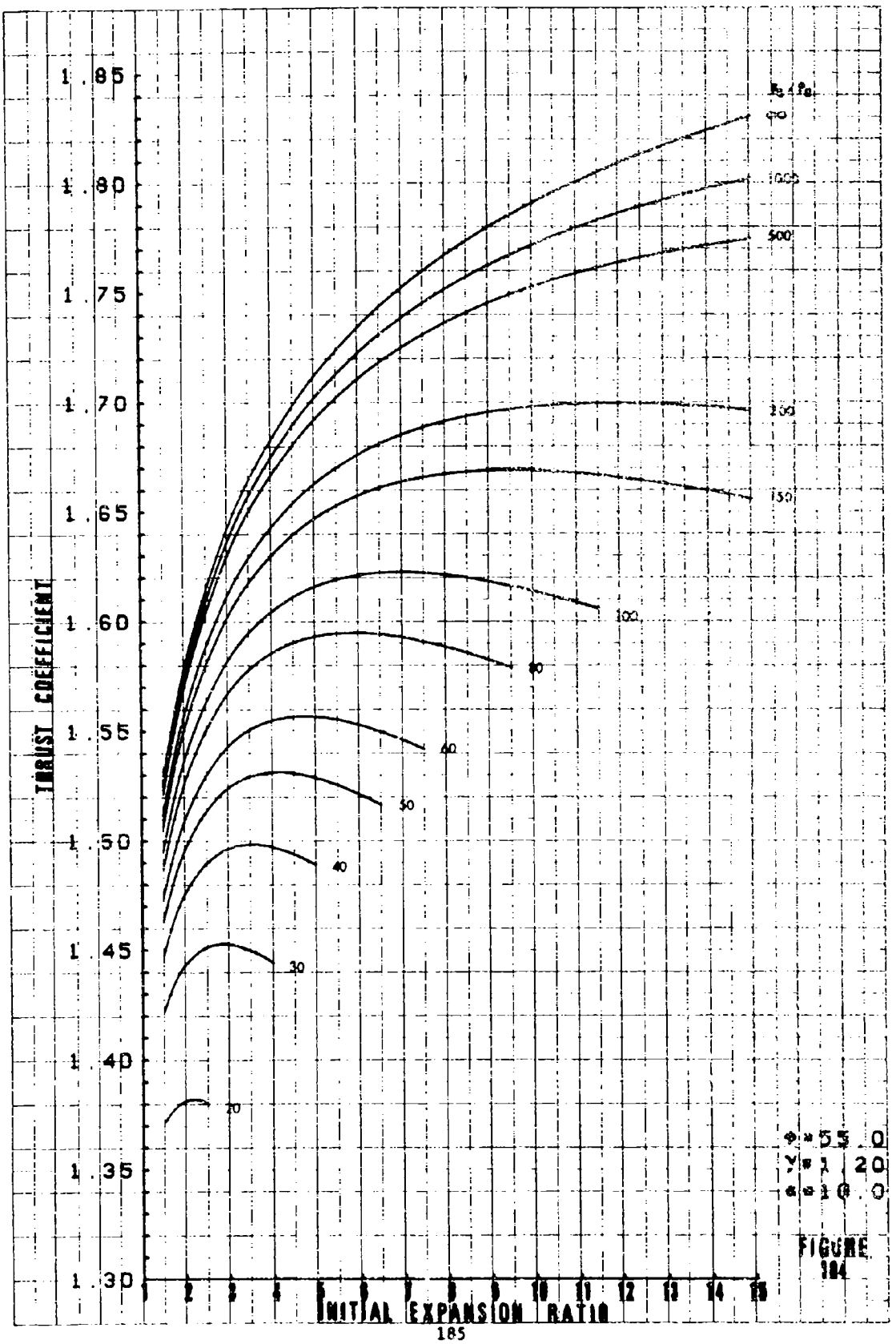

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 55.0
γ = 1.20
α = 10.0

FIGURE 104

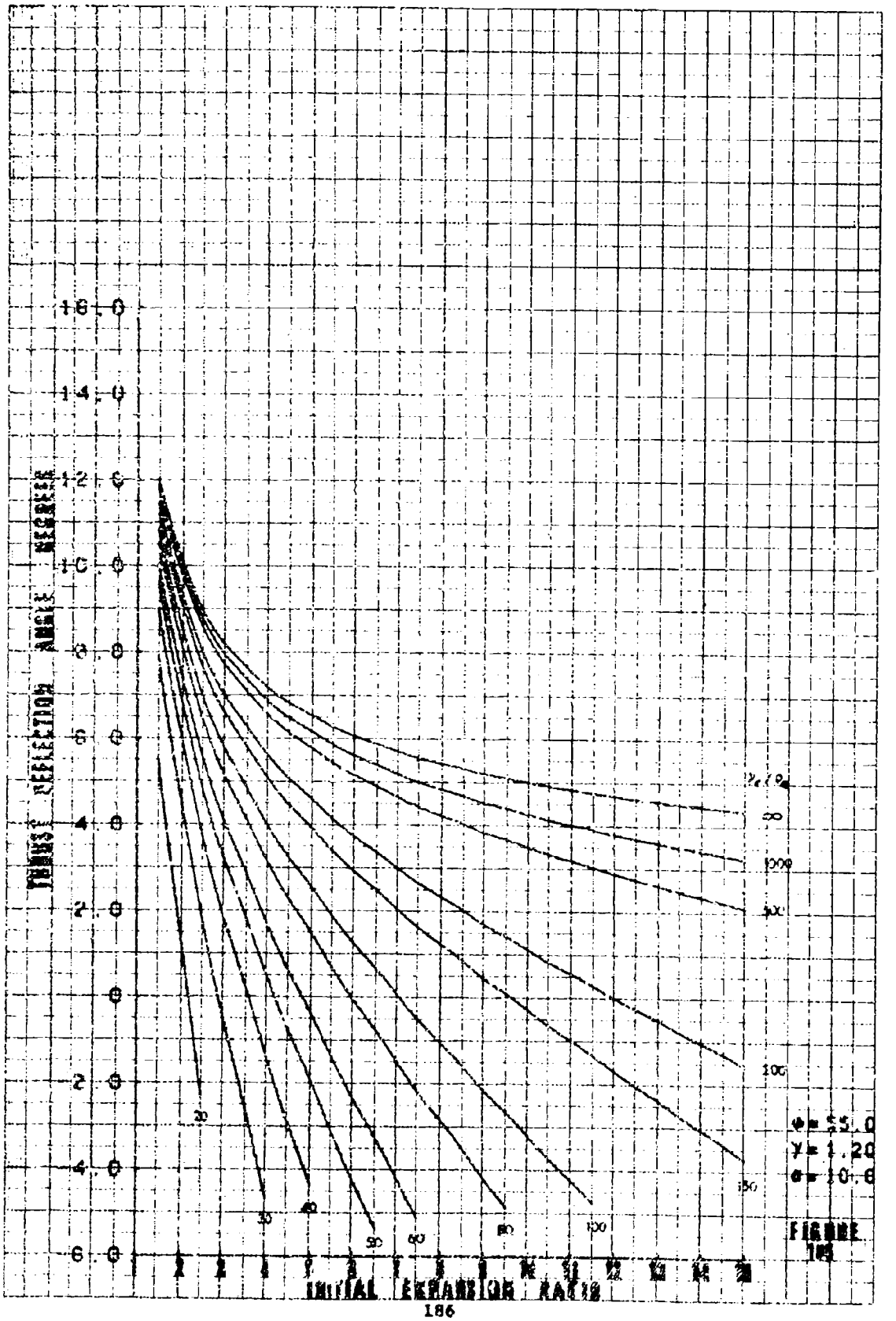

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
∞
1000
500
100
φ = 55.0
γ = 1.20
α = 10.0

FIGURE 104

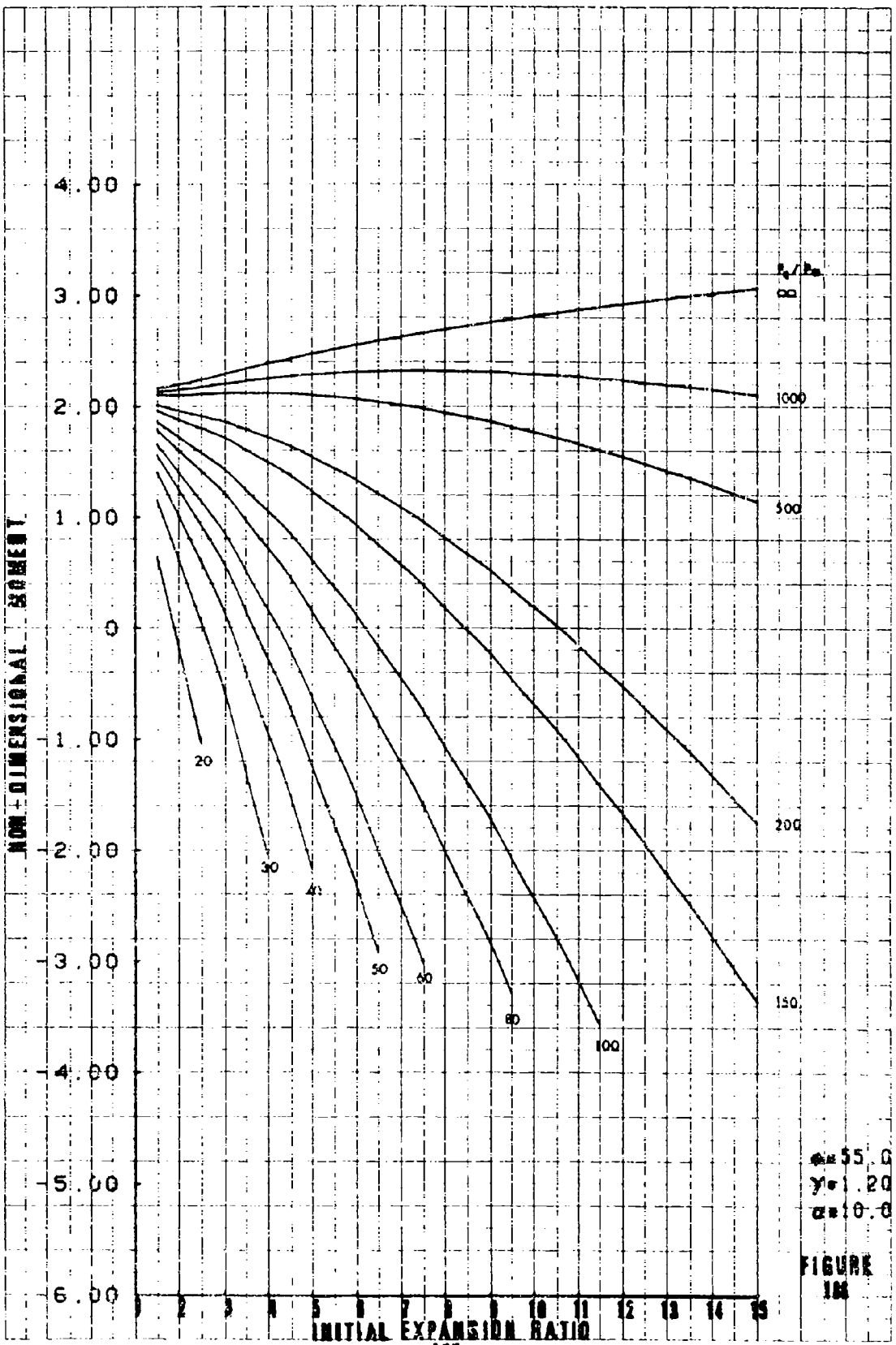

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=55.0
γ=1.20
α=10.0

FIGURE 186

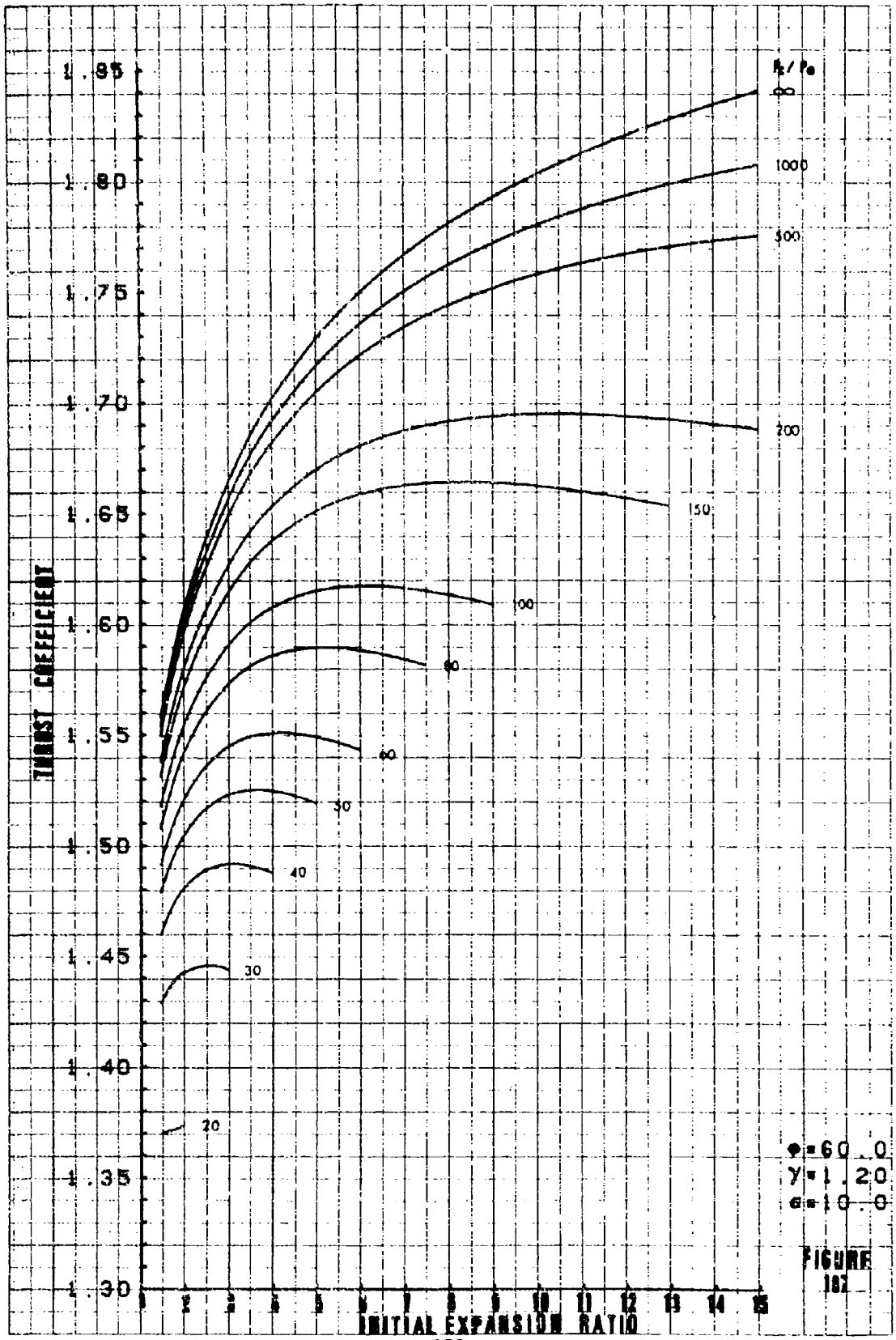

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=60.0
γ=1.20
σ=10.0

FIGURE 102

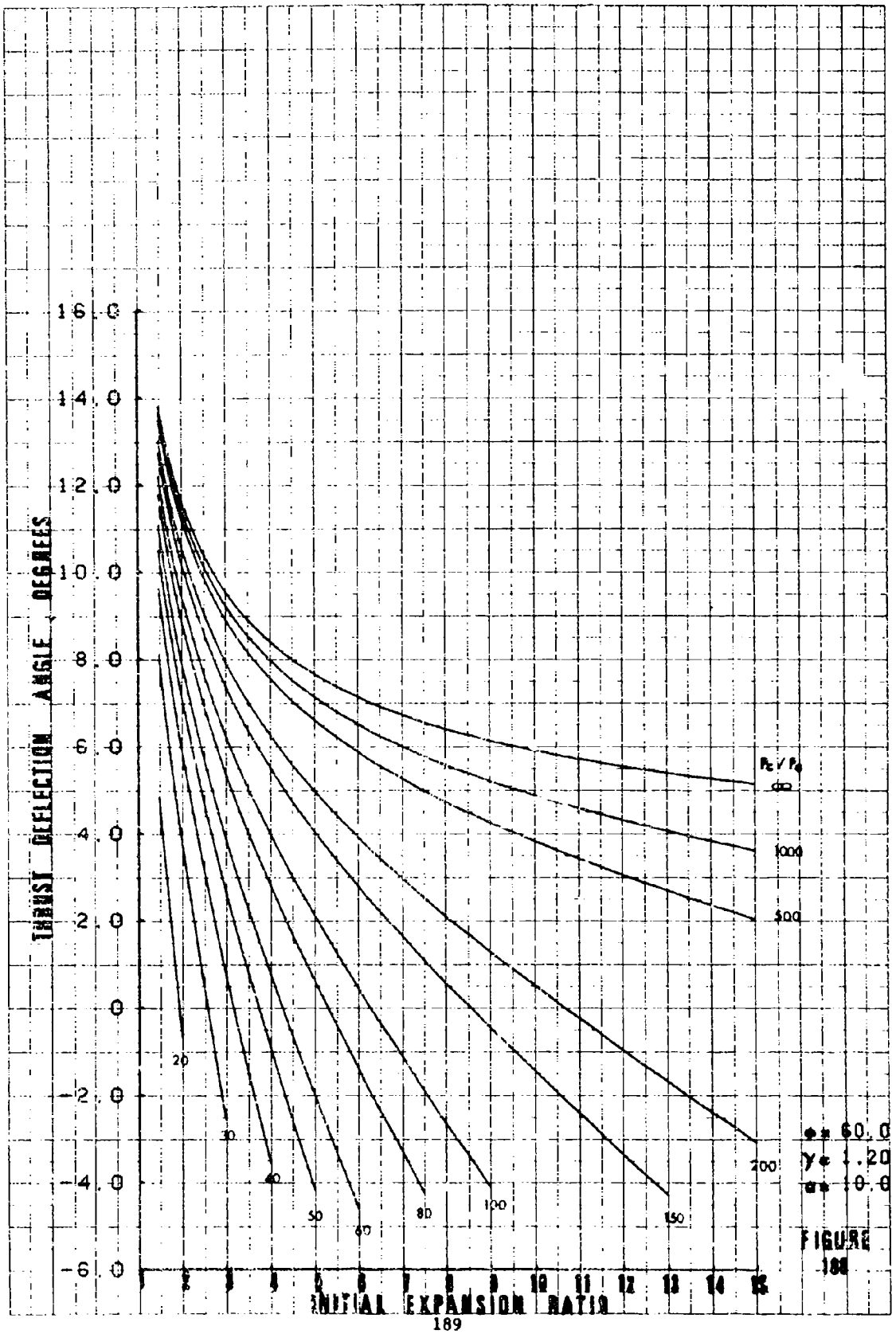

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.20
α = 10.0

FIGURE 188

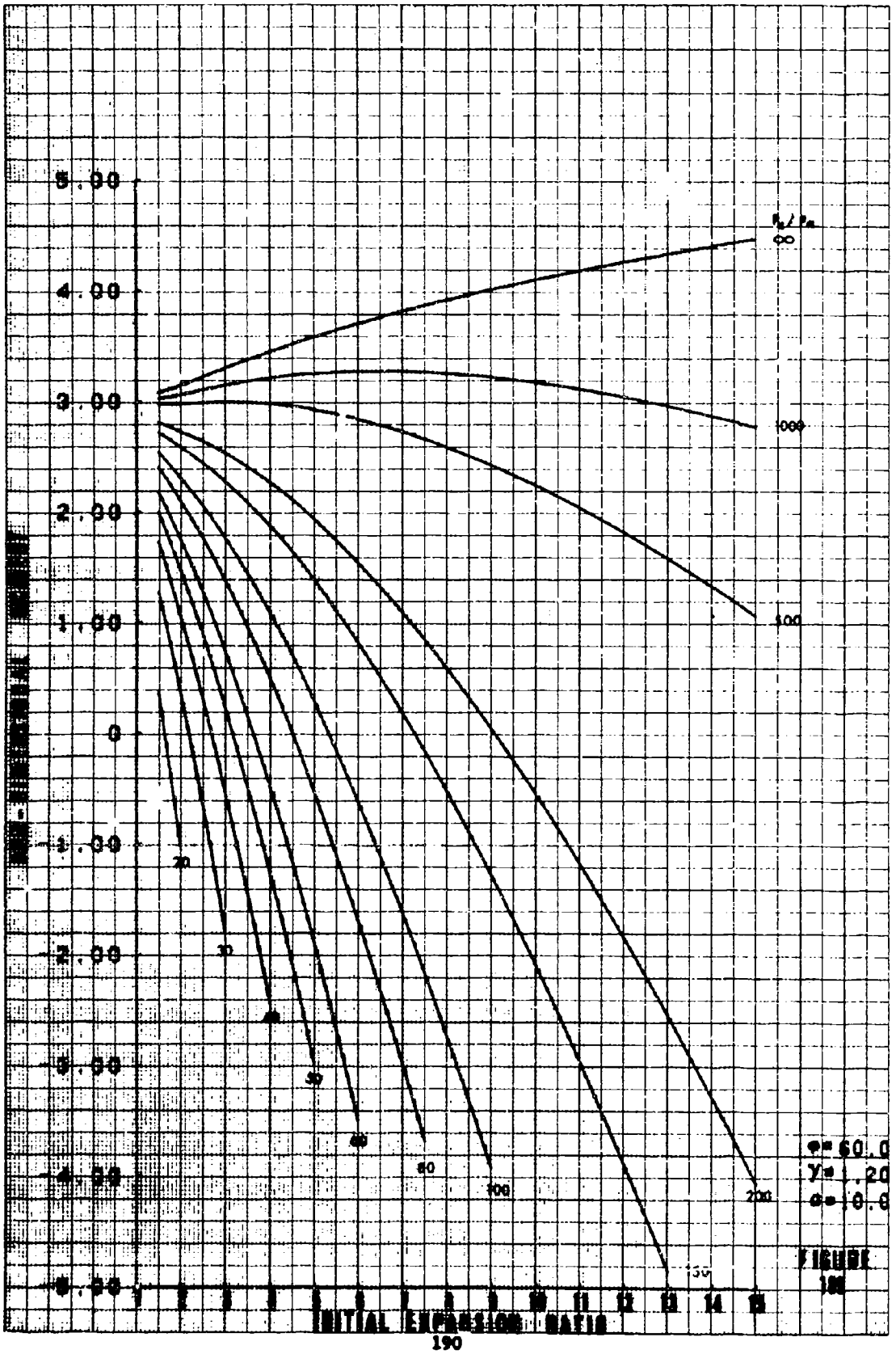
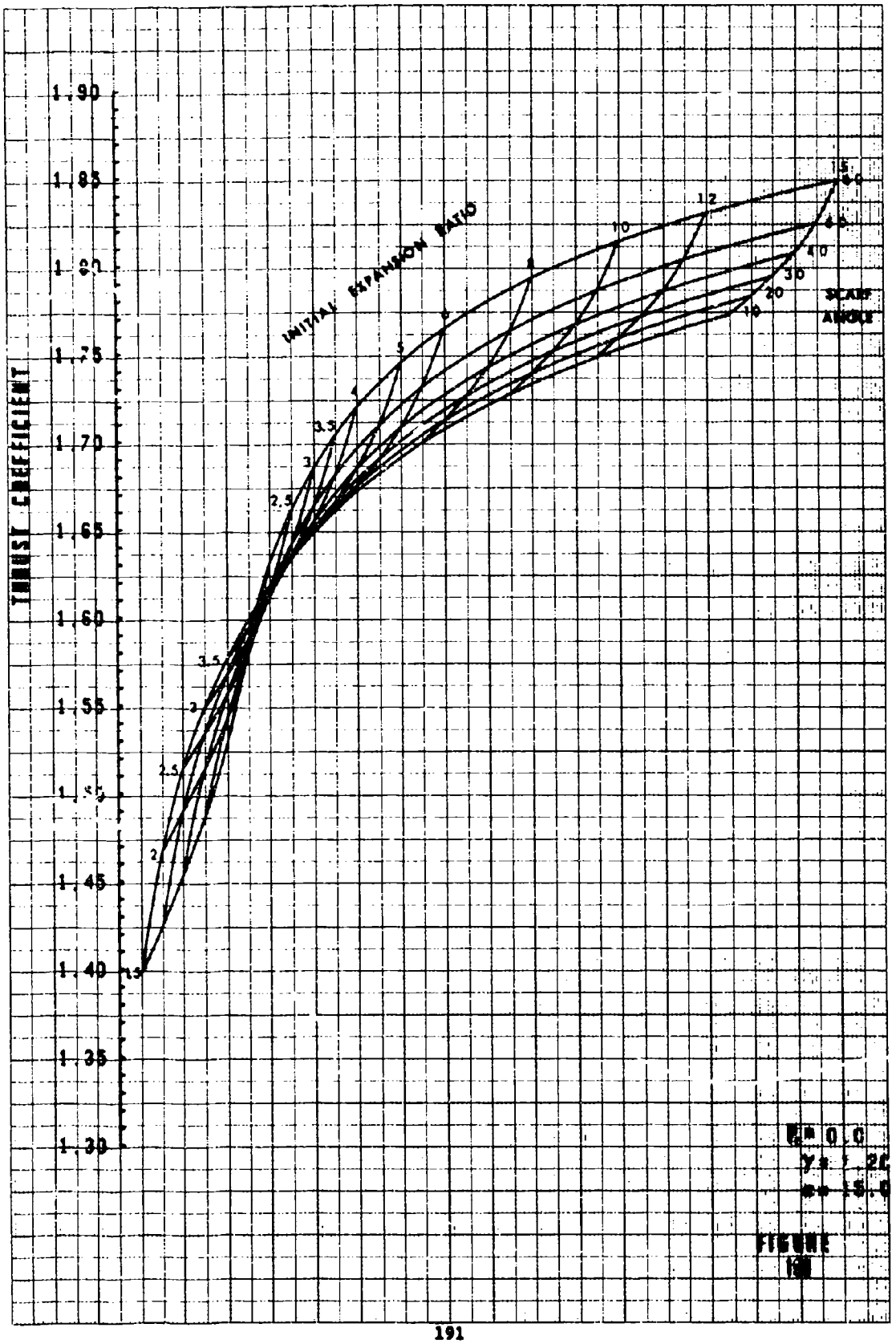

5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_b/P_a
∞
1000
500
20
30
40
50
60
80
100
200
φ= 60.0
γ= 1.20
α= 10.0

FIGURE 18


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE

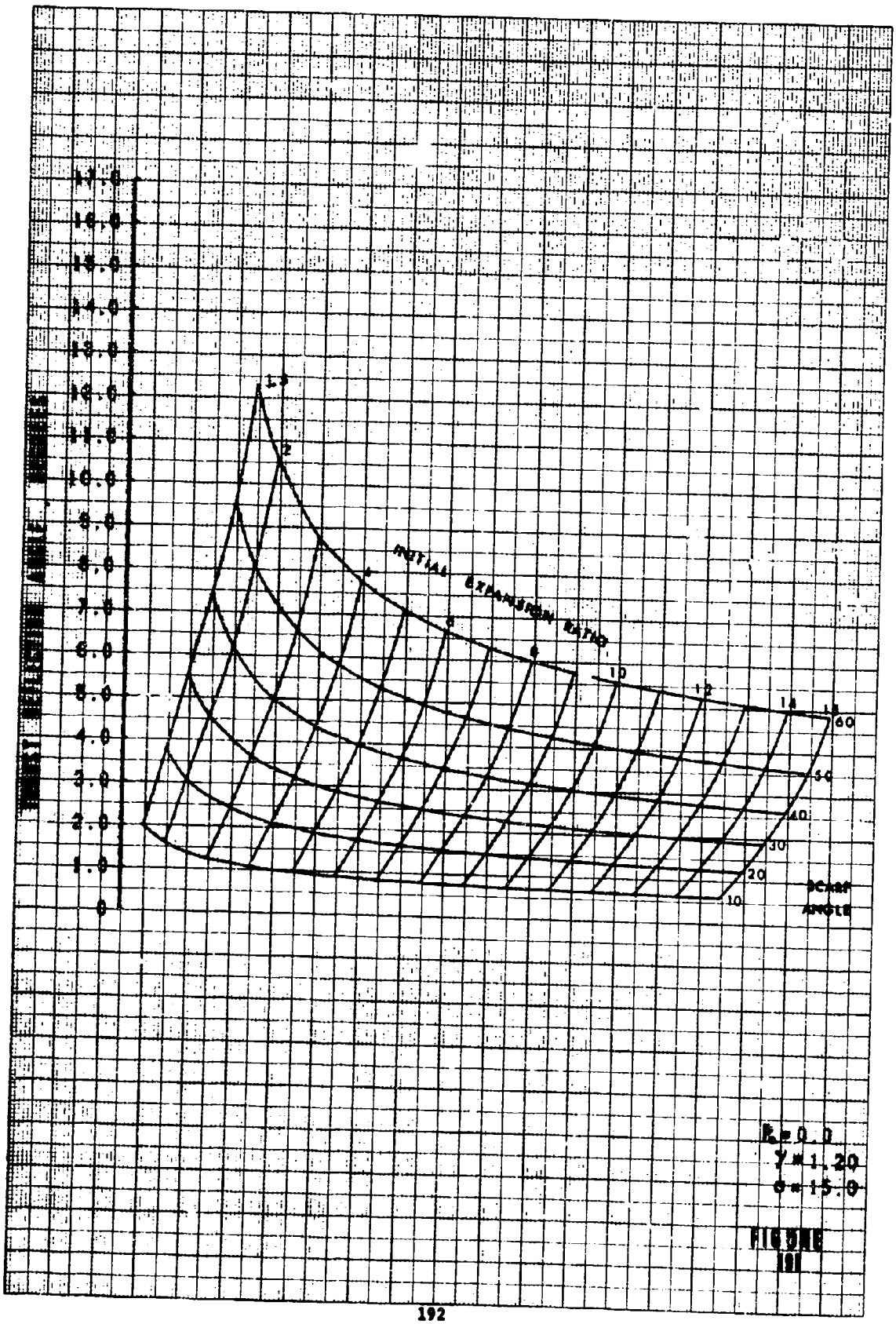

17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.1
2
4
5
6
10
12
14
16
60
50
40
30
20
10
INITIAL EXPANSION RATIO
SCARF ANGLE
K=0.0
γ=1.20
θ=15.0

FIGURE 101

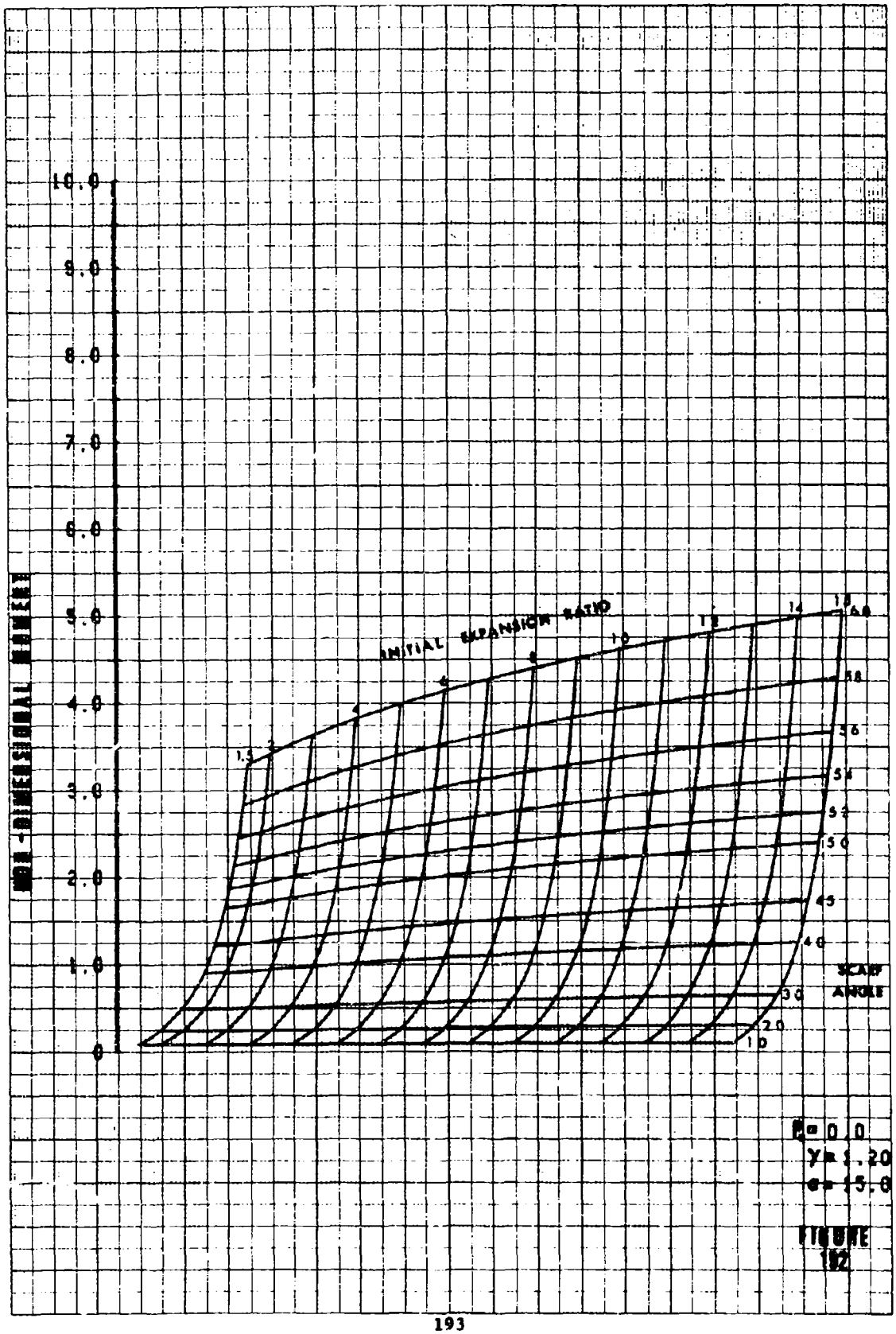

NON-DIMENSIONAL RANGE
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
16
18
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
β= 0.0
γ= 1.20
θ= 15.0

FIGURE 102

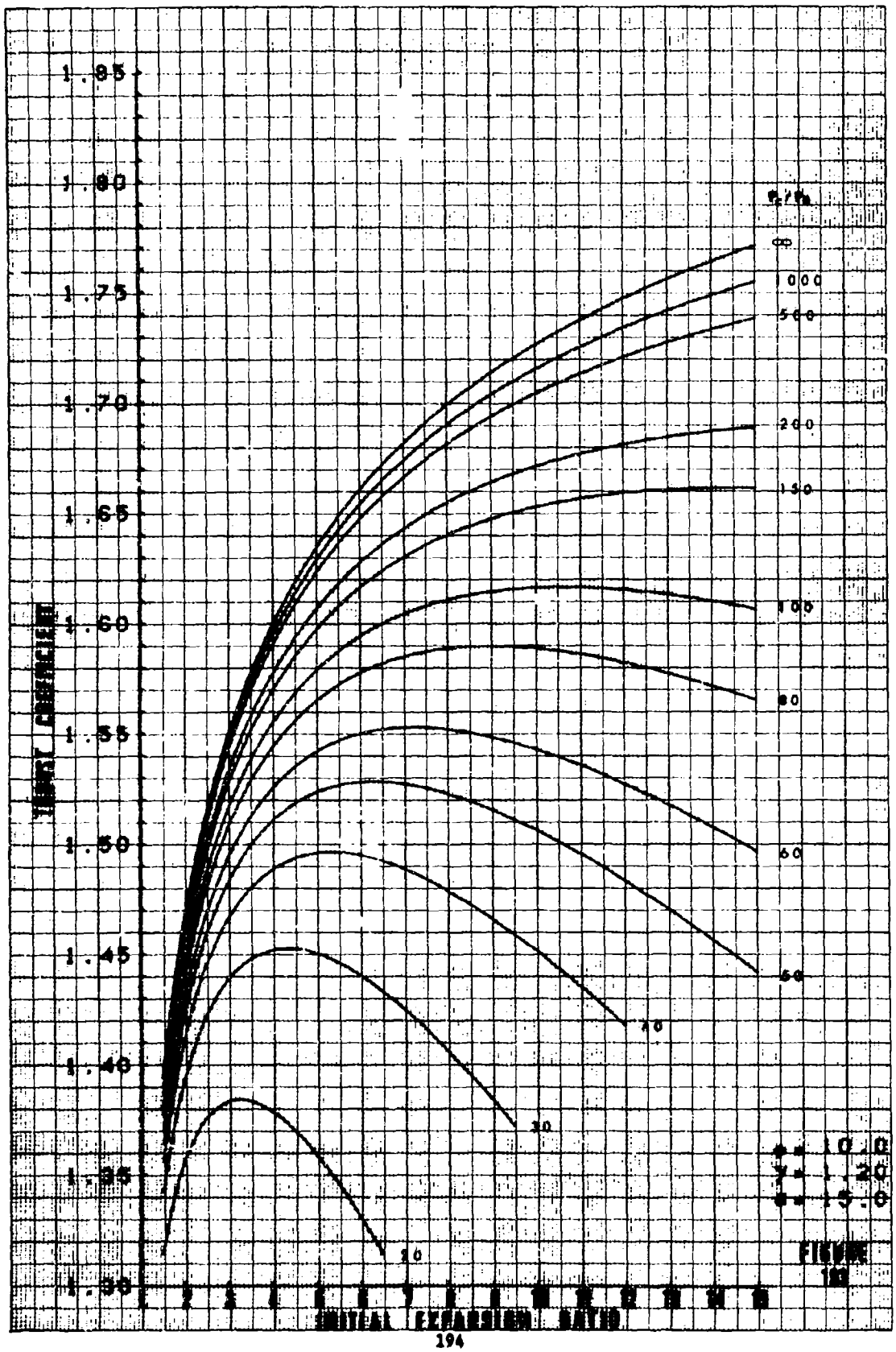

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
10

FIGURE 100

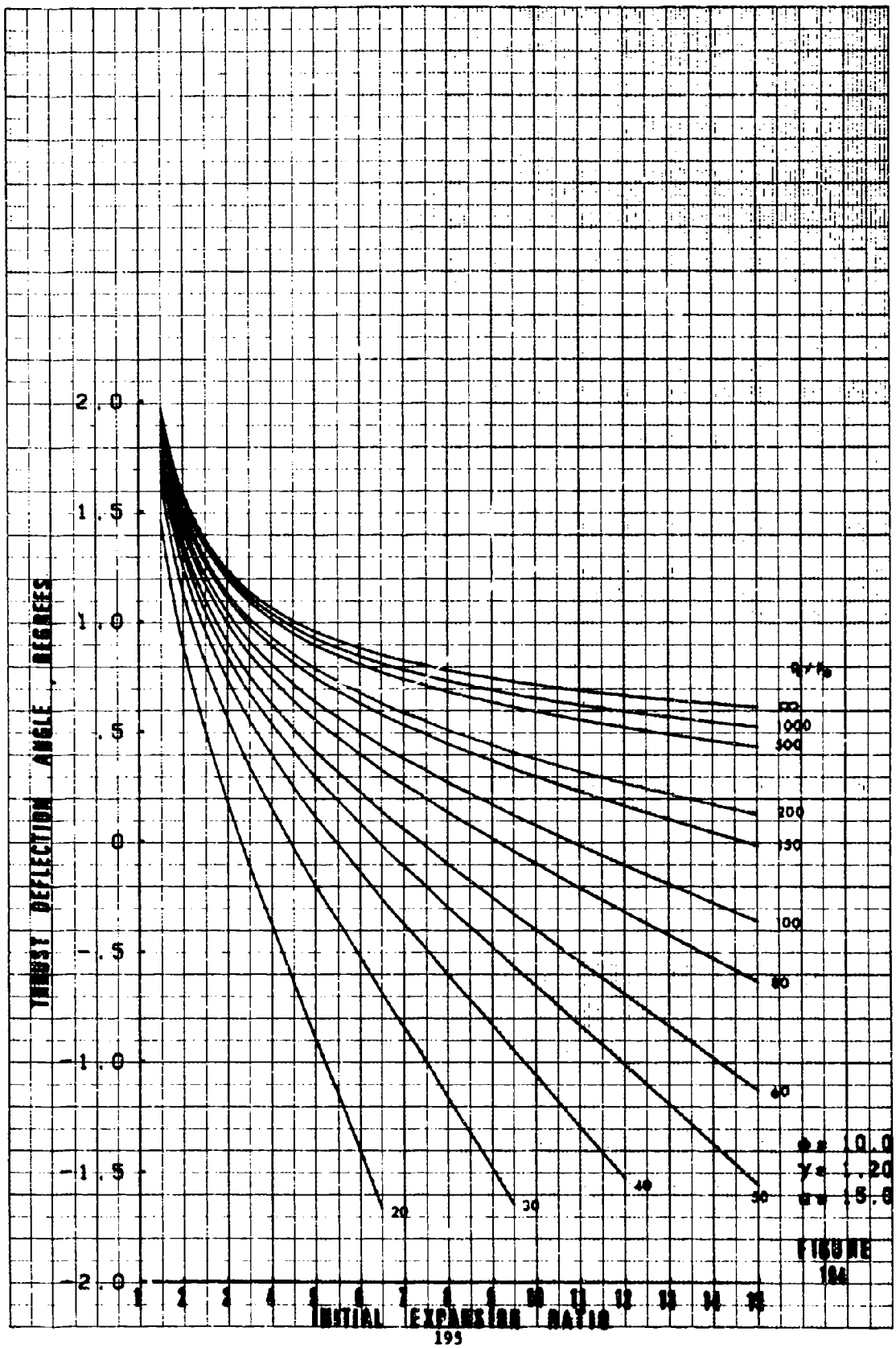
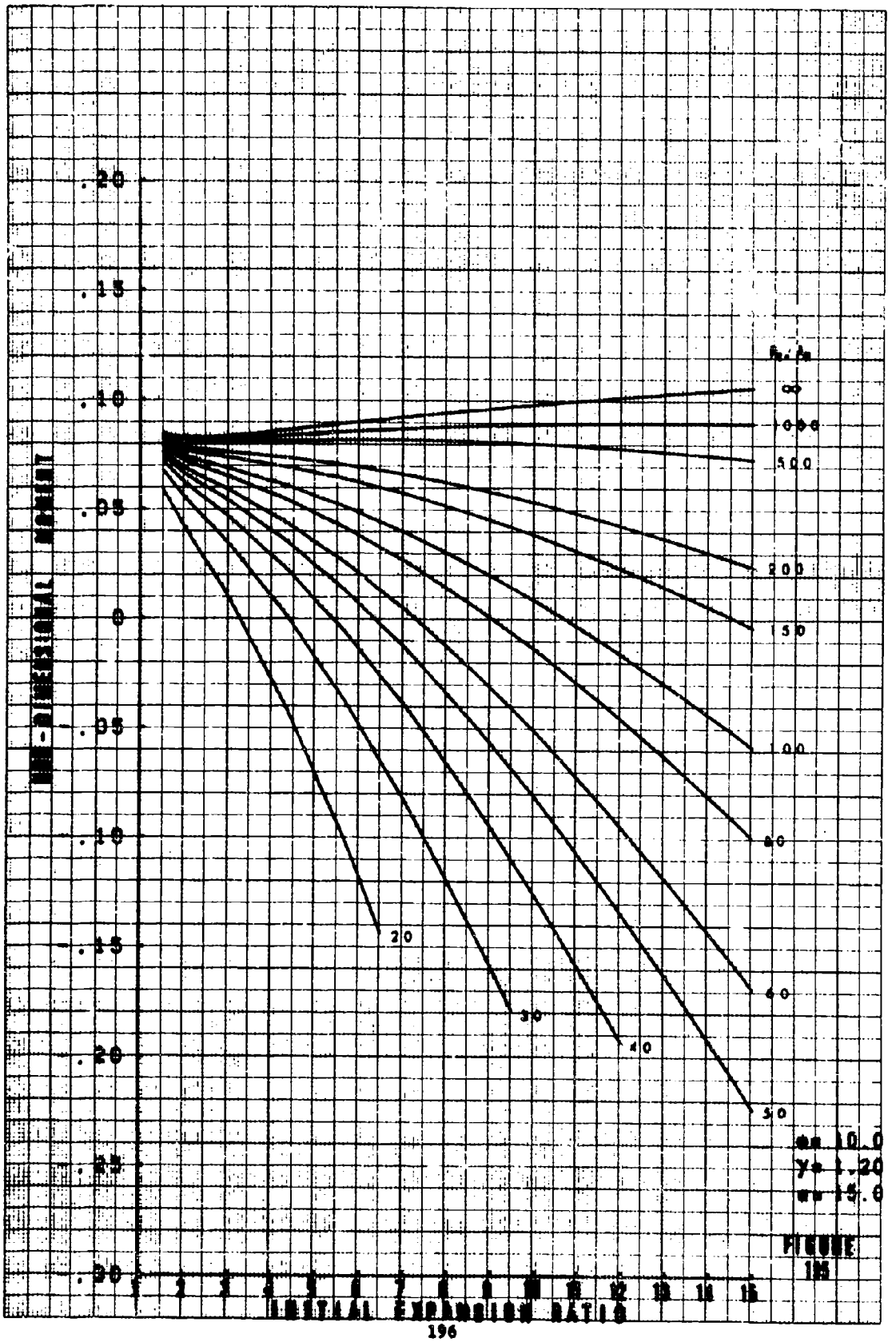
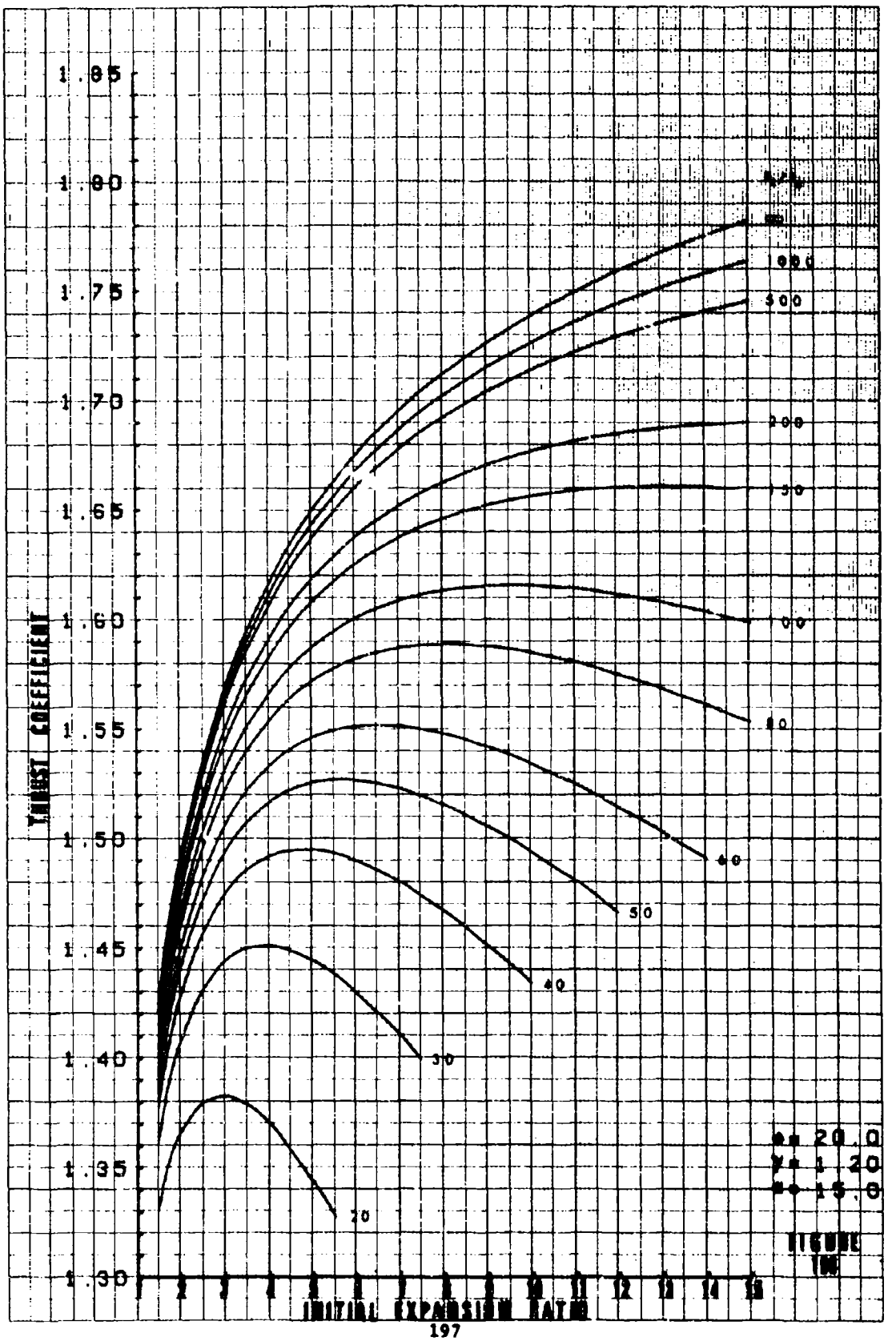

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
500
1000
∞
φ = 10.0
γ = 1.20
α = 15.0

FIGURE 194


.20
.15
.10
.05
0
.05
.10
.15
.20
.25
.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE
195



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1000
500
200
100
80
60
50
40
30
20

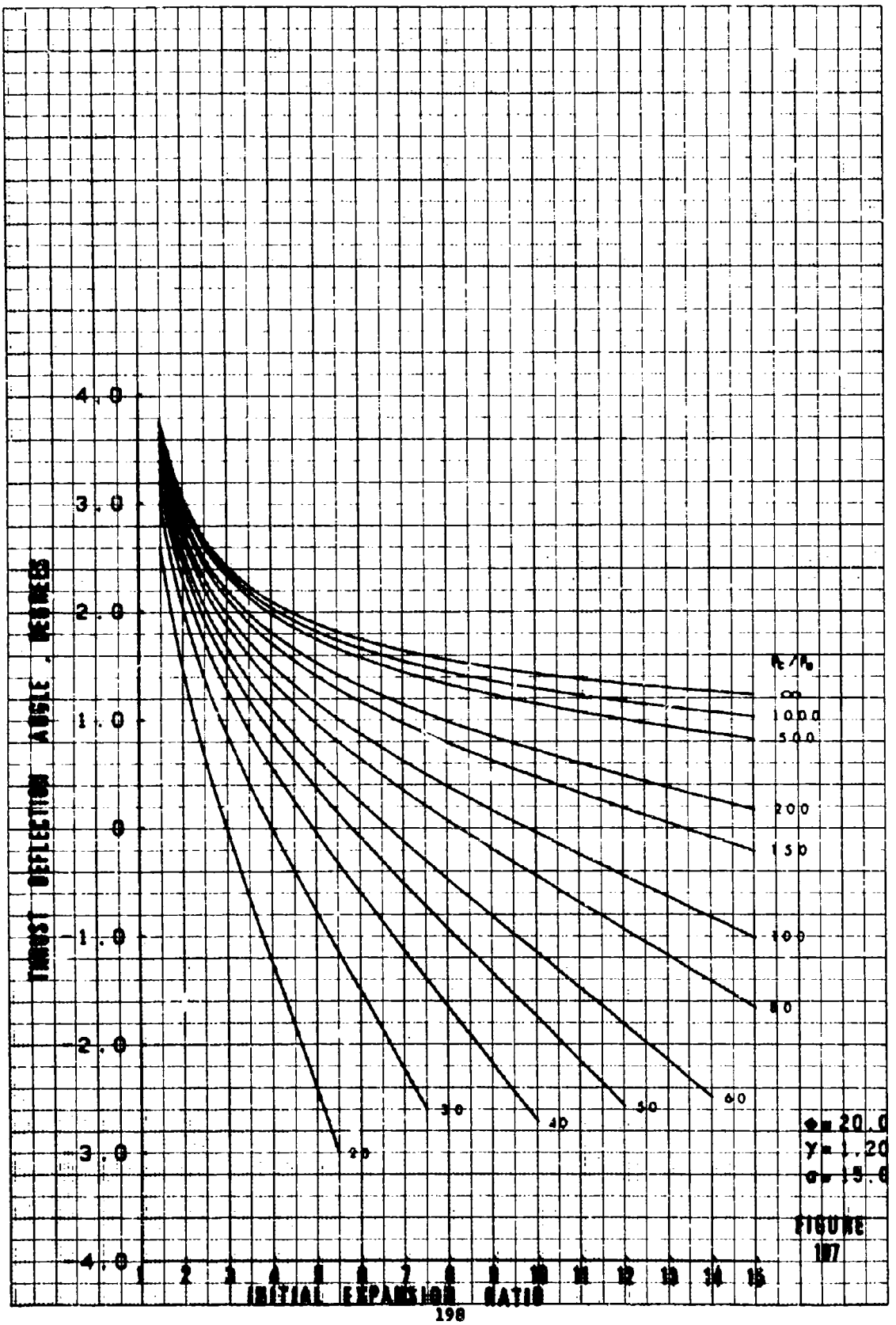
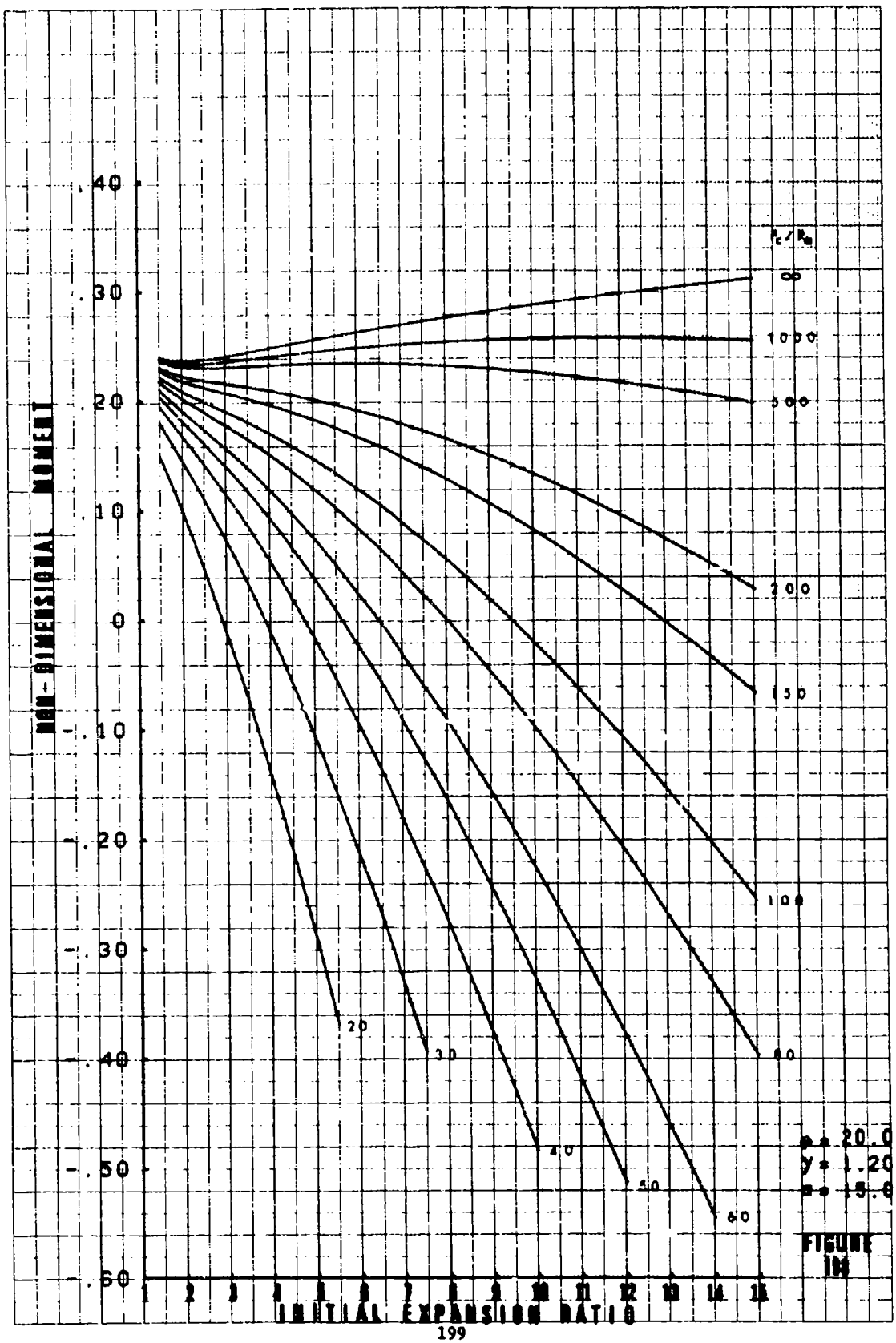

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R_t/R_0
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 20.0
γ = 1.20
α = 15.0

FIGURE 107



NON-DIMENSIONAL MOMENT
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
P_c/P_m
∞
1000
500
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 198

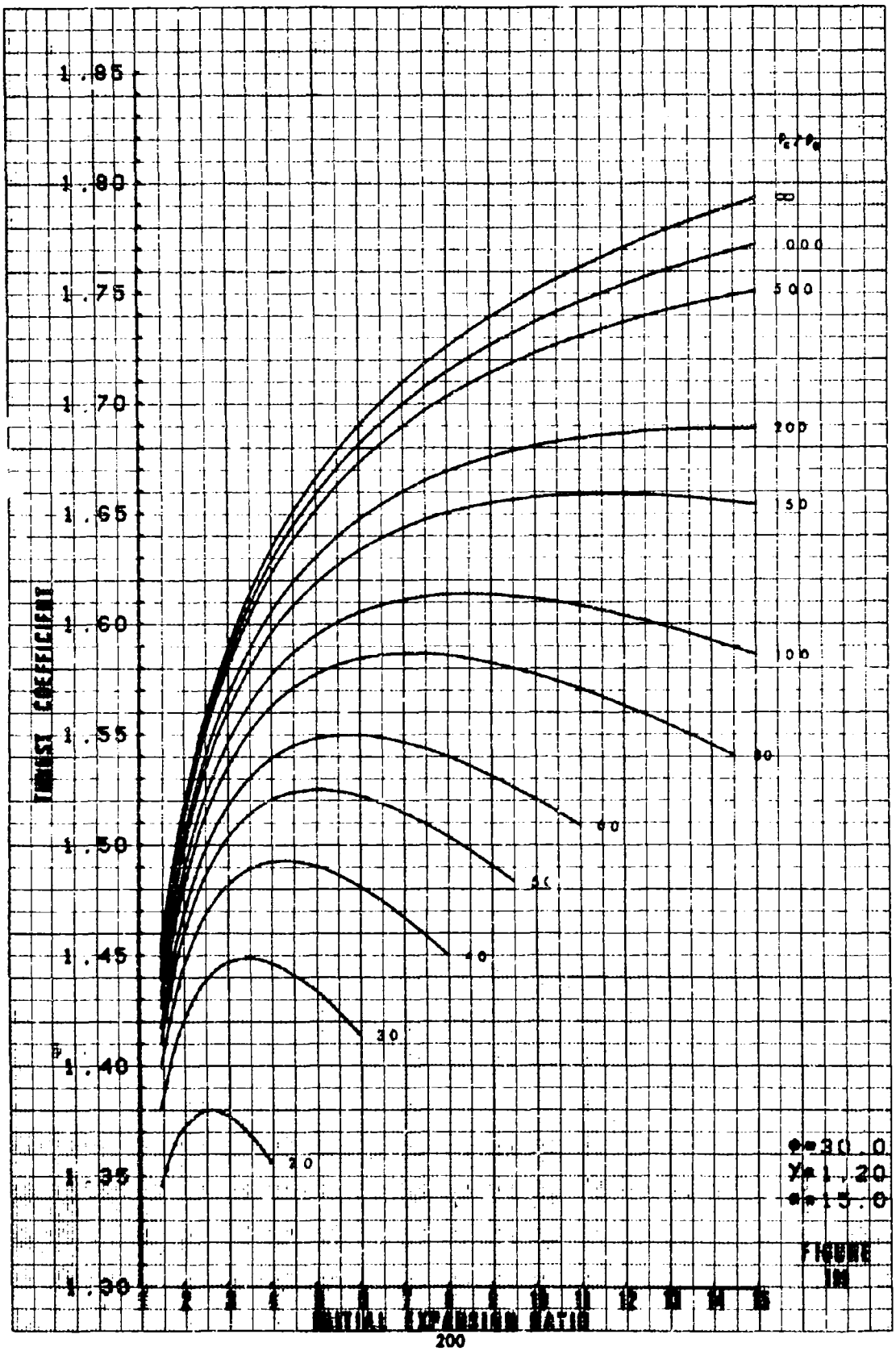

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=30.0
γ=1.20
θ=15.0

FIGURE 1M

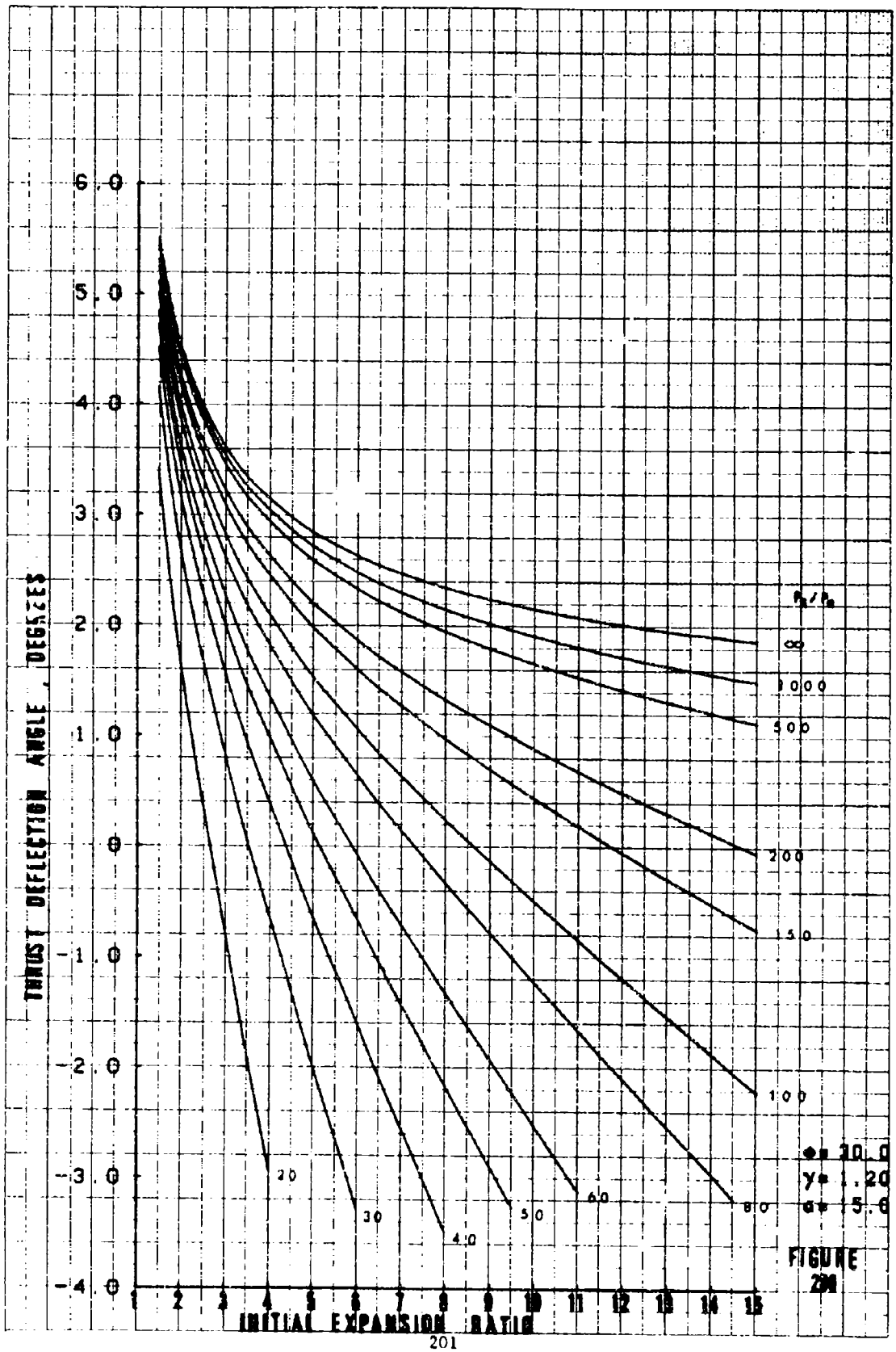
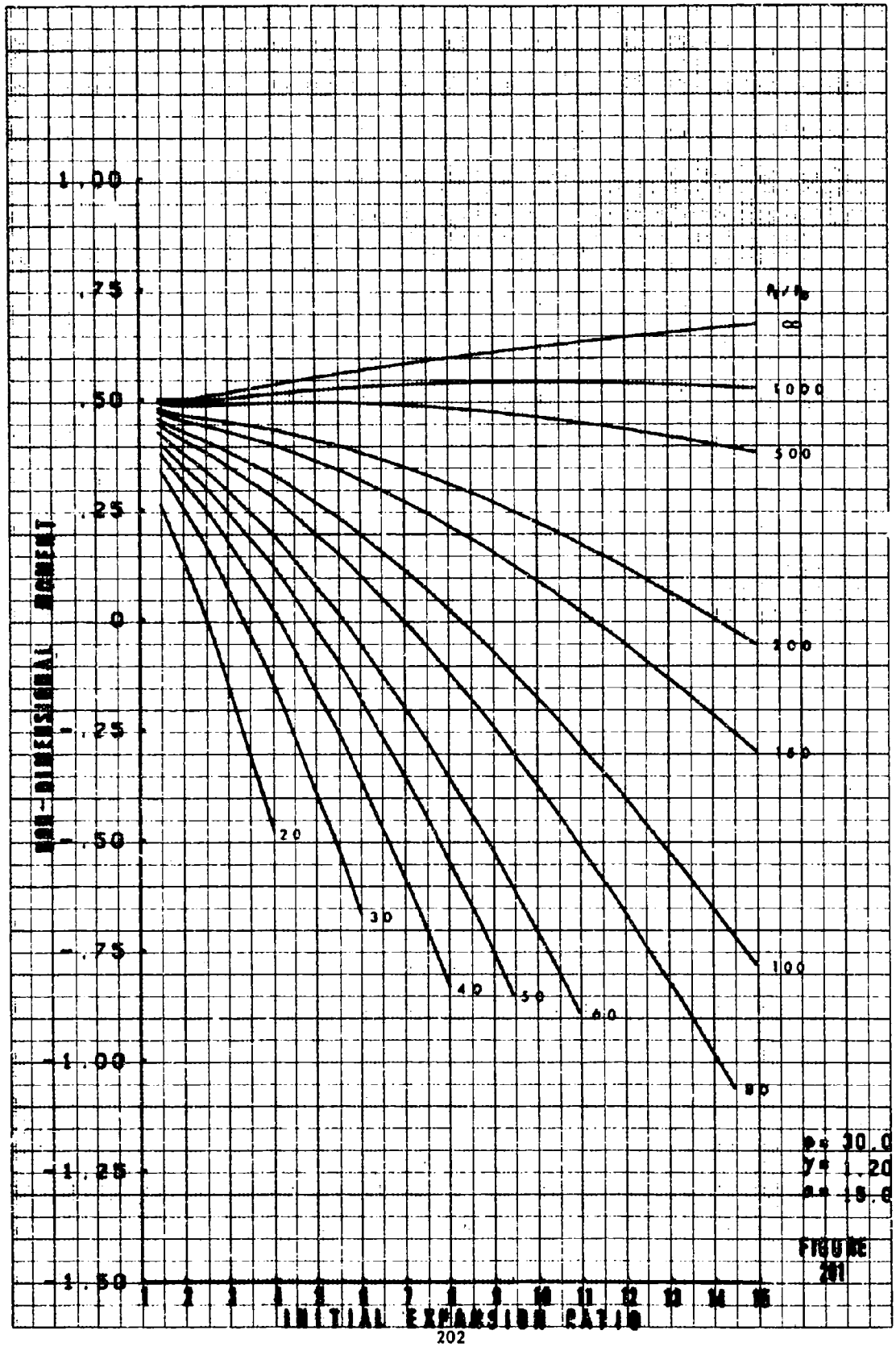

THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
p_2/p_1
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.20
α= 5.6

FIGURE 29



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 201

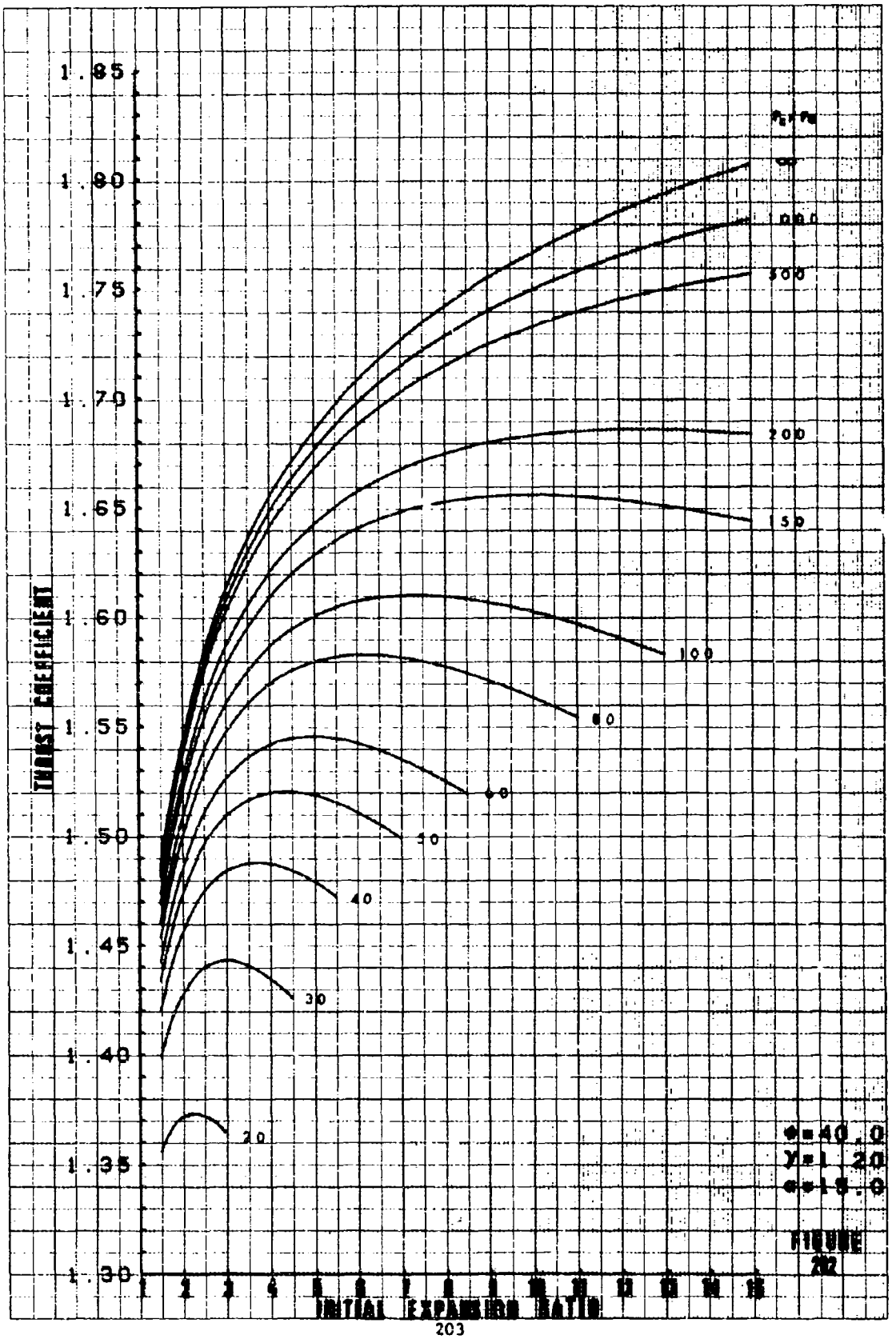

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=40.0
γ=1.20
θ=15.0

FIGURE 202

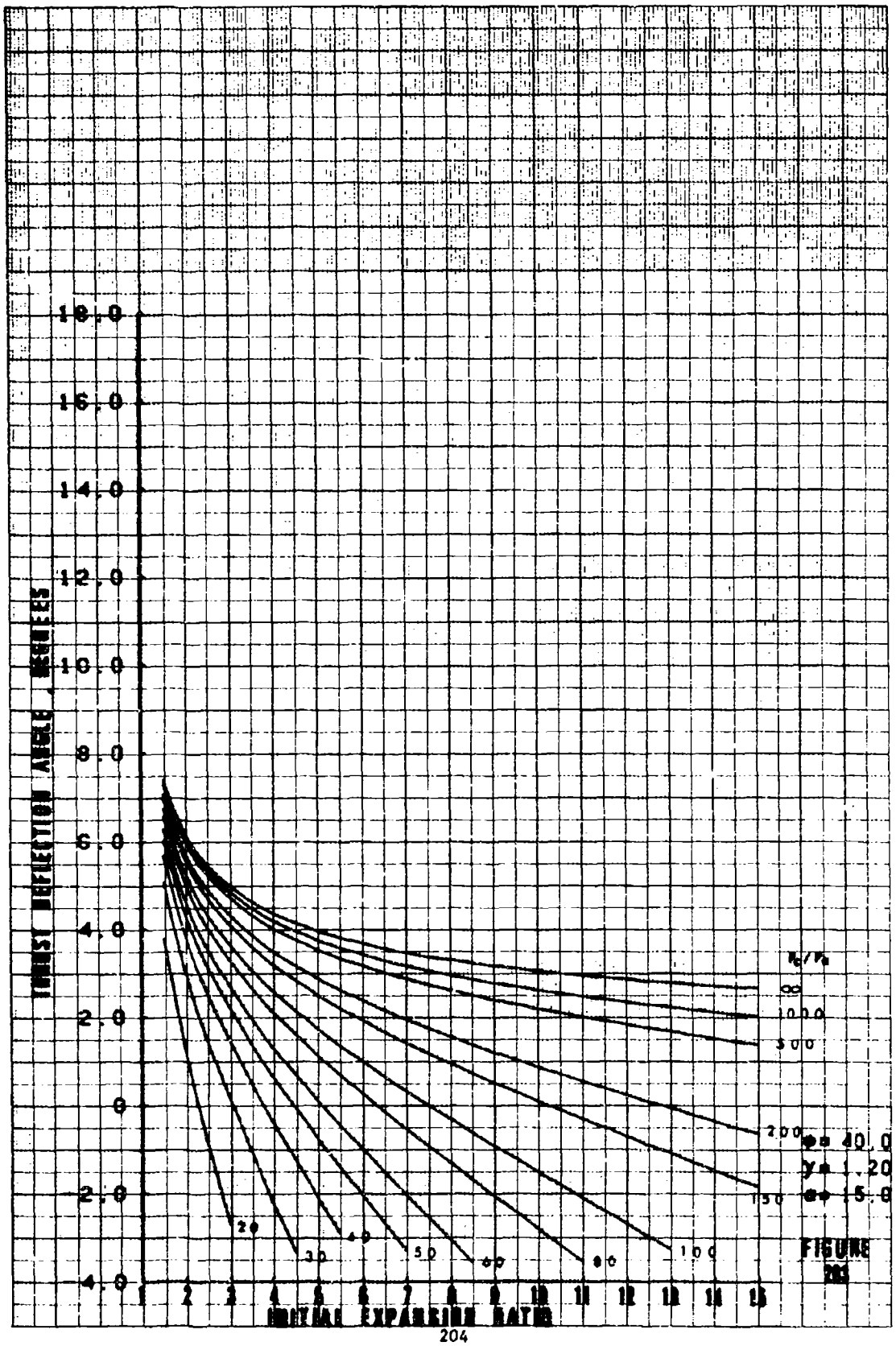

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
NOZZLE EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.20
φ = 15.0

FIGURE 205

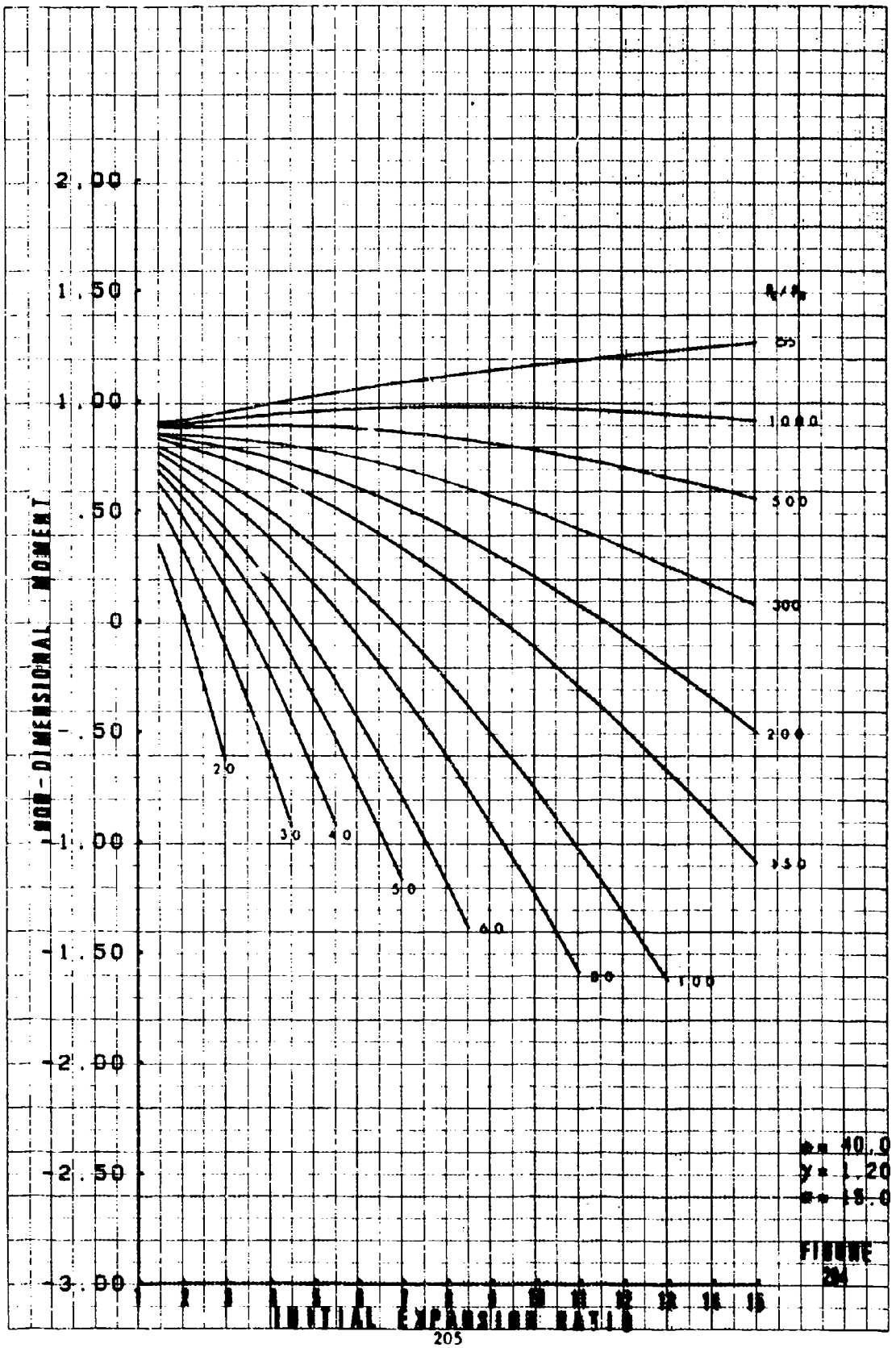
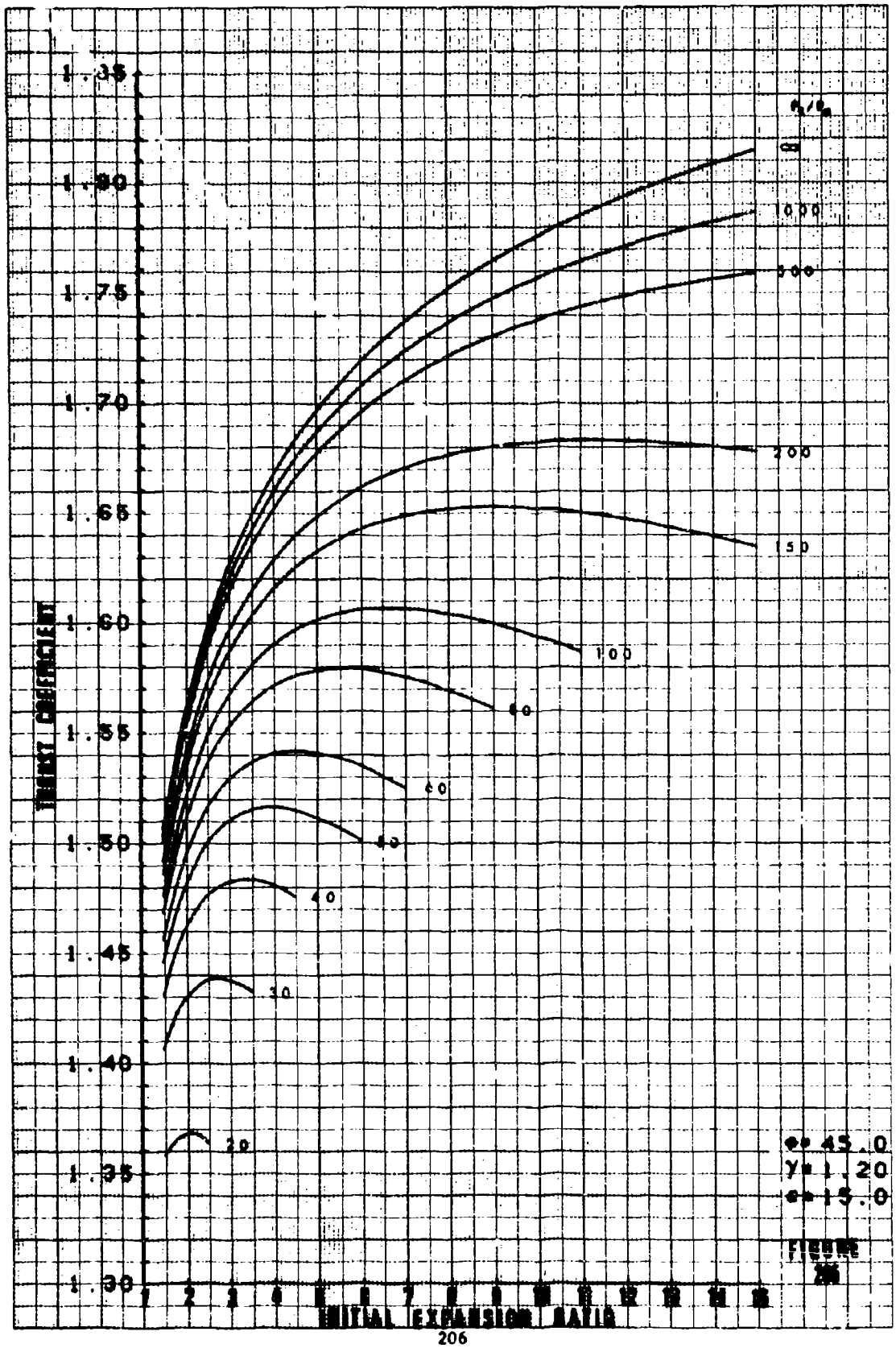

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
55
1000
500
300
200
150
γ = 1.20

FIGURE 26



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.20
α = 15.0

FIGURE 206

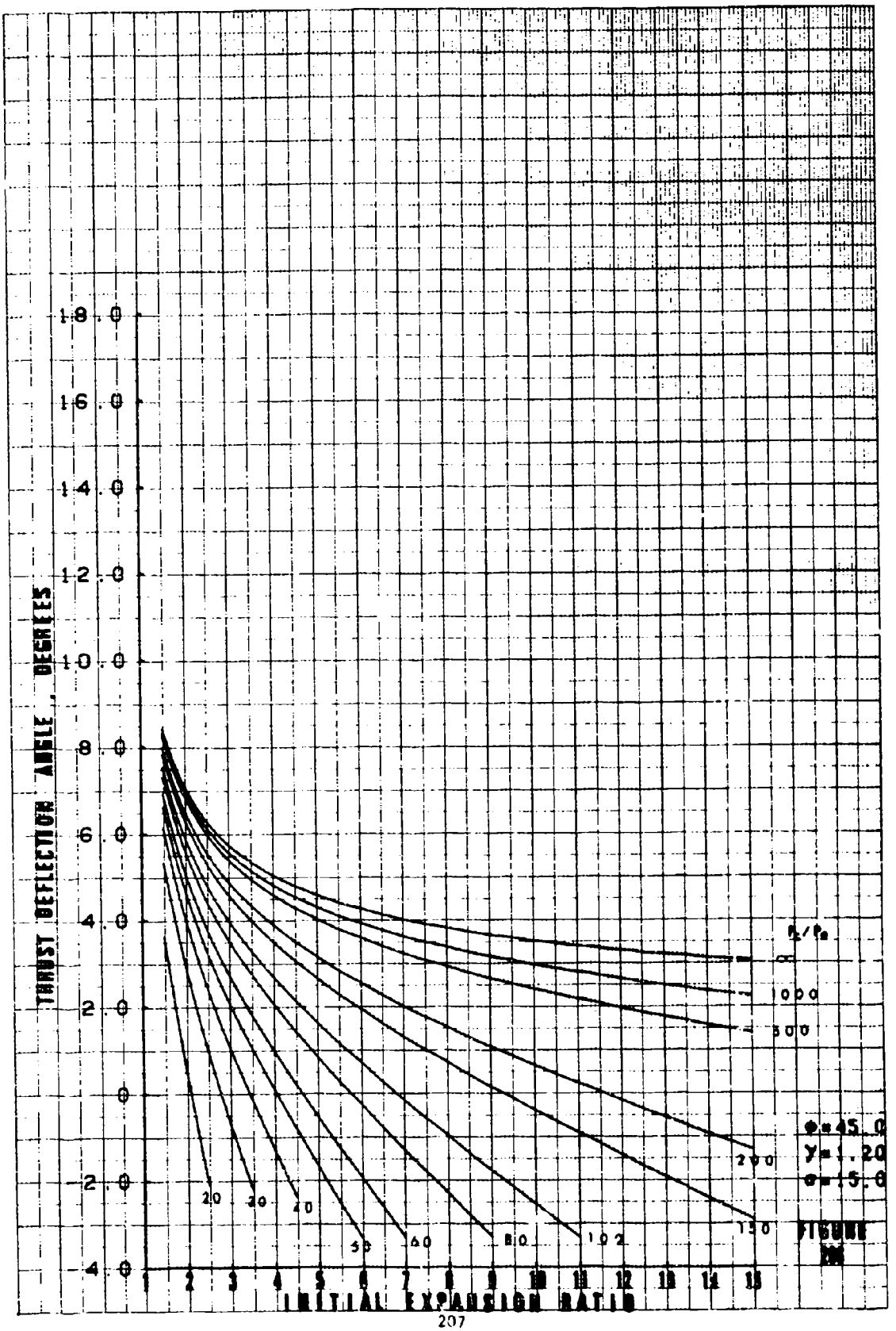
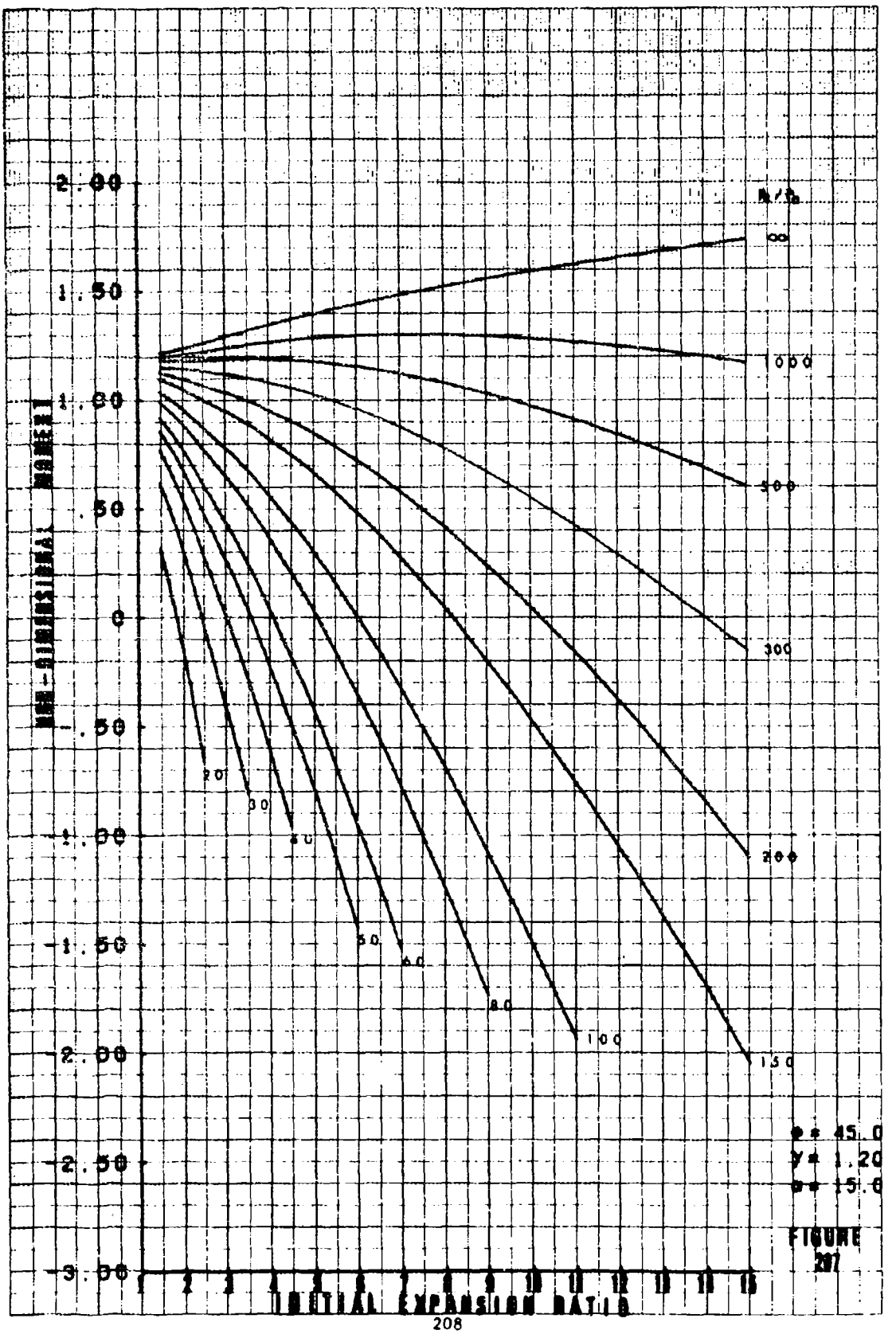
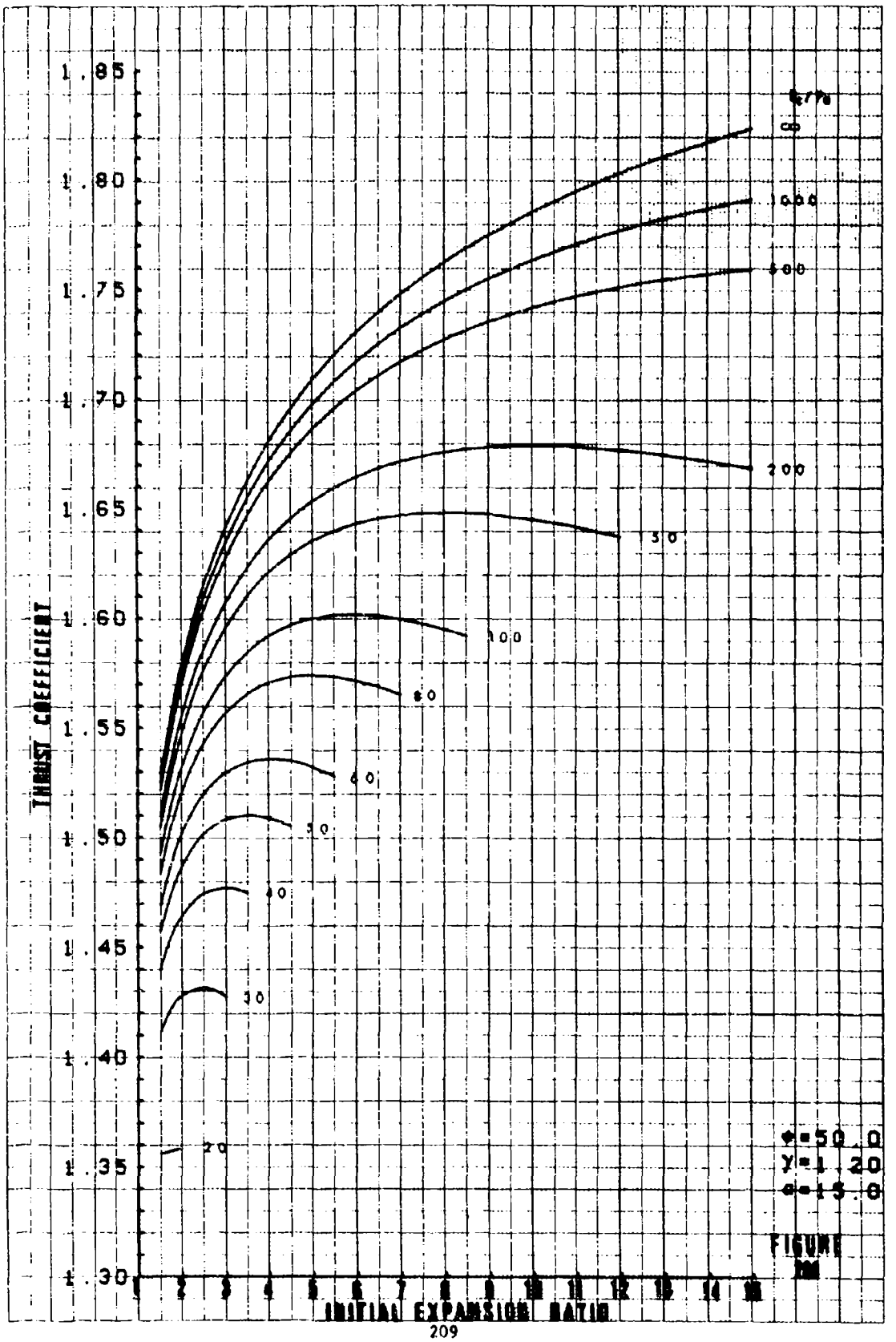

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
102
80
60
50
40
30
20
φ=45.0
γ=1.20
σ=15.0

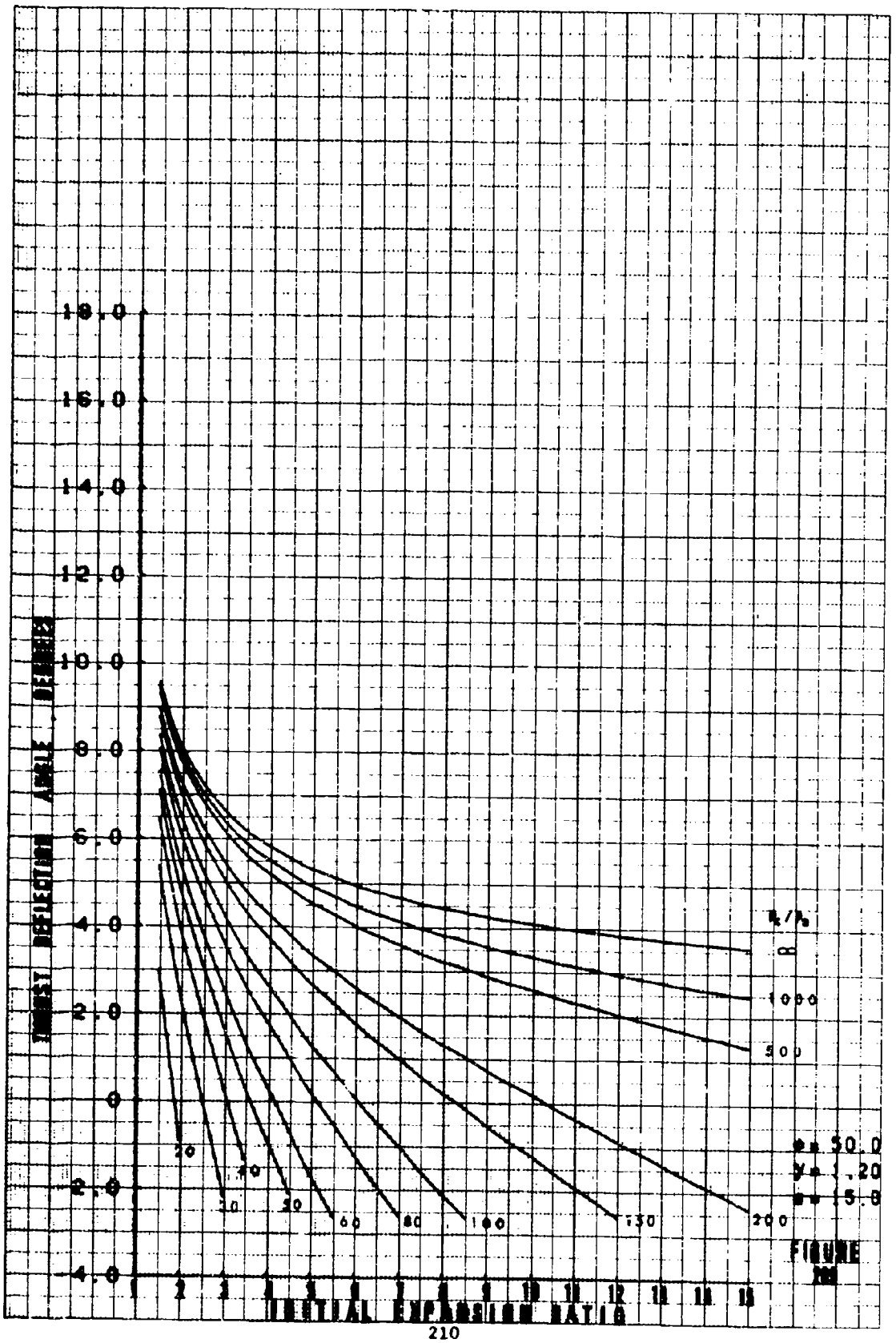
FIGURE 206



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_1/P_0
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.20
α = 15.0

FIGURE 207


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
50
100
80
60
50
40
30
20
φ=50.0
γ=1.20
α=15.0
FIGURE



18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
e = 50.0
γ = 1.20
e = 15.0
FIGURE

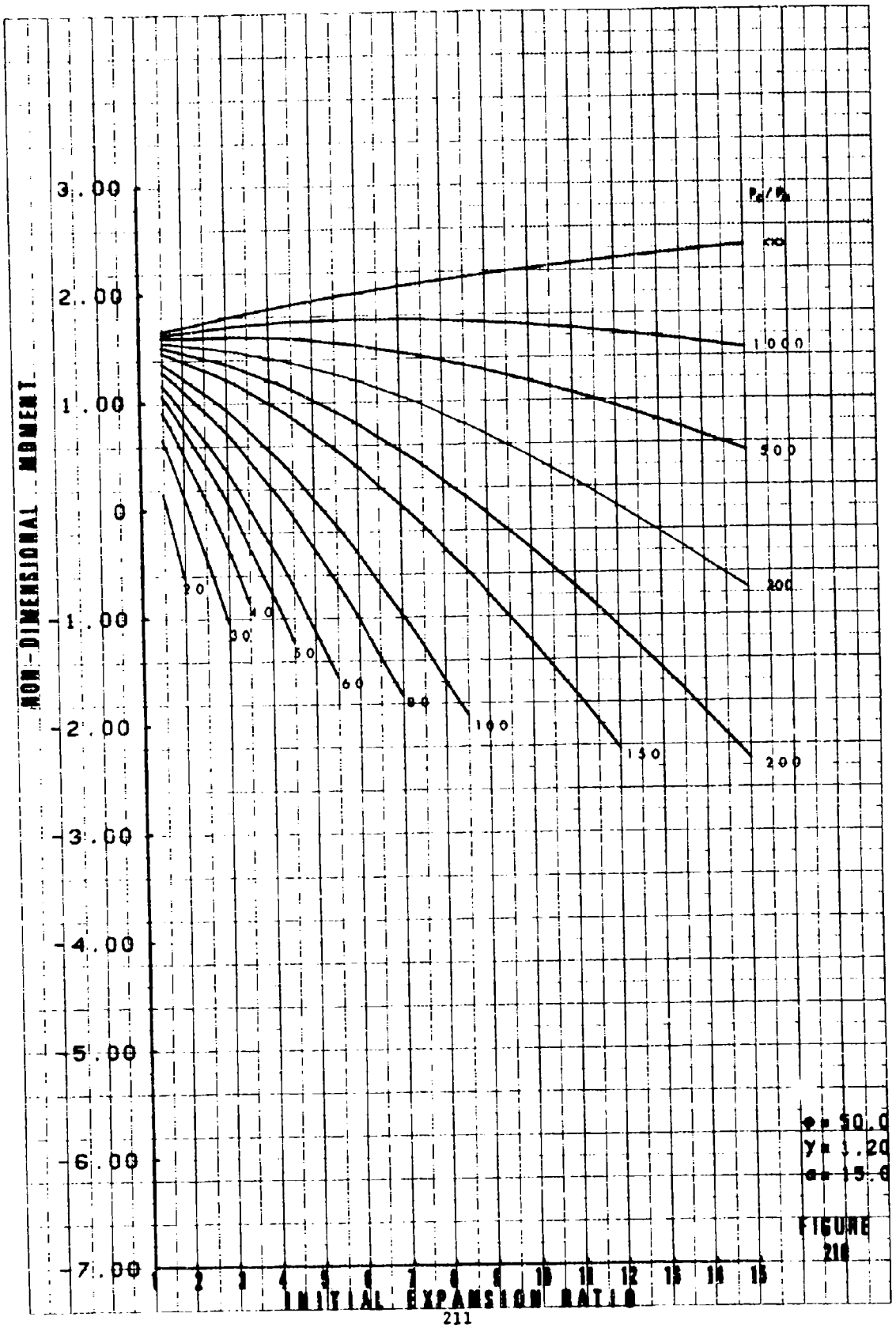
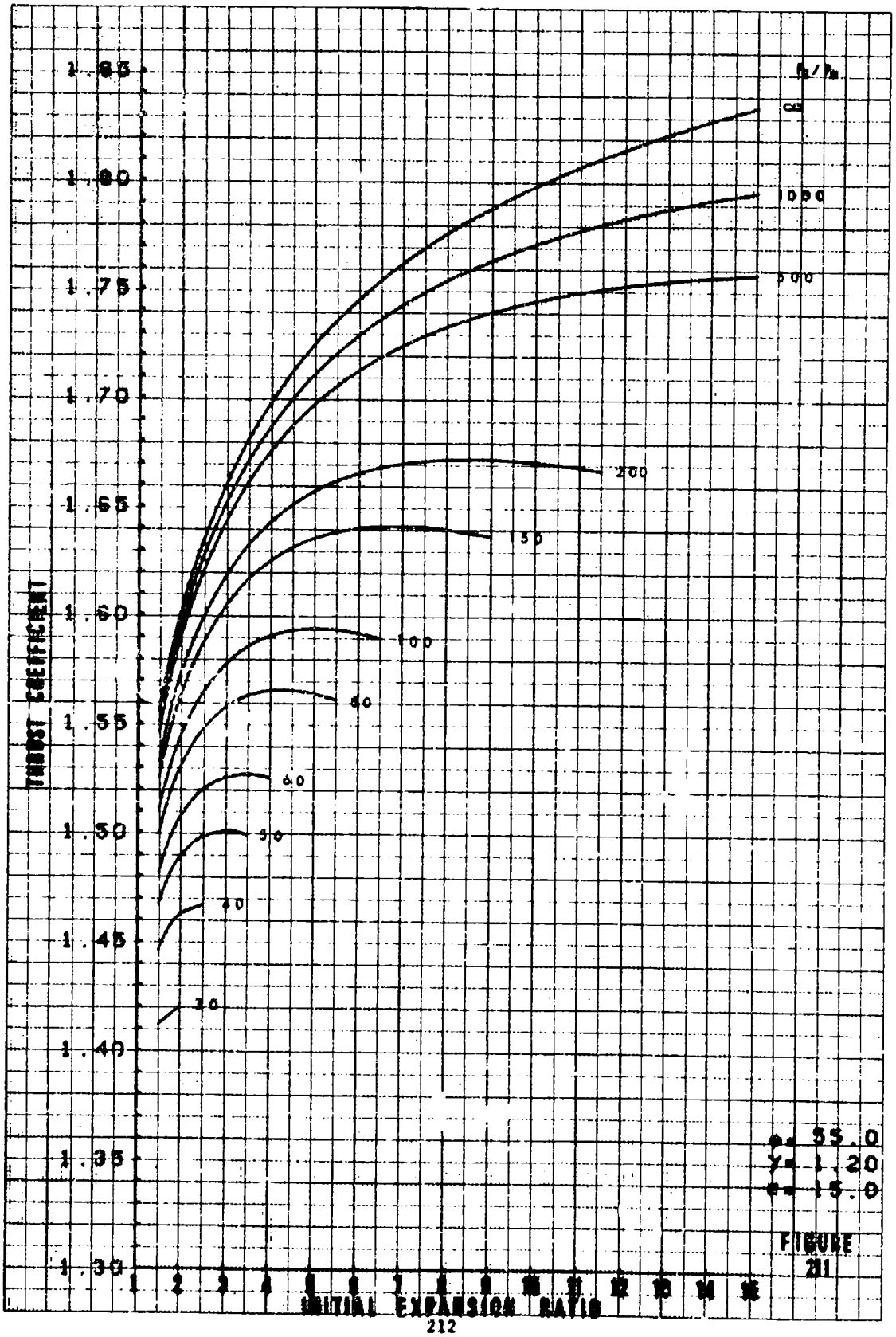

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.20
α = 15.0

FIGURE 210



THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
φ= 55.0
γ= 1.20
θ= 15.0

FIGURE 211

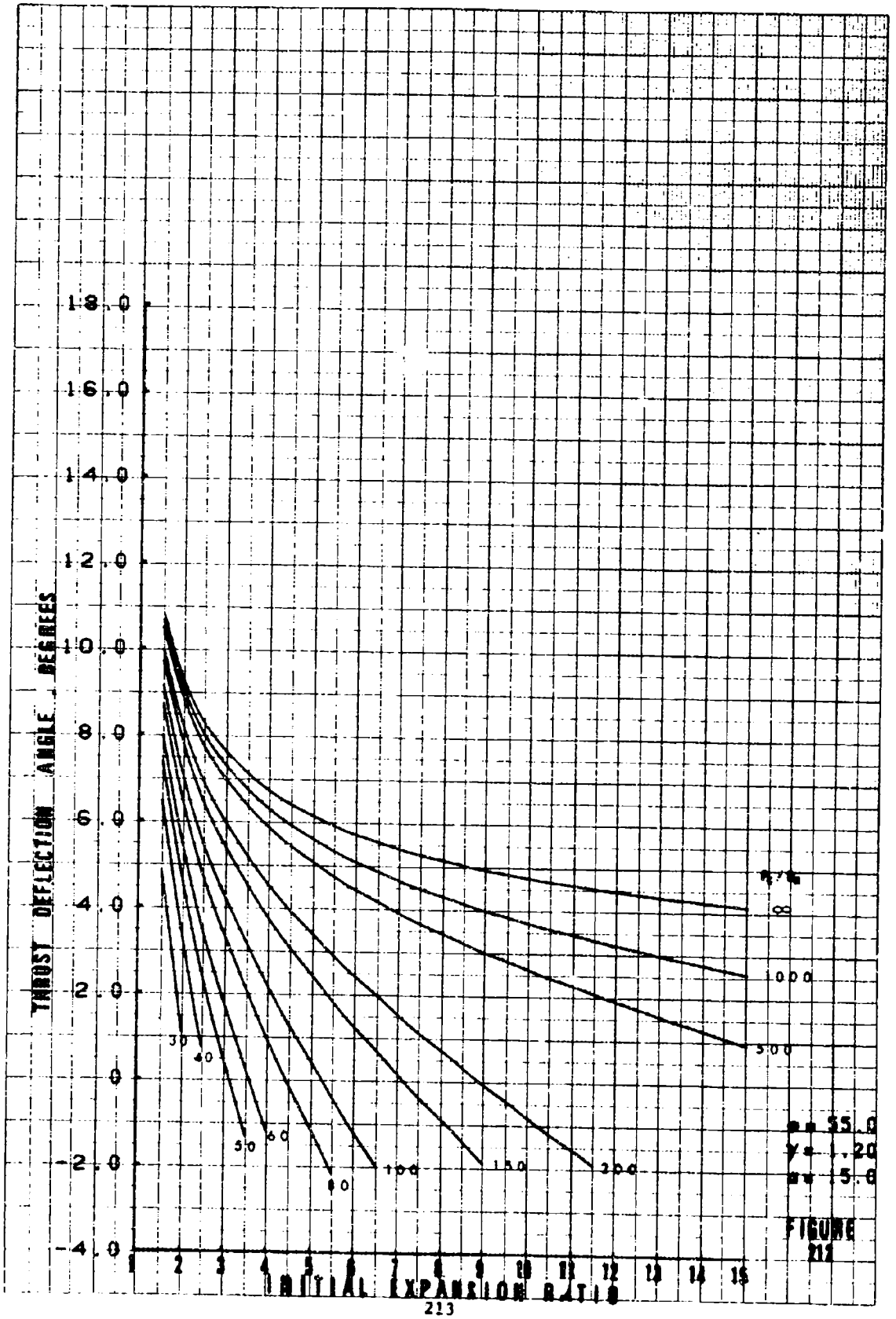

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
500
1000
∞
γ = .20

FIGURE 212

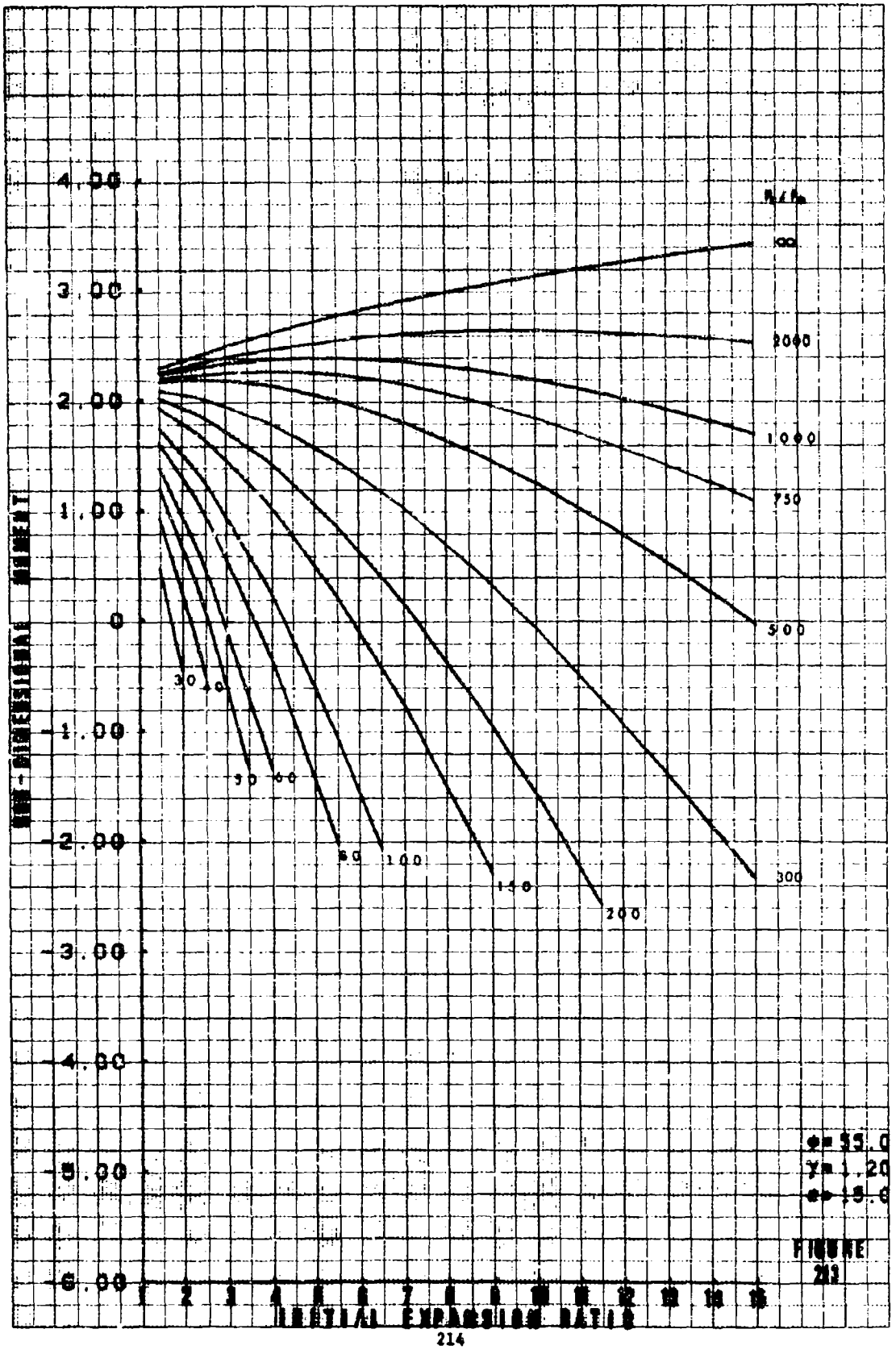

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
100
2000
1000
750
500
300
200
150
100
80
60
50
40
30
φ=55.0
γ=1.20
ε=15.0

FIGURE 213

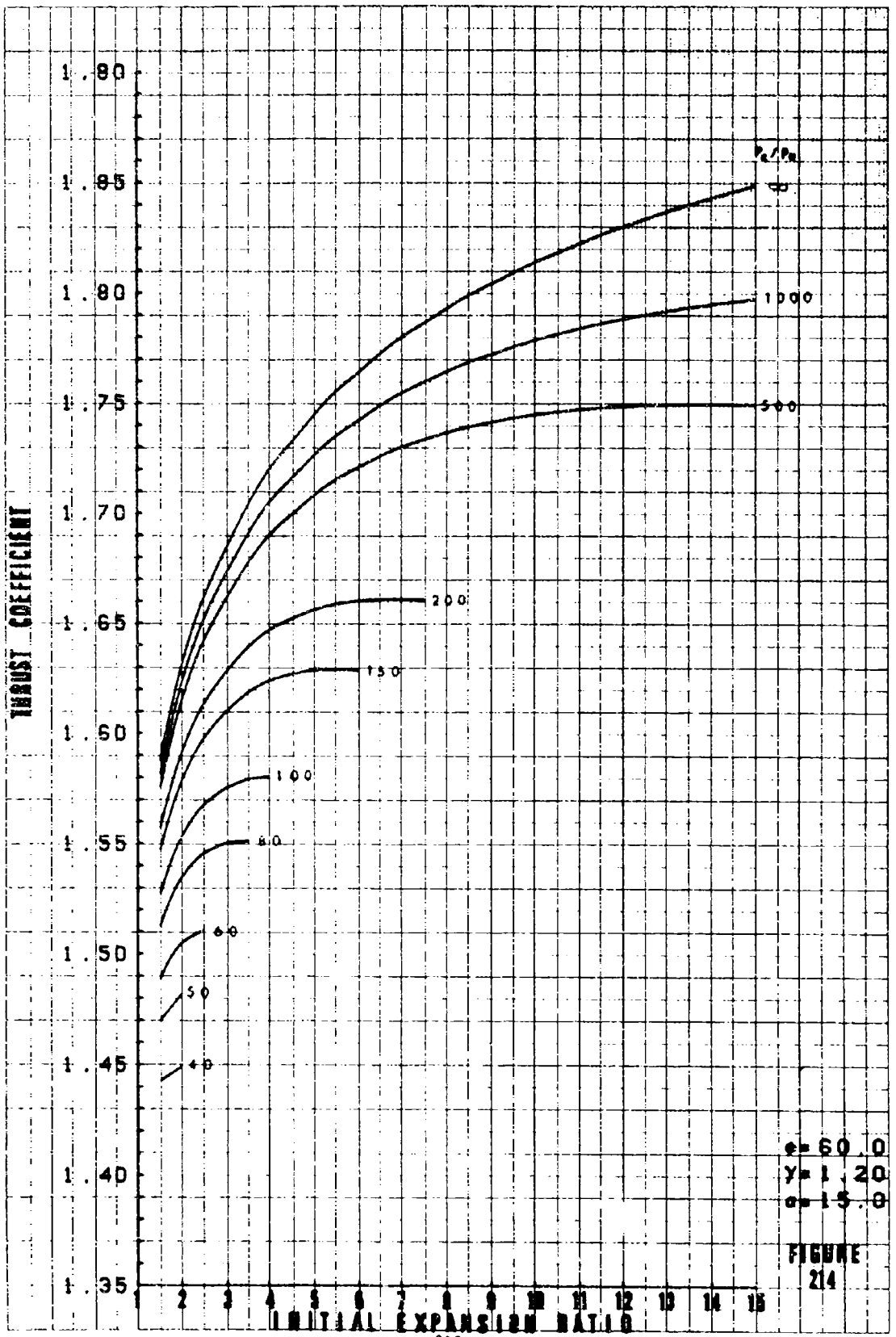

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_e/P_a
∞
1000
500
200
150
100
80
60
50
40
e= 60.0
γ= 1.20
α= 15.0

FIGURE 214

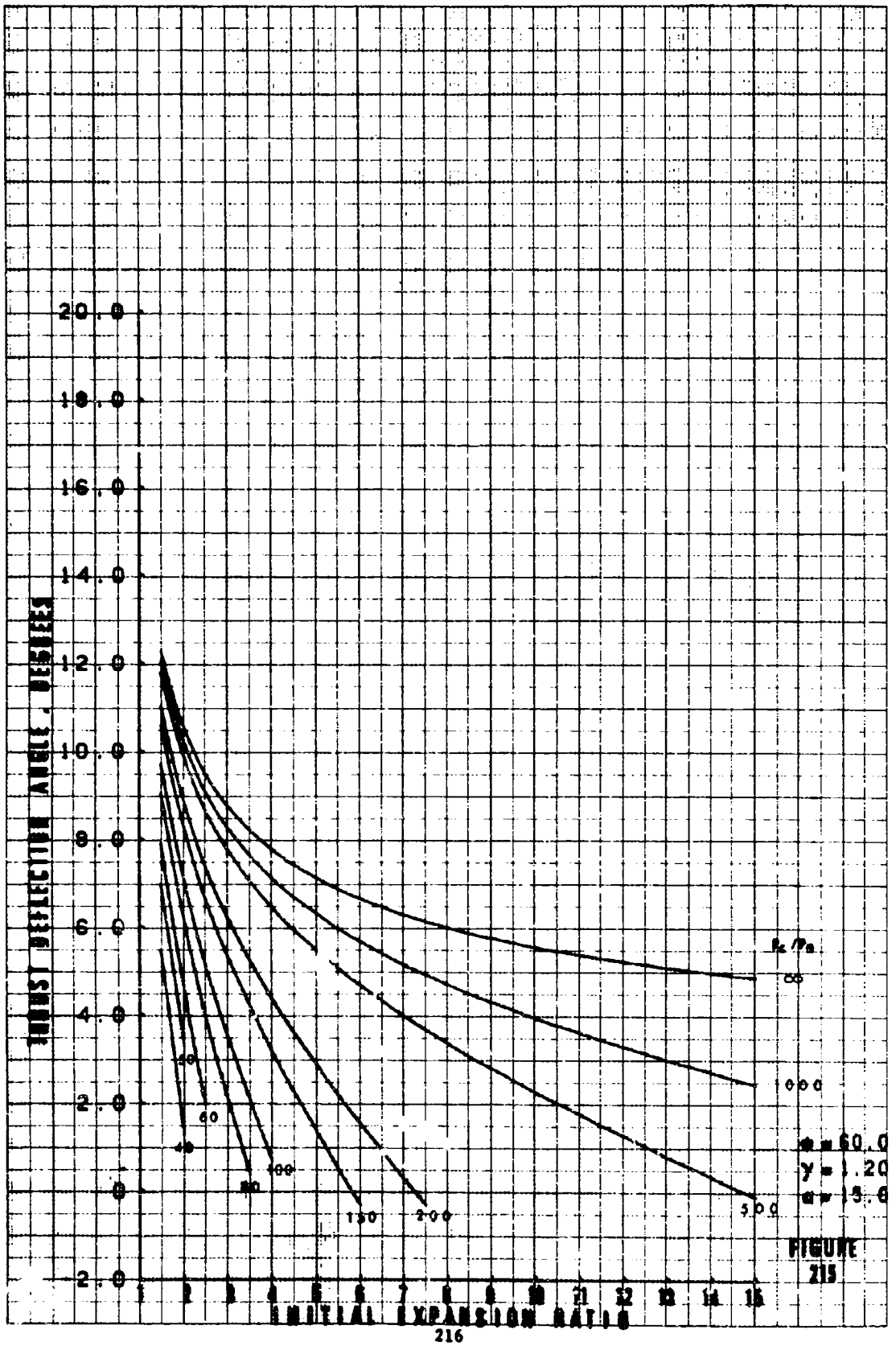
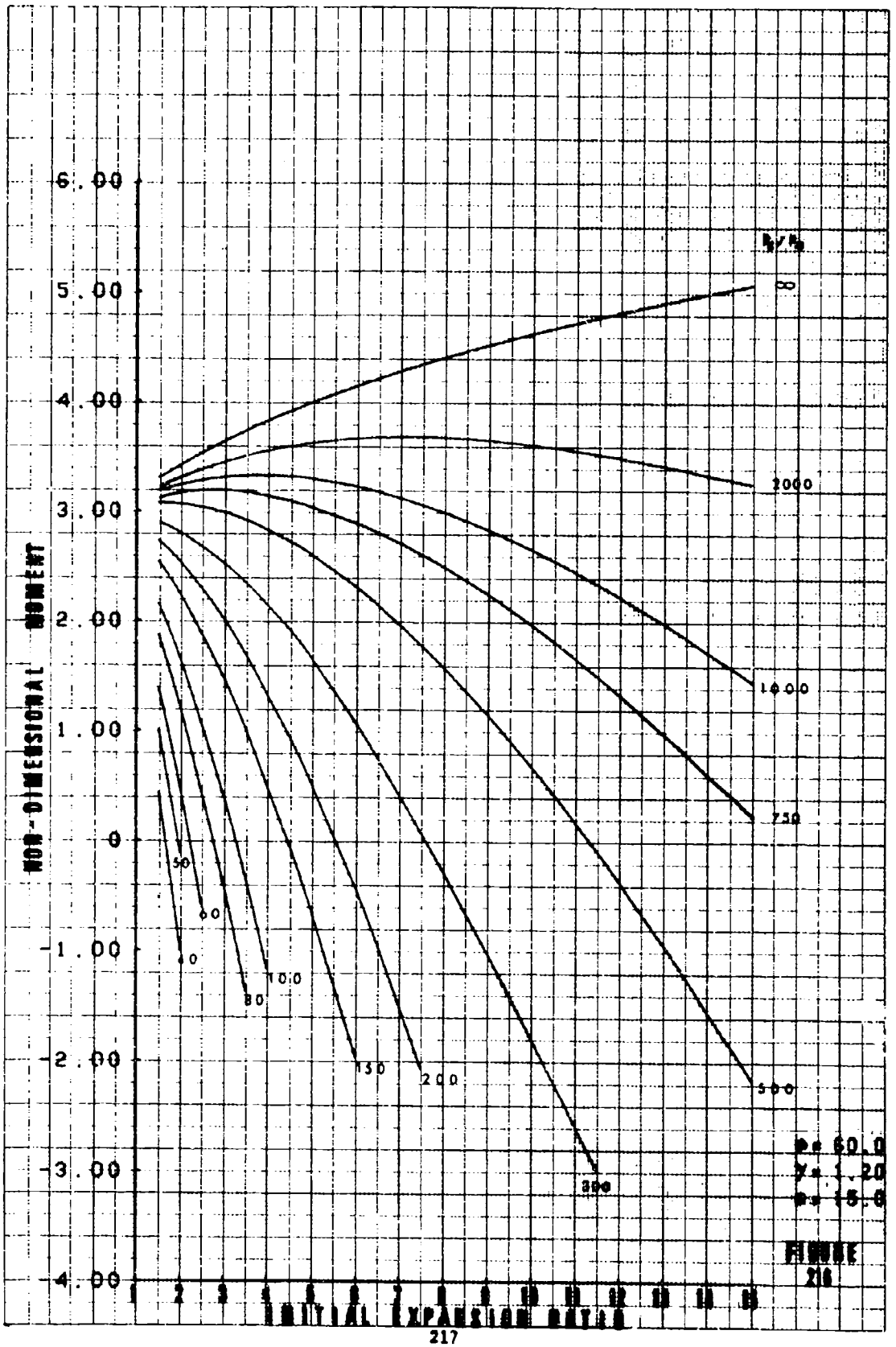
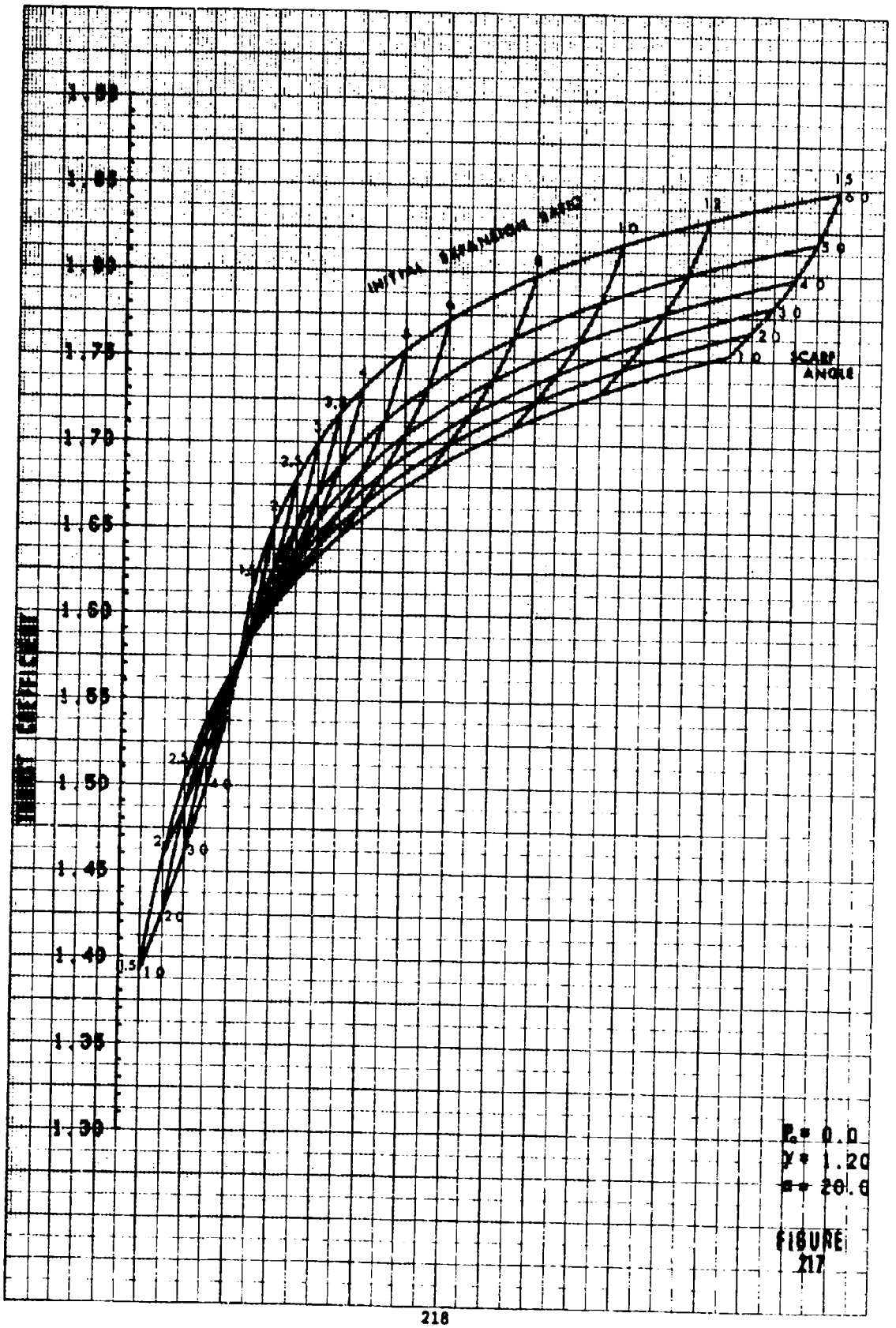

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
40
φ = 60.0
γ = 1.20
α = 15.6

FIGURE 215



NON-DIMENSIONAL MOMENT
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
Φ= 60.0
γ= 1.20

FIGURE 216



1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
P_o = 0.0
γ = 1.20
α = 20.0

FIGURE 217

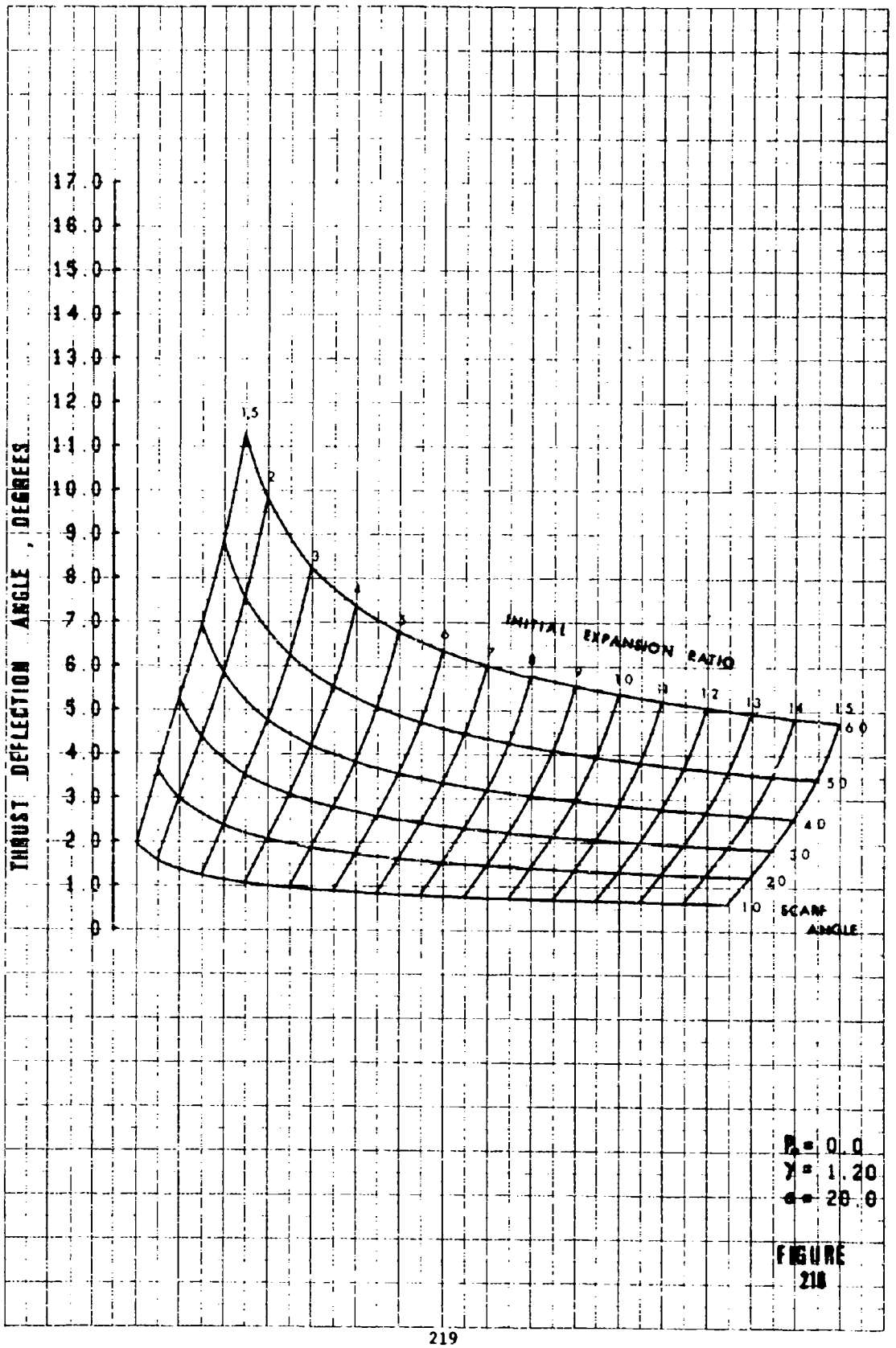

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.20
α = 28.0

FIGURE 21B

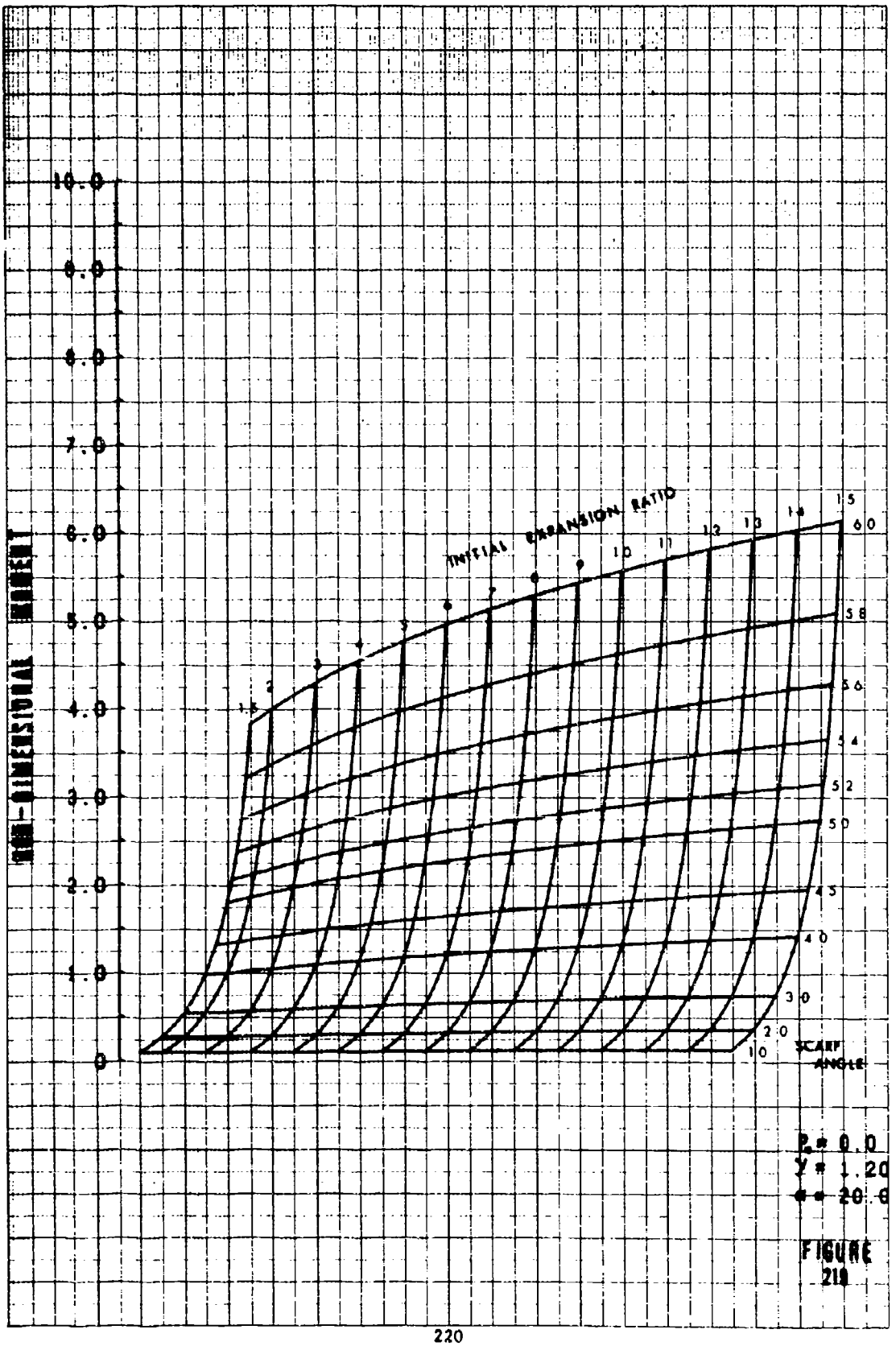

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P = 0.0
γ = 1.20
θ = 20.0

FIGURE 21B

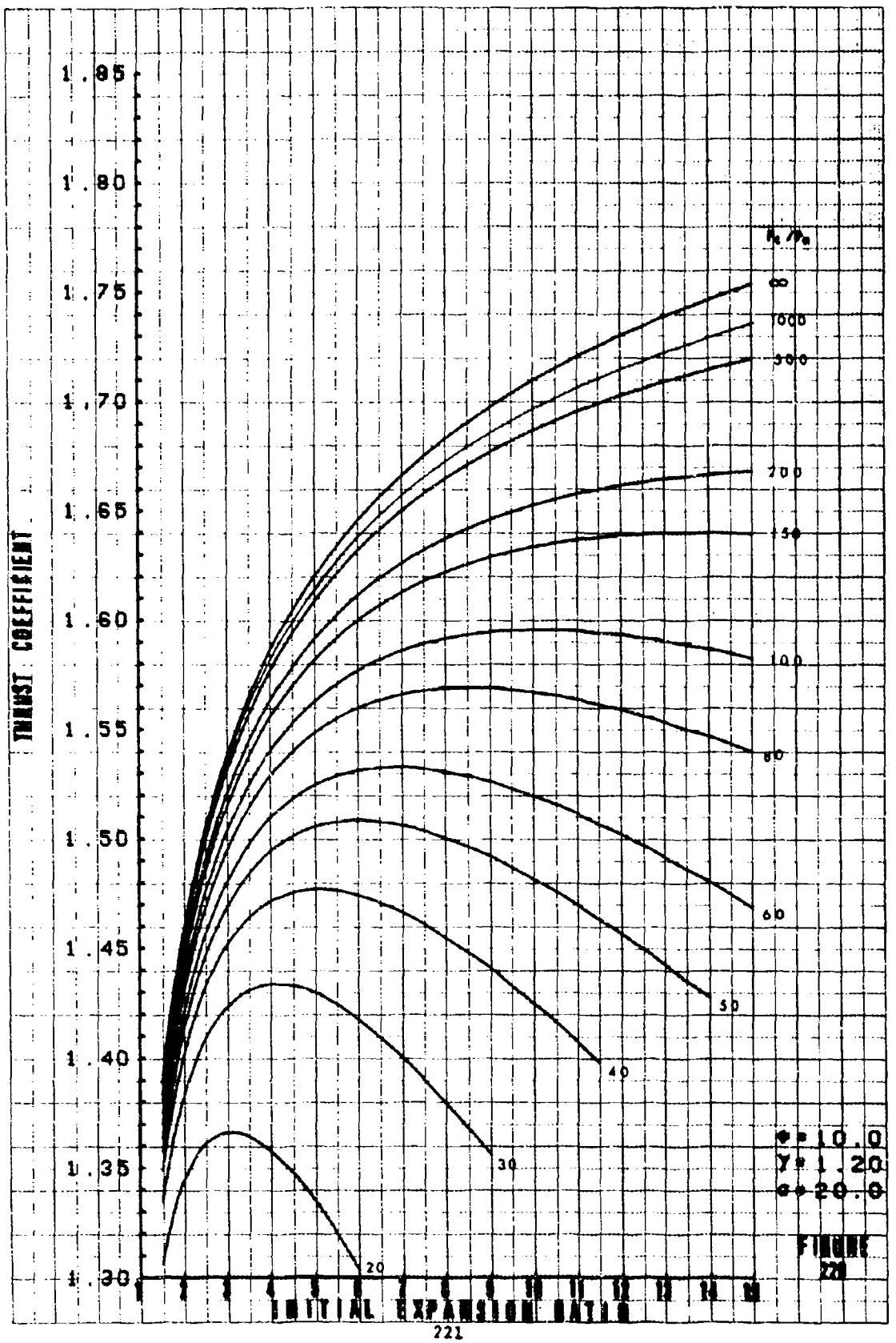

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
300
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.20
σ = 20.0

FIGURE 220

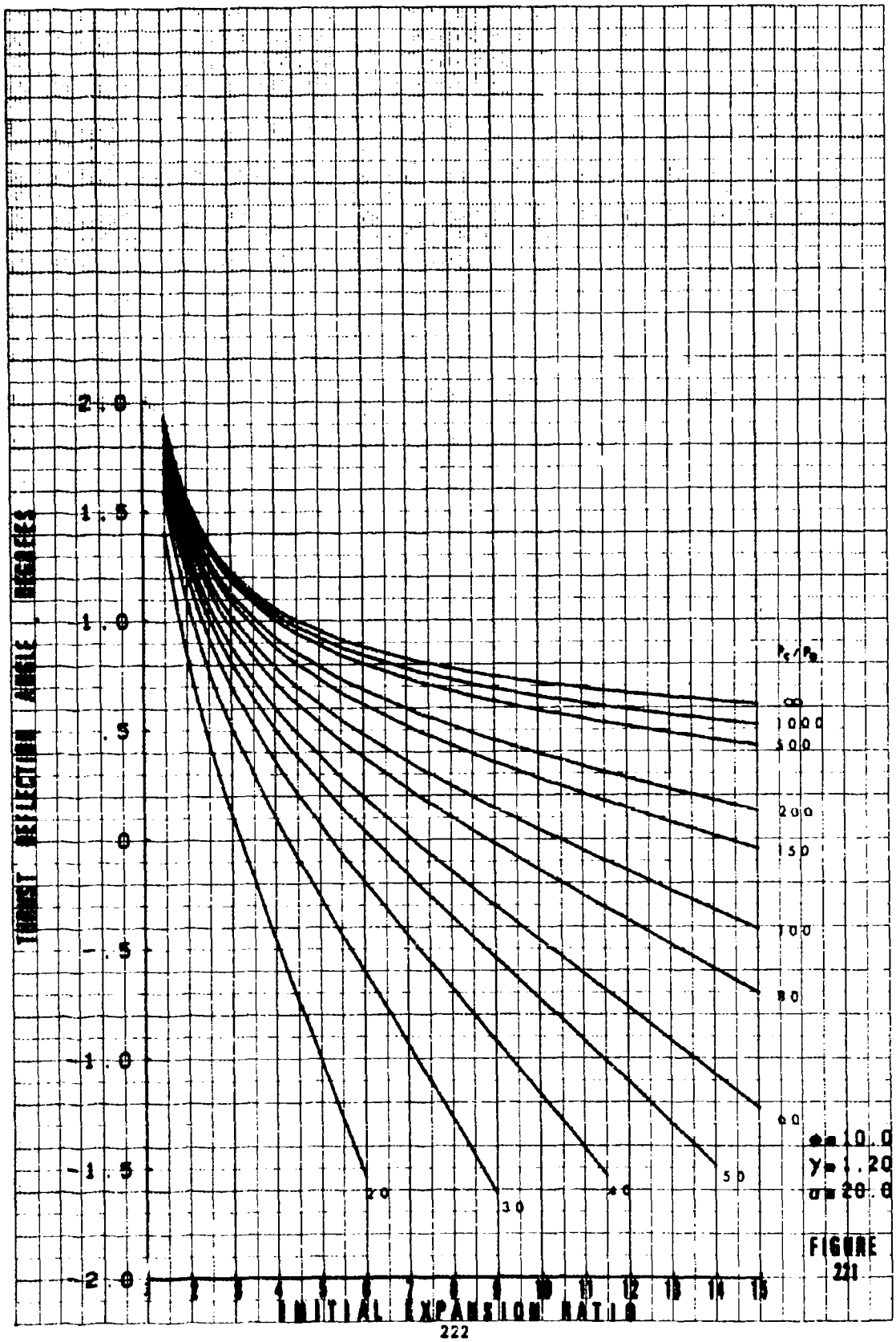

TURNING DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ=10.0
γ=1.20
σ=20.0

FIGURE 221

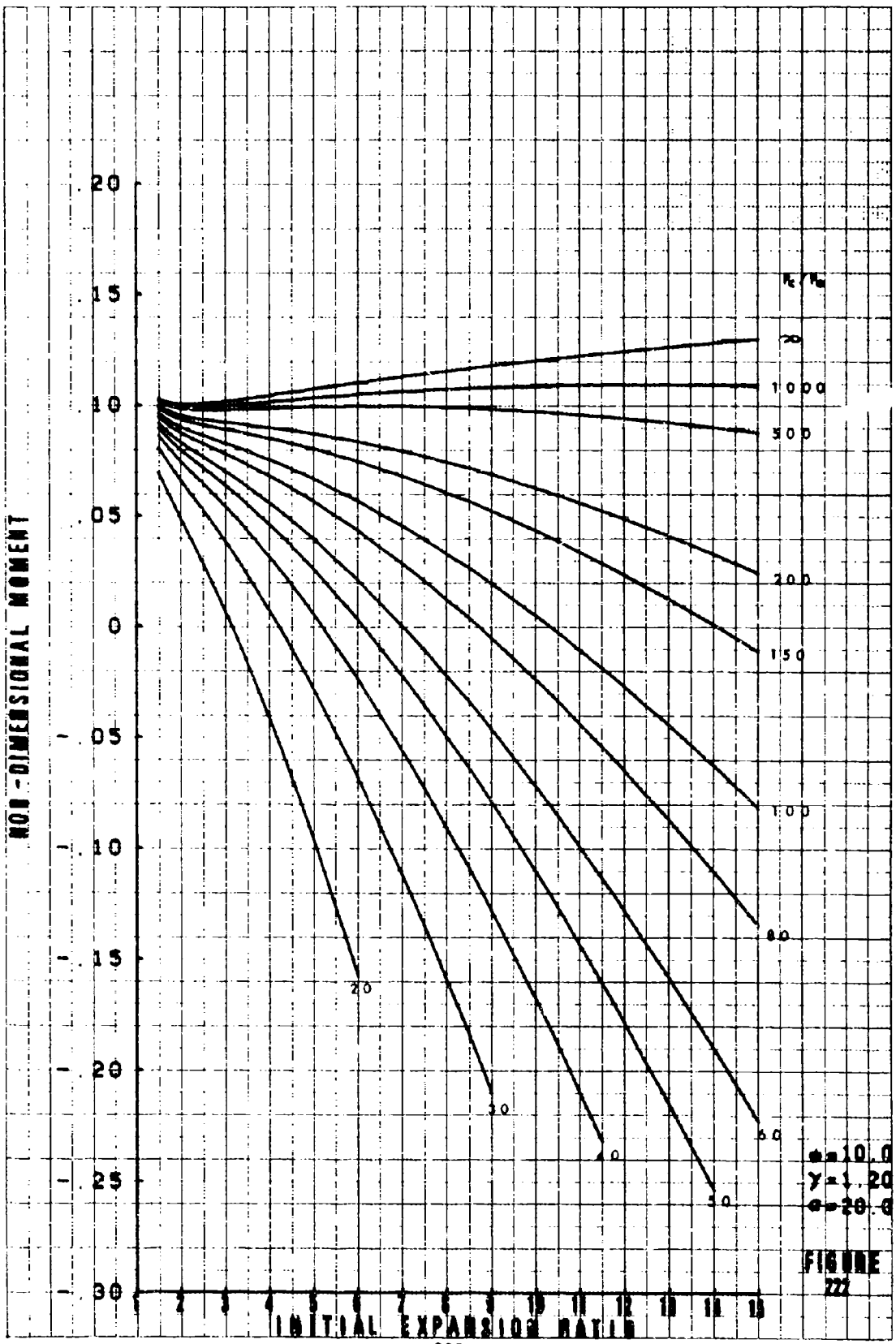

NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=10.0
γ=1.20
α=20.0

FIGURE 222

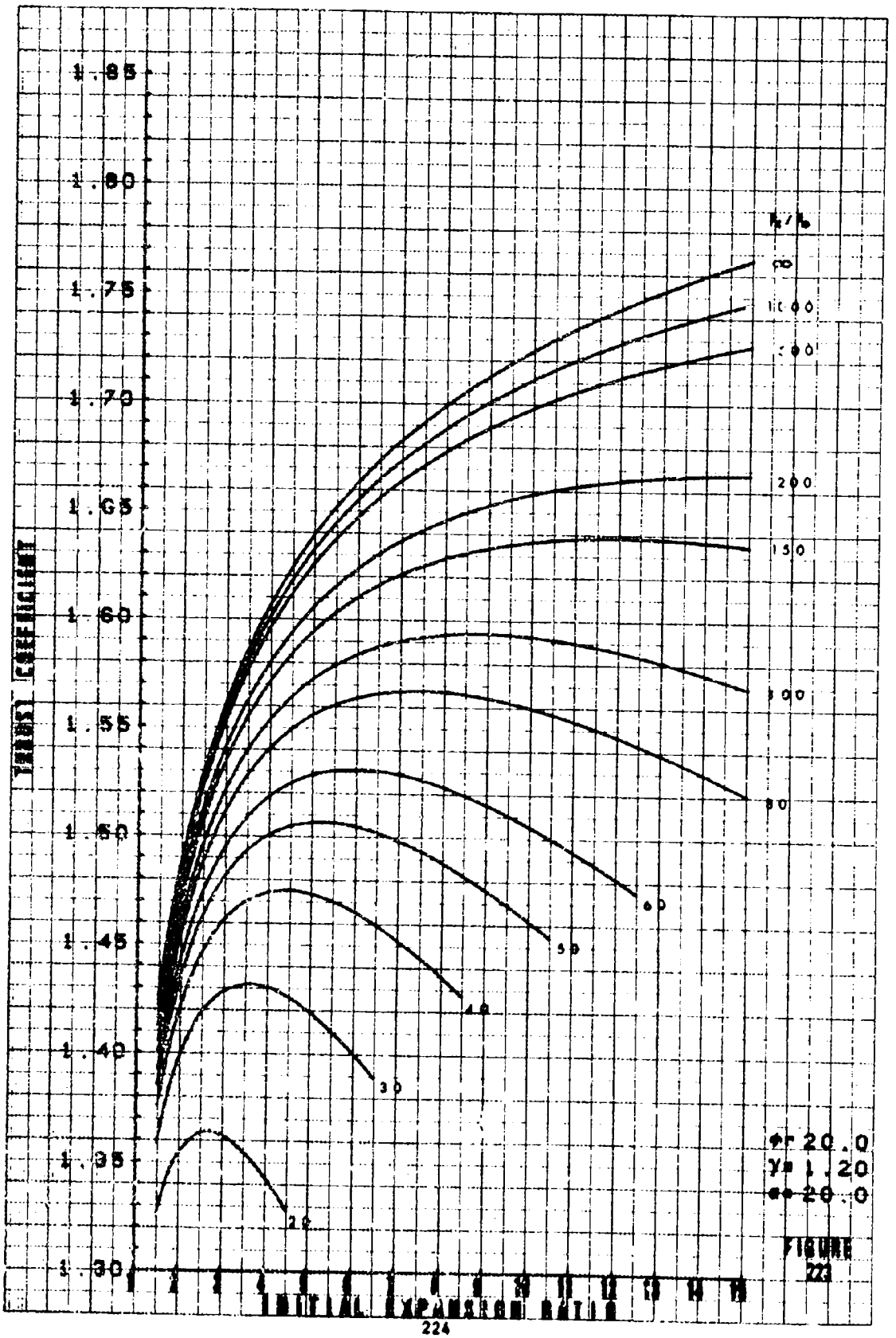

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φr 20.0
γ= 1.20
φe 20.0

FIGURE 223

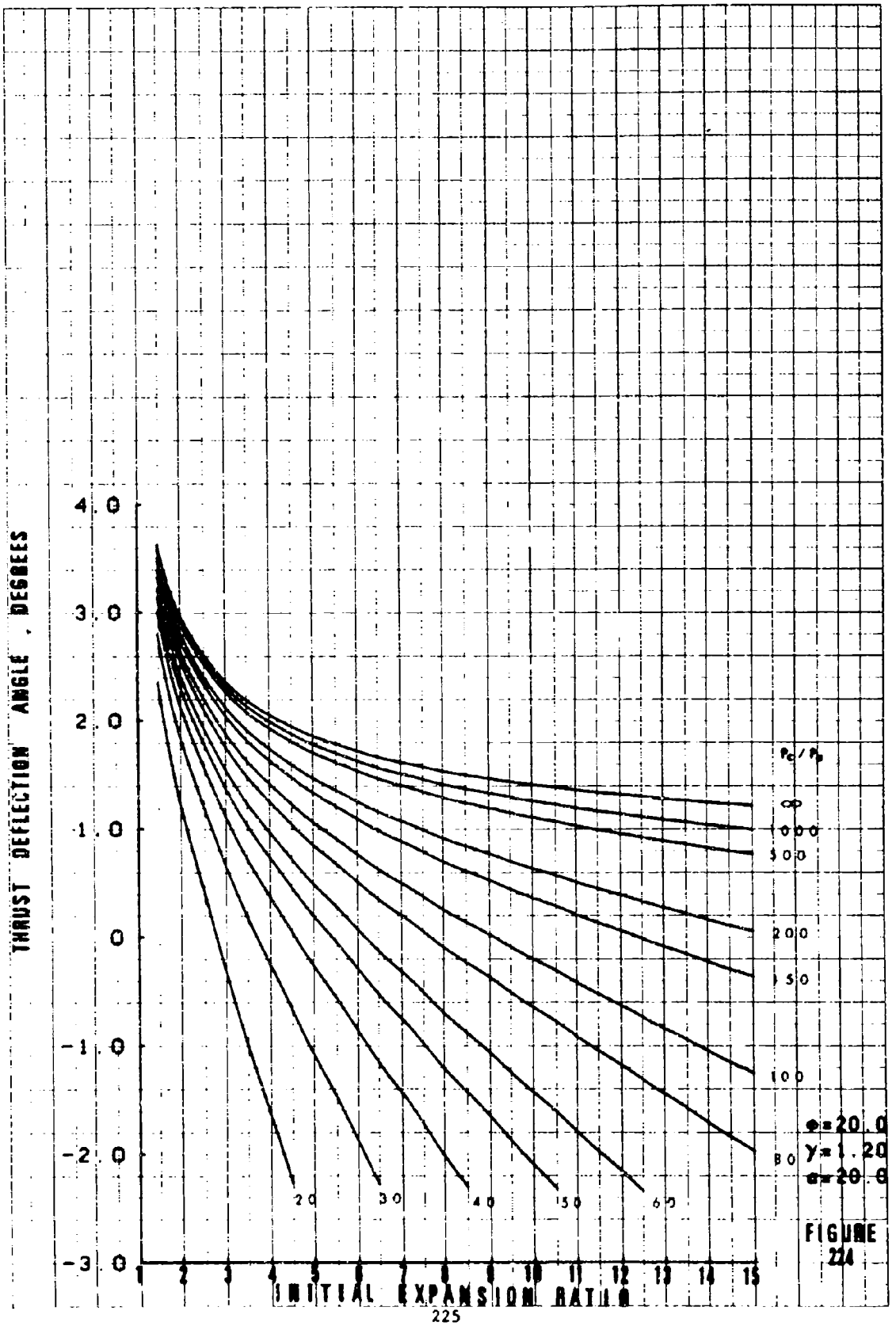

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_b
∞
1000
500
200
150
100
80
20
30
40
50
60
φ=20.0
γ=1.20
α=20.0

FIGURE 224

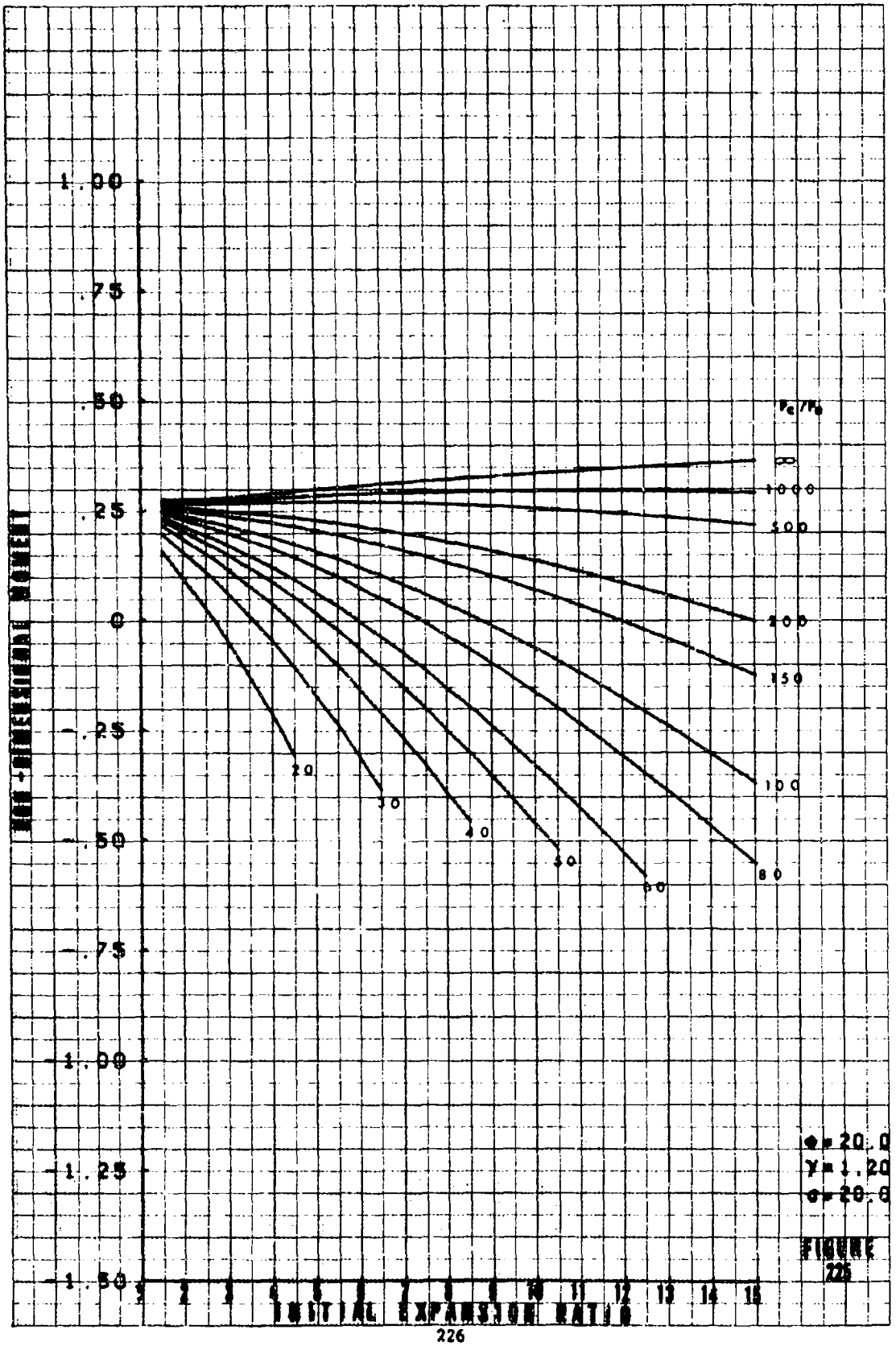

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_e/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
θ = 20.0

FIGURE 225

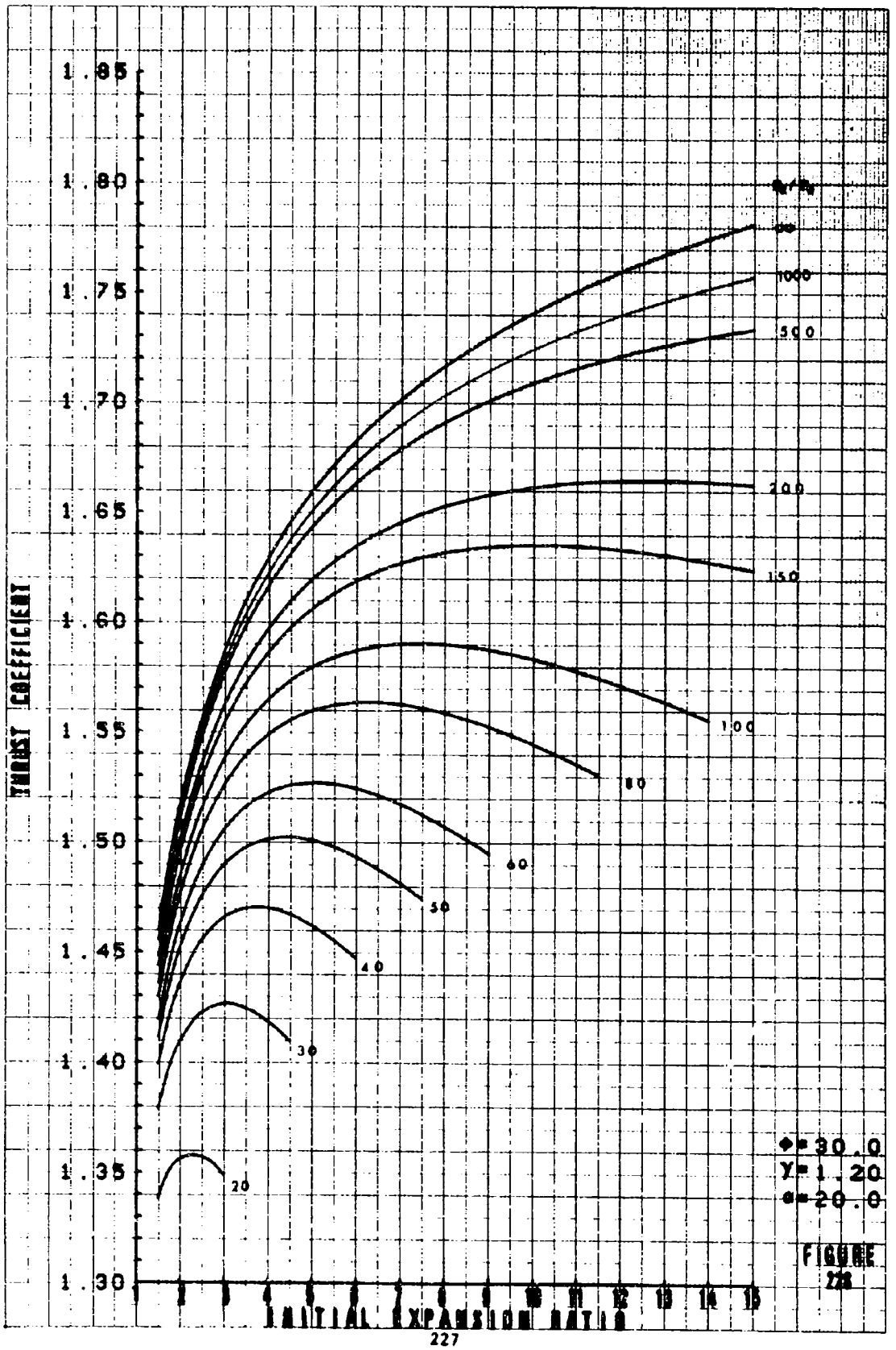

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ=30.0
γ=1.20
α=20.0

FIGURE 22B

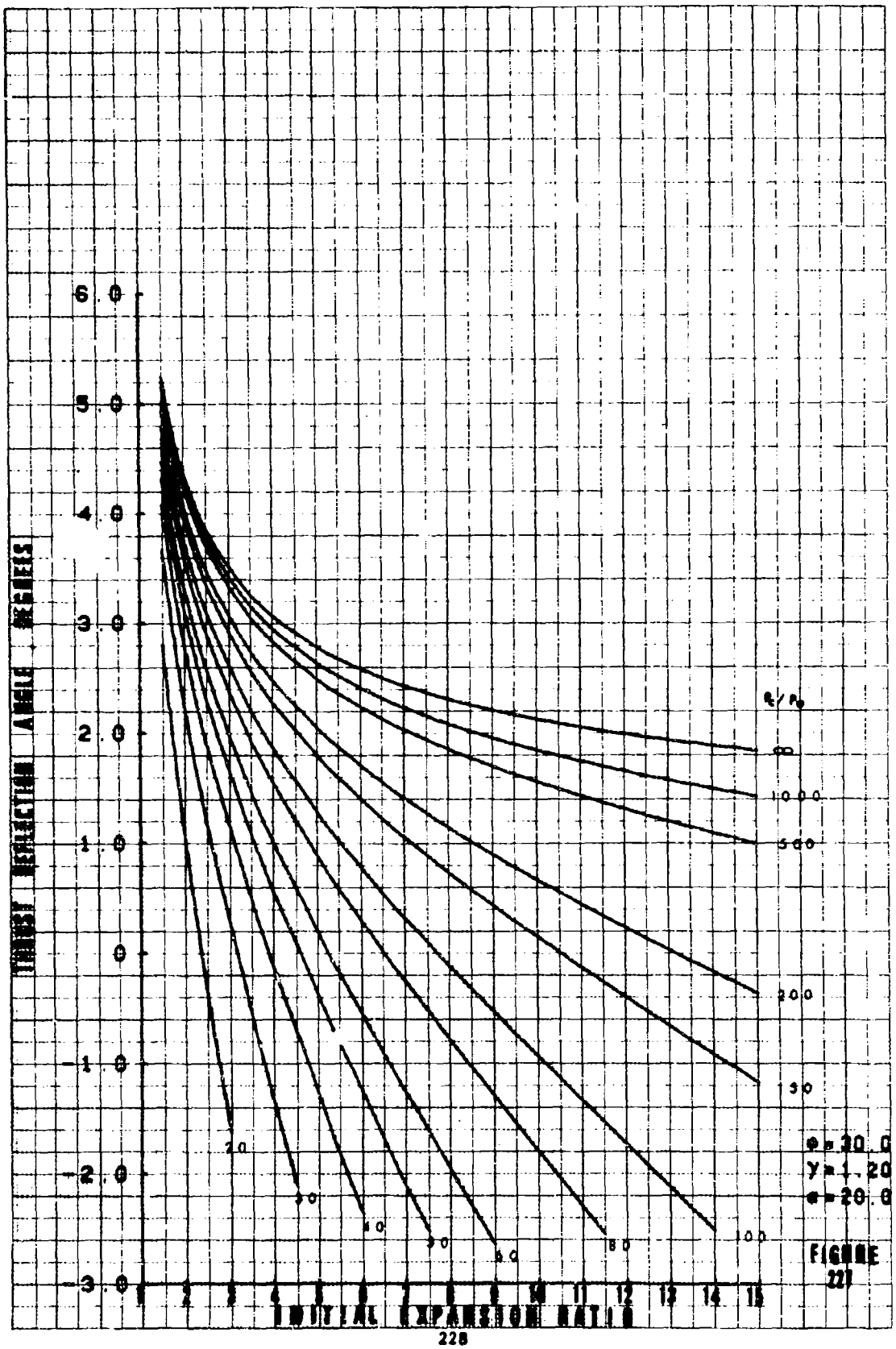

THRUST DEFLECTION ANGLE - DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
R/R0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.20
α = 20.0

FIGURE 221

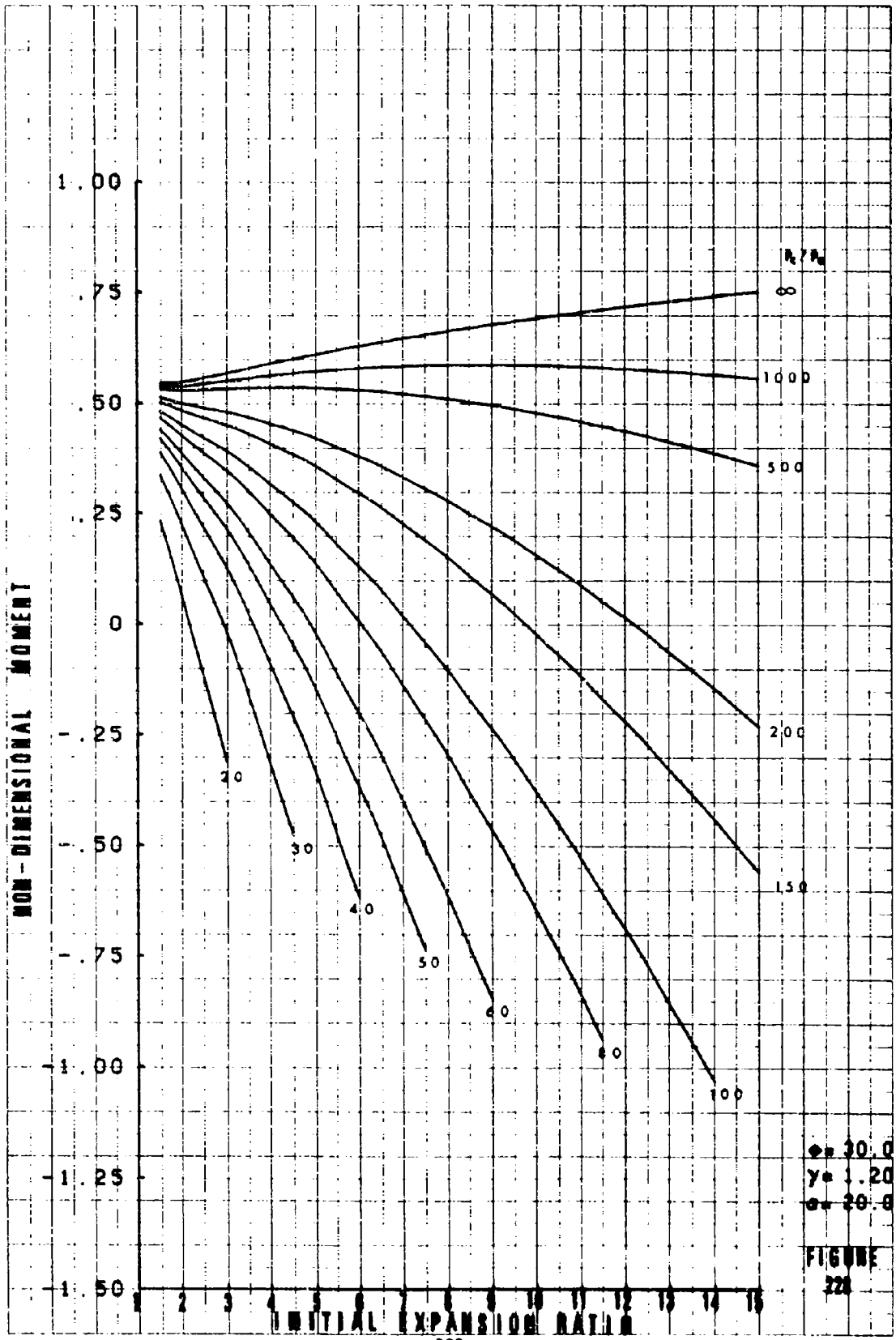

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.20
σ= 20.0

FIGURE 22A

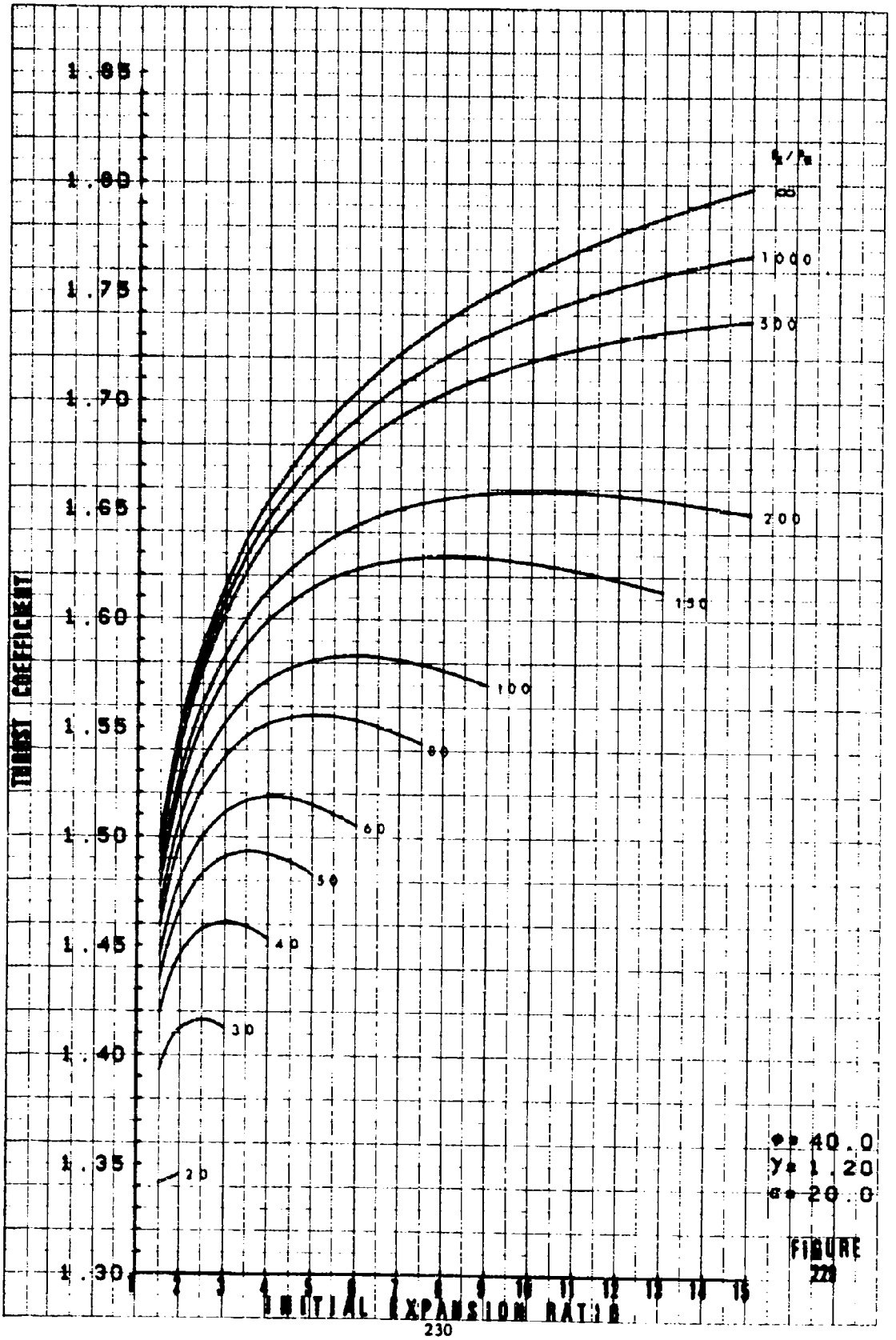

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
300
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.20
α = 20.0

FIGURE 22

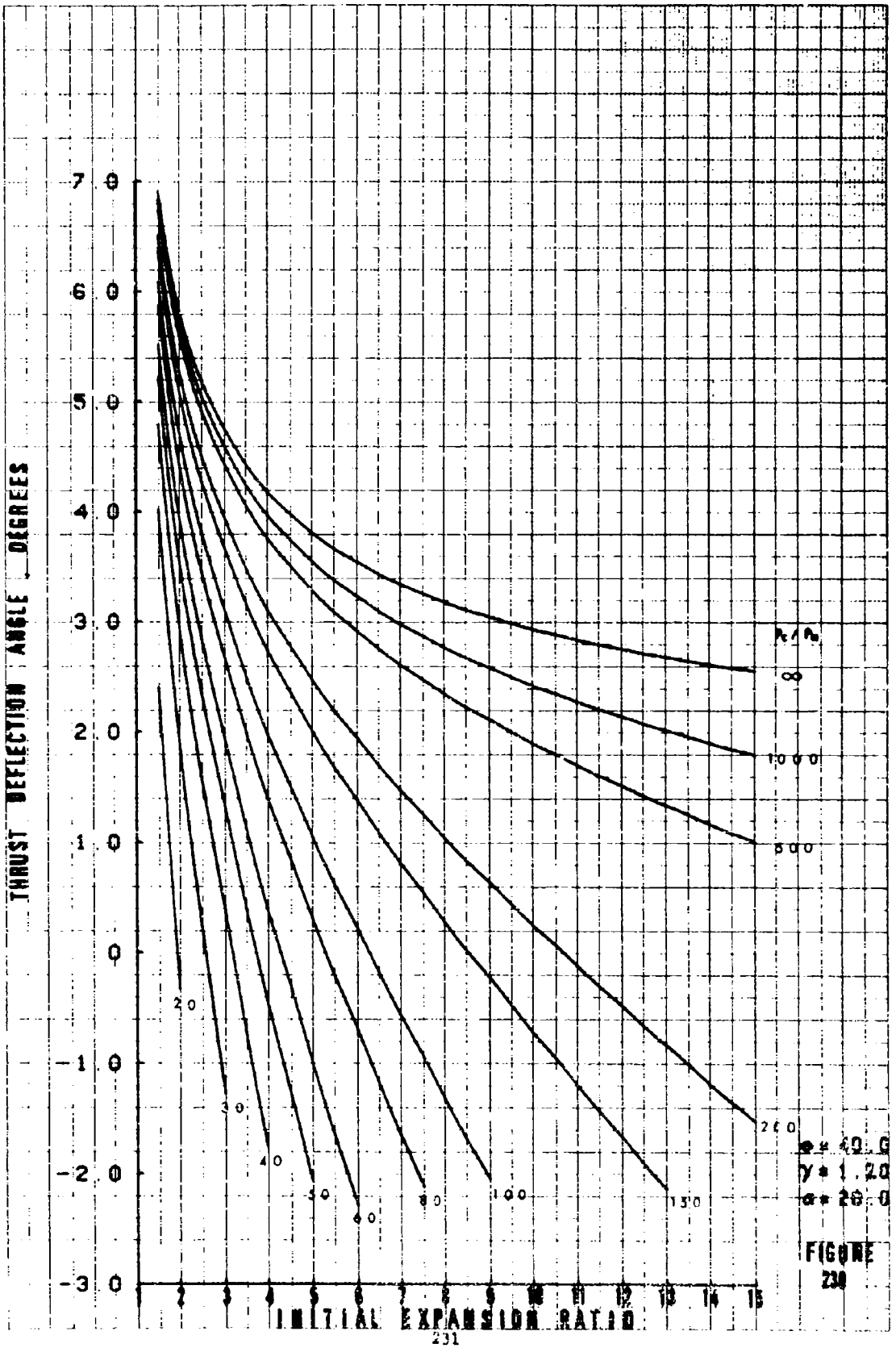

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
h/h_0
∞
1000
500
260
150
100
80
60
50
40
30
20
θ = 40.0
γ = 1.20
α = 20.0

FIGURE 230

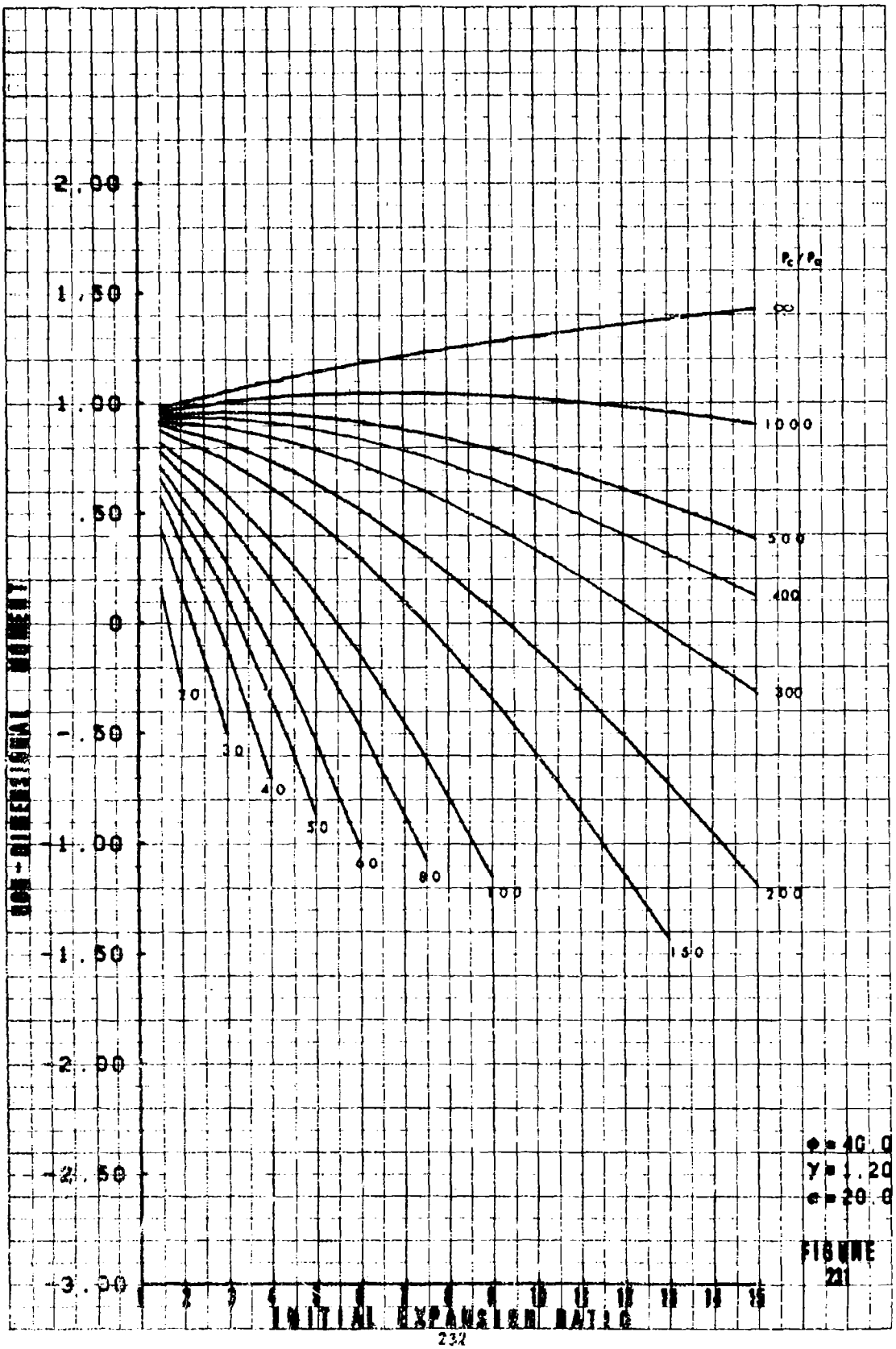

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL VELOCITY
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
400
300
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.20
e = 20.0

FIGURE 21

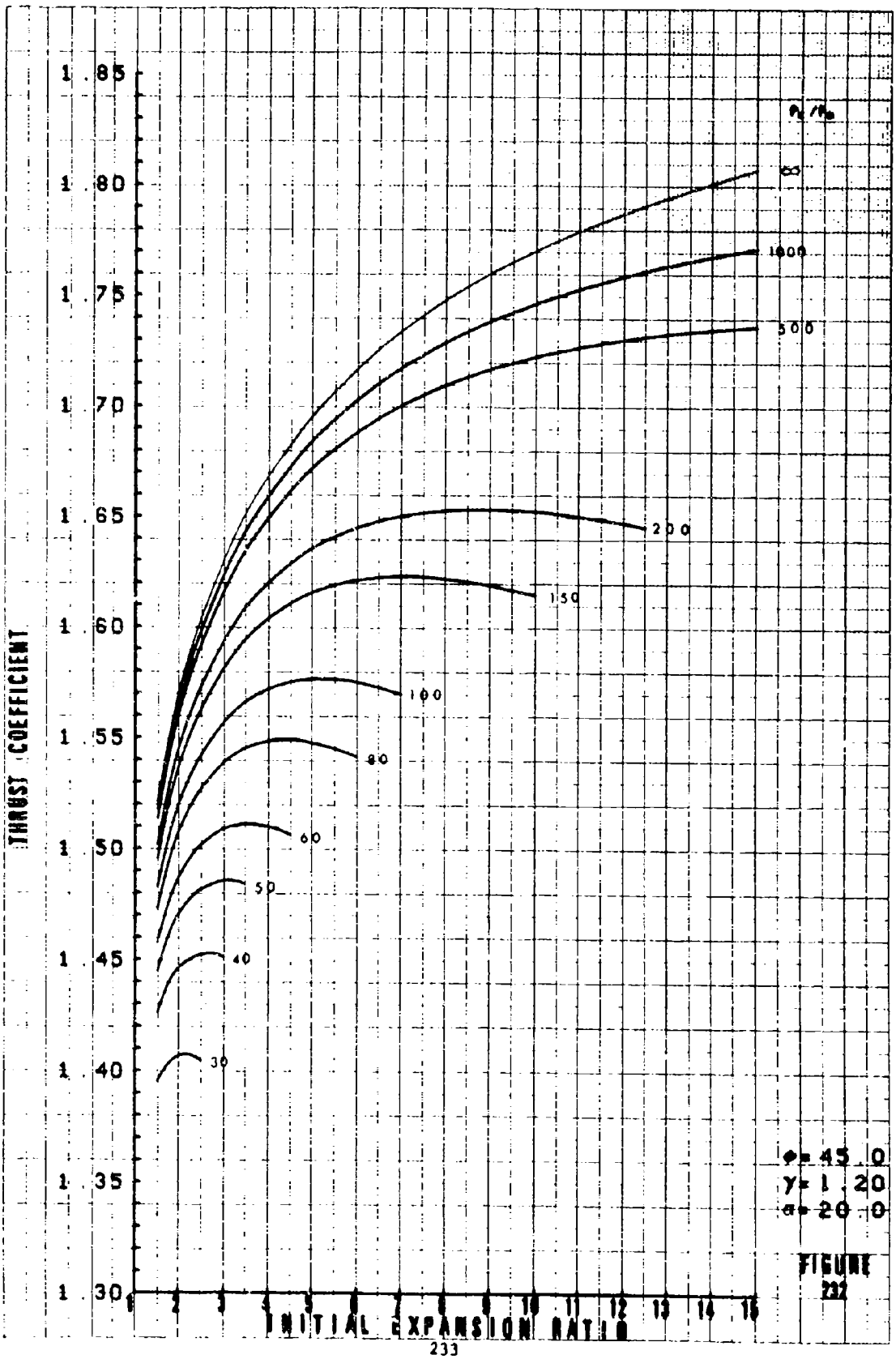

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
φ= 45.0
γ= 1.20
α= 20.0

FIGURE 232

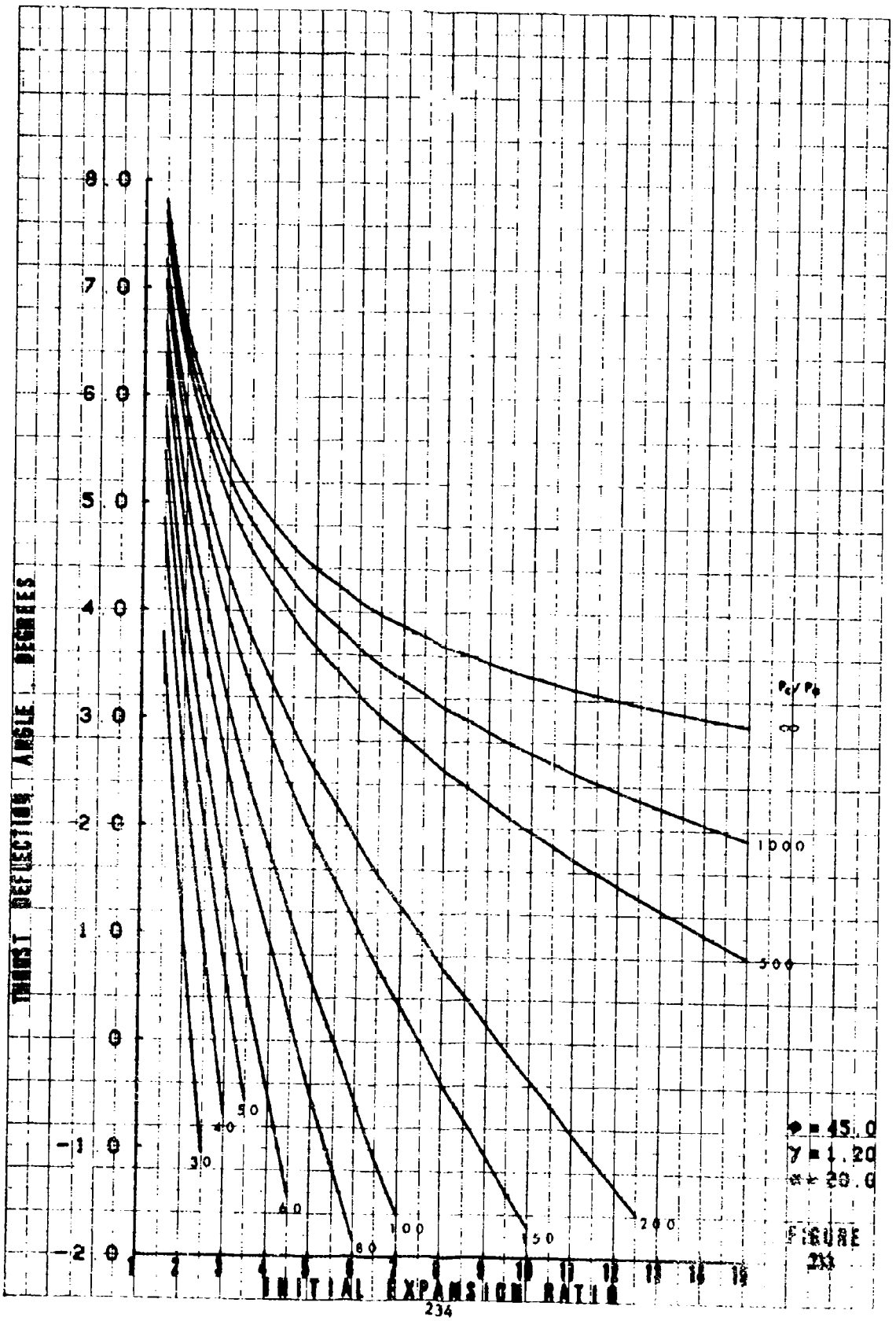

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
ϕ = 45.0
γ = 1.20
α = 20.0

FIGURE 233

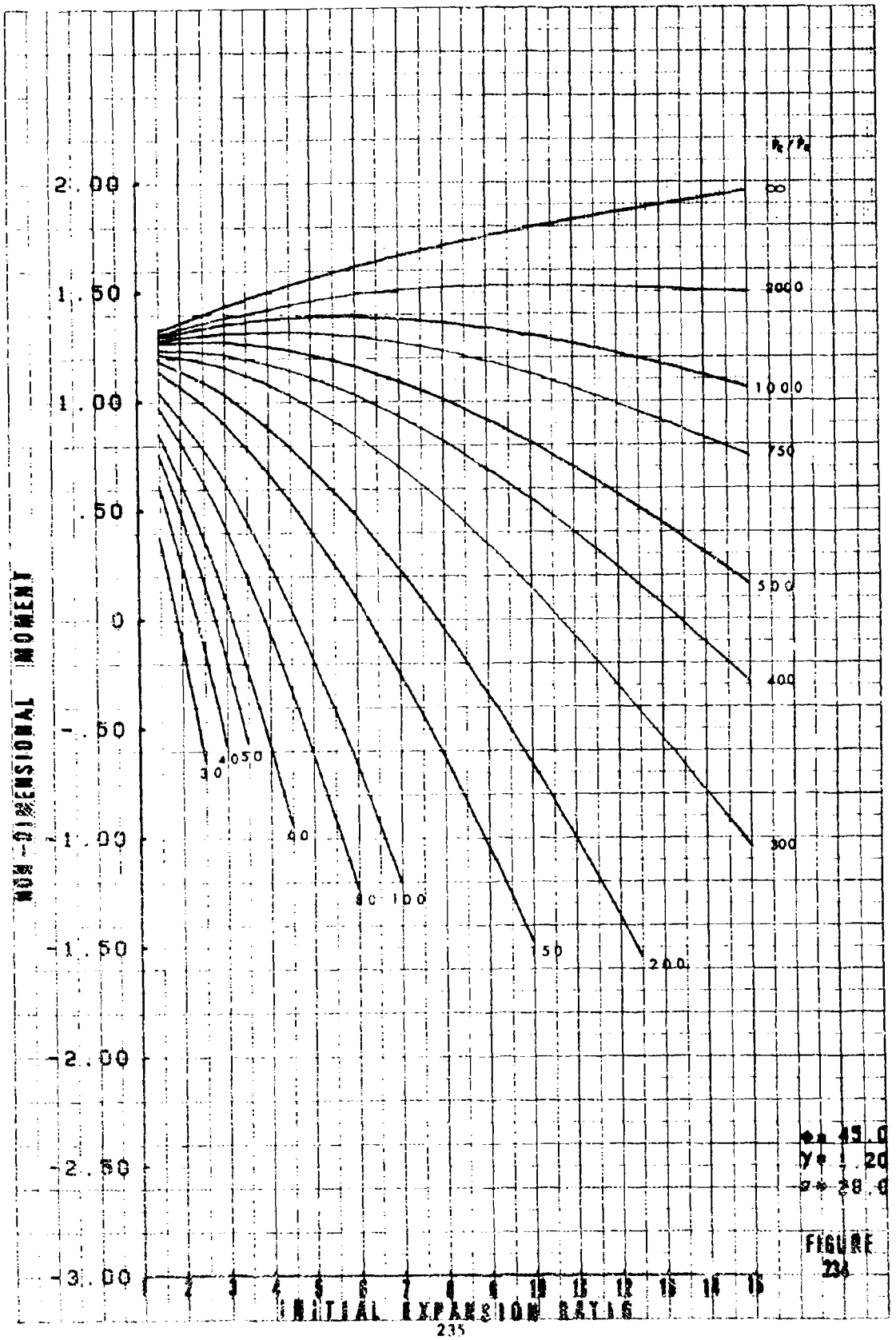

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40
30
γ = 1.20

FIGURE 234

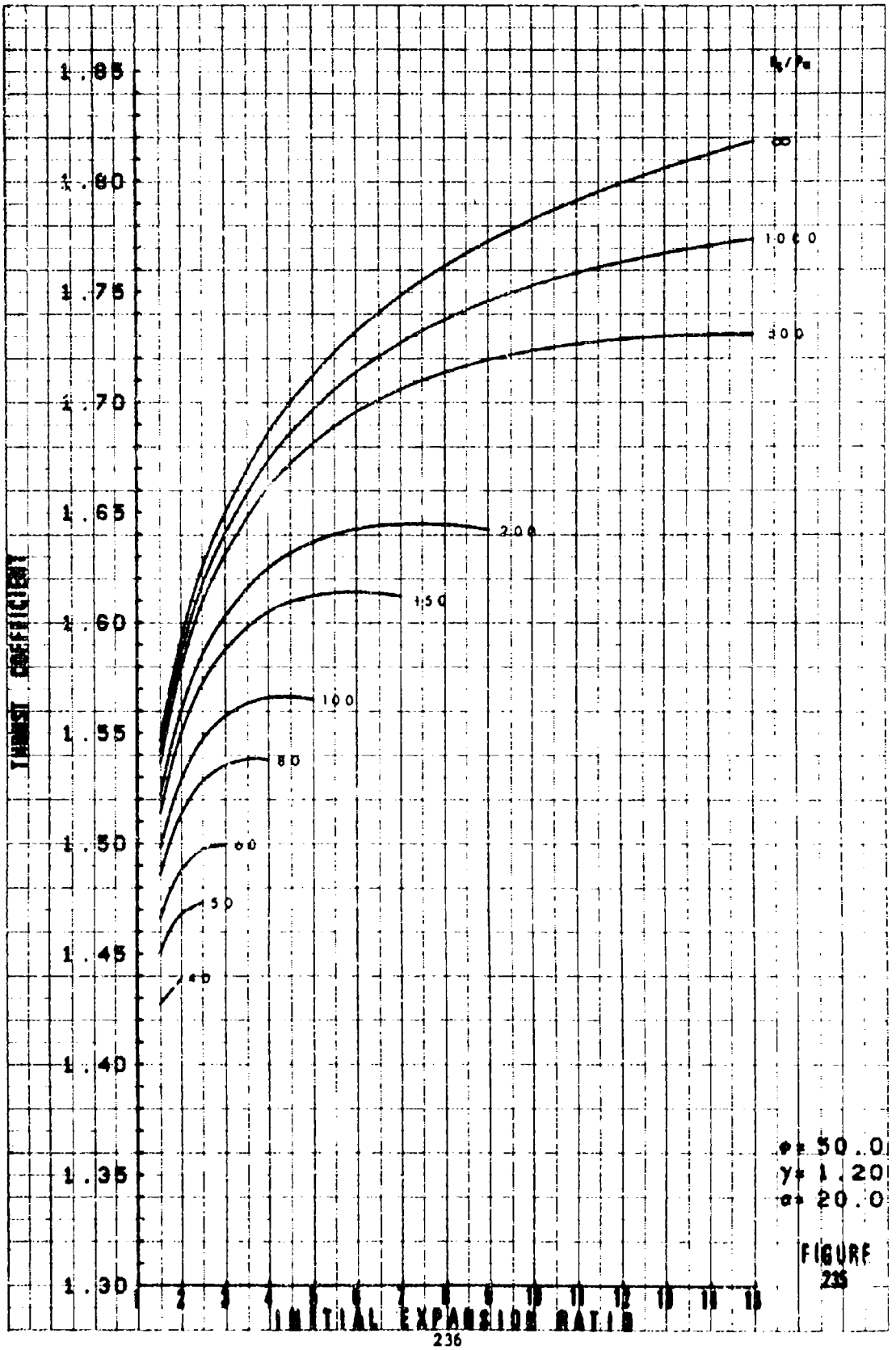

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
p_c/p_a
∞
1000
300
200
150
100
80
60
50
40
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
φ= 50.0
γ= 1.20
α= 20.0

FIGURE 235

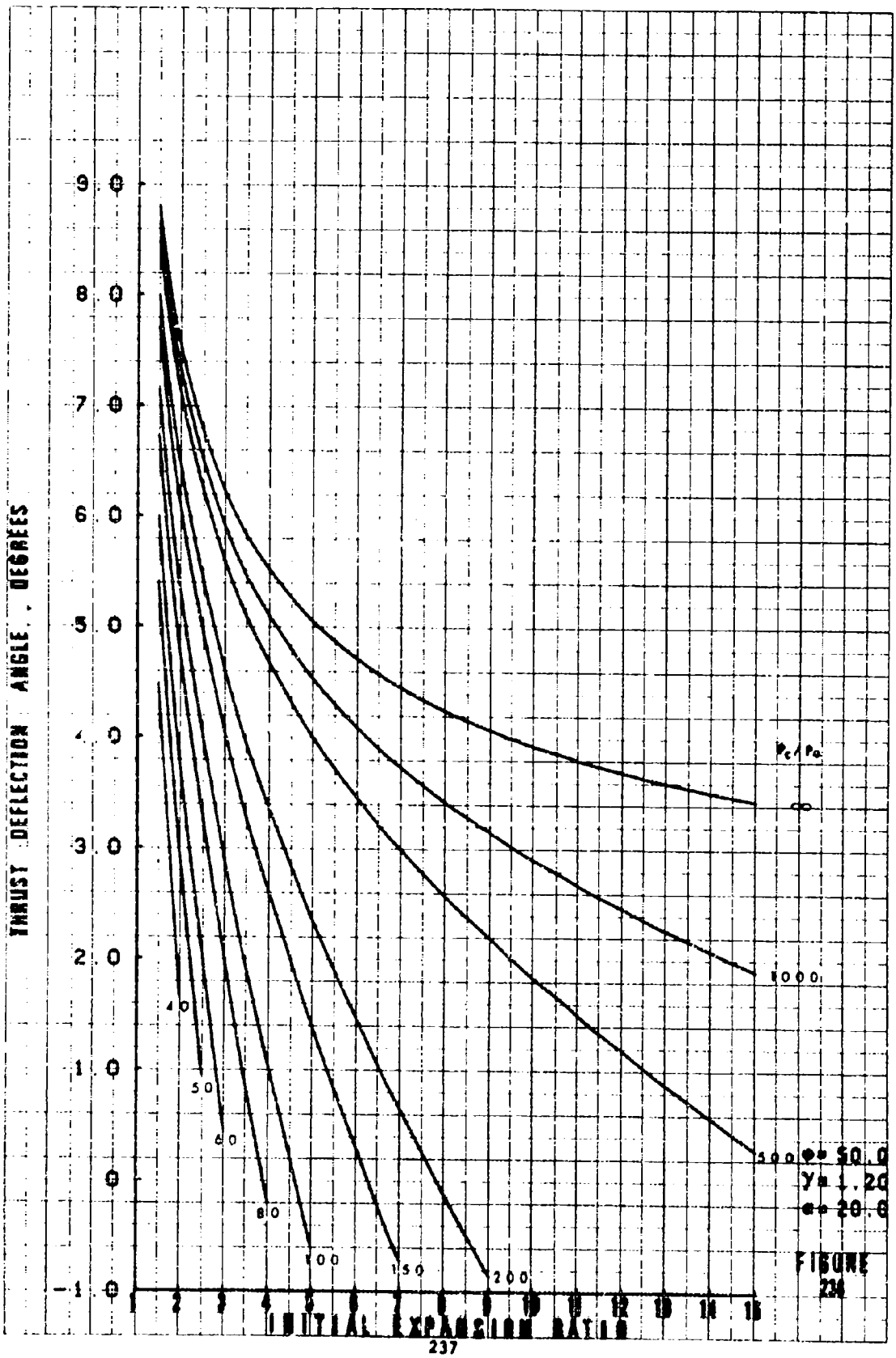

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
40
50
60
80
100
150
200
φ= 50.0
γ= 1.20
α= 20.0

FIGURE 234

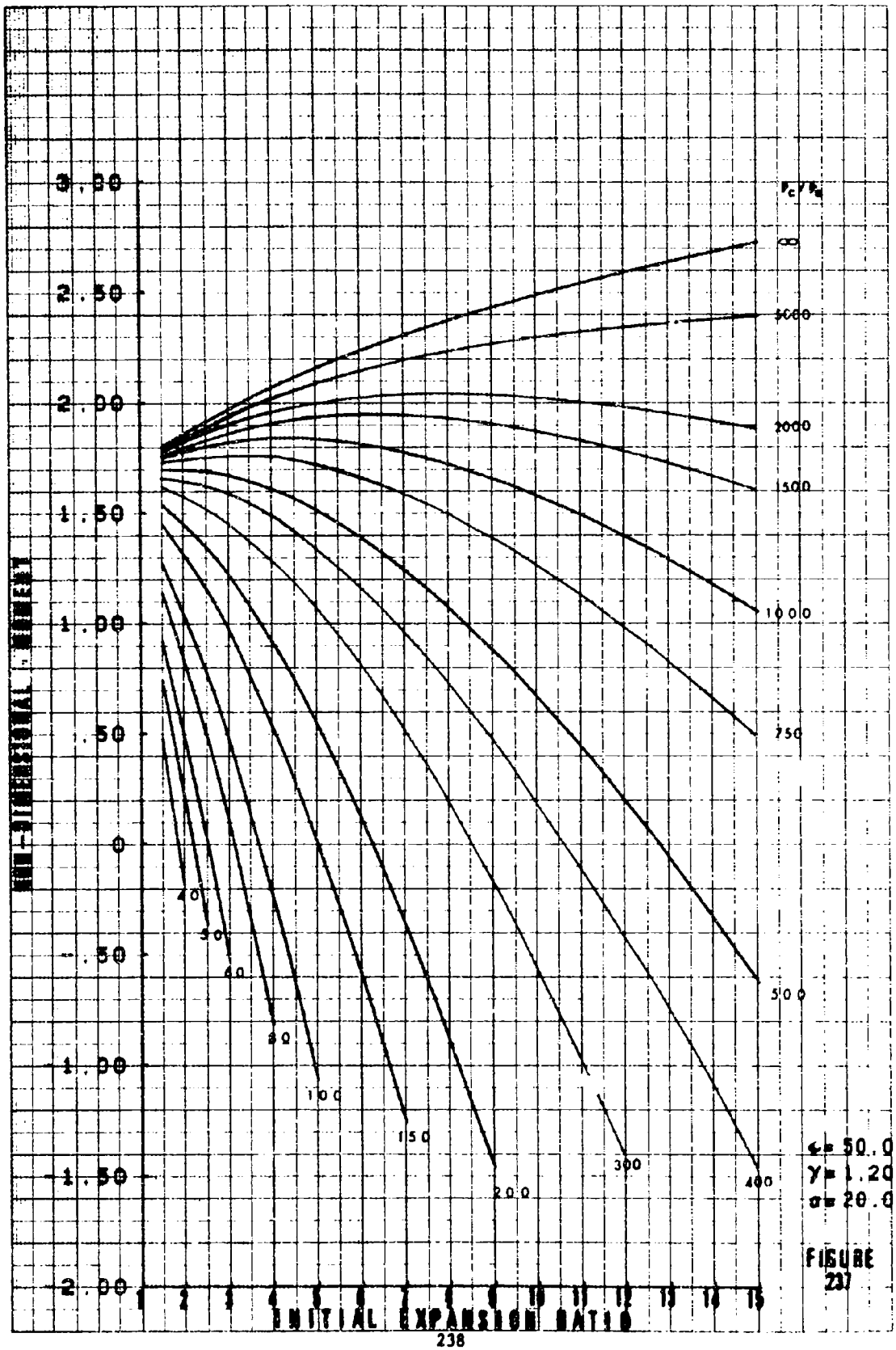

3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
5000
2000
1500
1000
750
500
400
300
200
150
100
80
60
50
40
ϵ= 50.0
γ= 1.20
α= 20.0

FIGURE 237

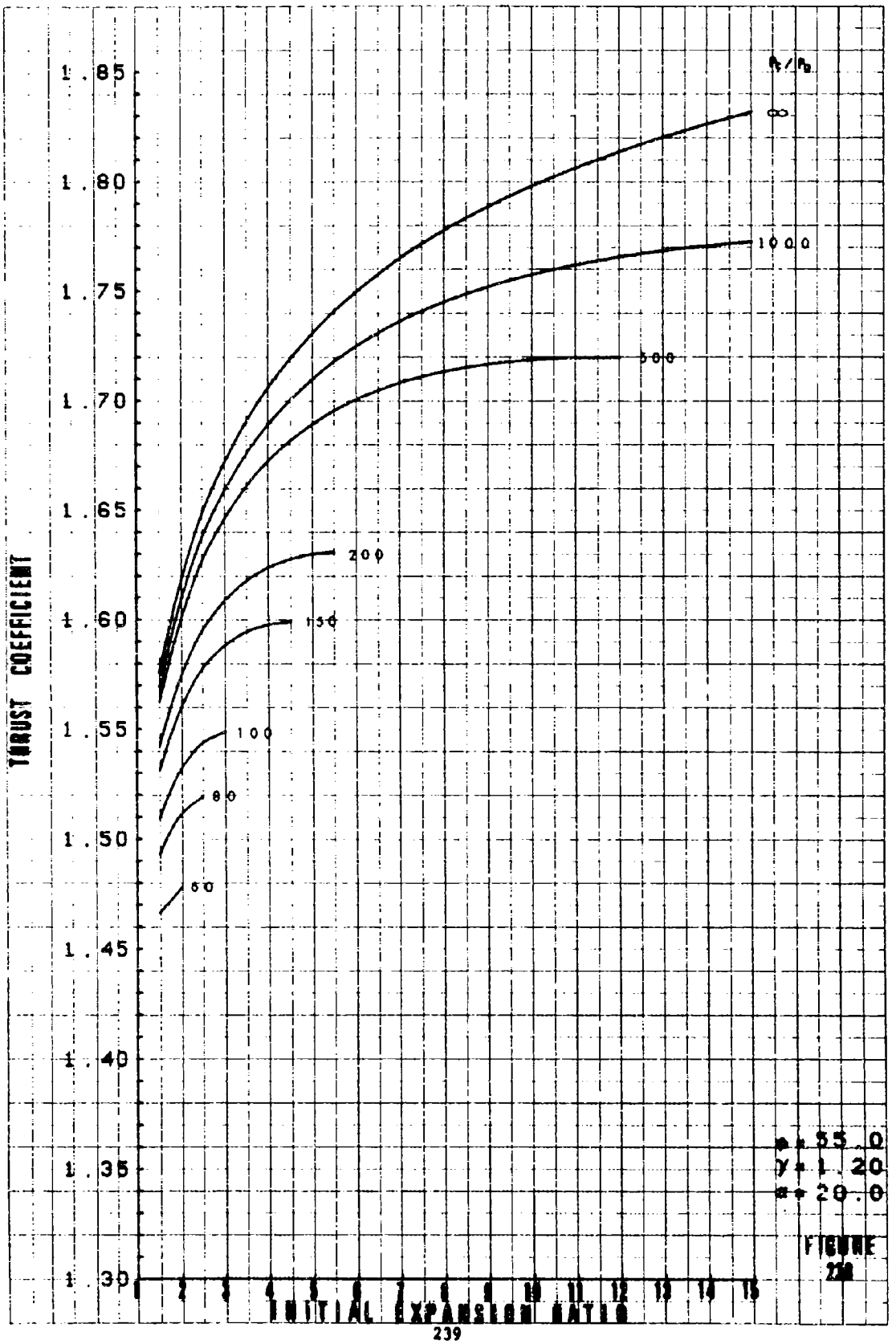
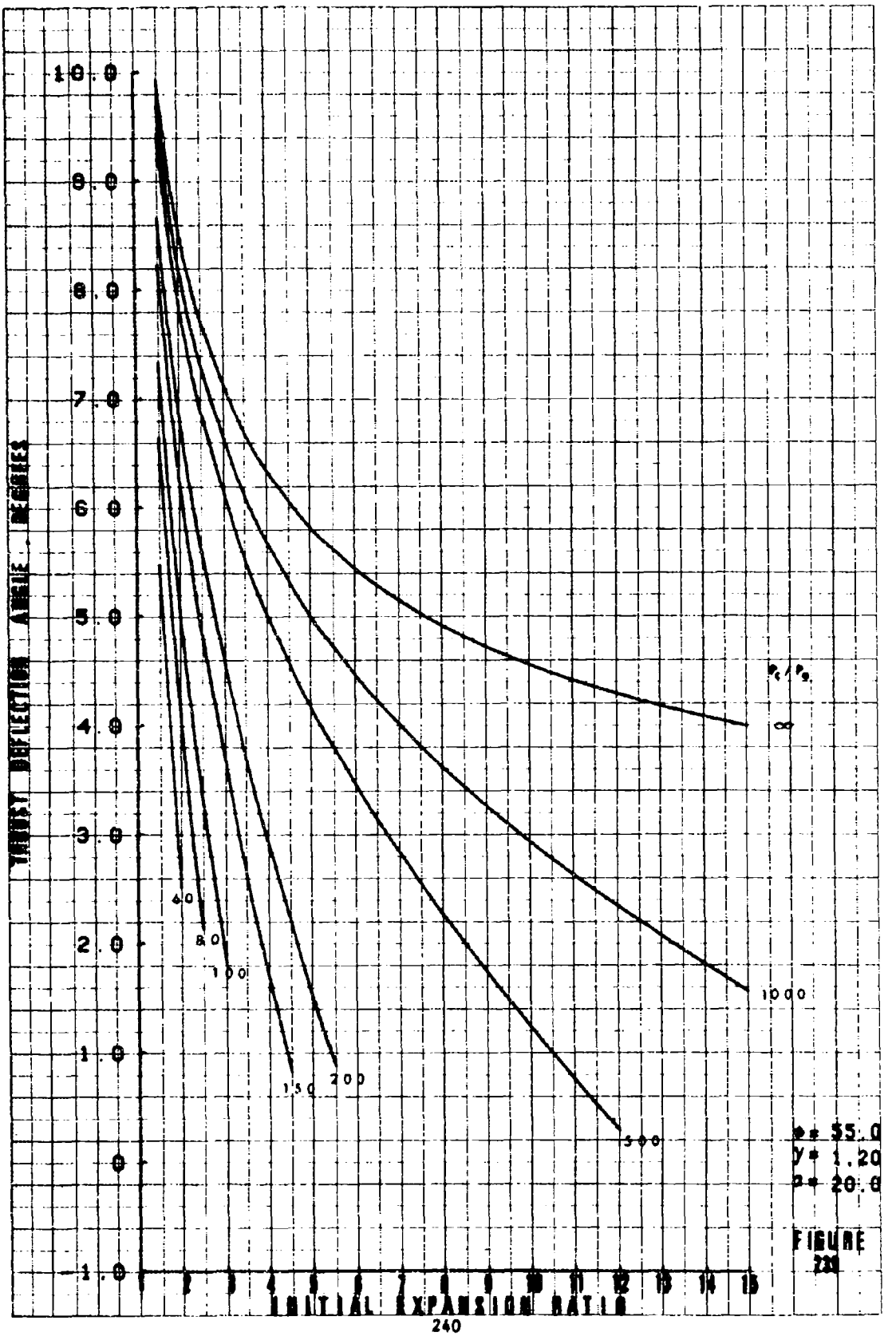

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_t/P_b
∞
1000
500
200
150
100
80
60
= 55.0
γ = 1.20
= 20.0

FIGURE 23B



10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_0
∞
1000
500
200
150
100
80
60
φ= 55.0
γ= 1.20
α= 20.0

FIGURE 231

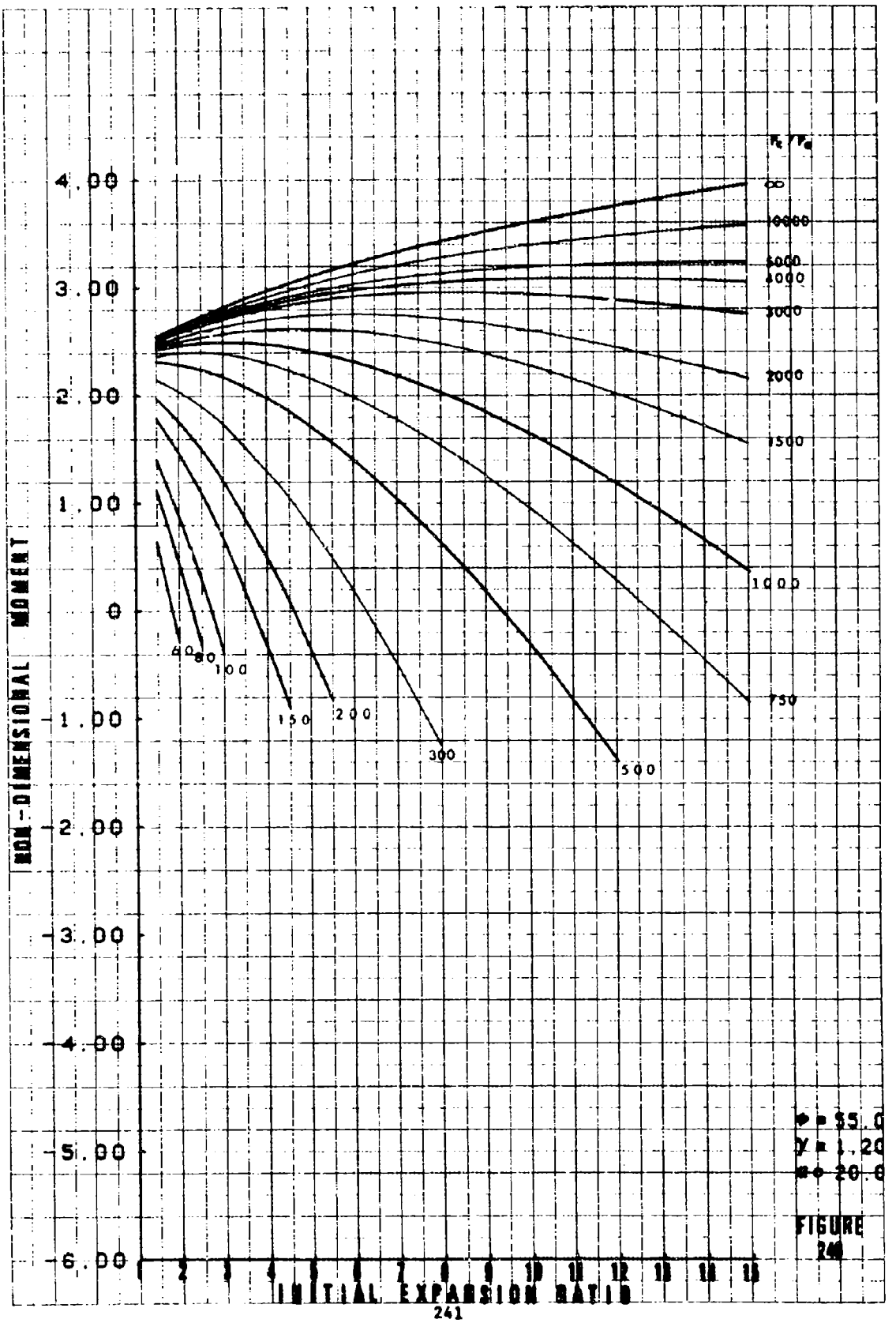

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
2
3
4
5
6
7
8
9
10
11
12
13
14
15
R_t/R_d
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
100
80
60
φ = 55.0
γ = 1.20
θ = 20.0

FIGURE 240

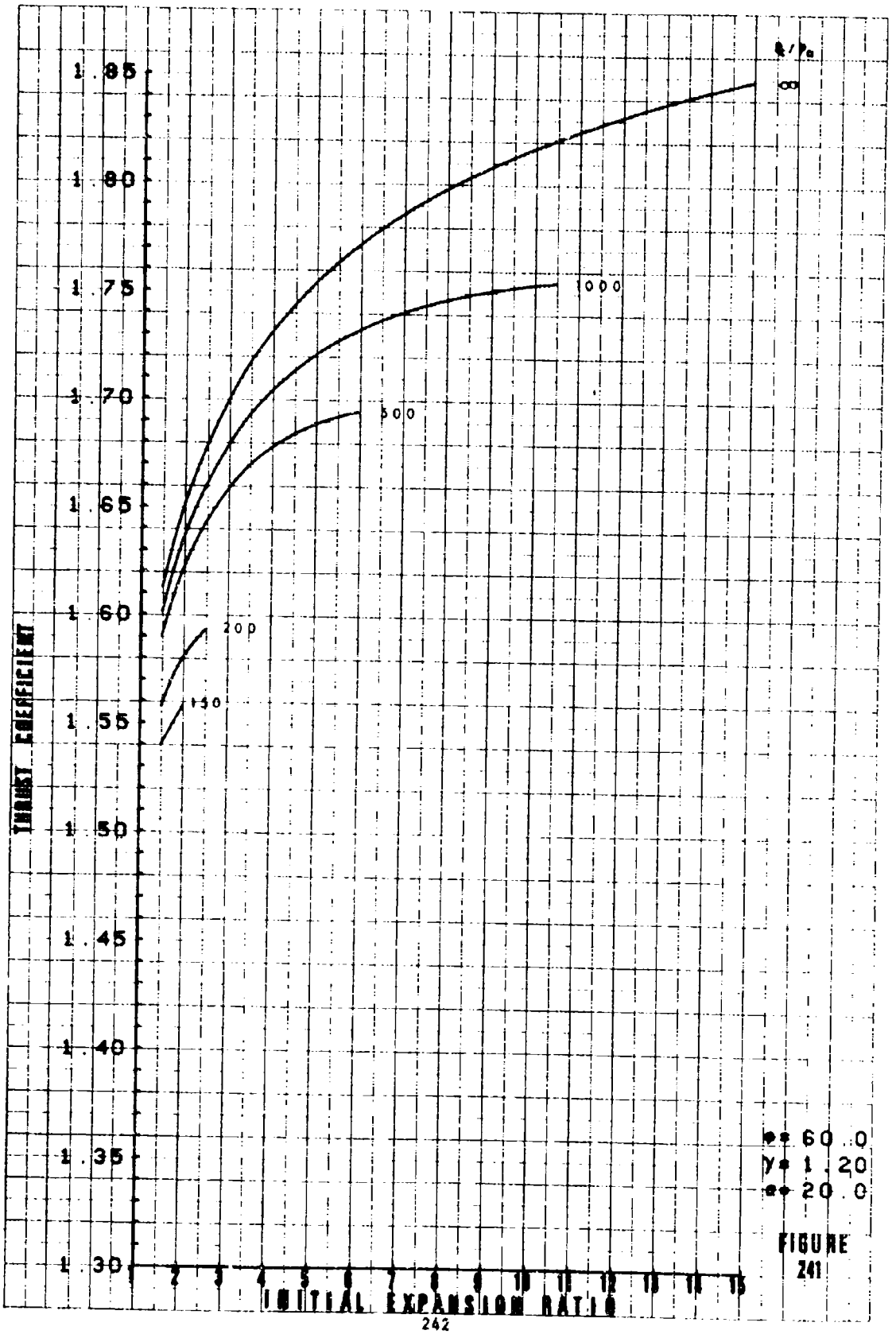

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
θ= 60.0
γ= 1.20
α= 20.0

FIGURE 241

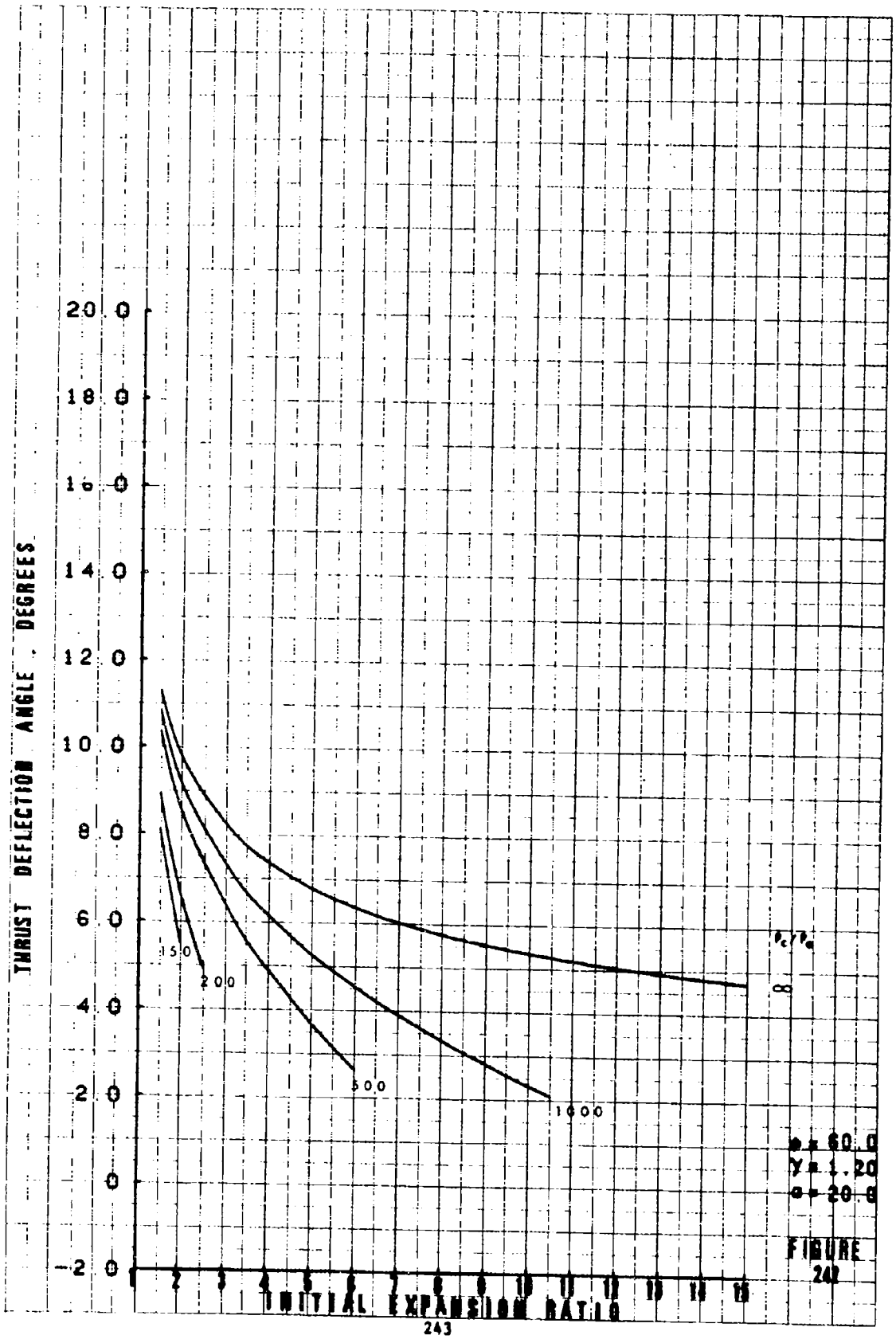

THRUST DEFLECTION ANGLE , DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
150
200
500
1000
∞
P_c/P_a
φ = 60.0
γ = 1.20
α = 20.0

FIGURE 242

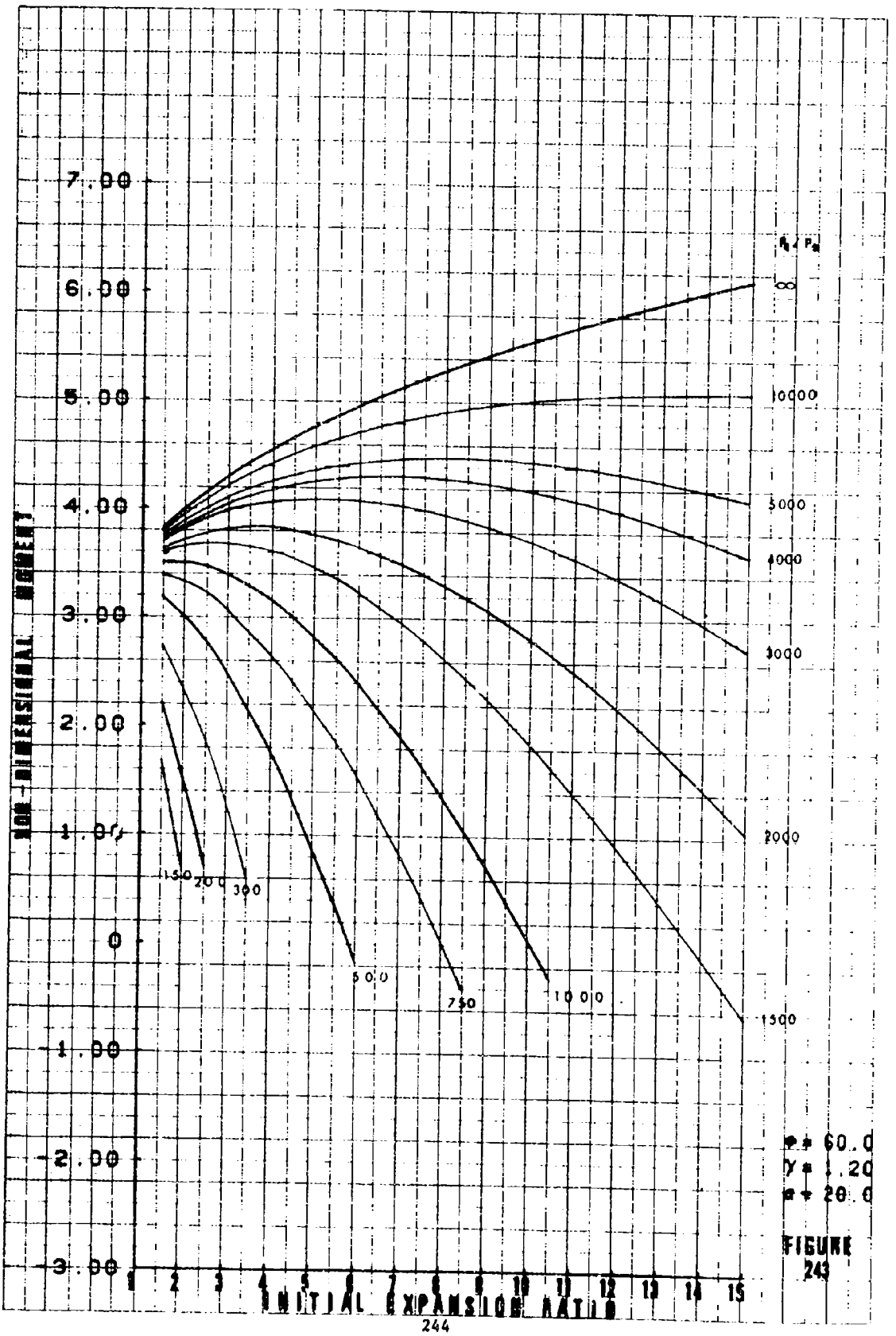

7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
10000
5000
4000
3000
2000
1500
150
200
300
500
750
1000
γ = 1.20
α = 20.0

FIGURE 243

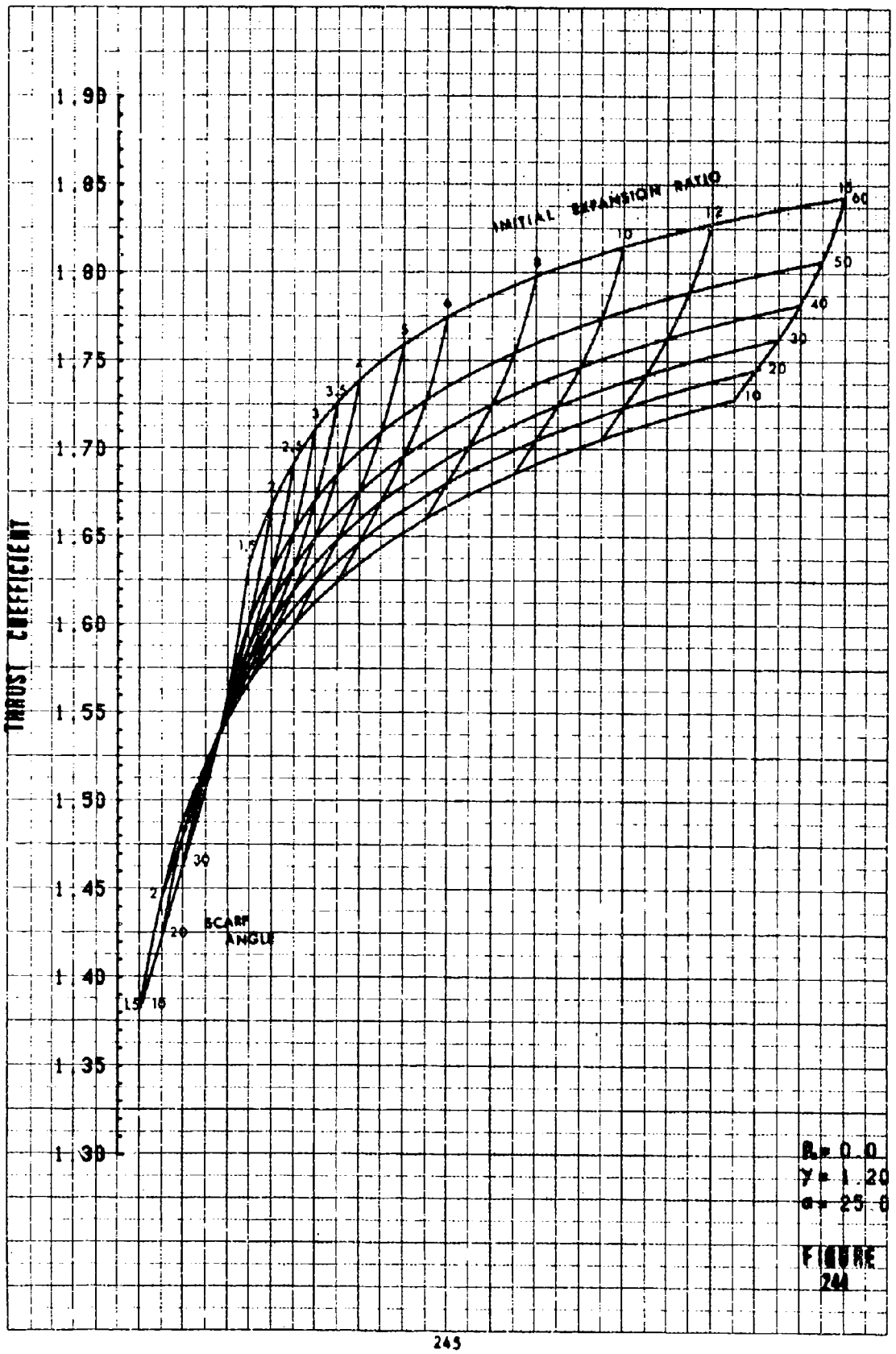

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
B = 0.0
γ = 1.20
α = 25.0

FIGURE 244

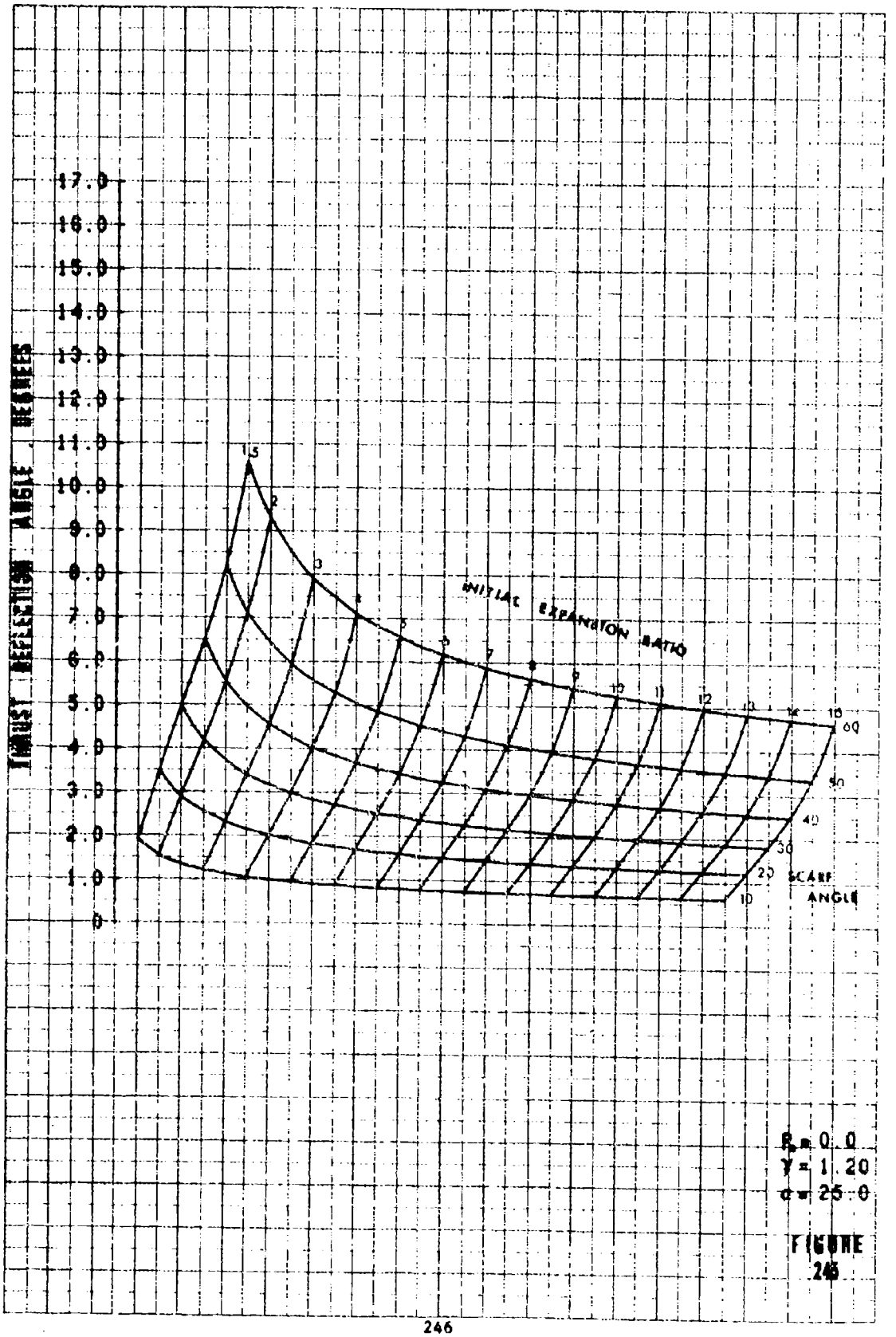

THRUST DEFLECTION ANGLE DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE
$P_b = 0.0$
$\gamma = 1.20$
$\alpha = 25.0$

FIGURE 246

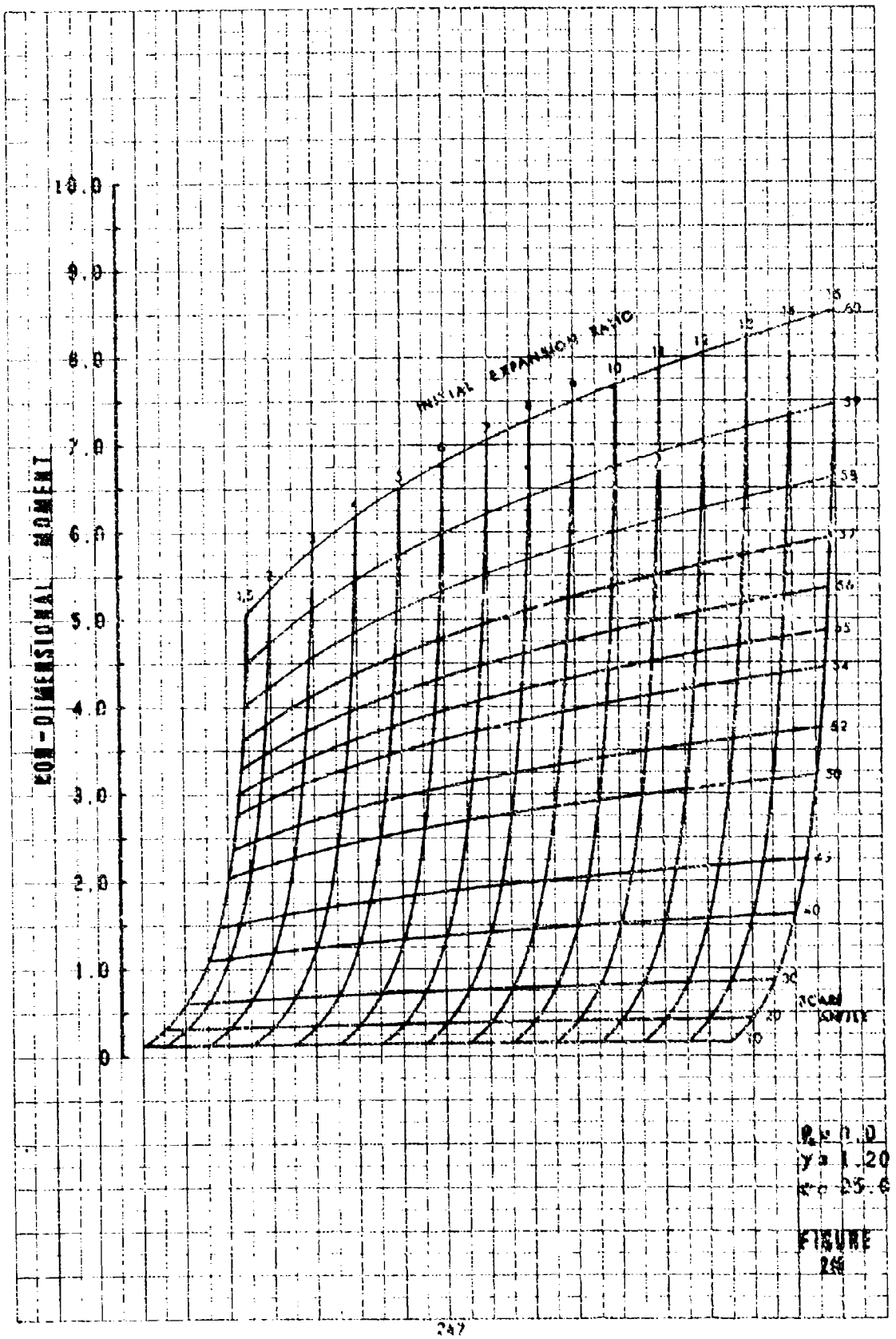

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCALE
ANGLE
P_o = 0.0
γ = 1.20
κ = 25.6

FIGURE 26

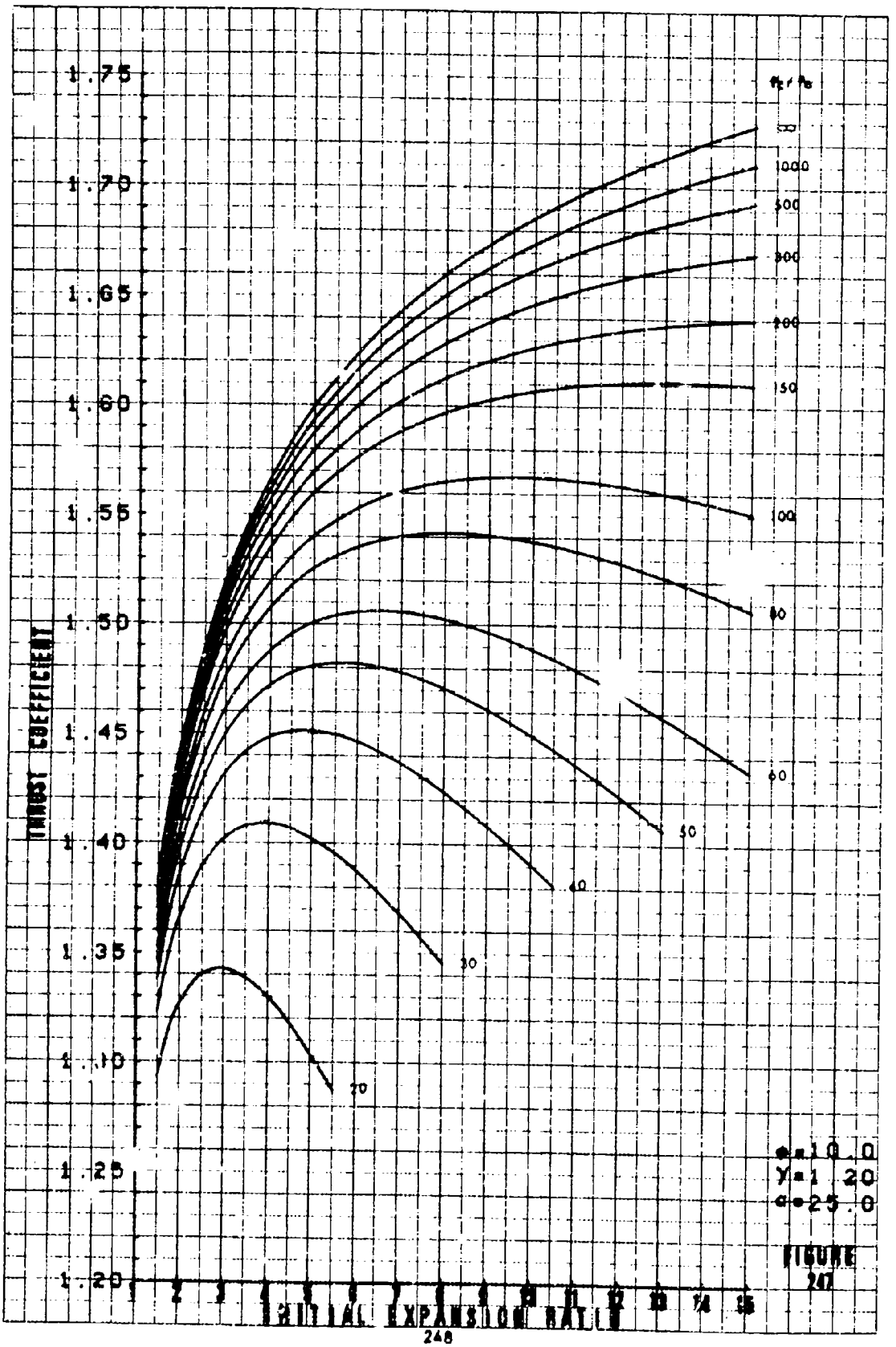

THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
γ=1.20
α=25.0

FIGURE 247

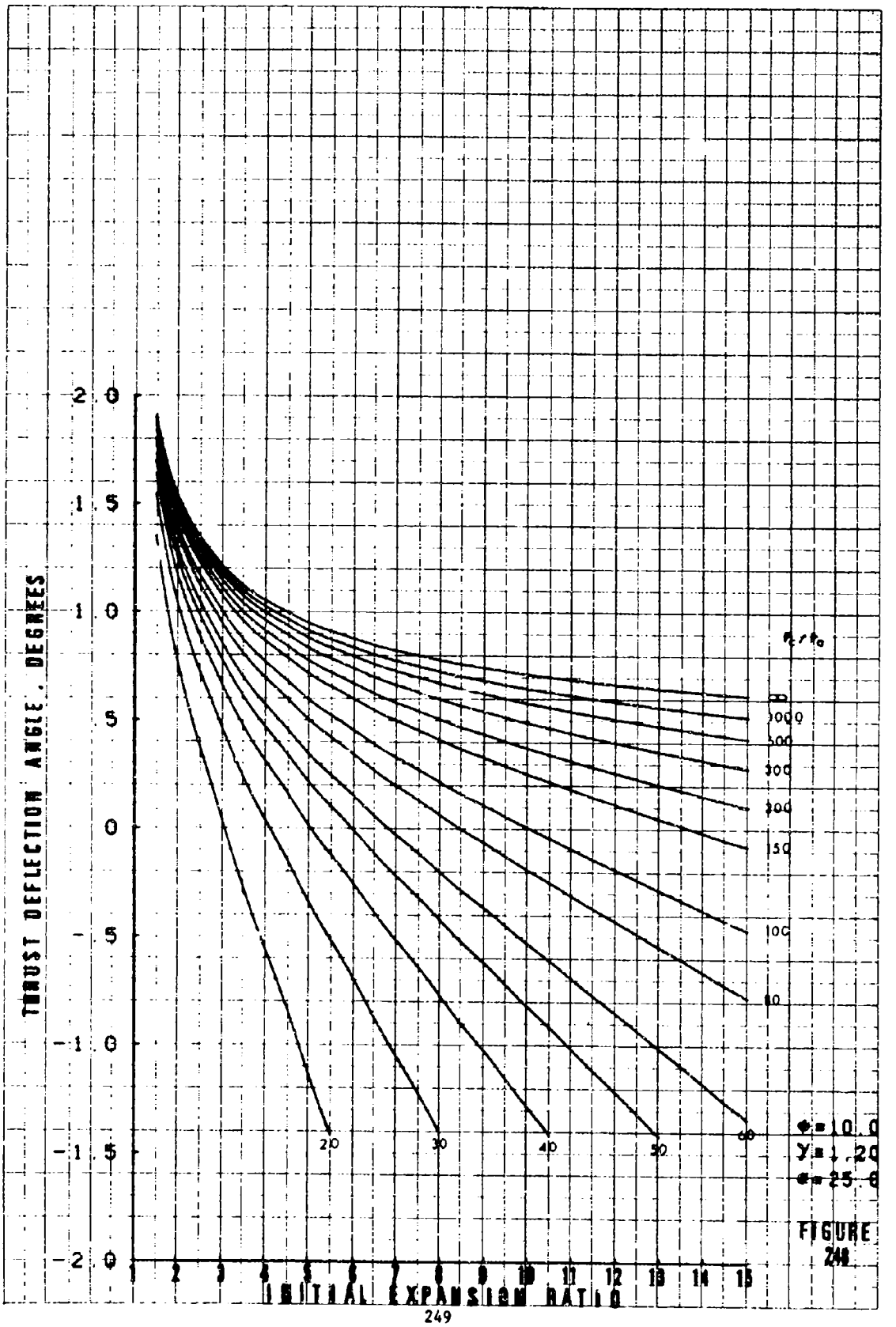
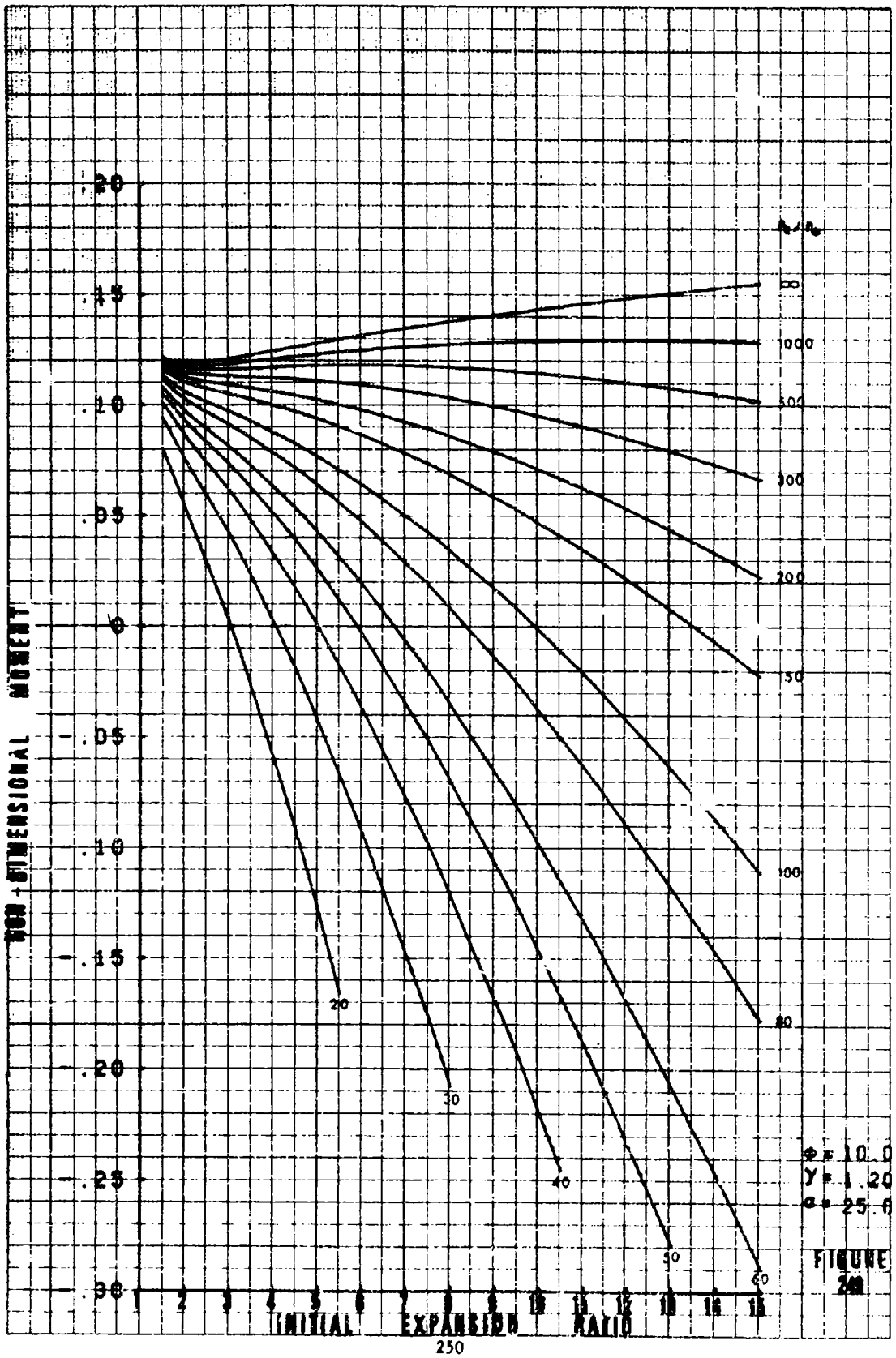
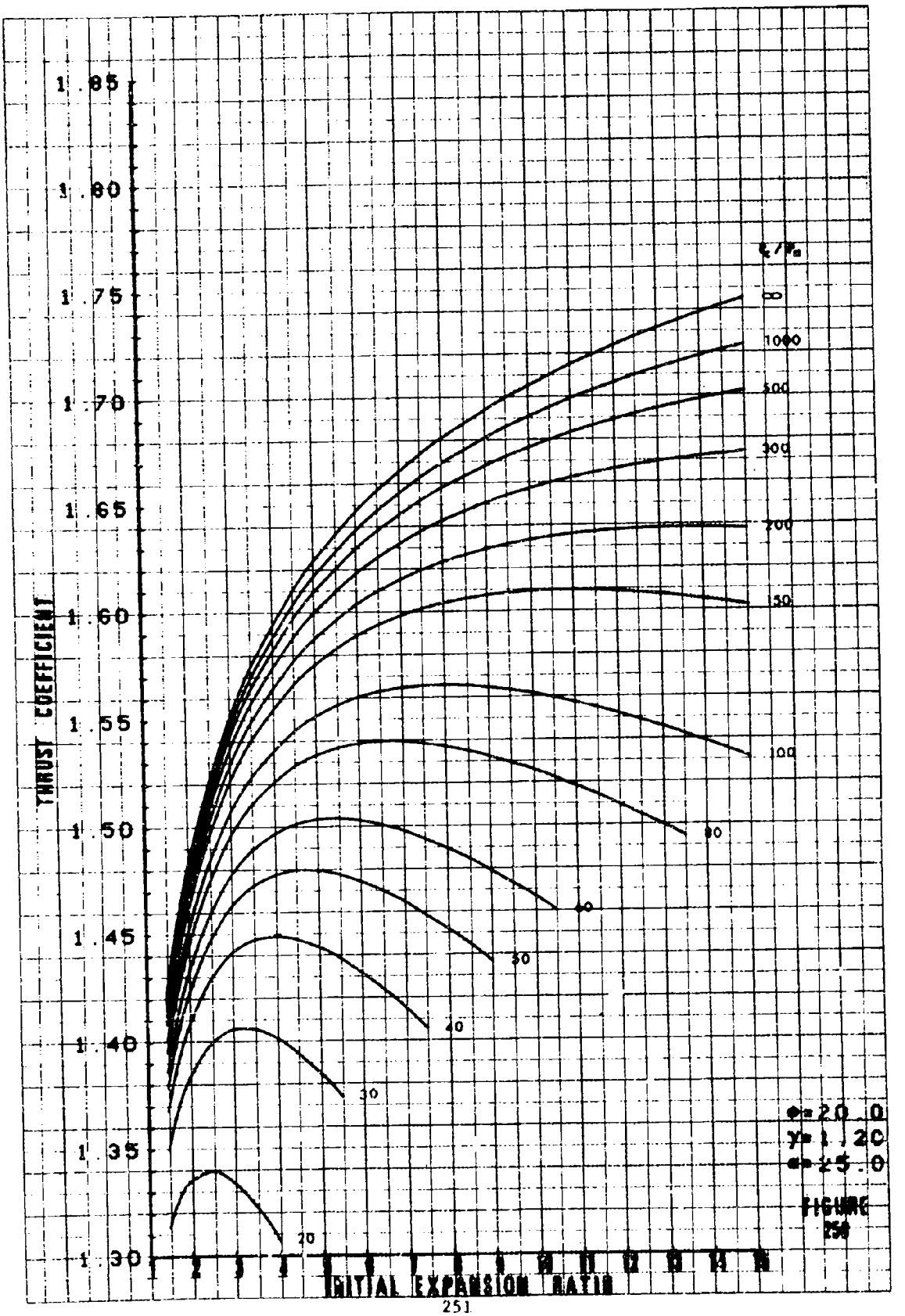

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
300
500
1000
φ = 10.0
γ = 1.20
α = 25.0

FIGURE 248



NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ = 10.0
γ = 1.20
α = 25.0

FIGURE 249



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.20
α=25.0

FIGURE 250

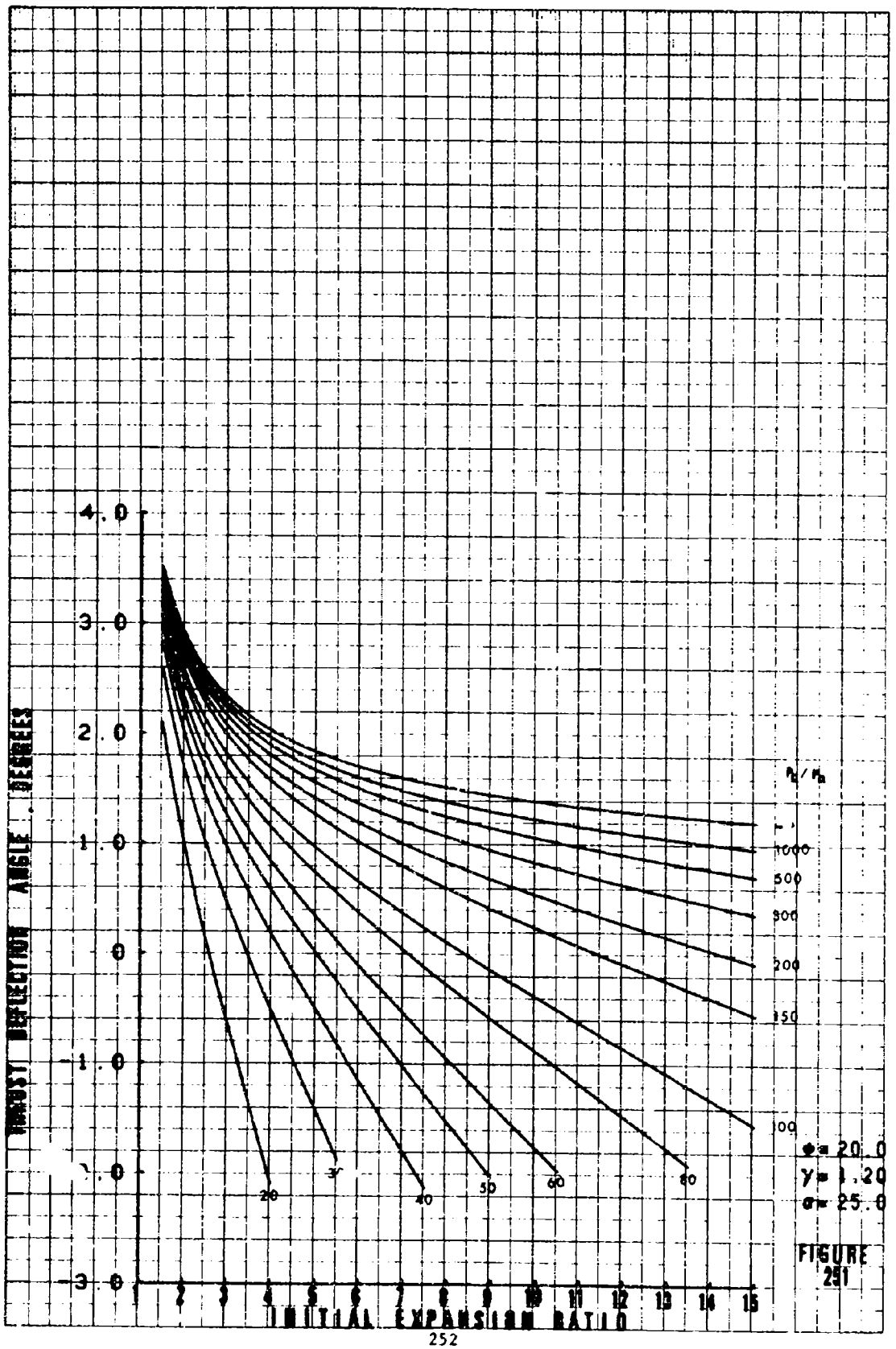
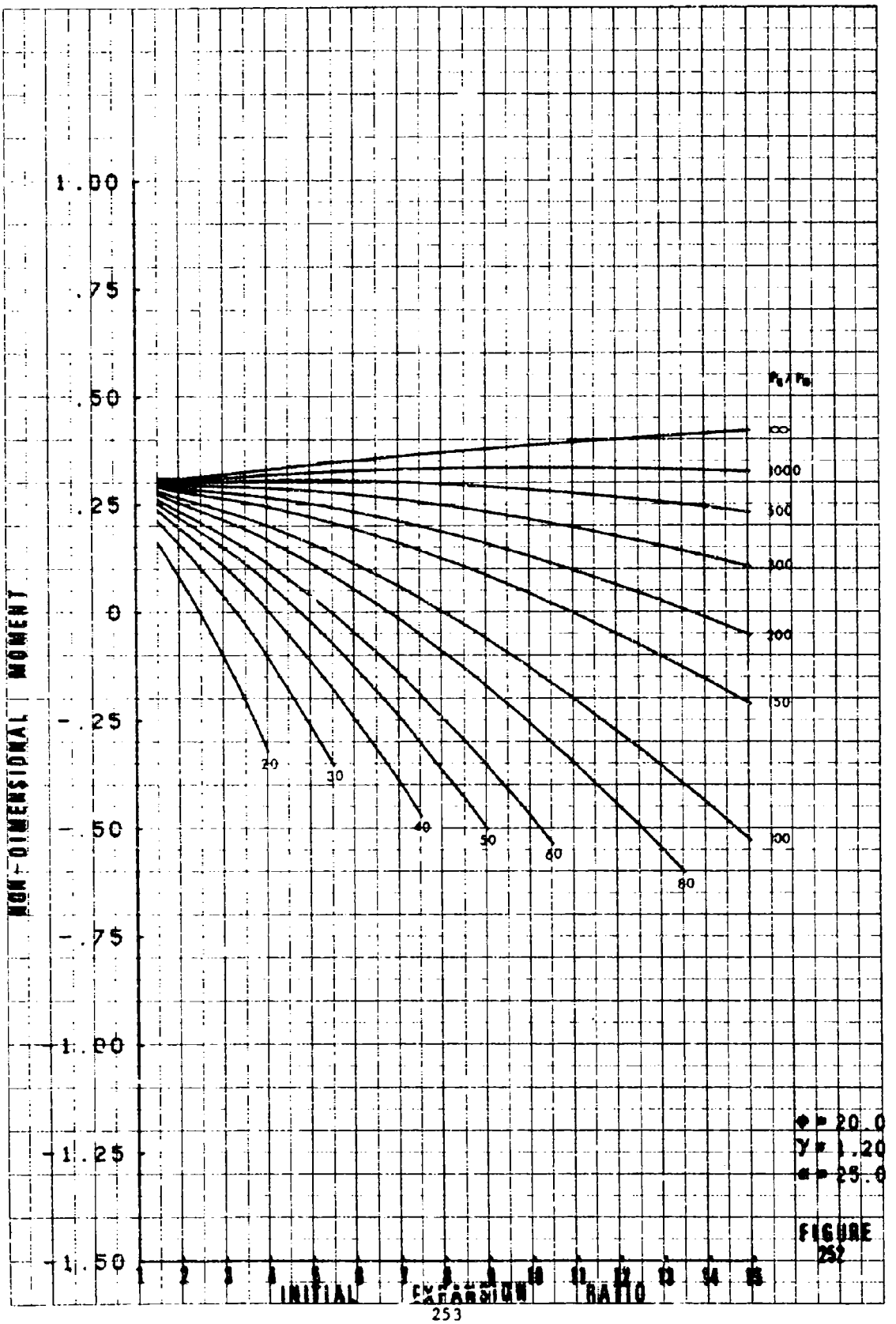

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.20
α = 25.0

FIGURE 251



NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_a/P_m
∞
1000
500
300
200
150
100
20
30
40
50
60
80
φ = 20.0
γ = 1.20
α = 25.0

FIGURE 252

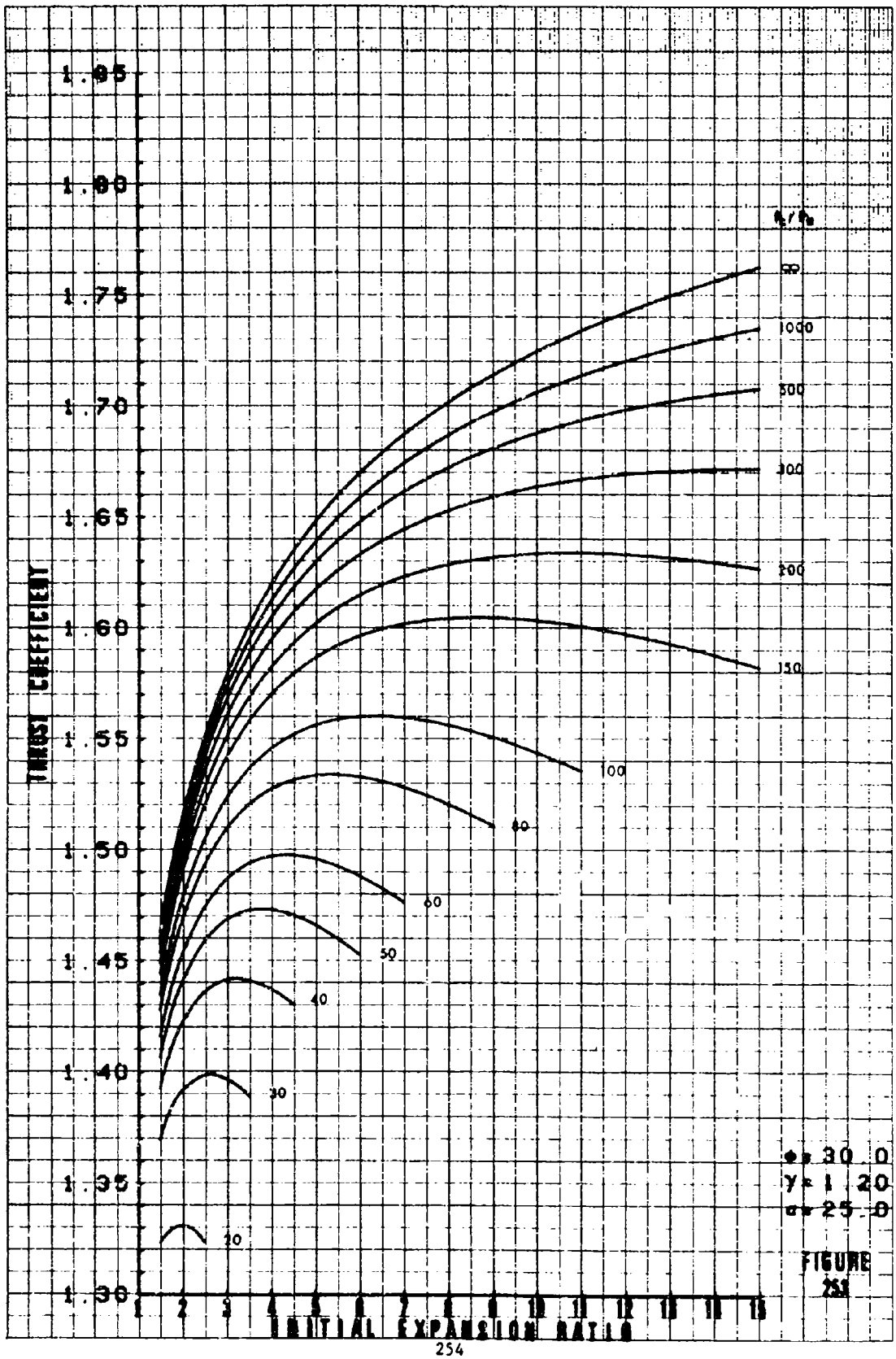

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.95
1.90
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
10
φ = 30.0
γ = 1.20
α = 25.0

FIGURE 251

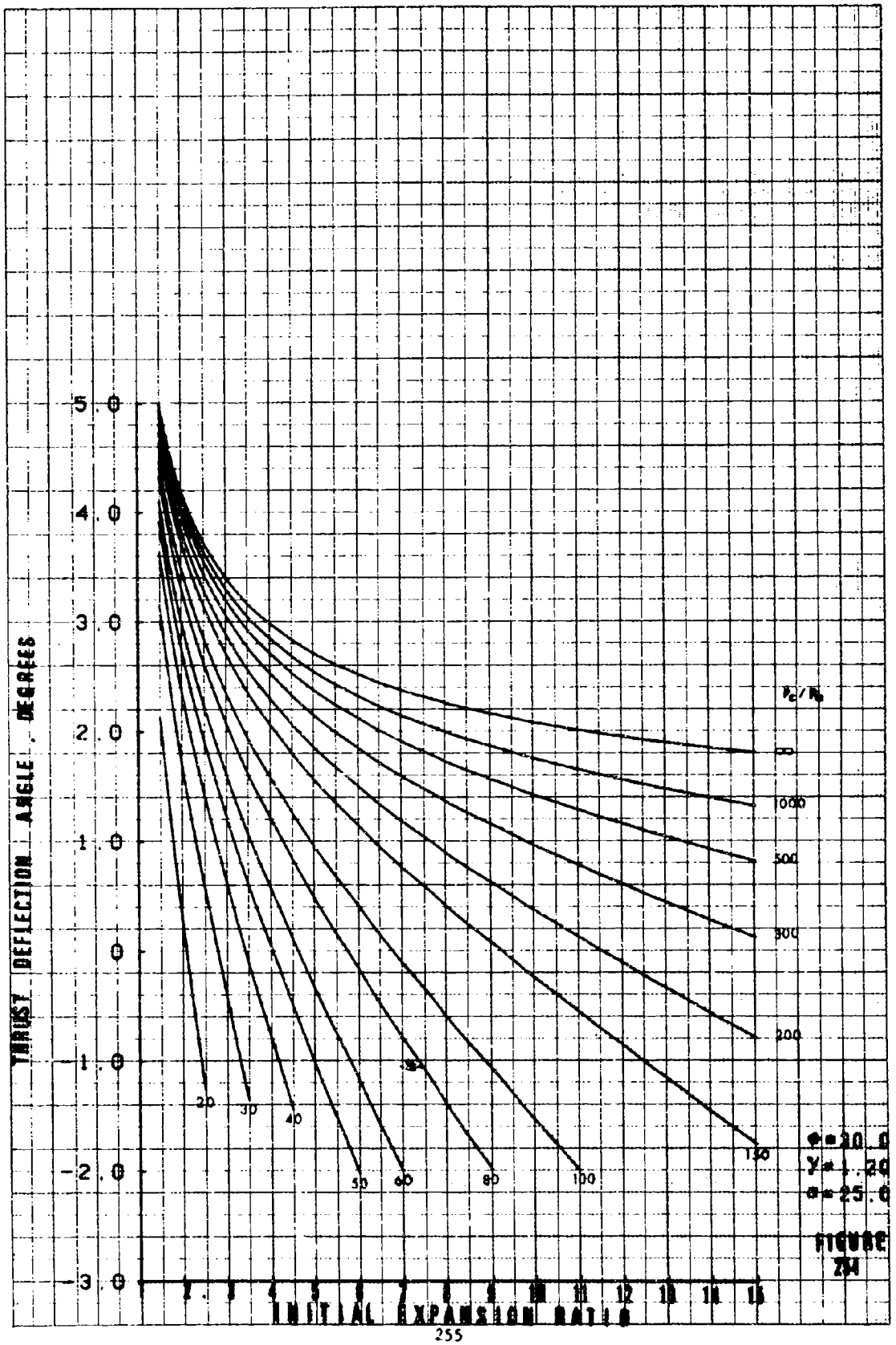
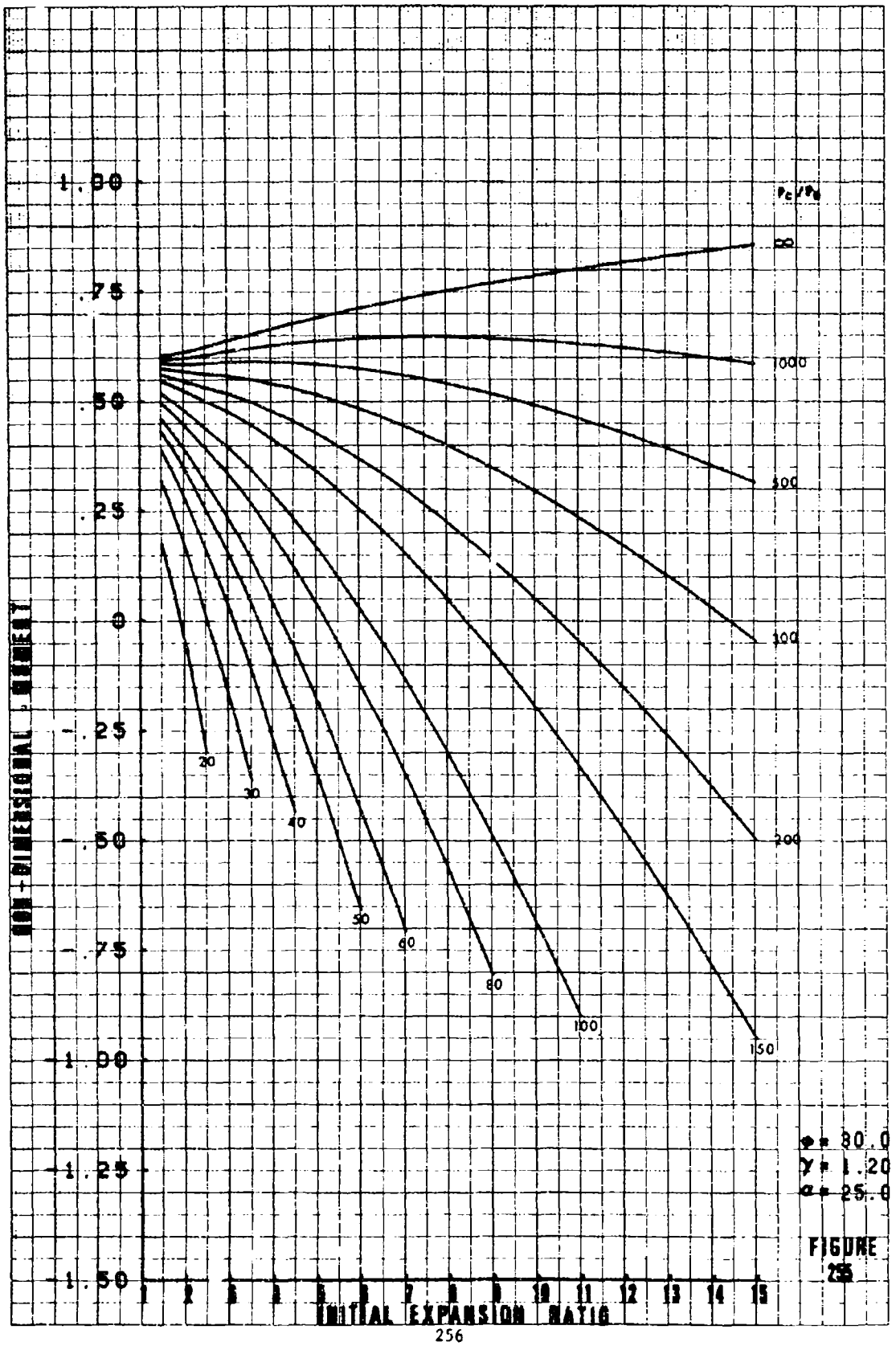
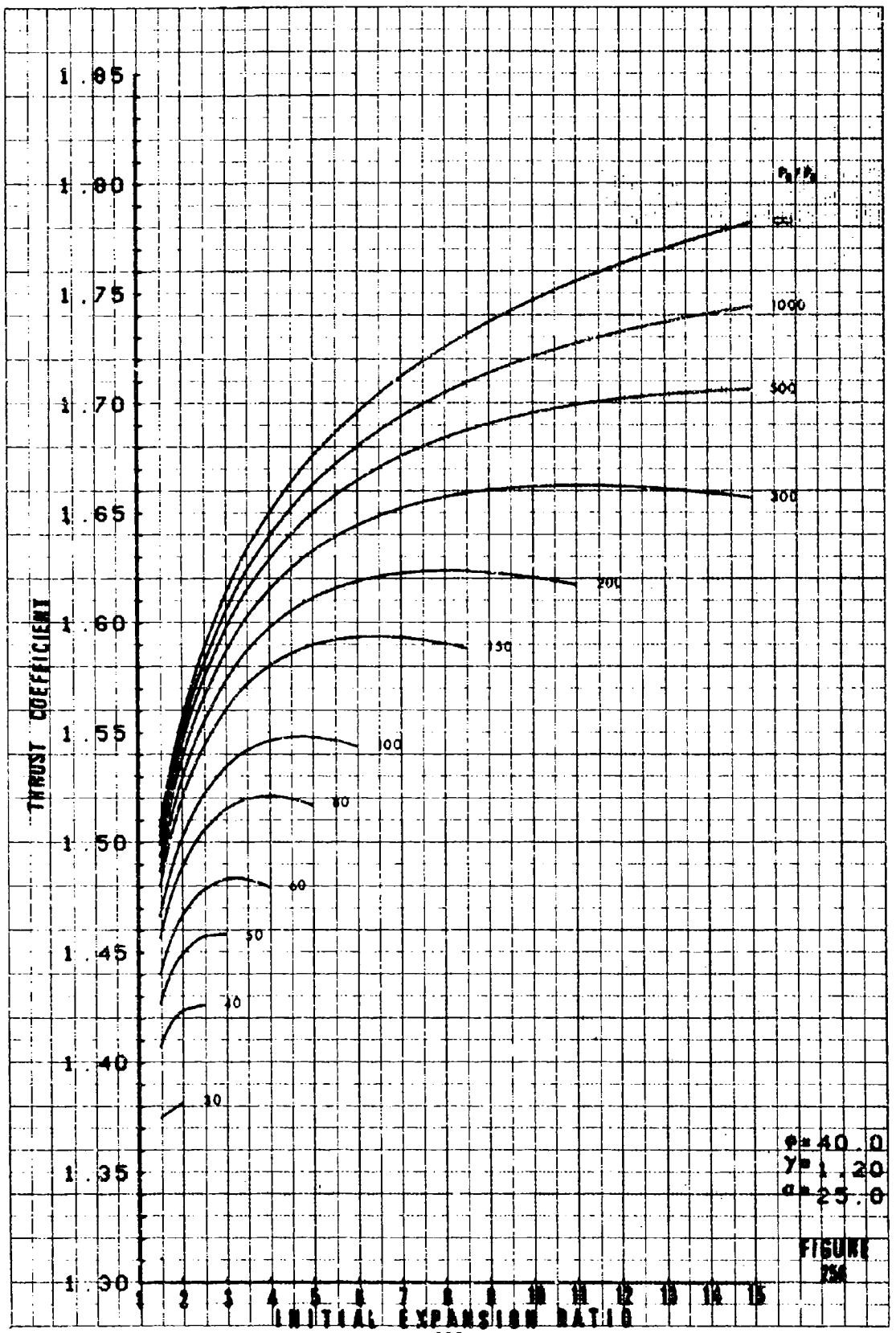

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
P_c/P_b
1000
500
300
200
150
100
80
60
50
40
30
20
φ=30.0
γ=1.20
θ=25.0

FIGURE 234



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
P_c/P_0
∞
1000
500
100
200
150
100
80
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
φ = 30.0
γ = 1.20
α = 25.0

FIGURE 255



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
300
200
150
100
80
60
50
40
30
φ=40.0
γ=1.20
α=25.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 256

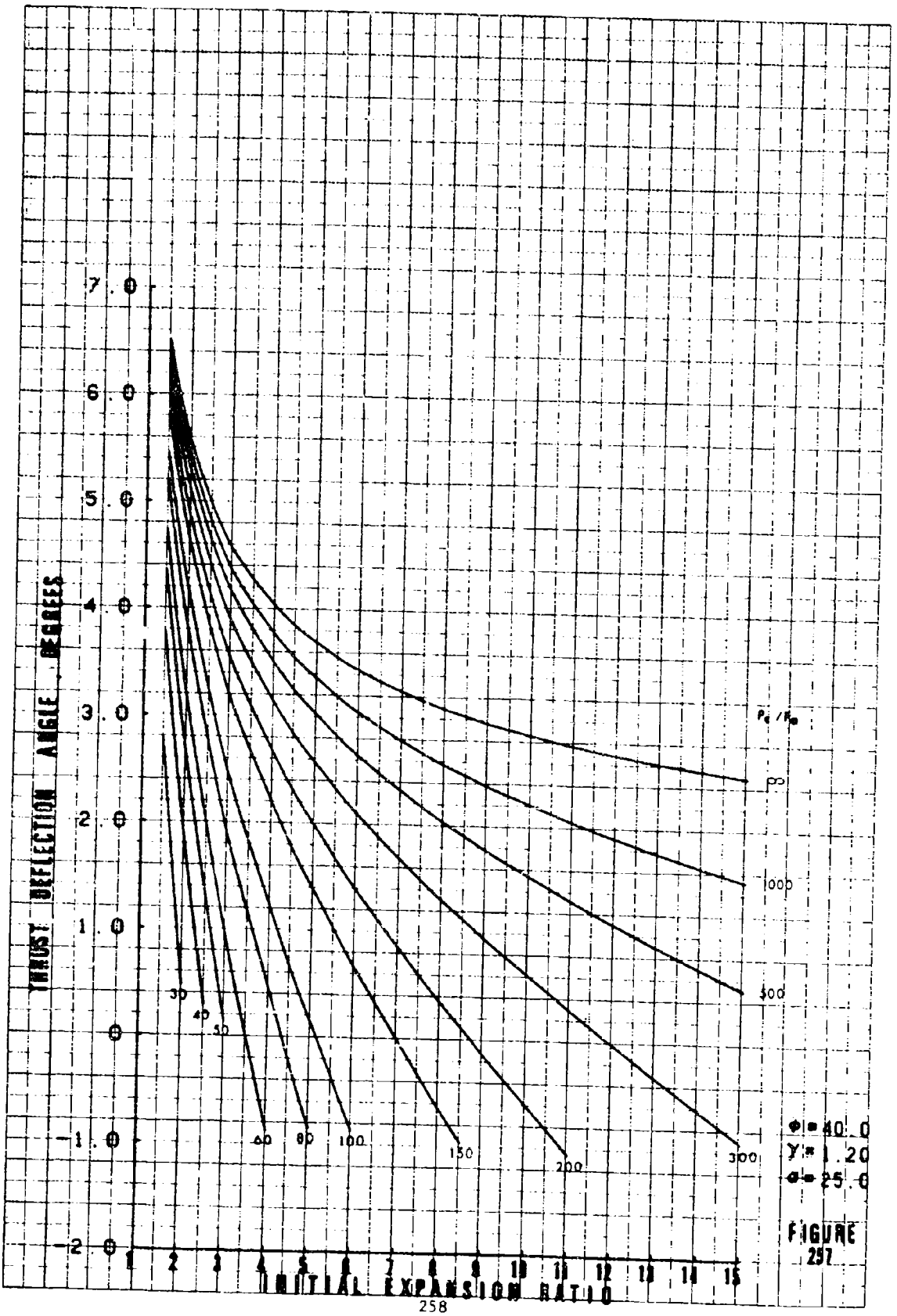

THRUST DEFLECTION ANGLE DEGREES
INITIAL EXPANSION RATIO
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
300
500
1000
∞
P_e/P_a
ϕ = 40.0
γ = 1.20
σ = 25.0

FIGURE 257

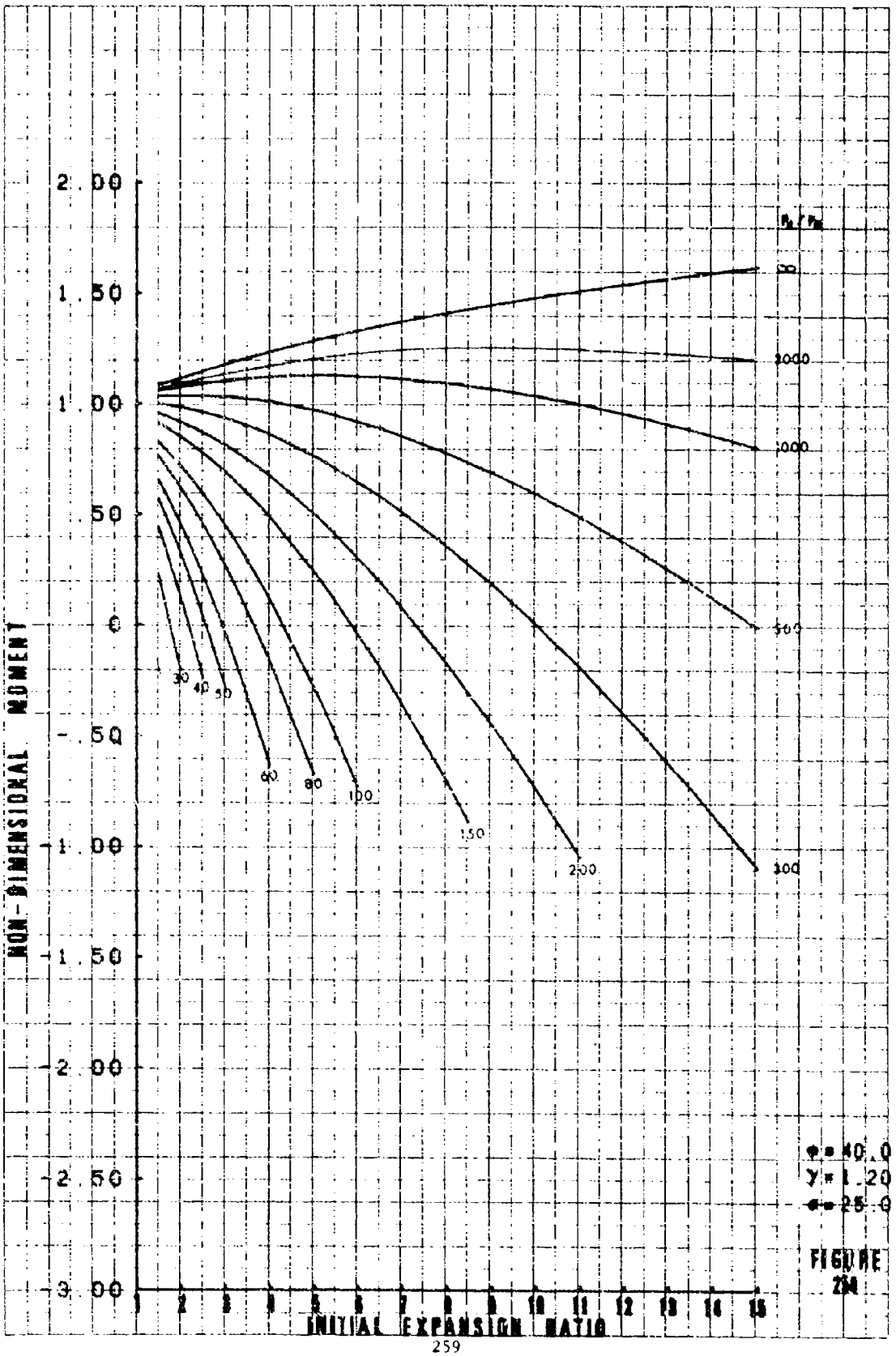

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
R_2/R_1
∞
2000
1000
500
300
30
40
50
60
80
100
150
200
φ = 40.0
γ = 1.20
α = 25.0

FIGURE 234

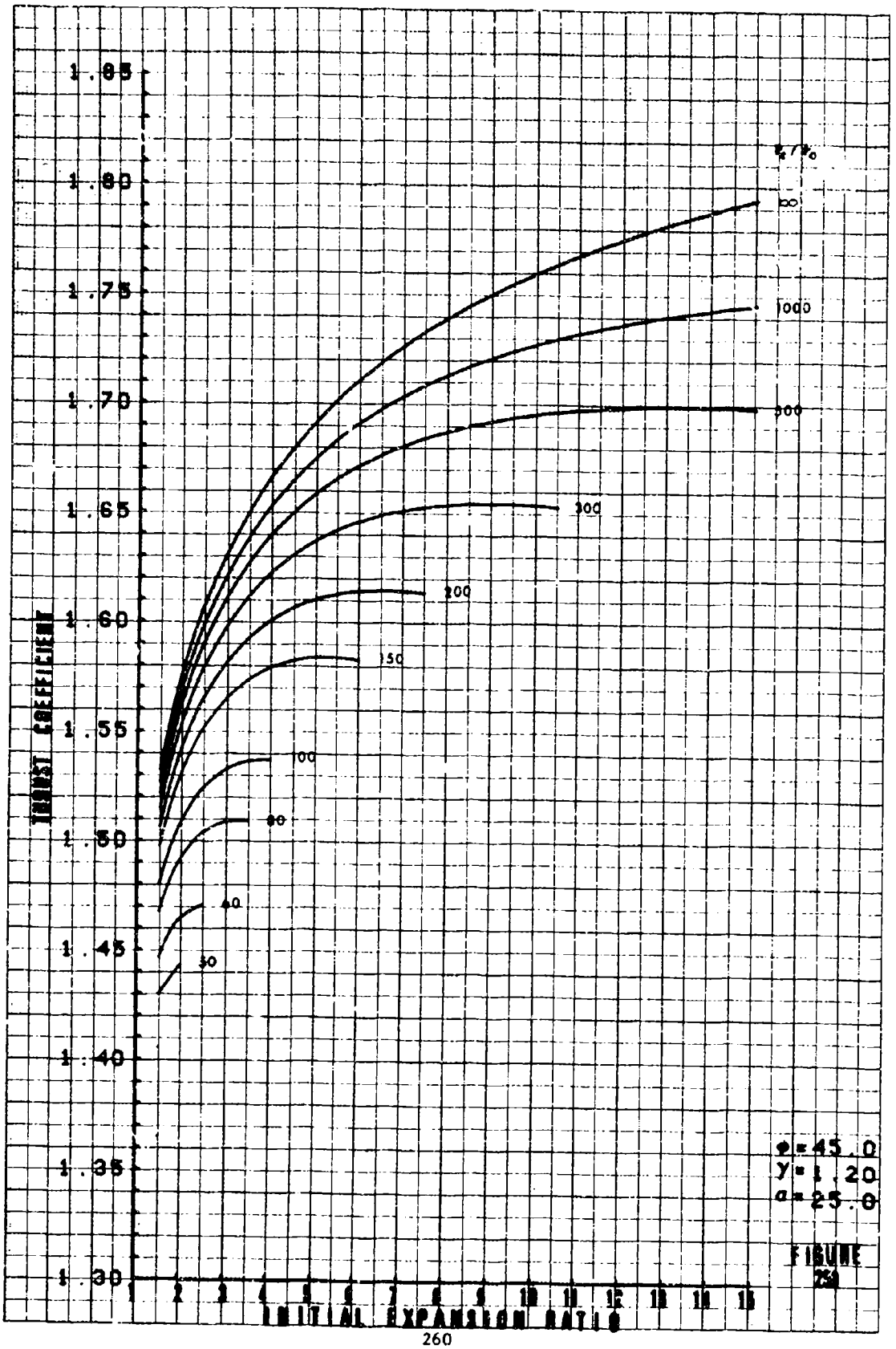
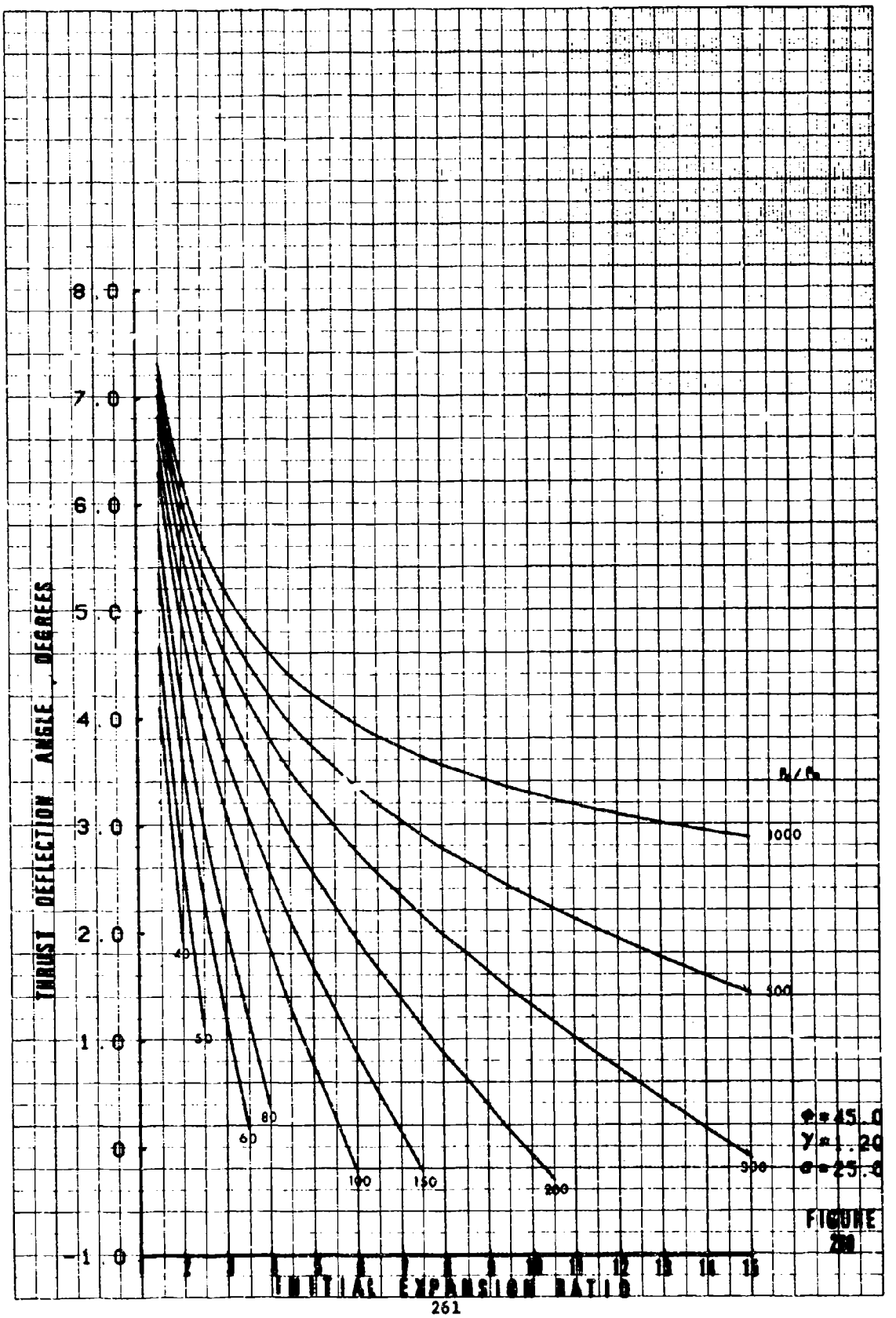

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_c/p_0
∞
1000
500
300
200
150
100
80
40
30
φ = 45.0
γ = 1.20
α = 25.0

FIGURE 26



THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80
60
50
40
φ = 45.0
γ = 1.20
σ = 25.0

FIGURE 2[illegible]

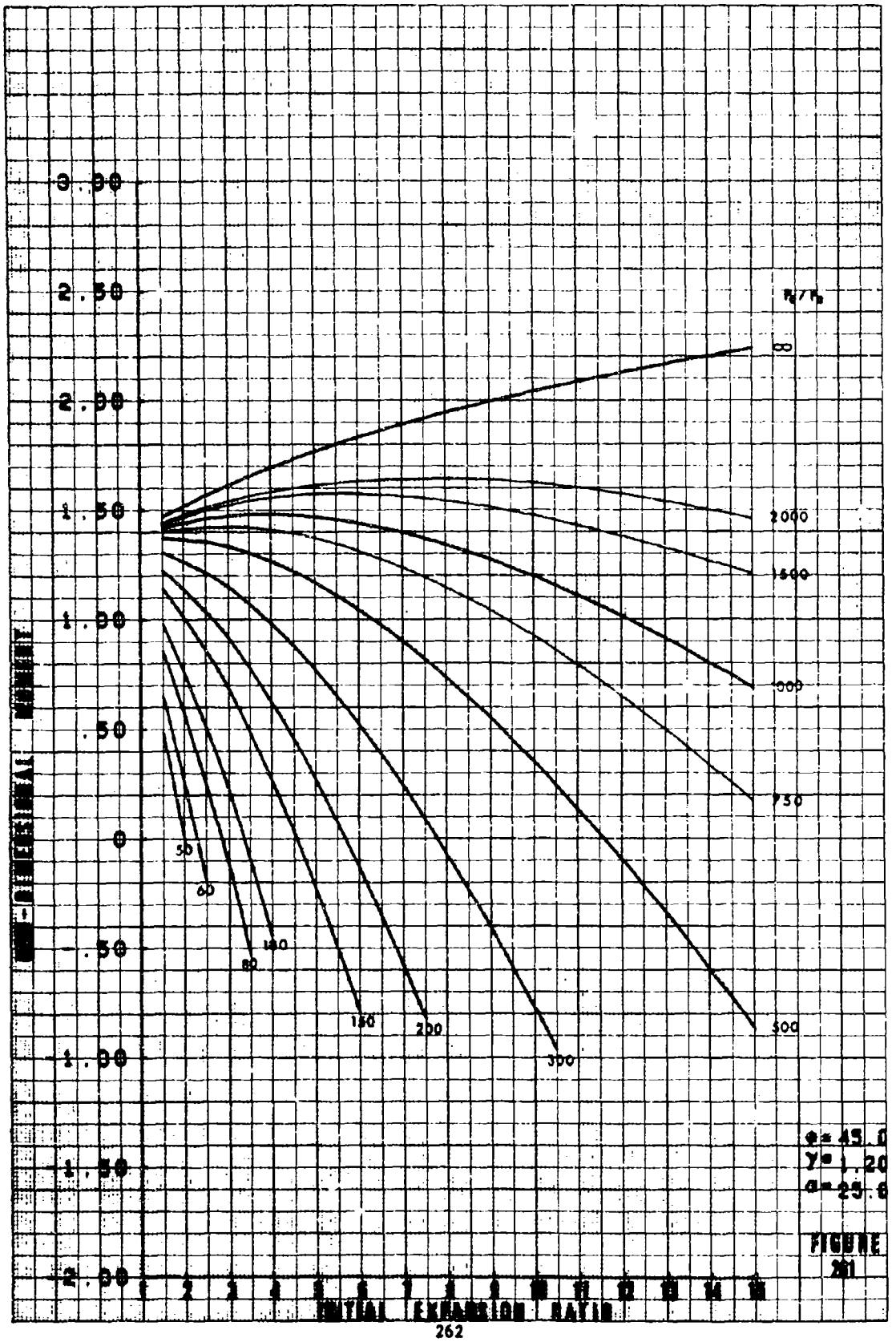
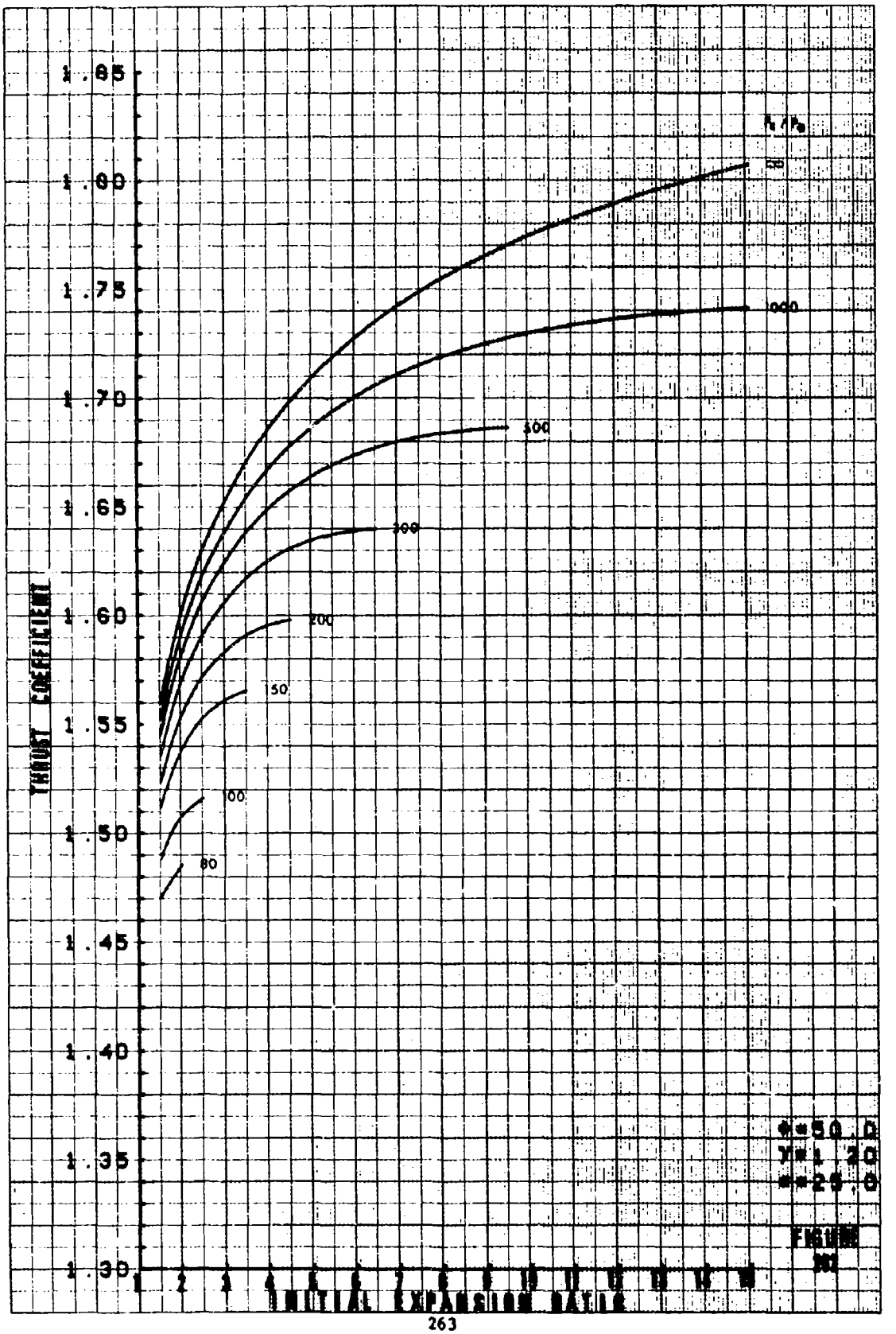
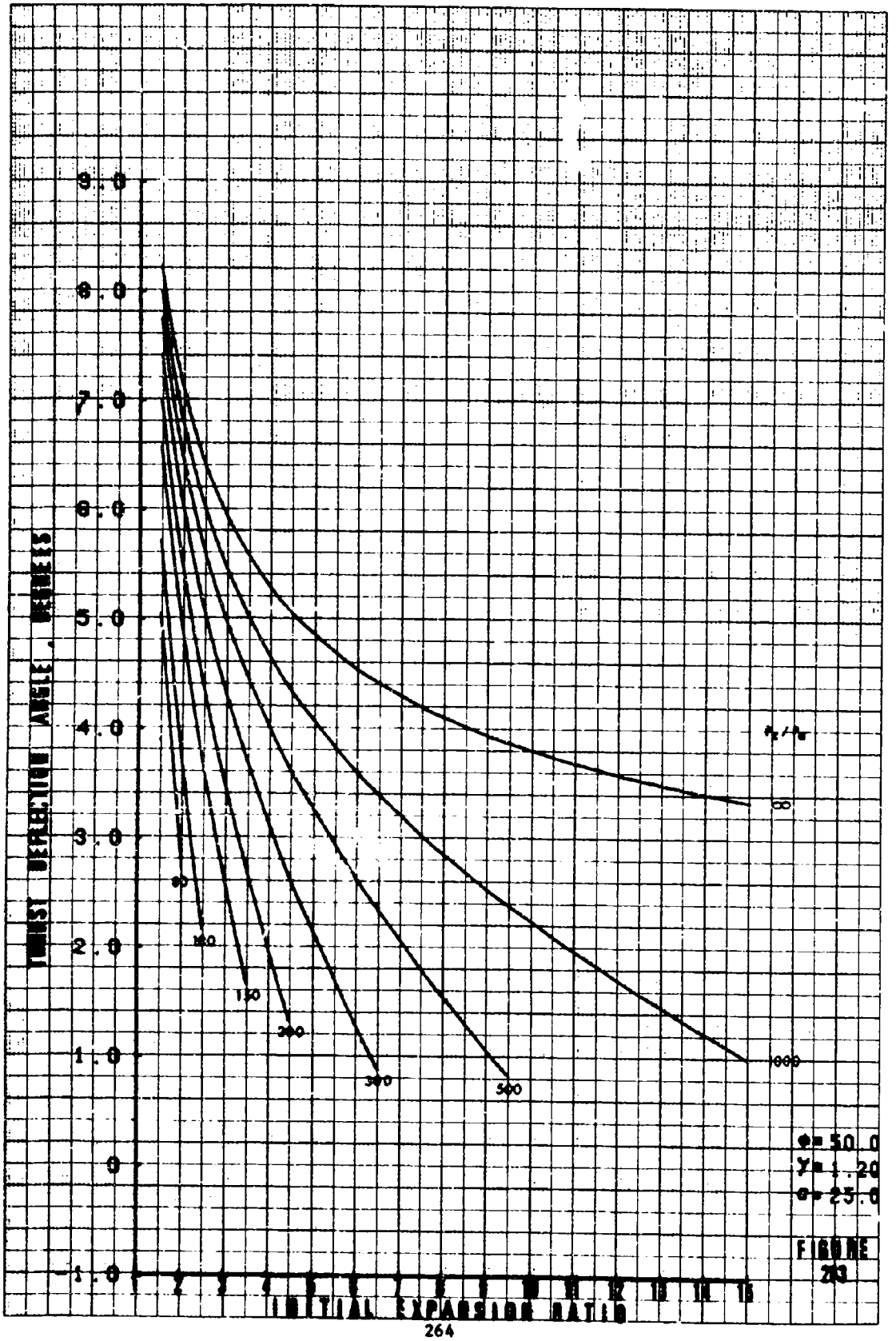

3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
2000
1500
1000
750
500
300
200
150
100
80
60
50
φ= 45.0
γ= 1.20
α= 25.6

FIGURE 261



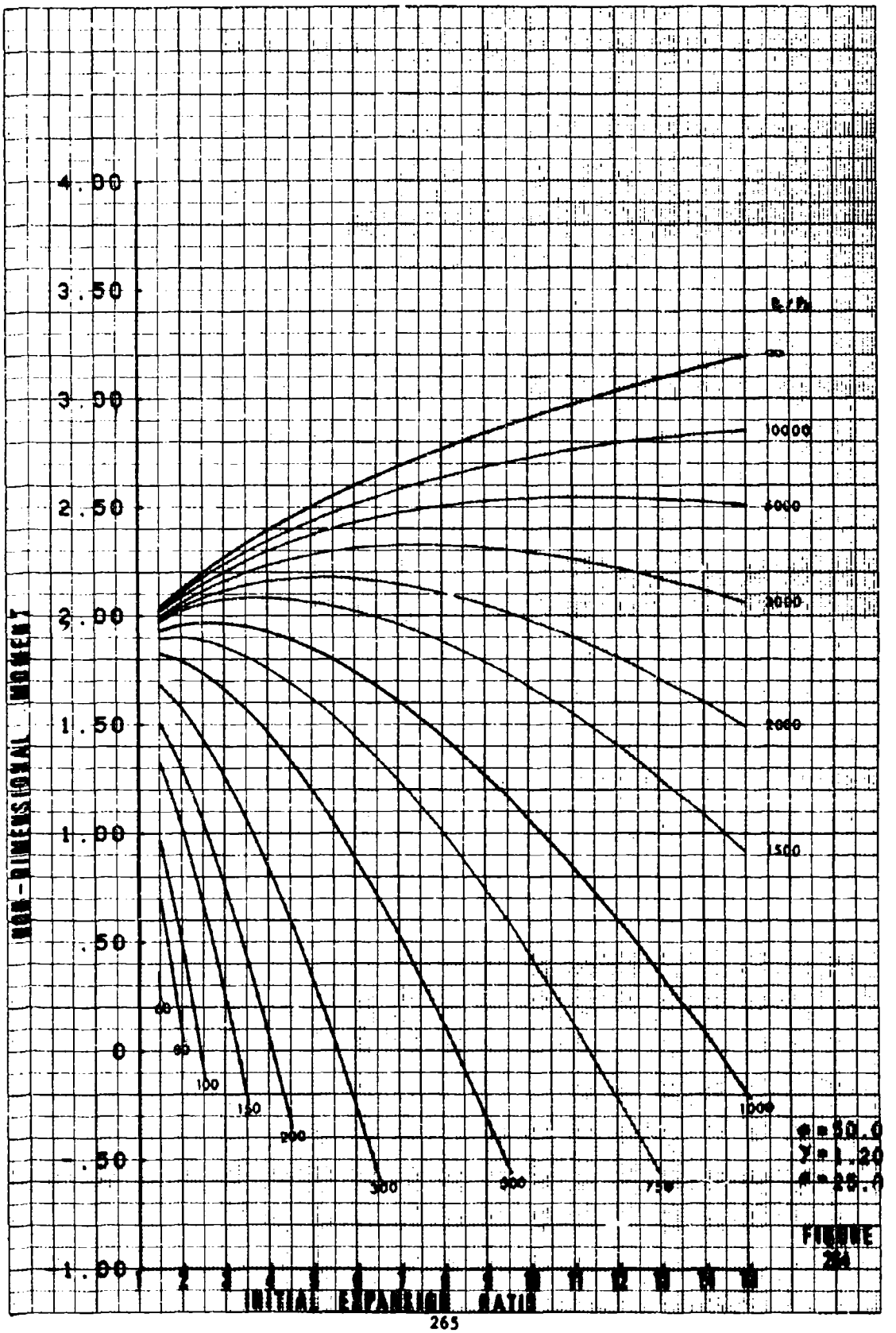
THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80

FIGURE 262



9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
80
100
150
200
300
500
1000
∞
Φ= 50.0
γ= 1.20
σ= 25.0

FIGURE 263



4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
10000
6000
3000
2000
1500
1000
750
500
300
200
150
100
80
60

FIGURE 264

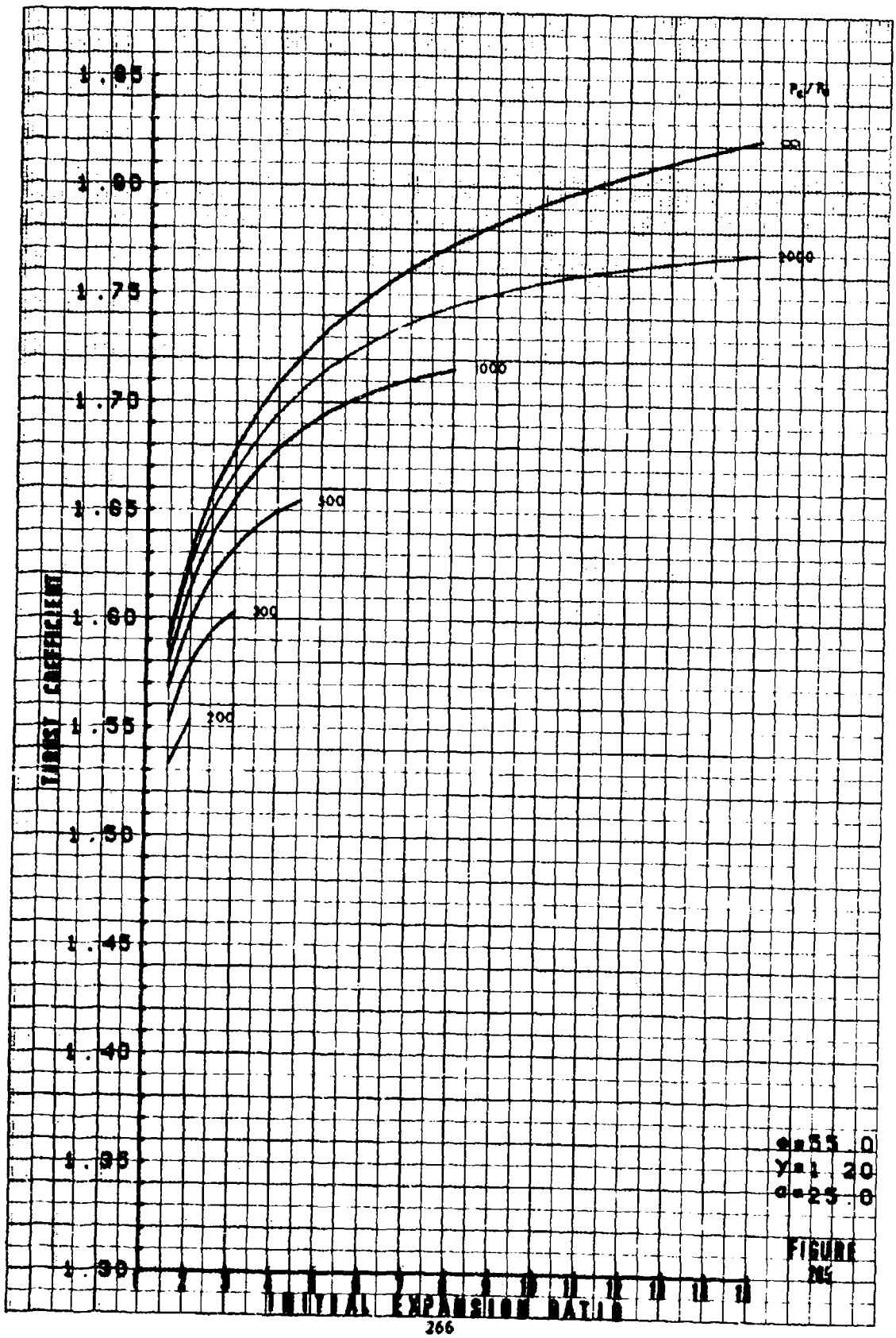
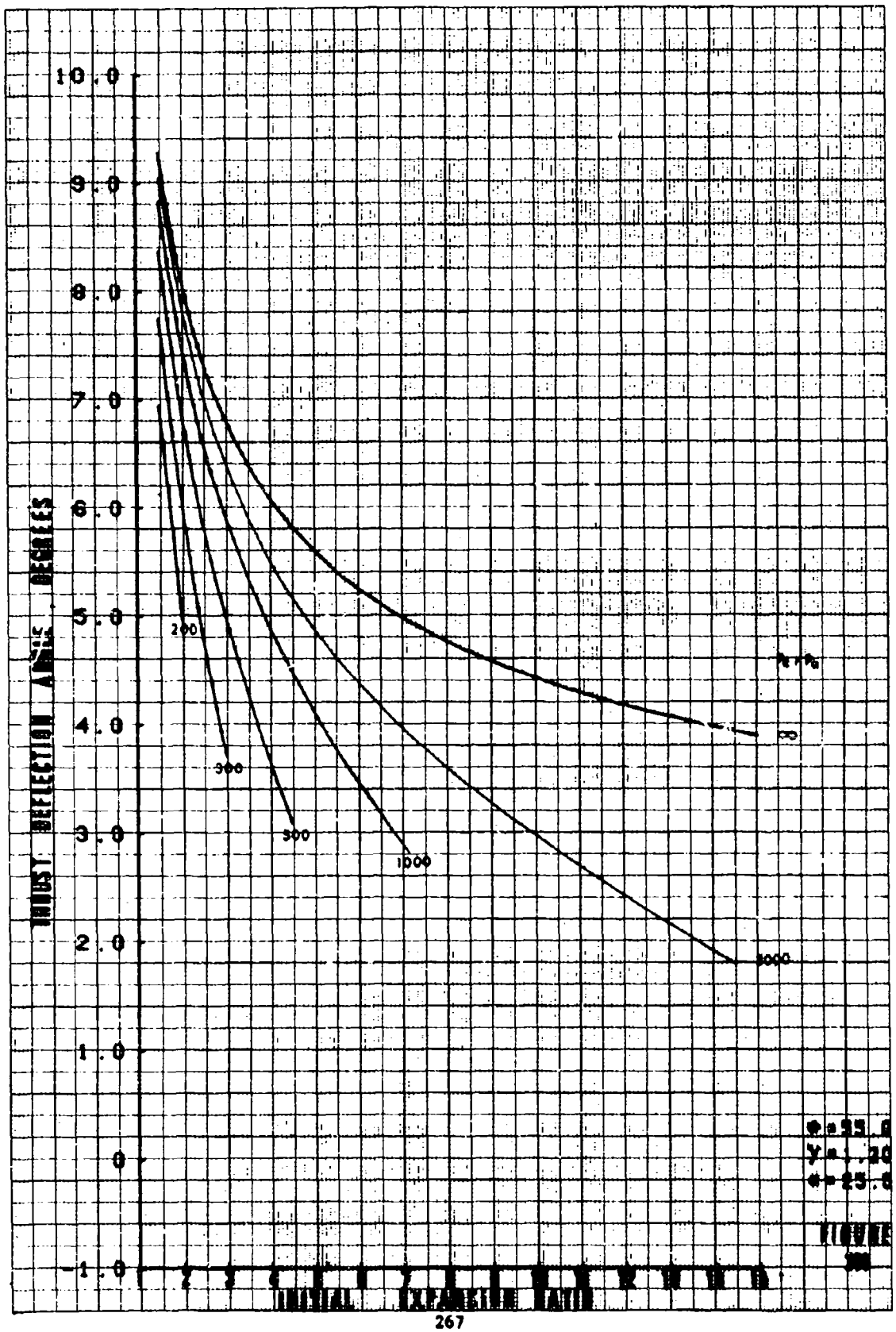
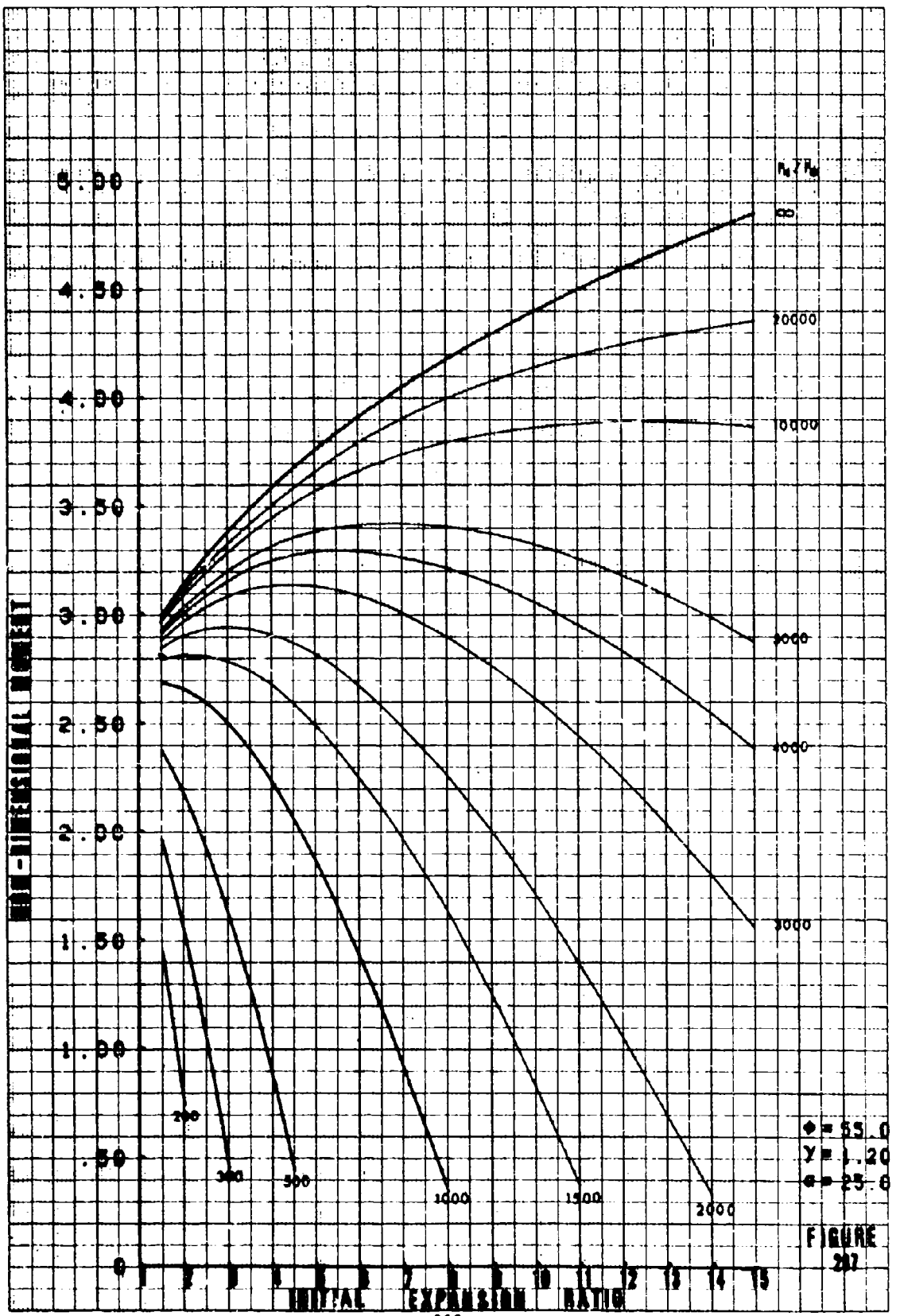

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
P_e/P_0
∞
1000
1000
500
300
200
e=55.0
γ=1.20
α=25.0
INITIAL EXPANSION RATIO

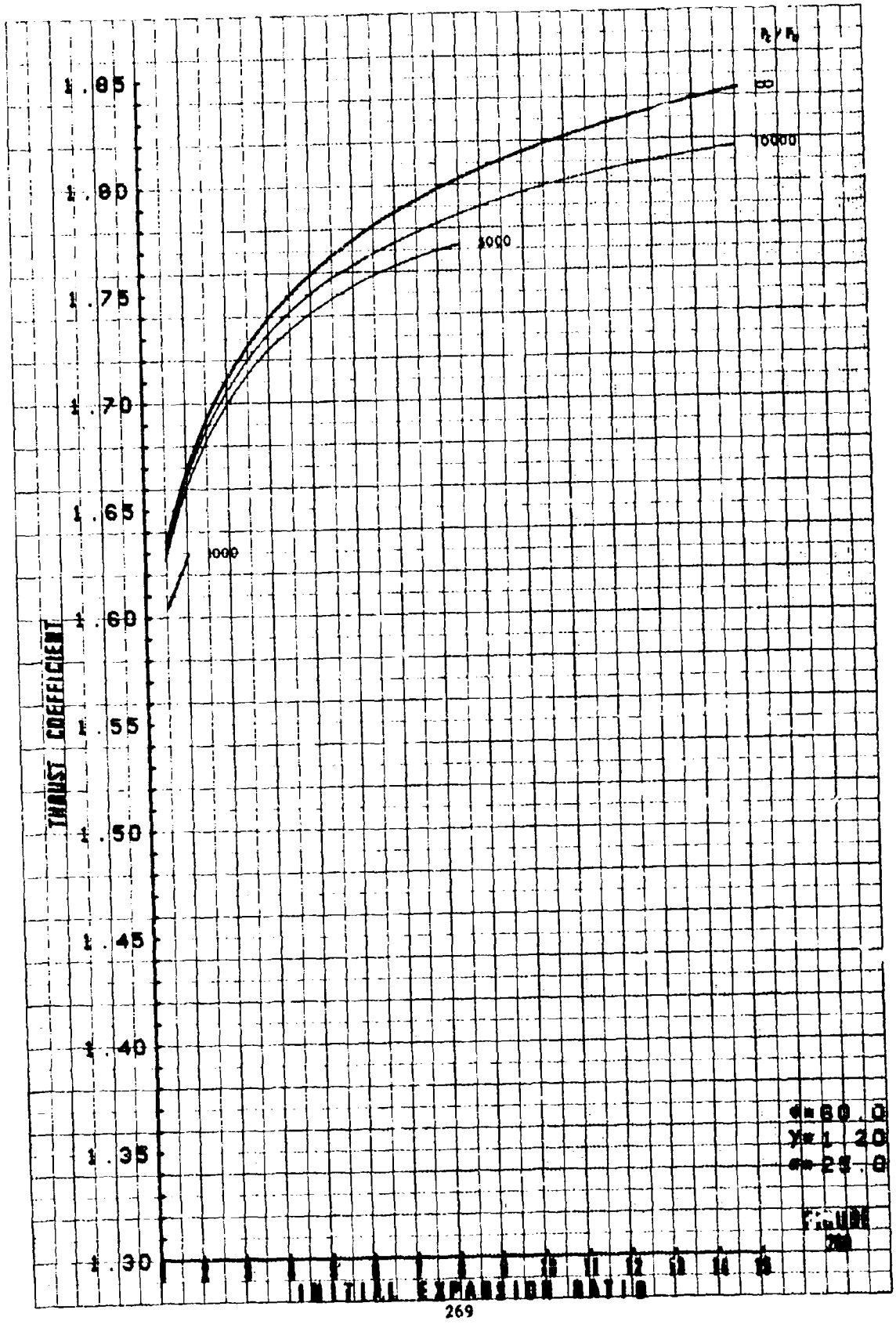
FIGURE 205


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
200
300
500
1000
3000
∞
INITIAL EXPANSION RATIO

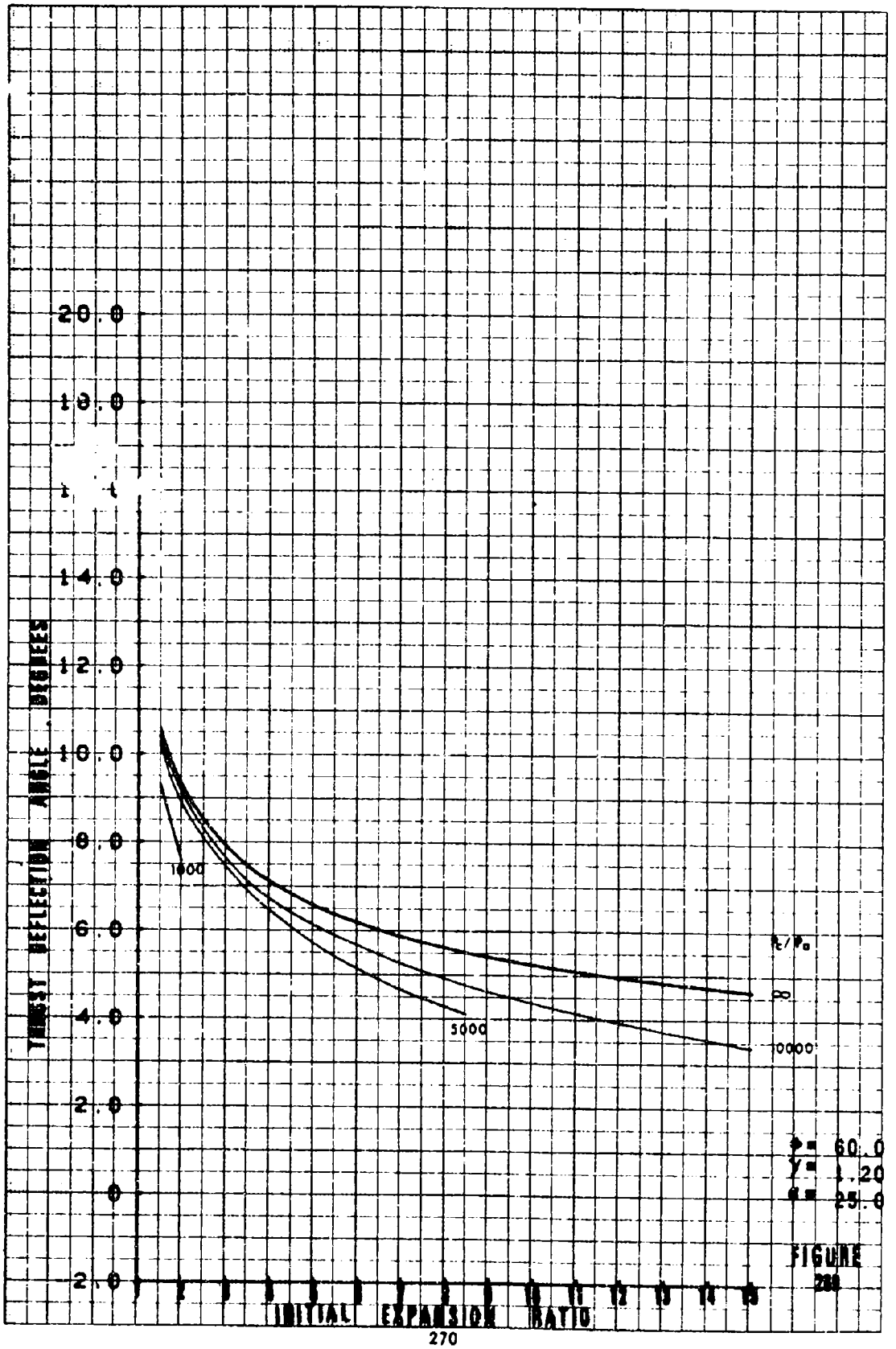


5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
20000
10000
5000
4000
3000
200
300
500
1000
1500
2000
Φ = 55.0
γ = 1.20
α = 25.0

FIGURE 287



P_c/P_0
∞
10000
1000
1000
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO



20.0
18.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
THRUST DEFLECTION ANGLE, DEGREES
1000
5000
10000
∞
P_c/P_o
ϕ = 60.0
γ = 1.20
α = 25.0
INITIAL EXPANSION RATIO

FIGURE 288

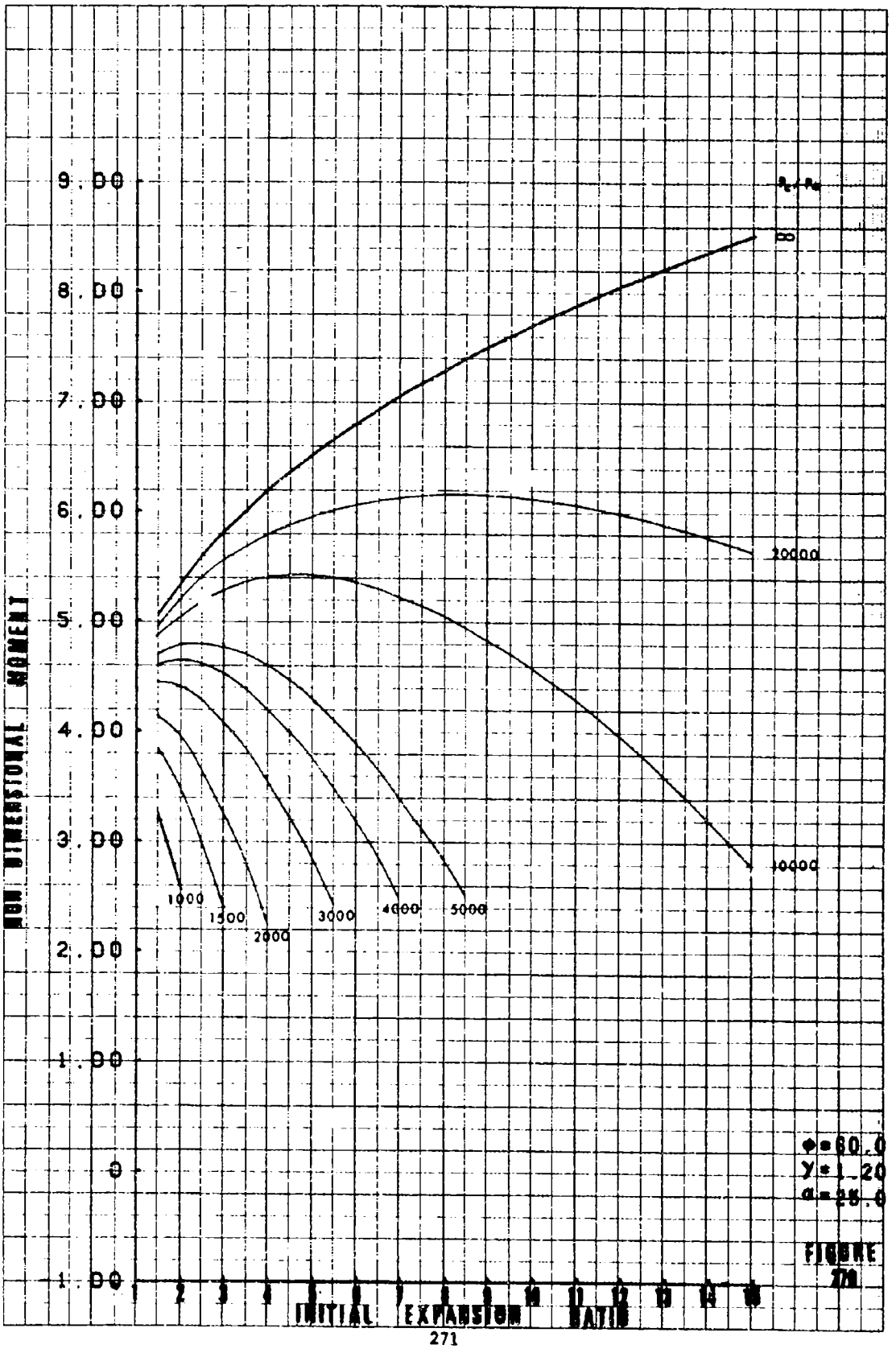
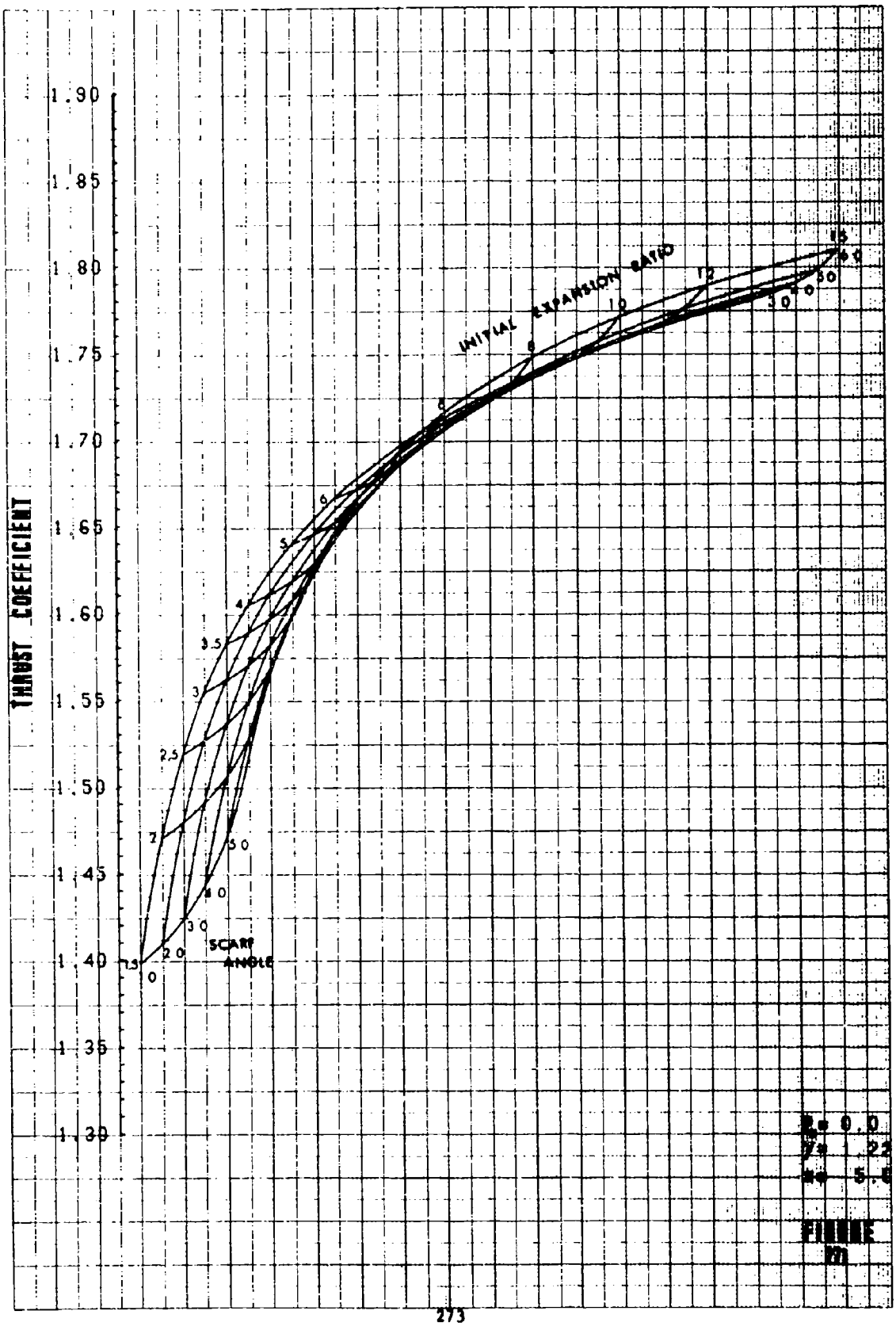

NON DIMENSIONAL MOMENT
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
R_c/R_a
∞
20000
10000
1000
1500
2000
3000
4000
5000
φ=60.0
γ=1.20
α=25.0

FIGURE 27A


THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
FIGURE

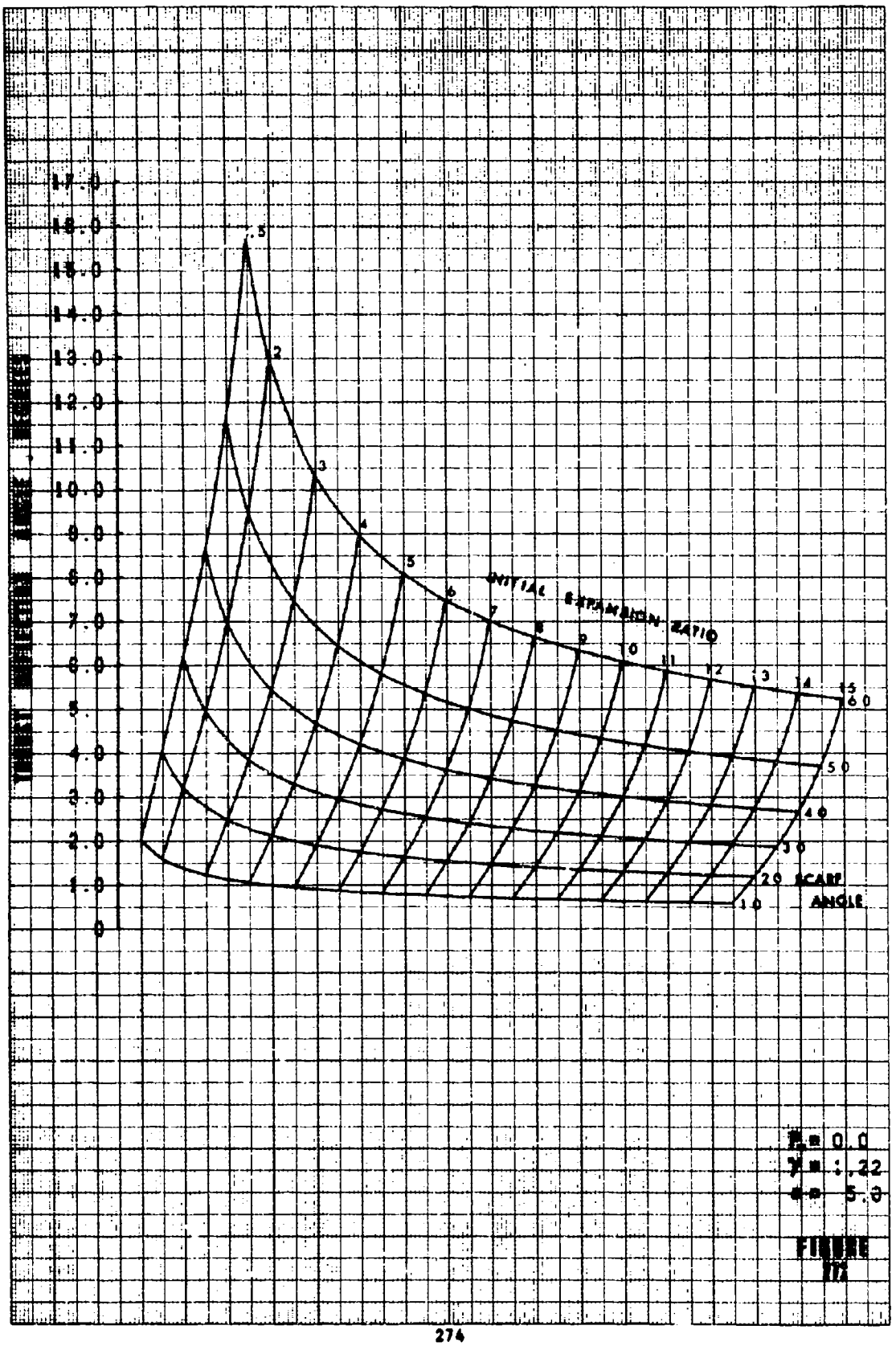

17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.
4.0
3.0
2.0
1.0
0
.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
INITIAL EXPANSION RATIO
SCARF ANGLE
M = 0.0
γ = 1.22
α = 5.0

FIGURE 17A

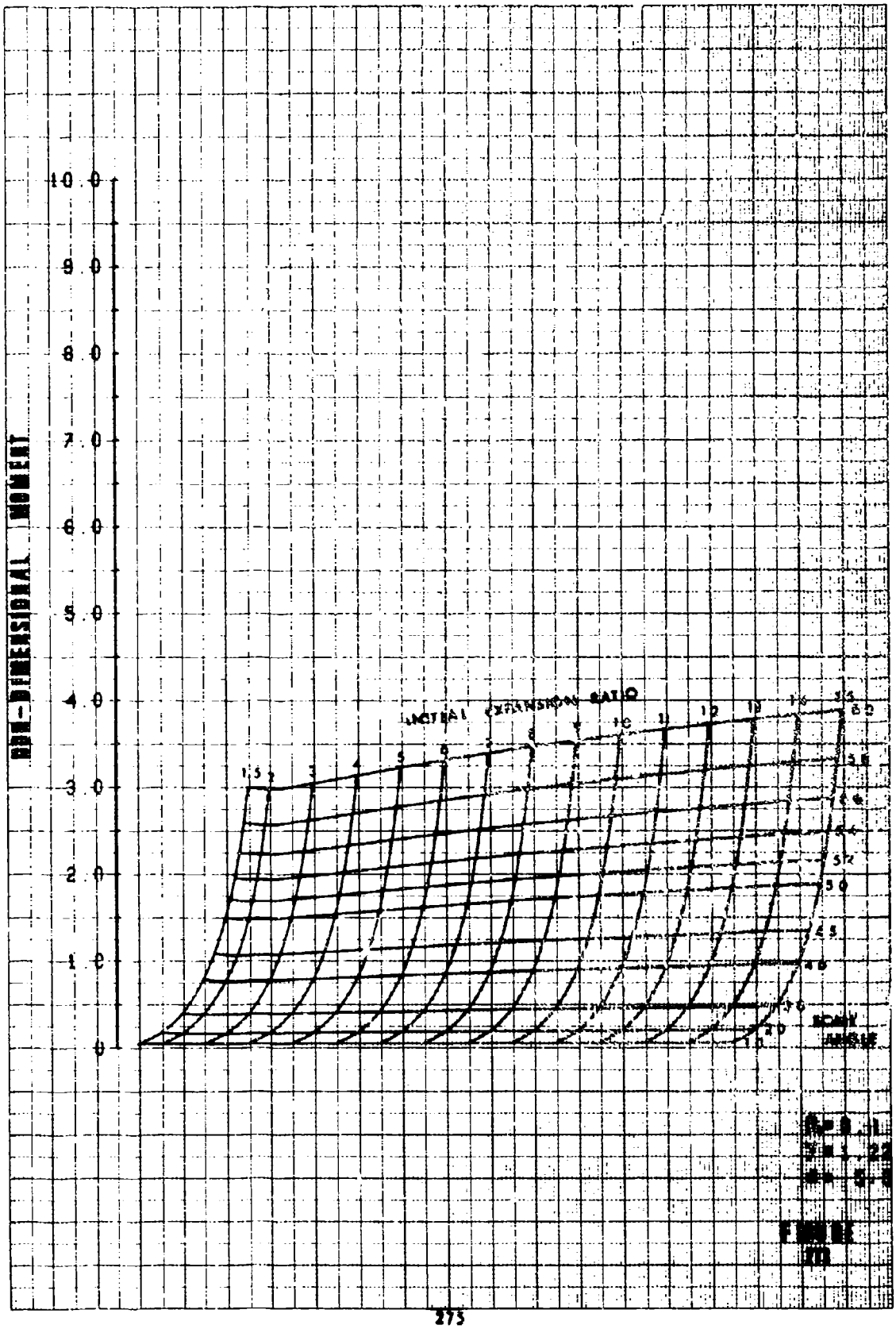

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCALE ANGLE

FIGURE 11

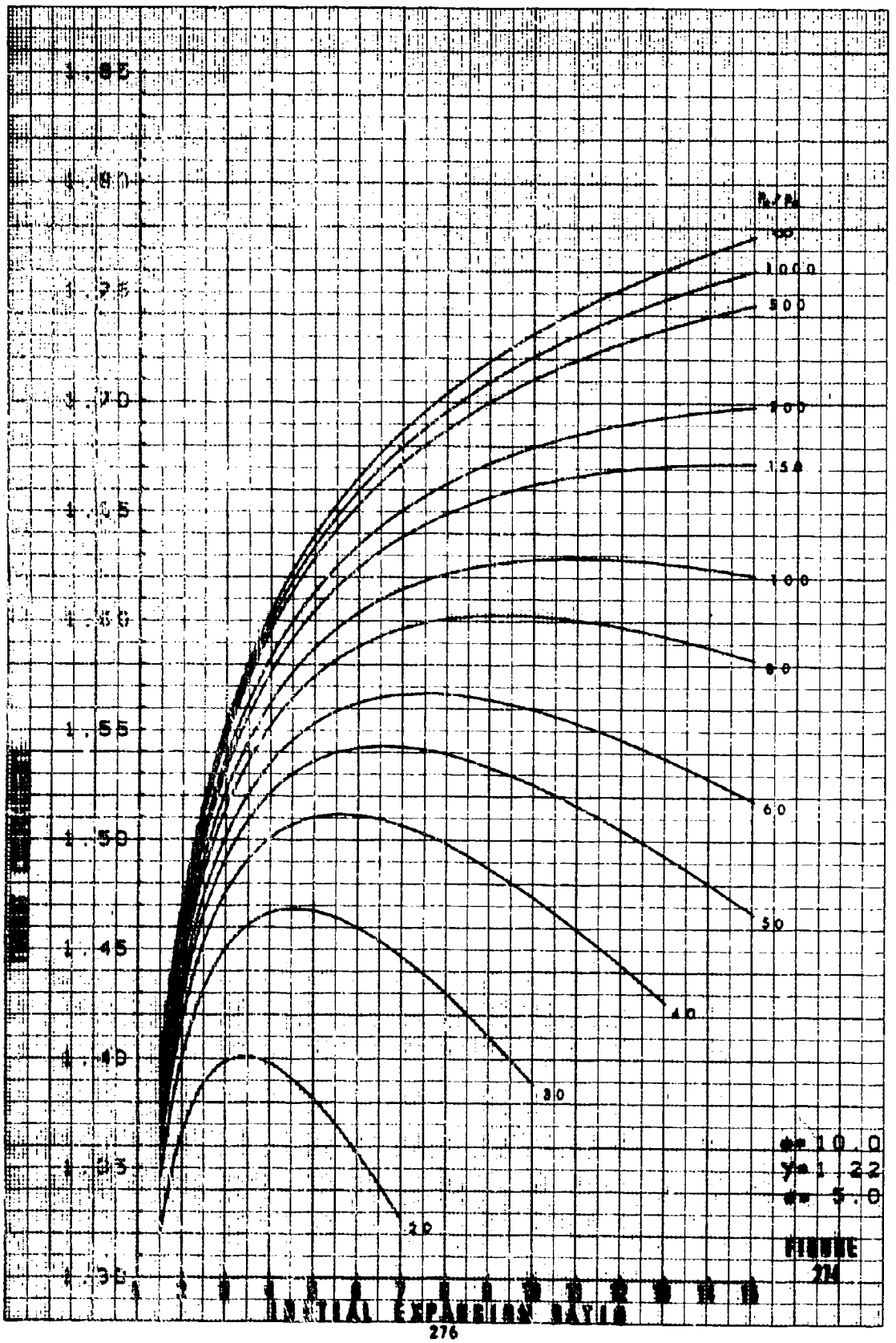
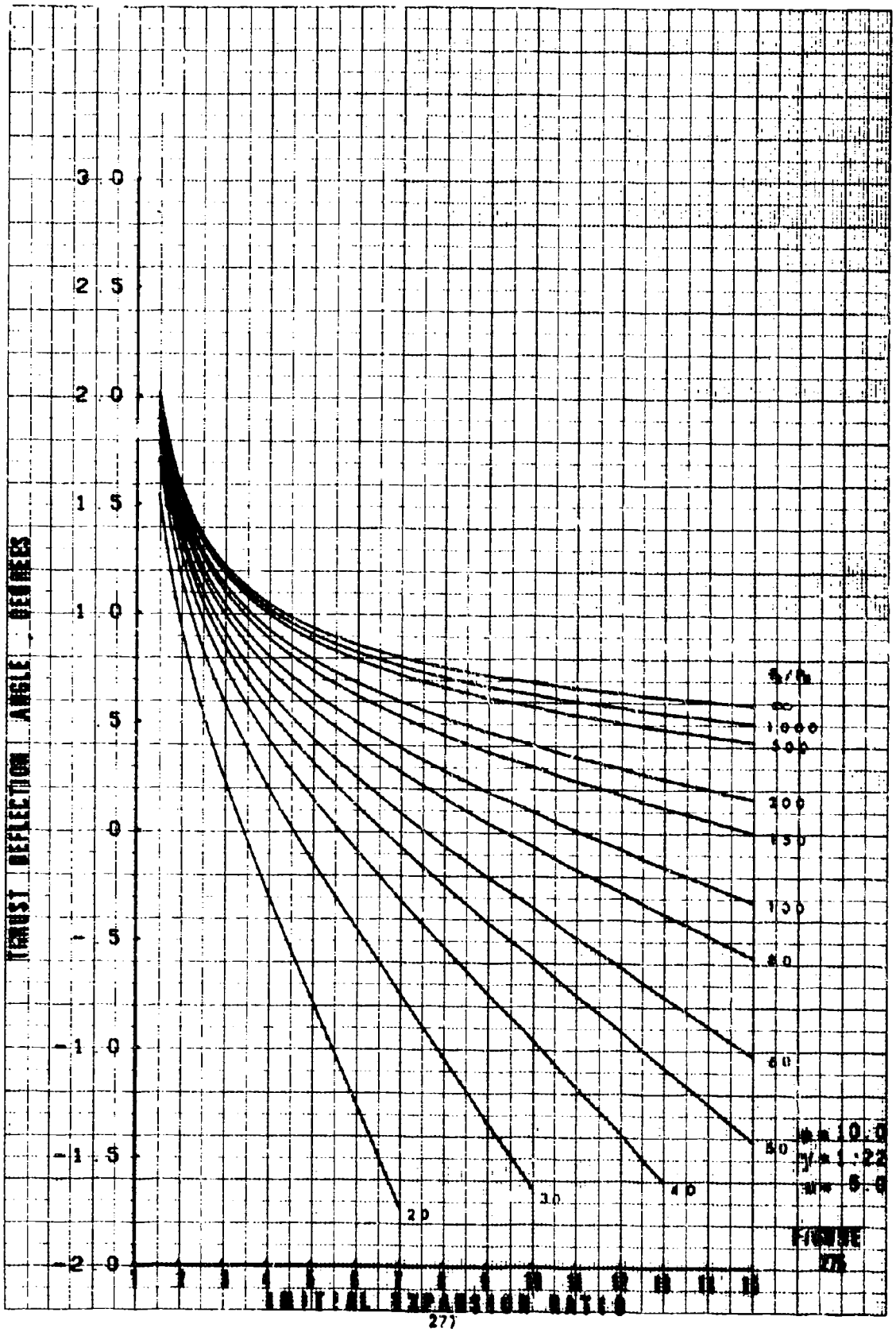
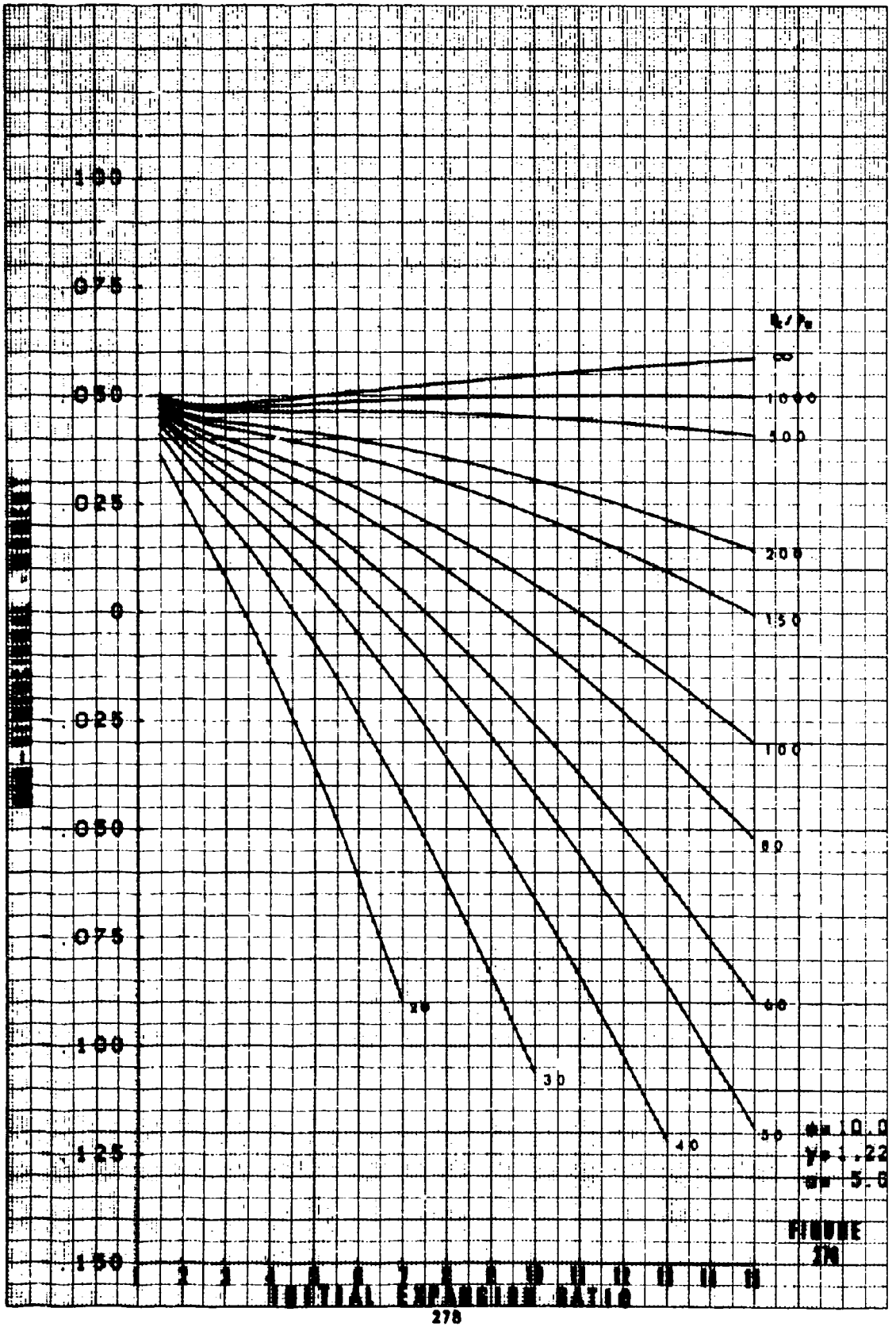

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1000
500
200
150
100
80
60
50
40
30
20
10.0
1.22
5.0
INITIAL EXPANSION RATIO

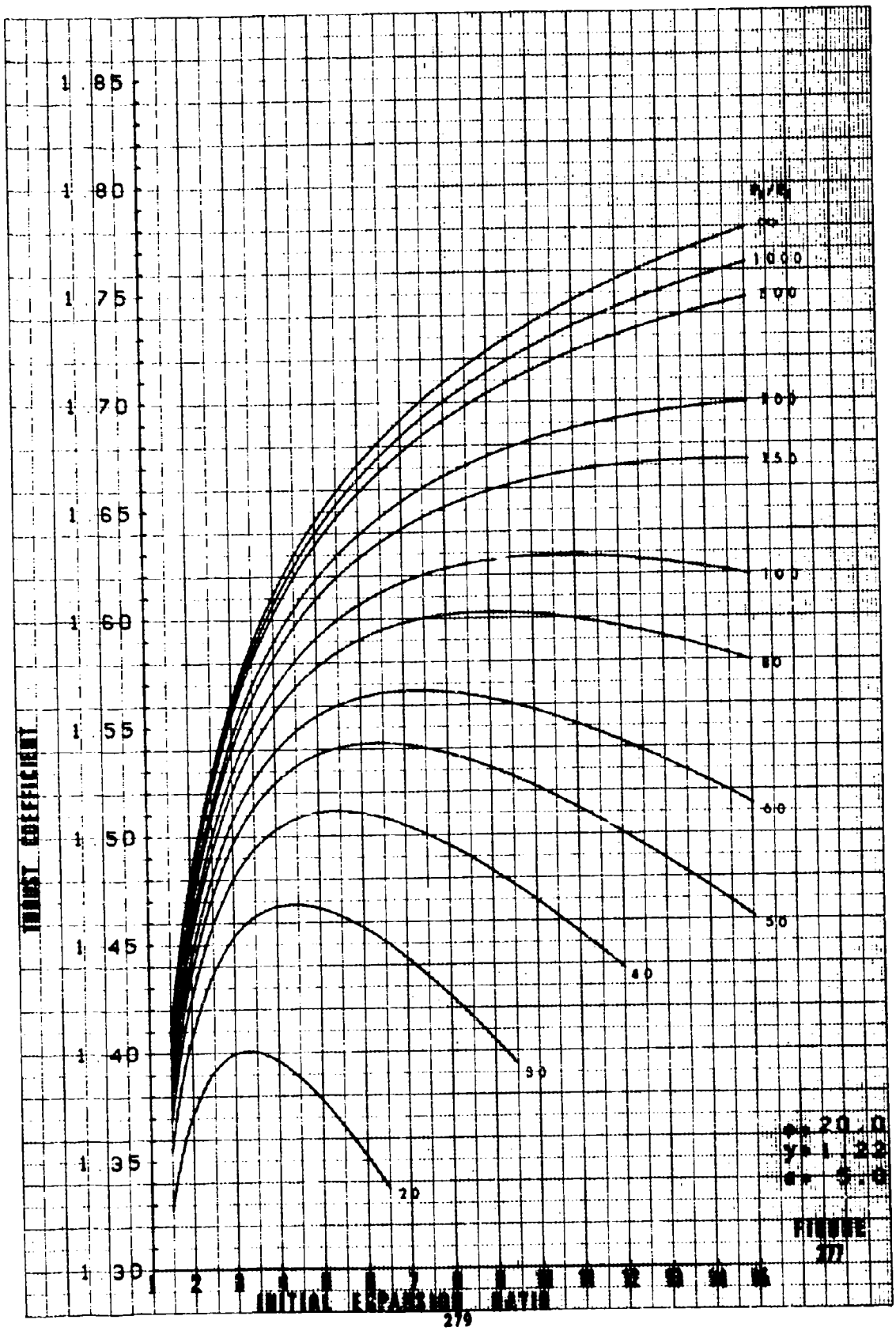
FIGURE 274


THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞
FIGURE



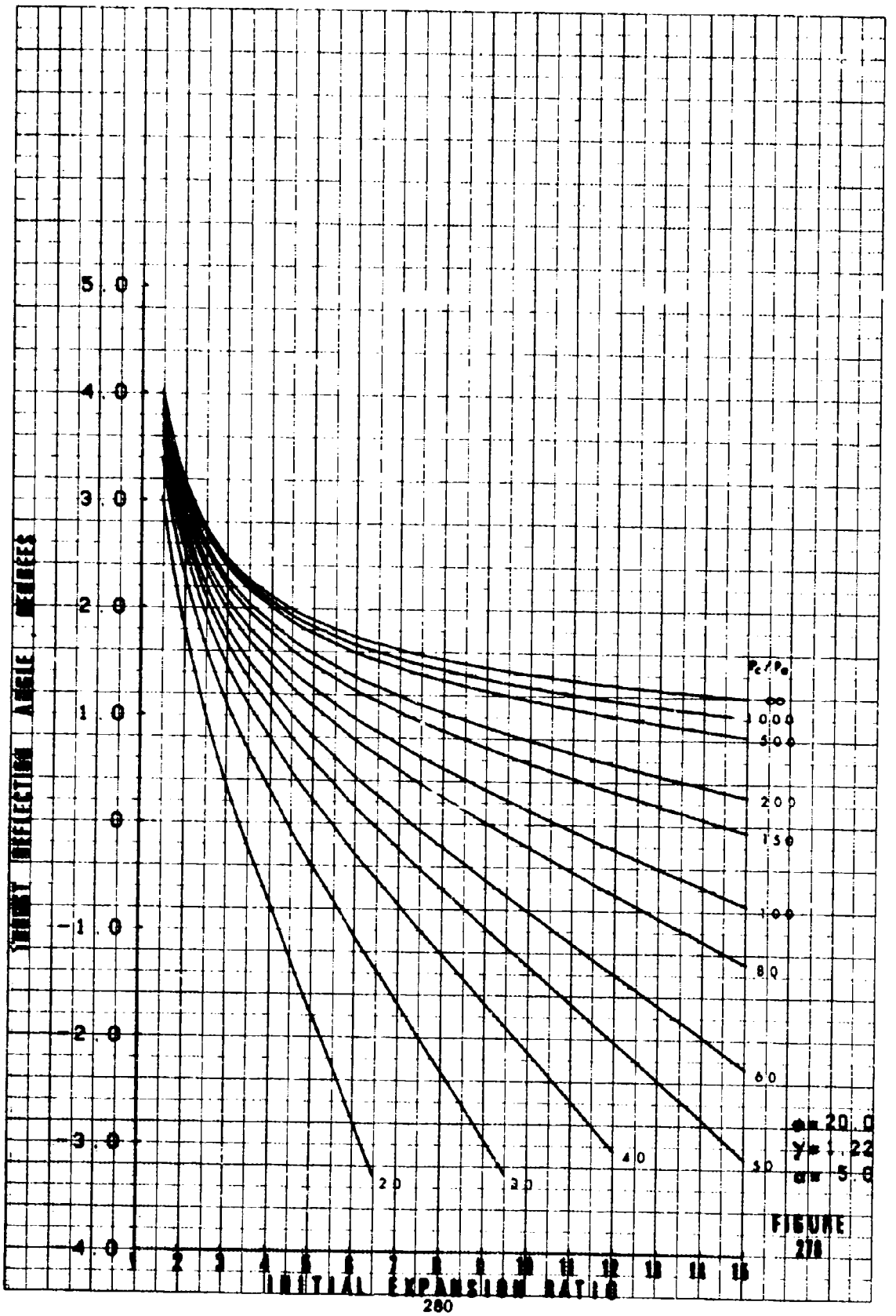
.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 278



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_1/P_2
∞
1000
500
200
250
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
α = 5.0

FIGURE 277



THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
α = 5.0

FIGURE 278

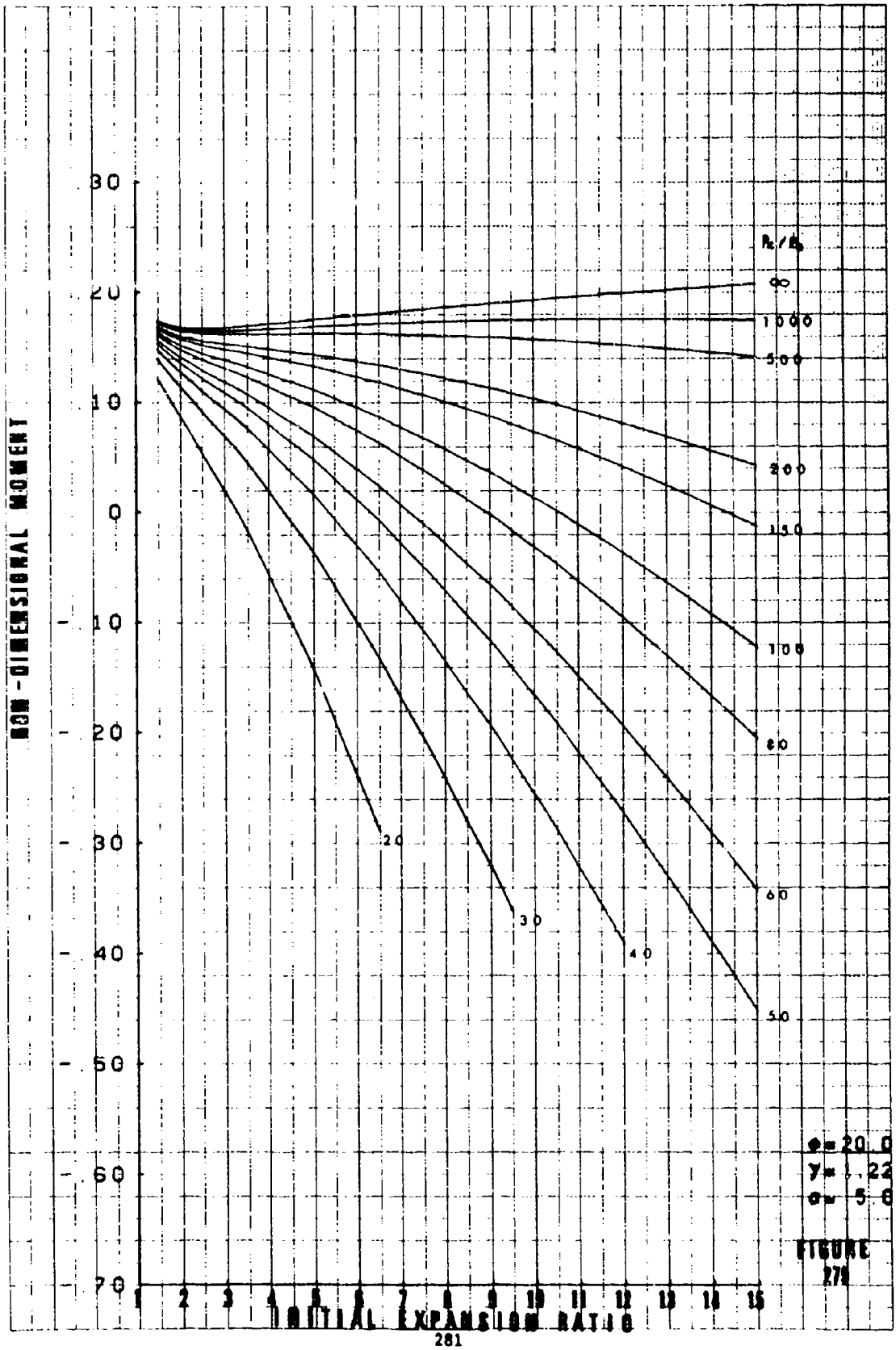
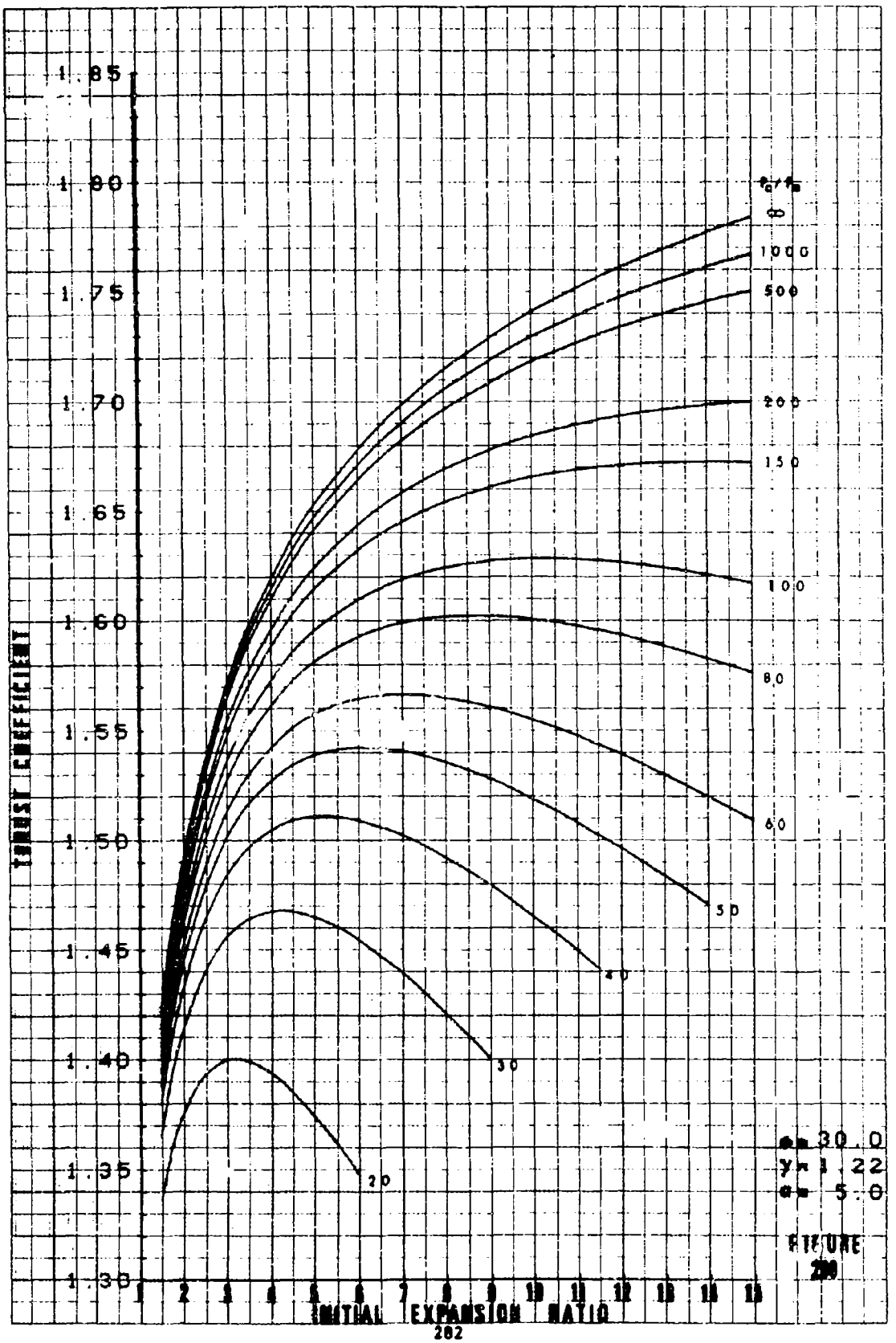

NON-DIMENSIONAL MOMENT
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
σ = 5.6

FIGURE 279



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_m
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 30.0
γ = 1.22
α = 5.0
FIGURE
200

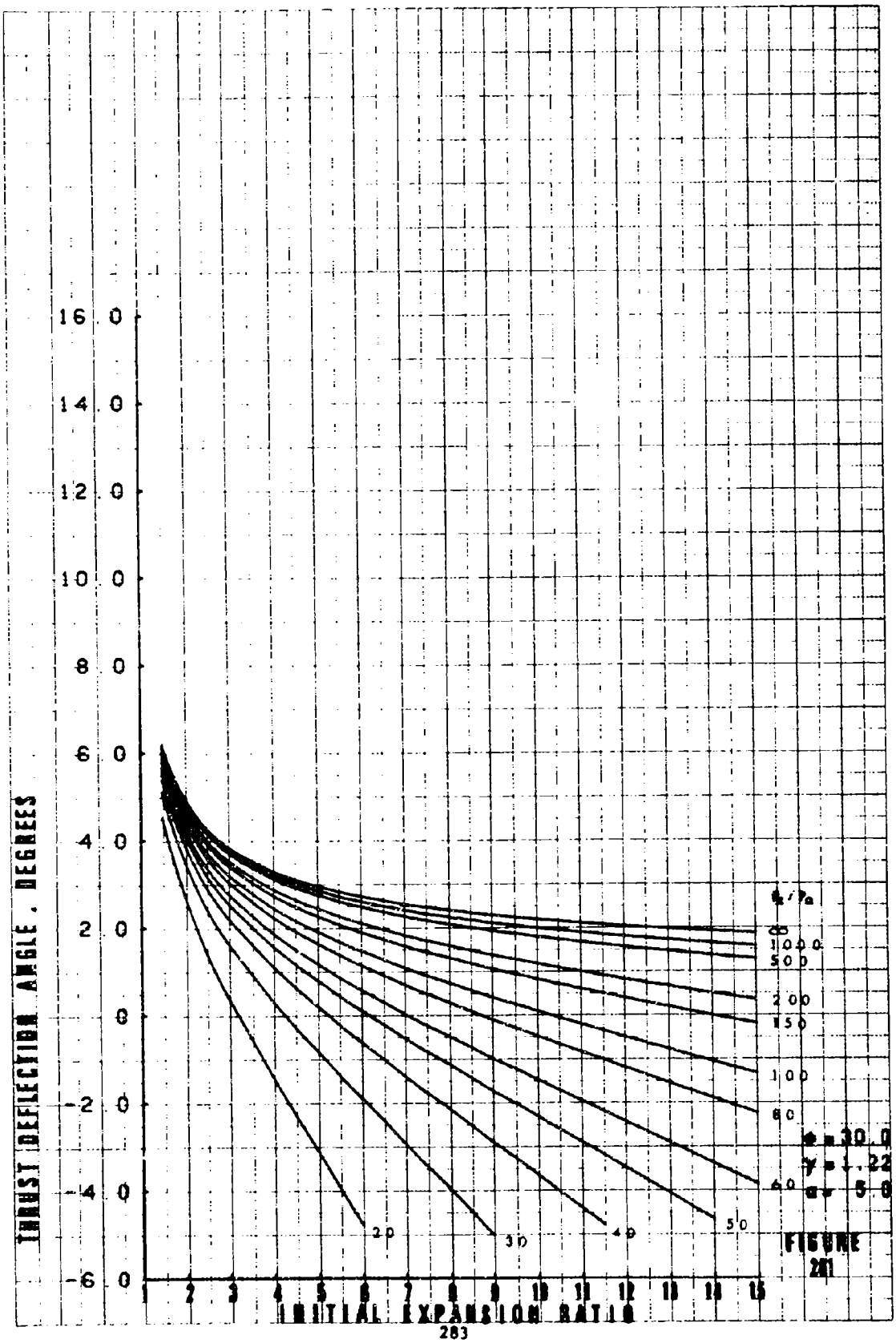

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.22
α = 5.0

FIGURE 281

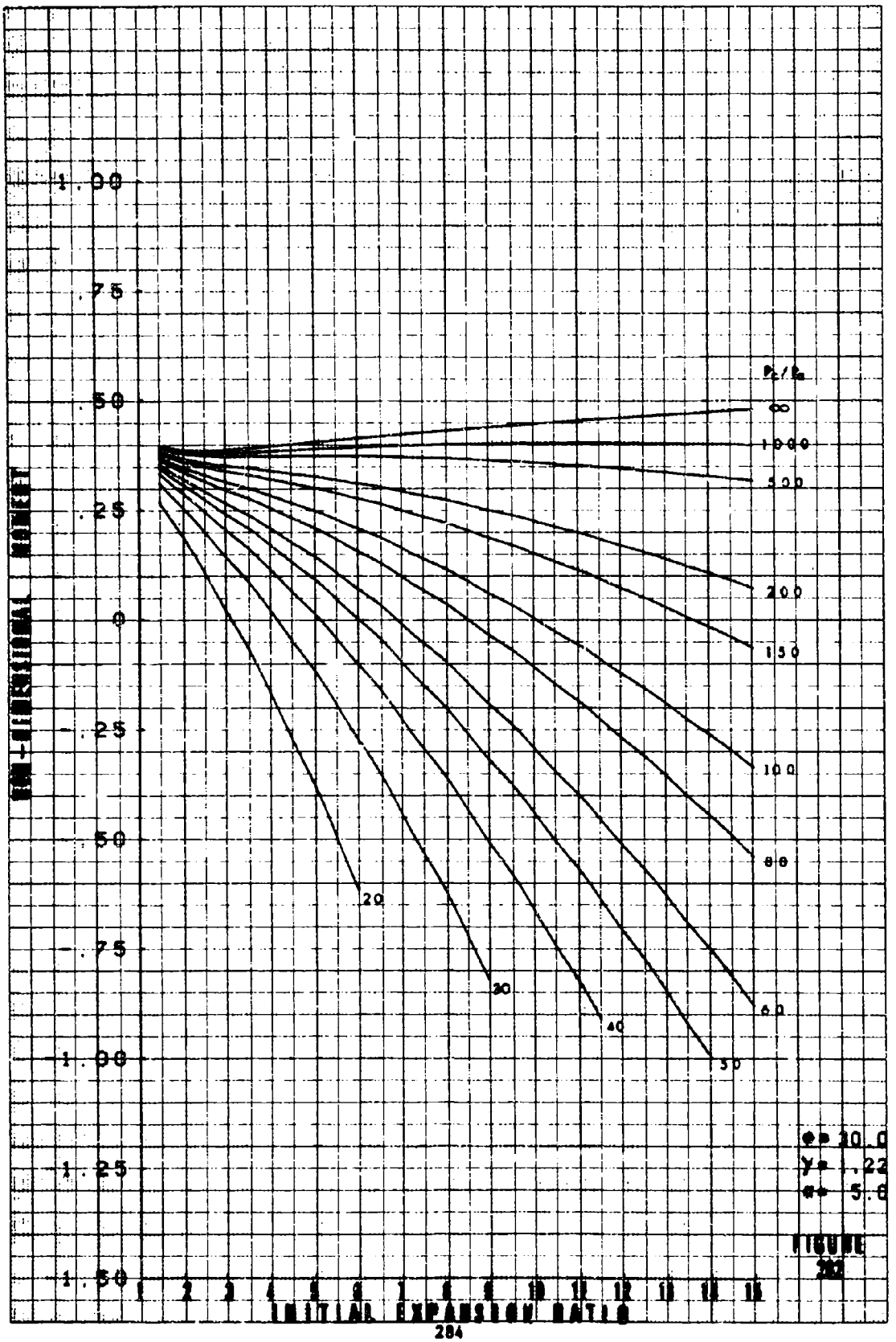

1.00
.75
.50
.25
0
.25
.50
.75
1.00
1.25
1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.22
α = 5.0

FIGURE 302

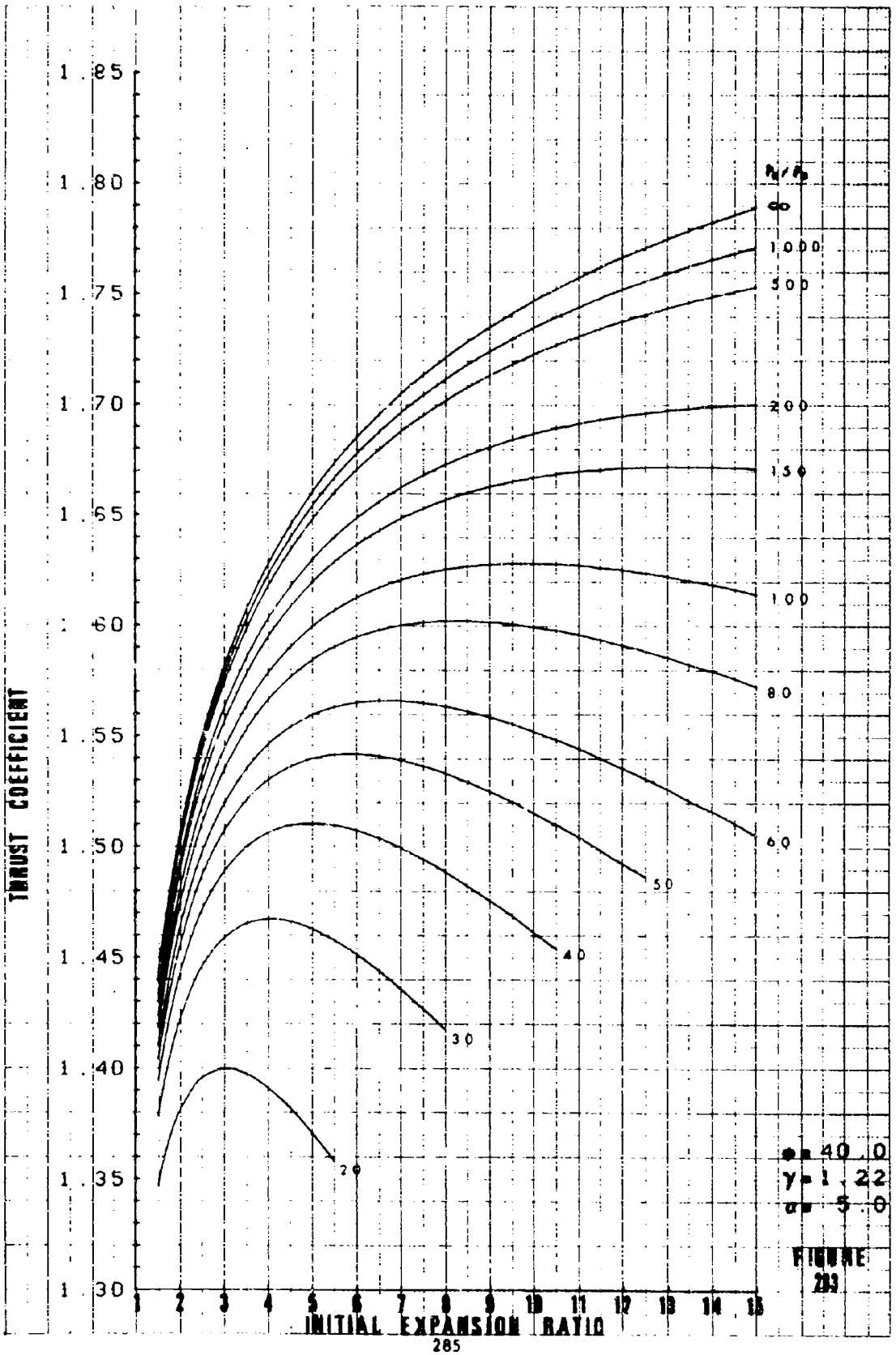

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_1/p_0
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 40.0
γ = 1.22
α = 5.0

FIGURE 283

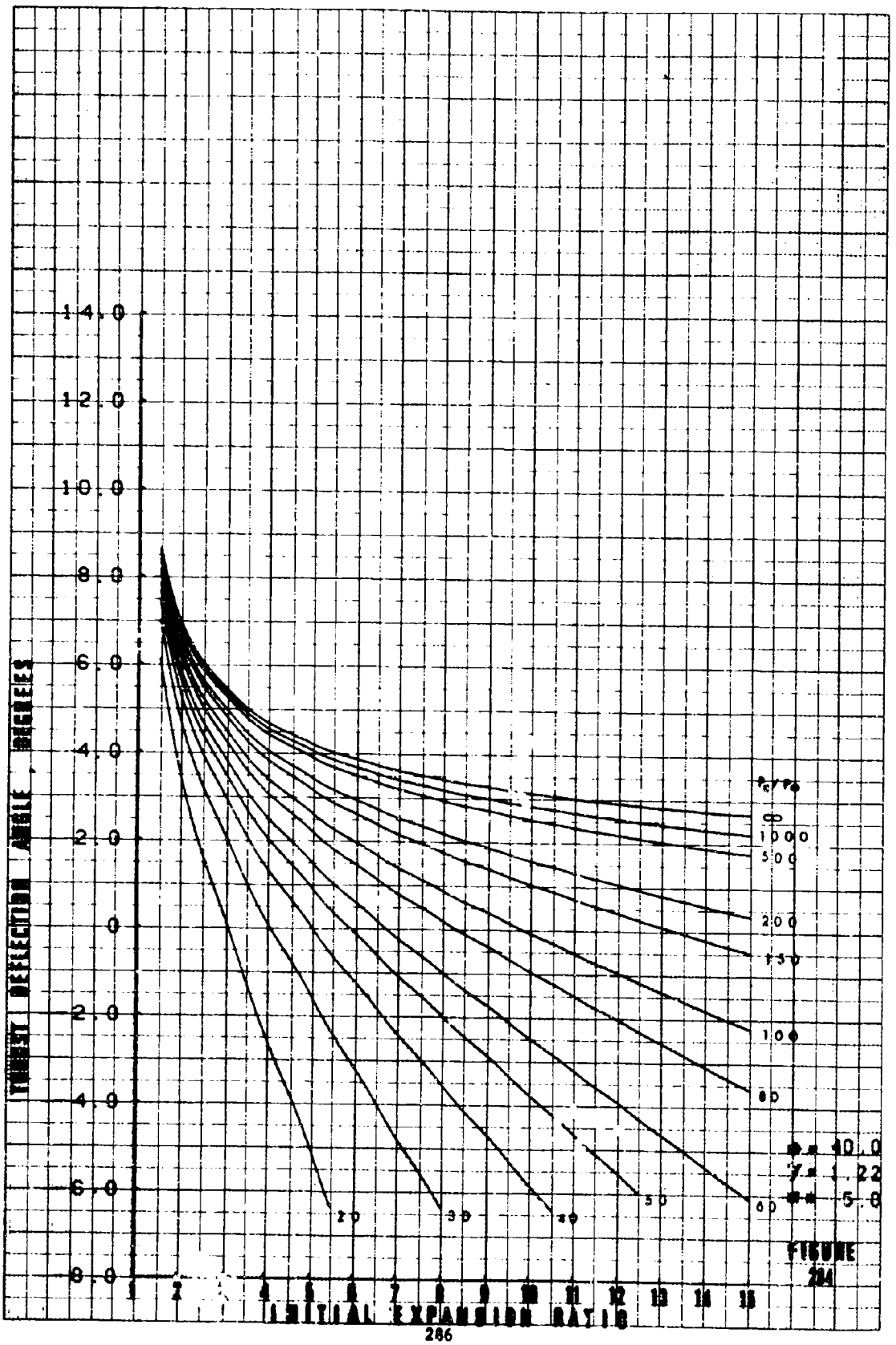
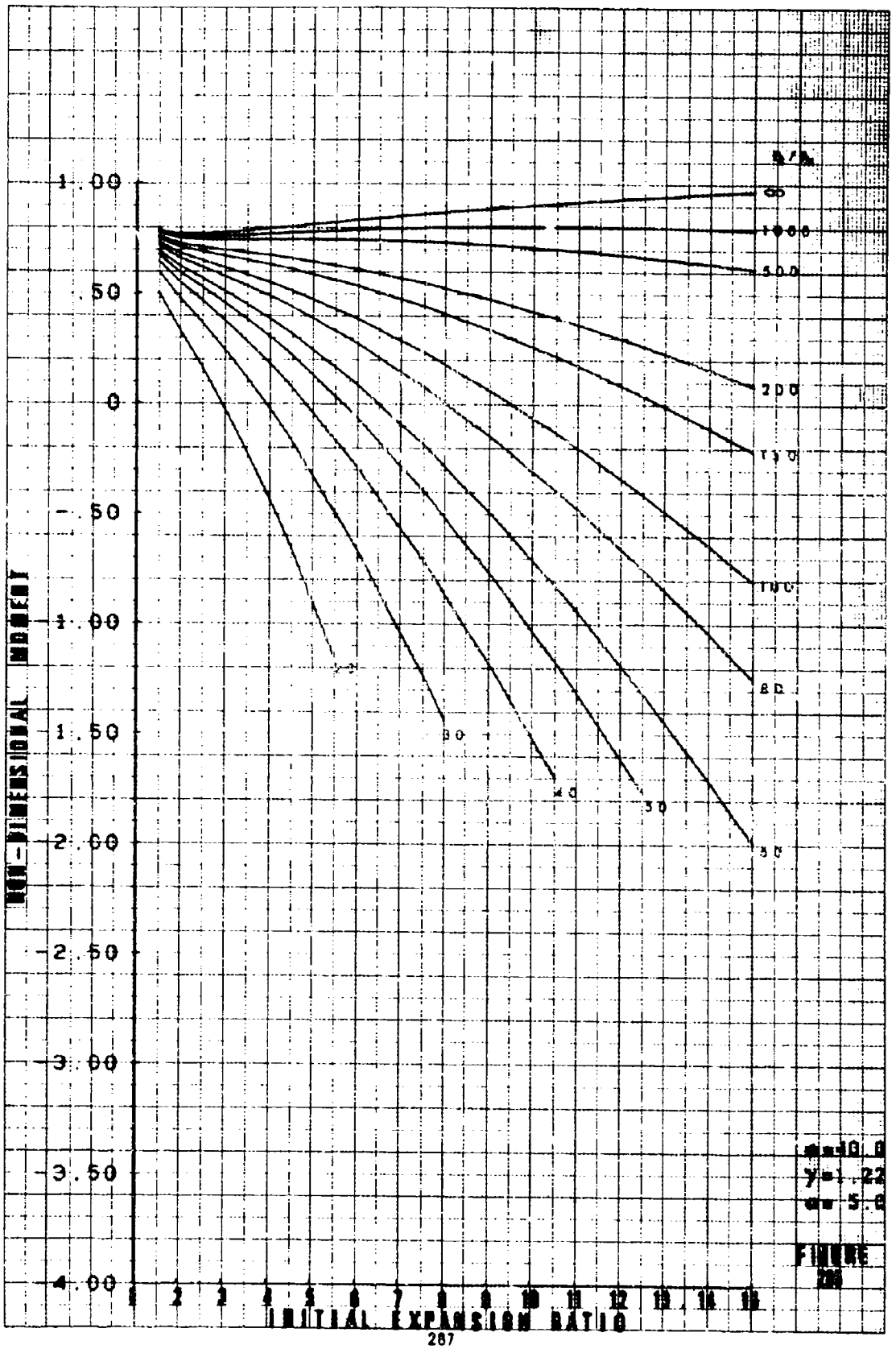

THRUST DEFLECTION ANGLE, DEGREES
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = 1.22
M_e = 5.8

FIGURE 204



1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 286

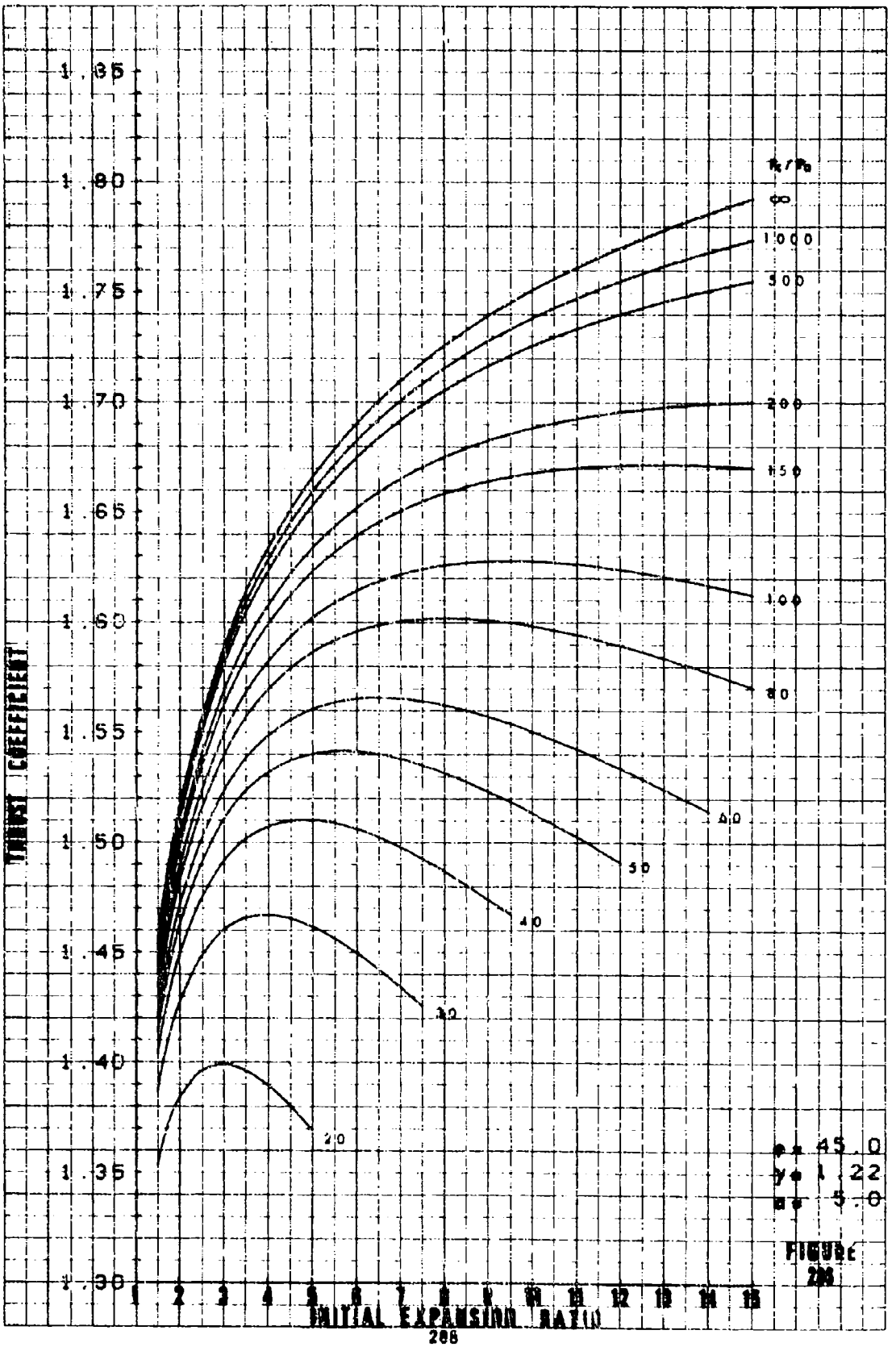
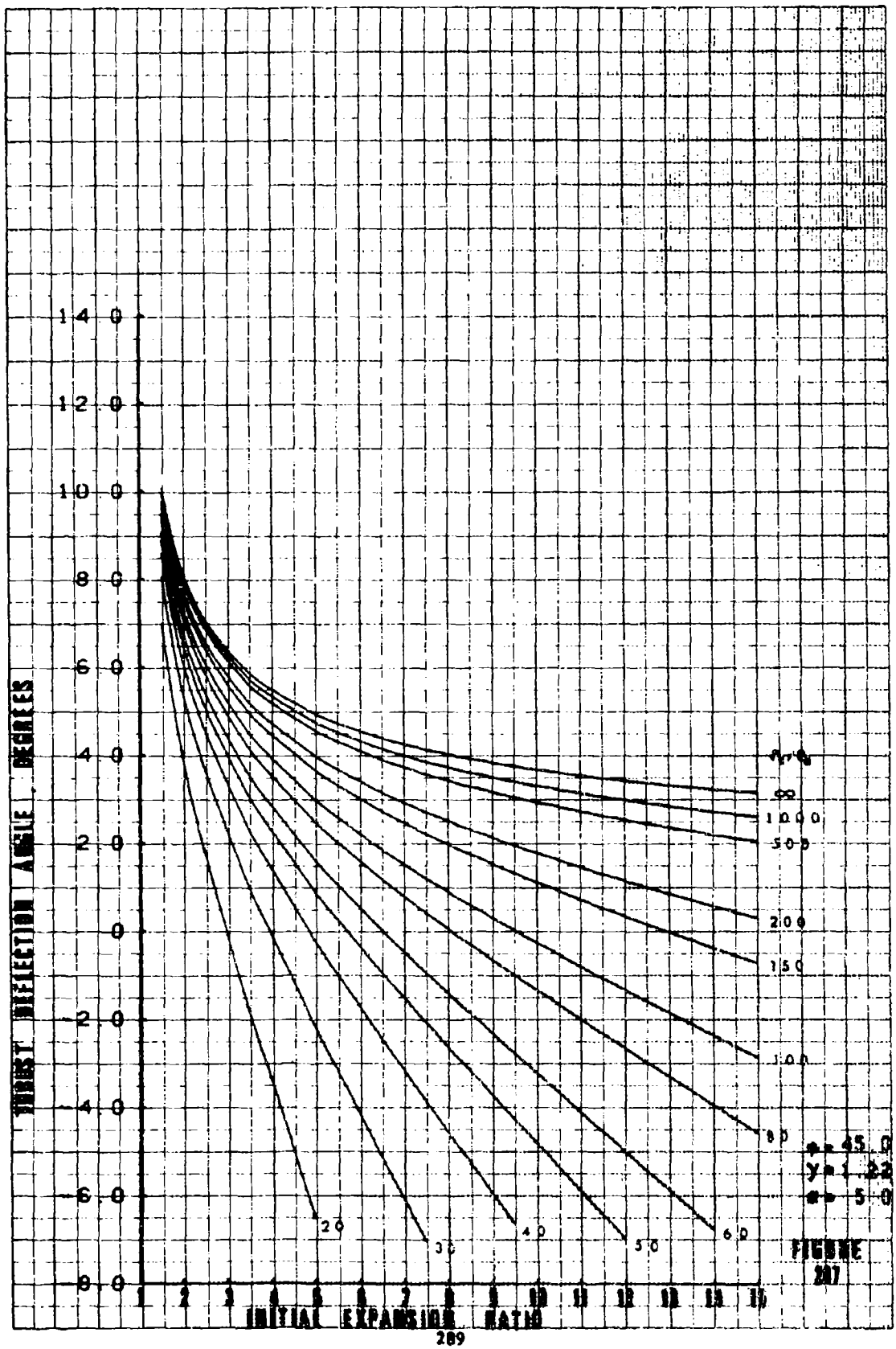

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
α = 45.0
γ = 1.22
ε = 5.0

FIGURE 206



14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
THRUST DEFLECTION ANGLE, DEGREES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.22
α = 5.0

FIGURE 287

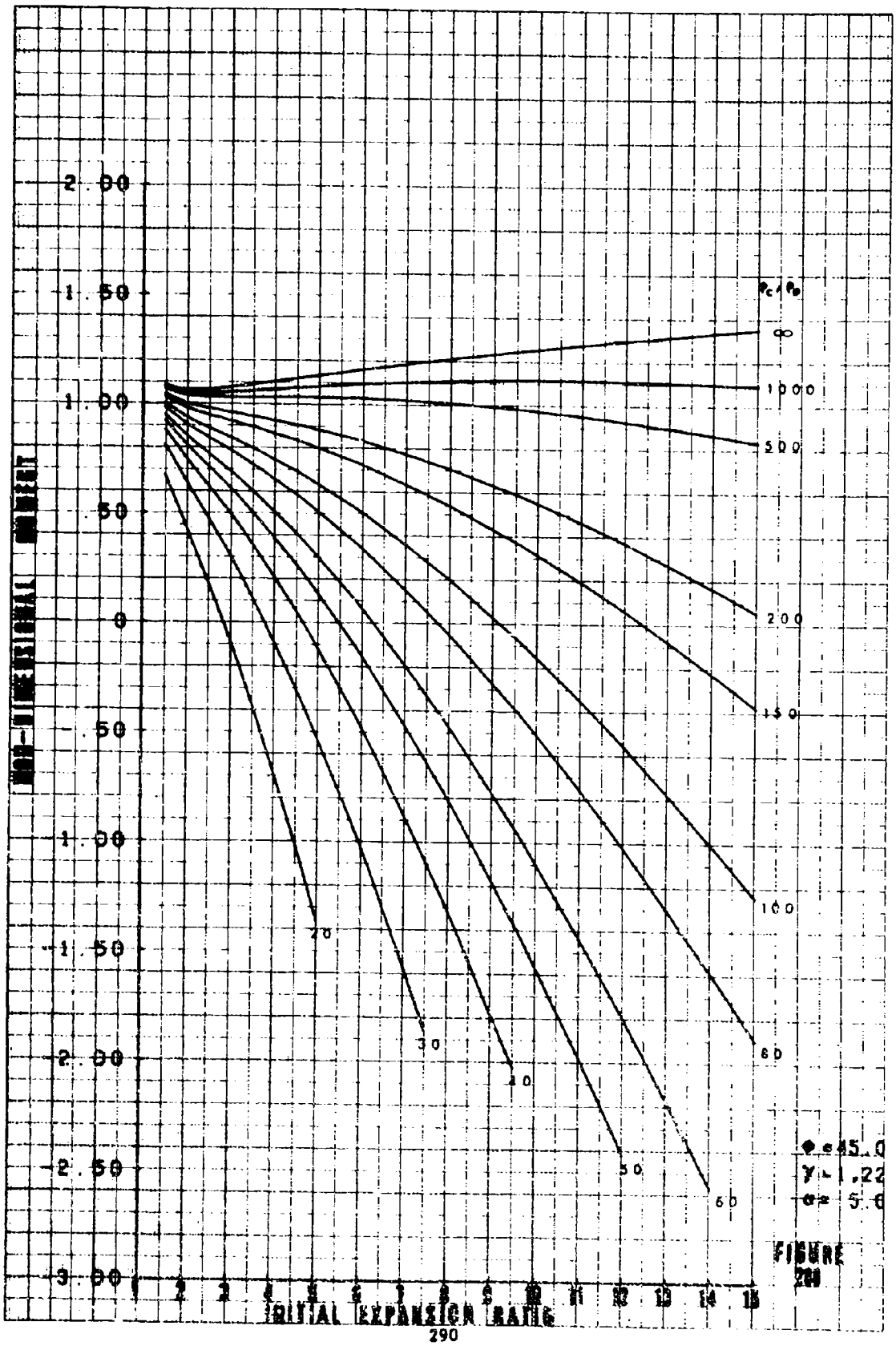

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_b
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 45.0
γ = 1.22
σ = 5.6

FIGURE 290

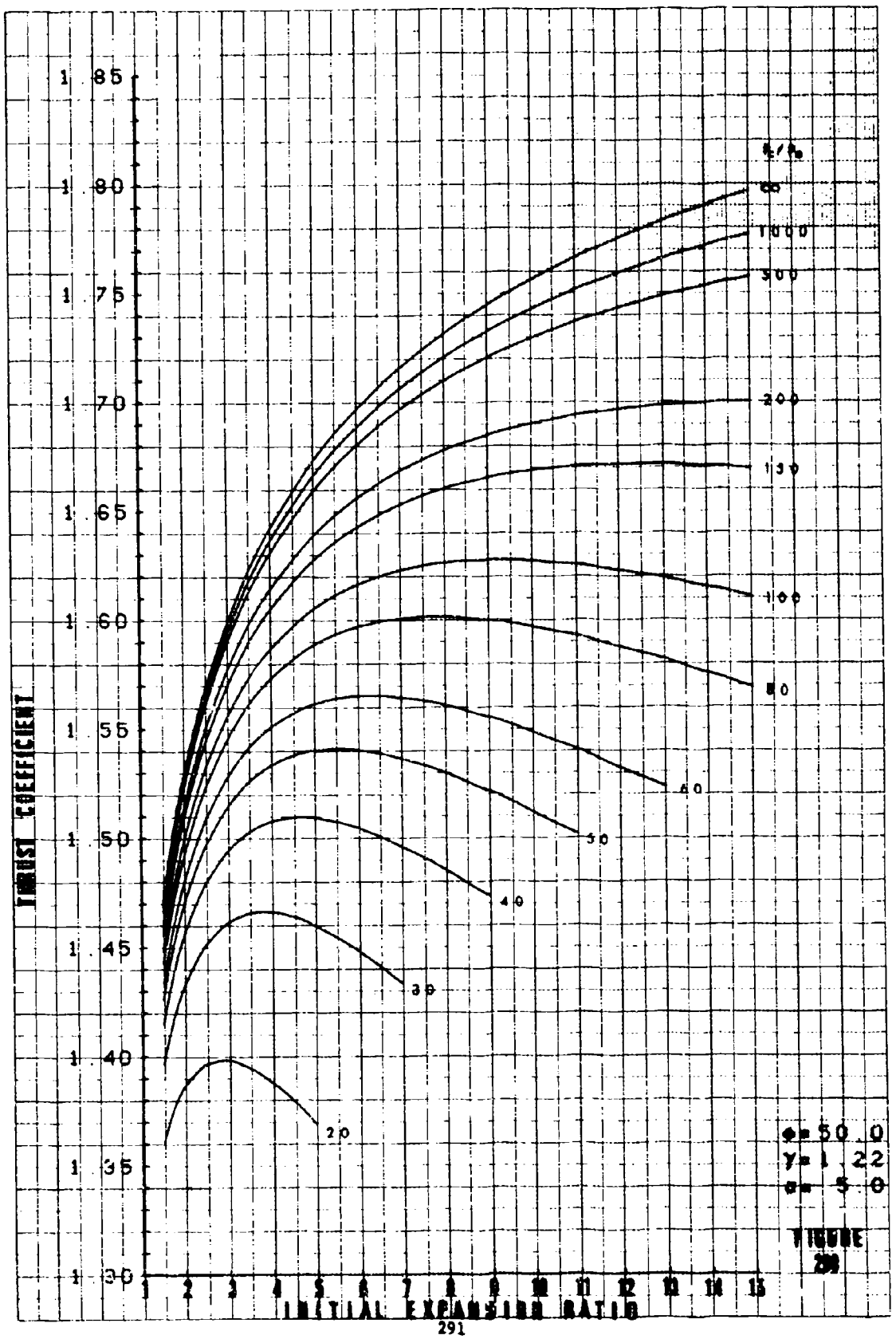
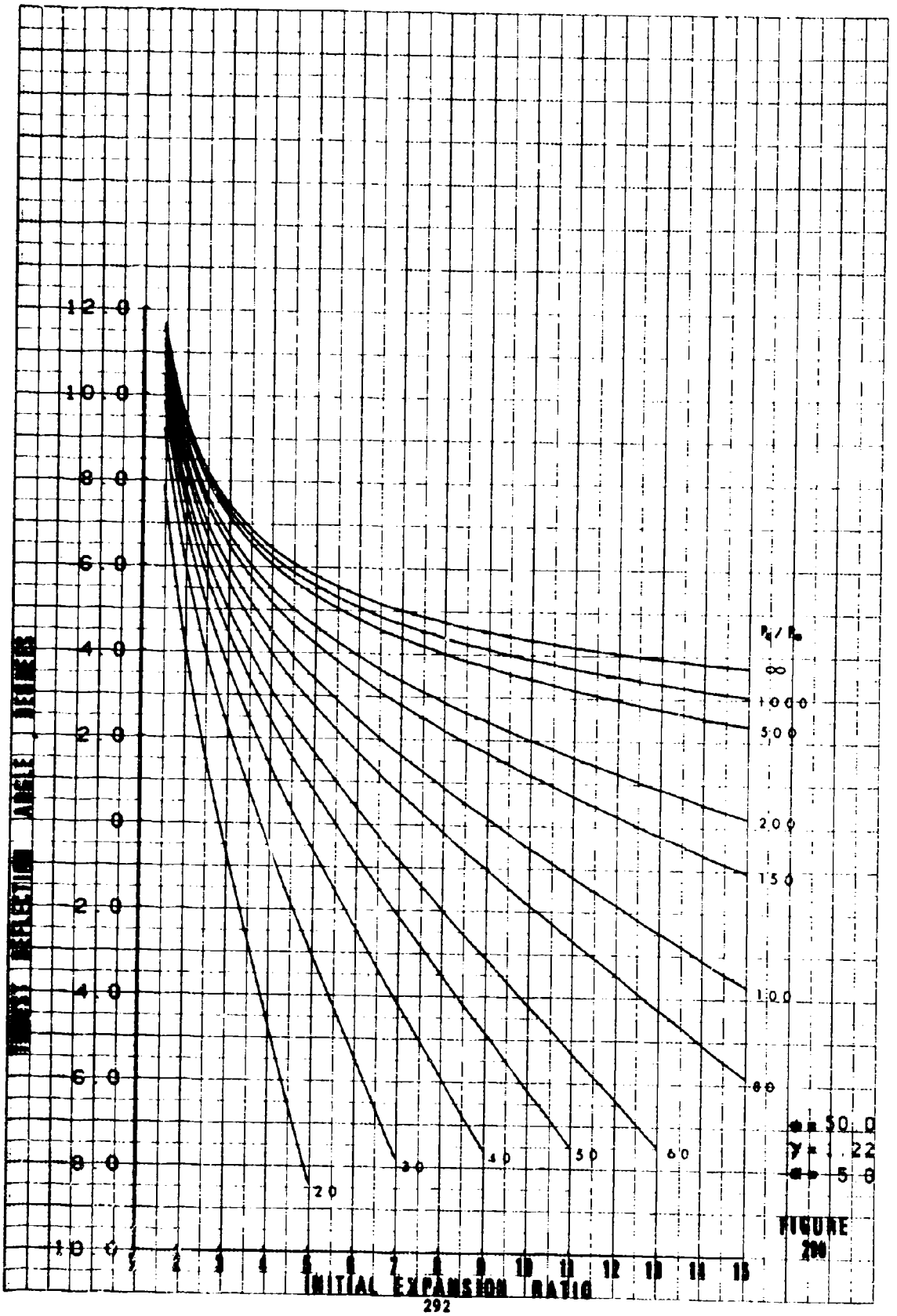

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.22
α= 5.0

FIGURE 28



12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
4.0
6.0
8.0
10.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_a/P_m
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 50.0
γ = 1.22
α = 5.0

FIGURE 290

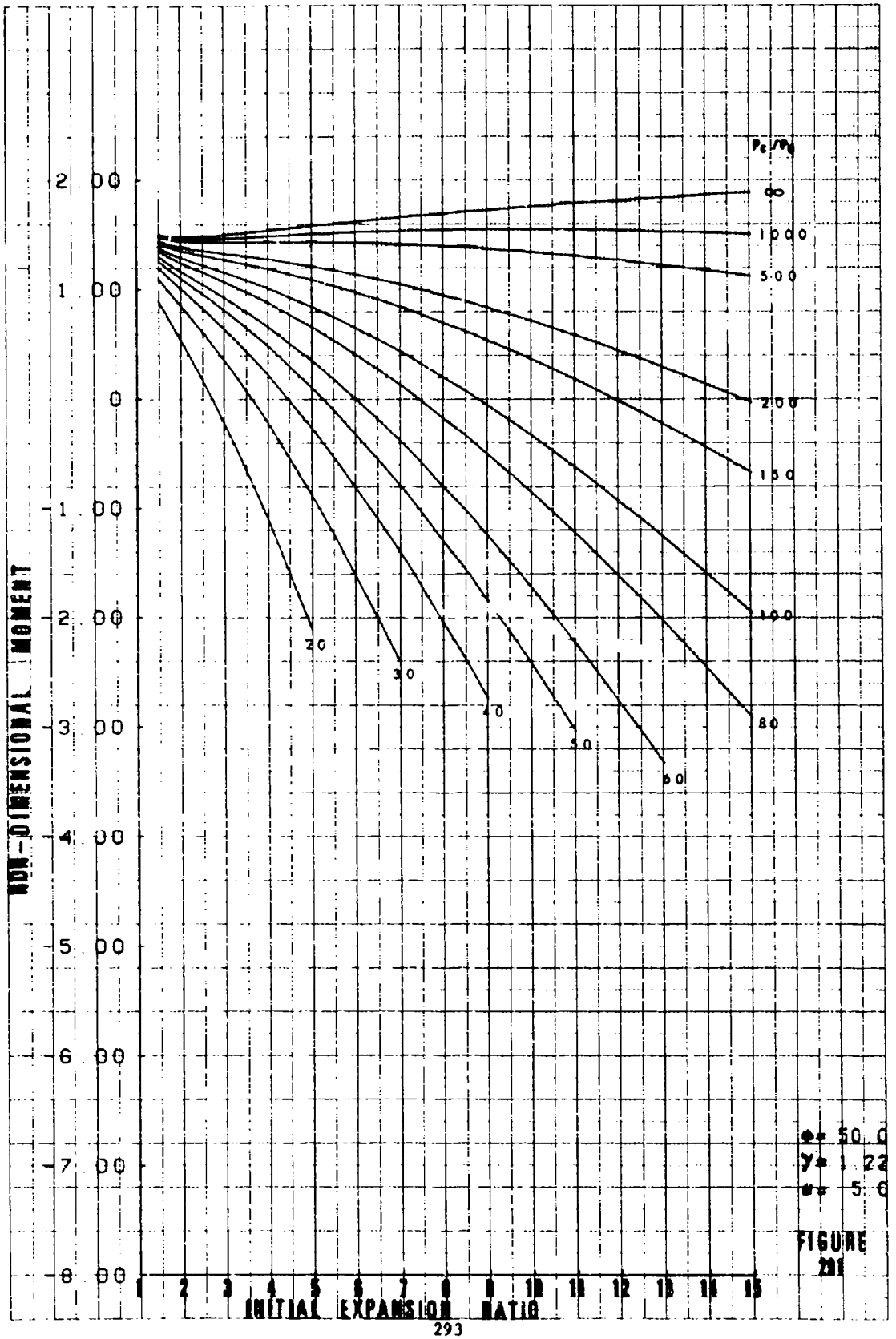

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.22
ε= 5.6

FIGURE 201

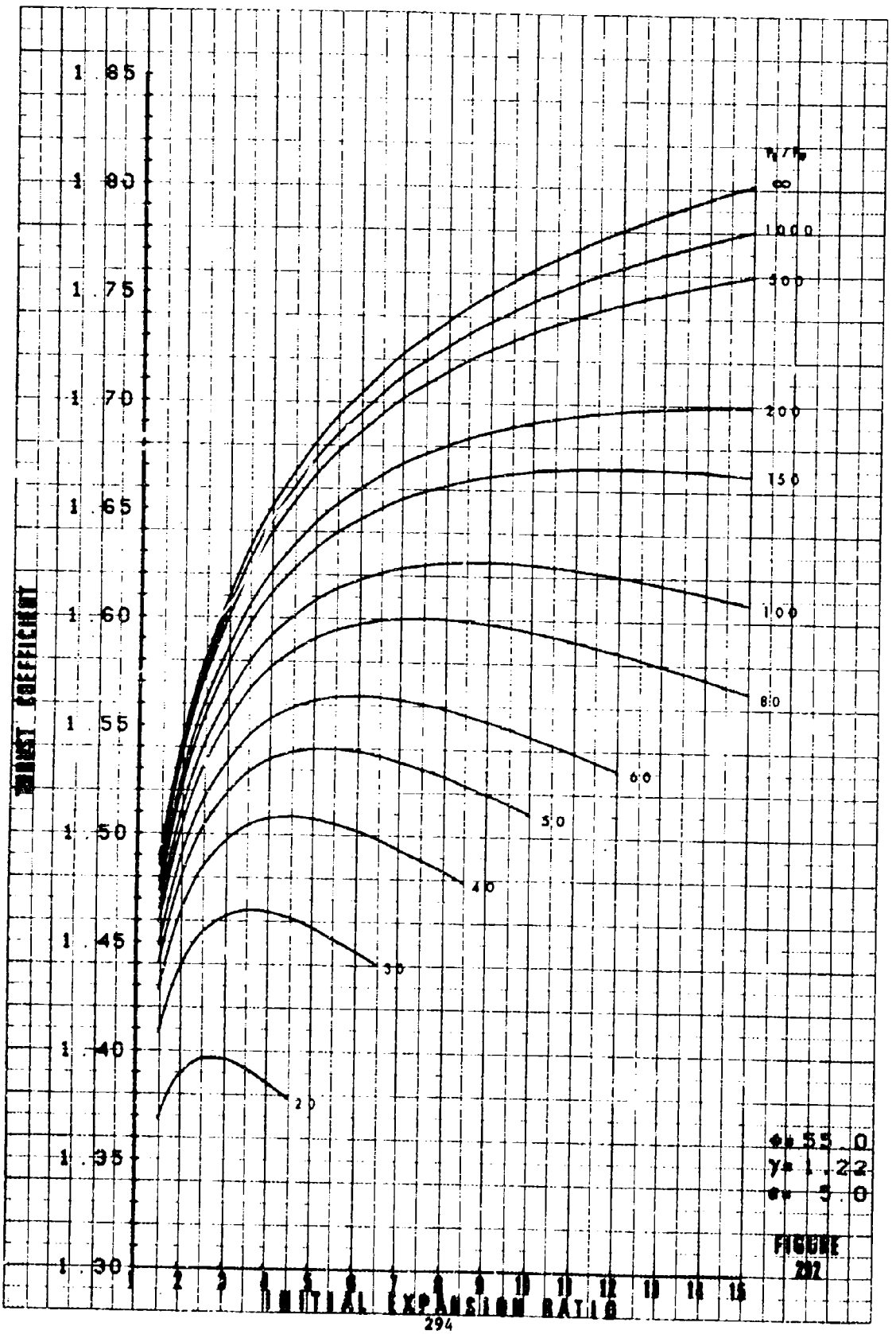

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_1/P_2
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 55.0
γ= 1.22
σ= 5.0

FIGURE 202

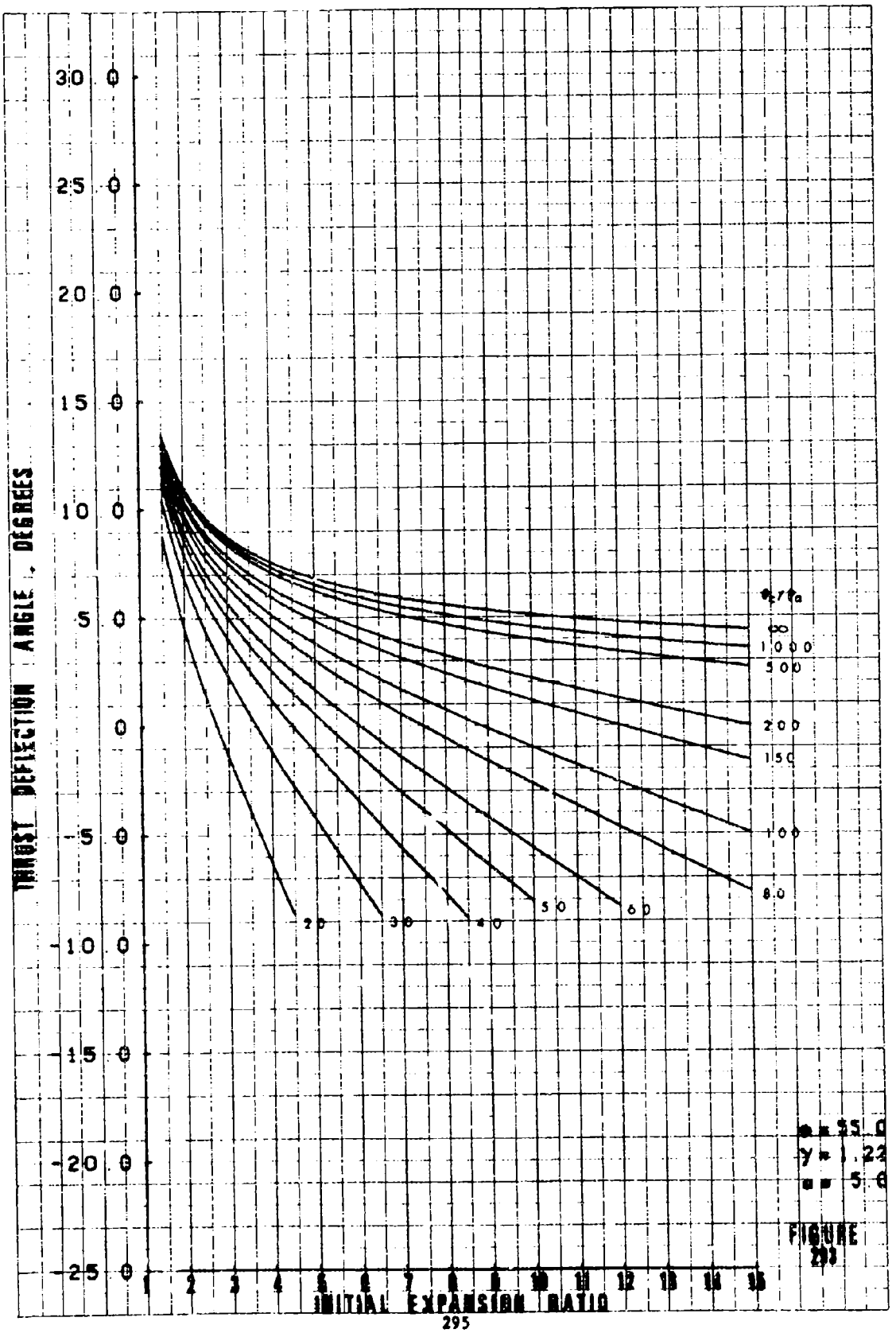

THRUST DEFLECTION ANGLE, DEGREES
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
-20.0
-25.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
θ_c/θ_a
∞
1000
500
200
150
100
80
60
50
40
30
20
θ = 55.0
γ = 1.22
α = 5.0

FIGURE 293

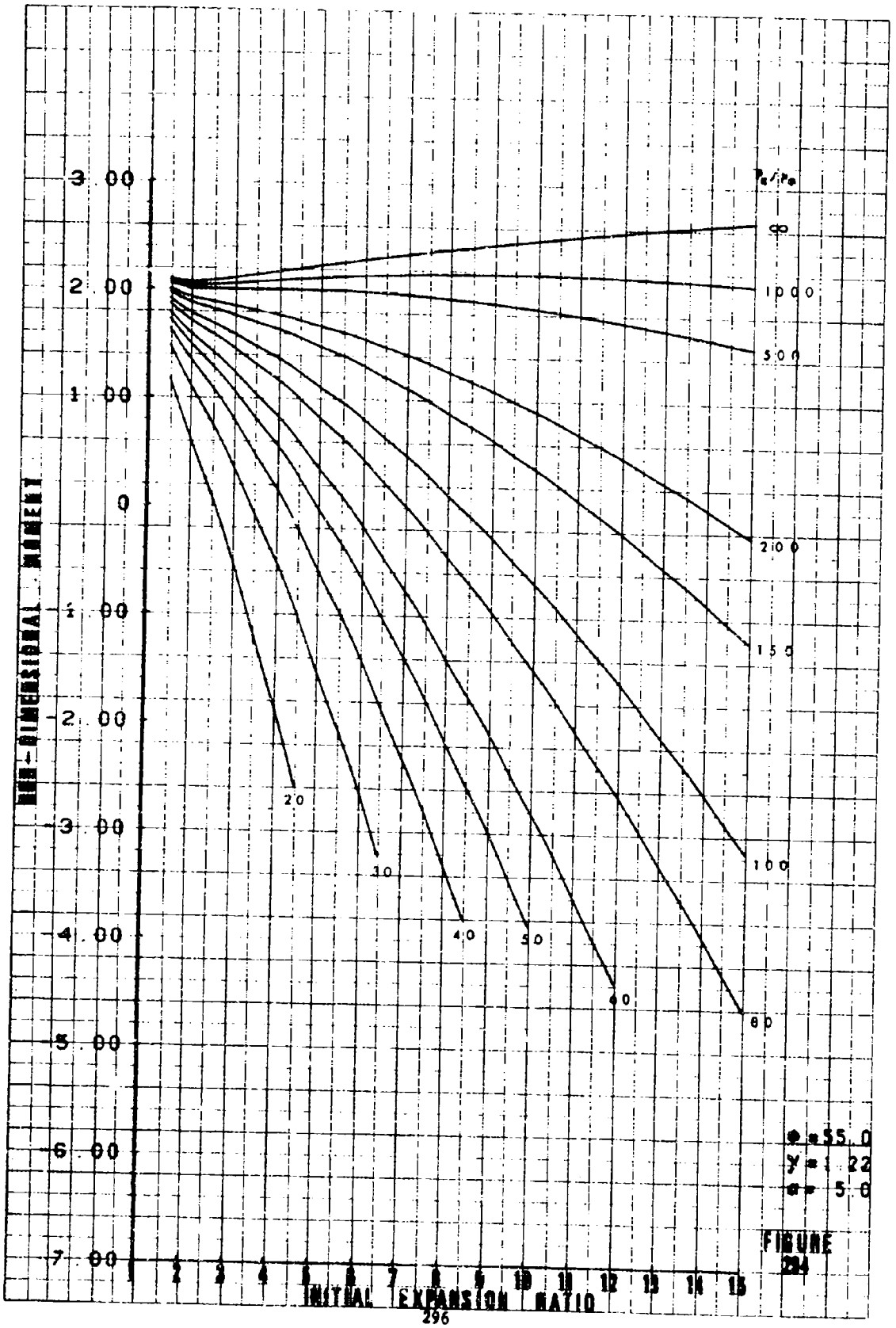

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_e/P_o
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 55.0
γ = 1.22
α = 5.0

FIGURE 294

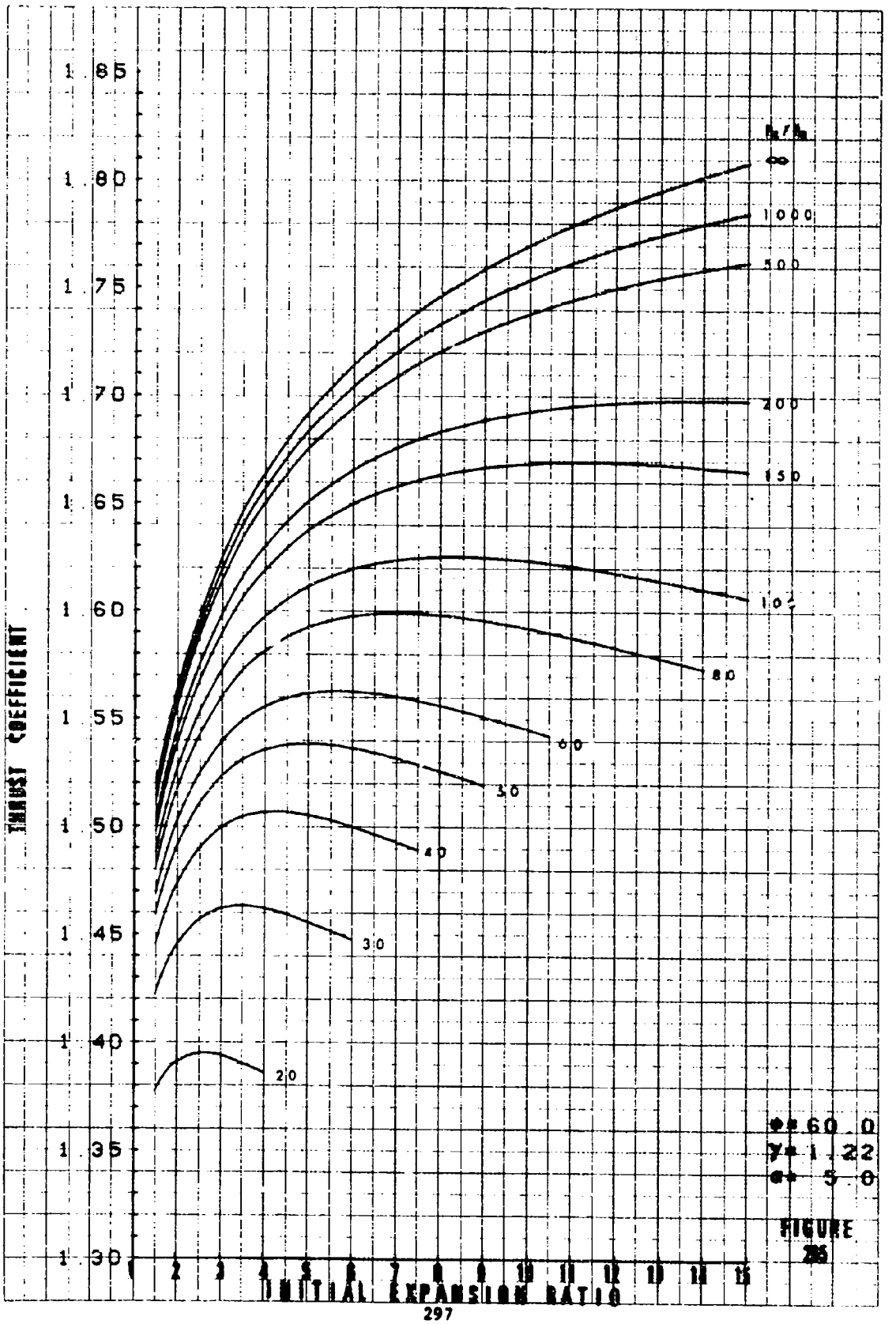

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
h_2/h_1
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.22
α= 5.0

FIGURE 26

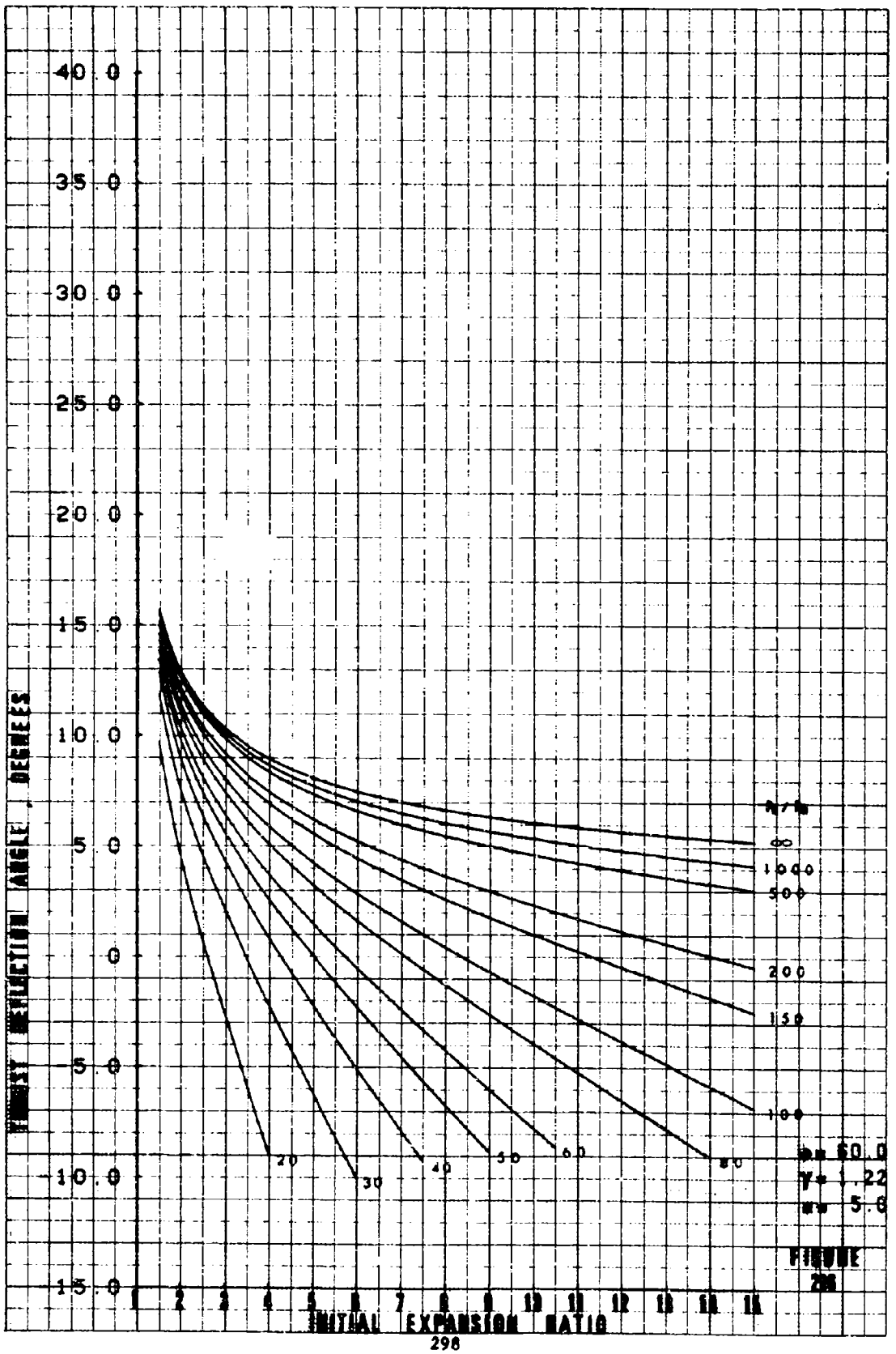

40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
-5.0
-10.0
-15.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.22
m= 5.6

FIGURE 28

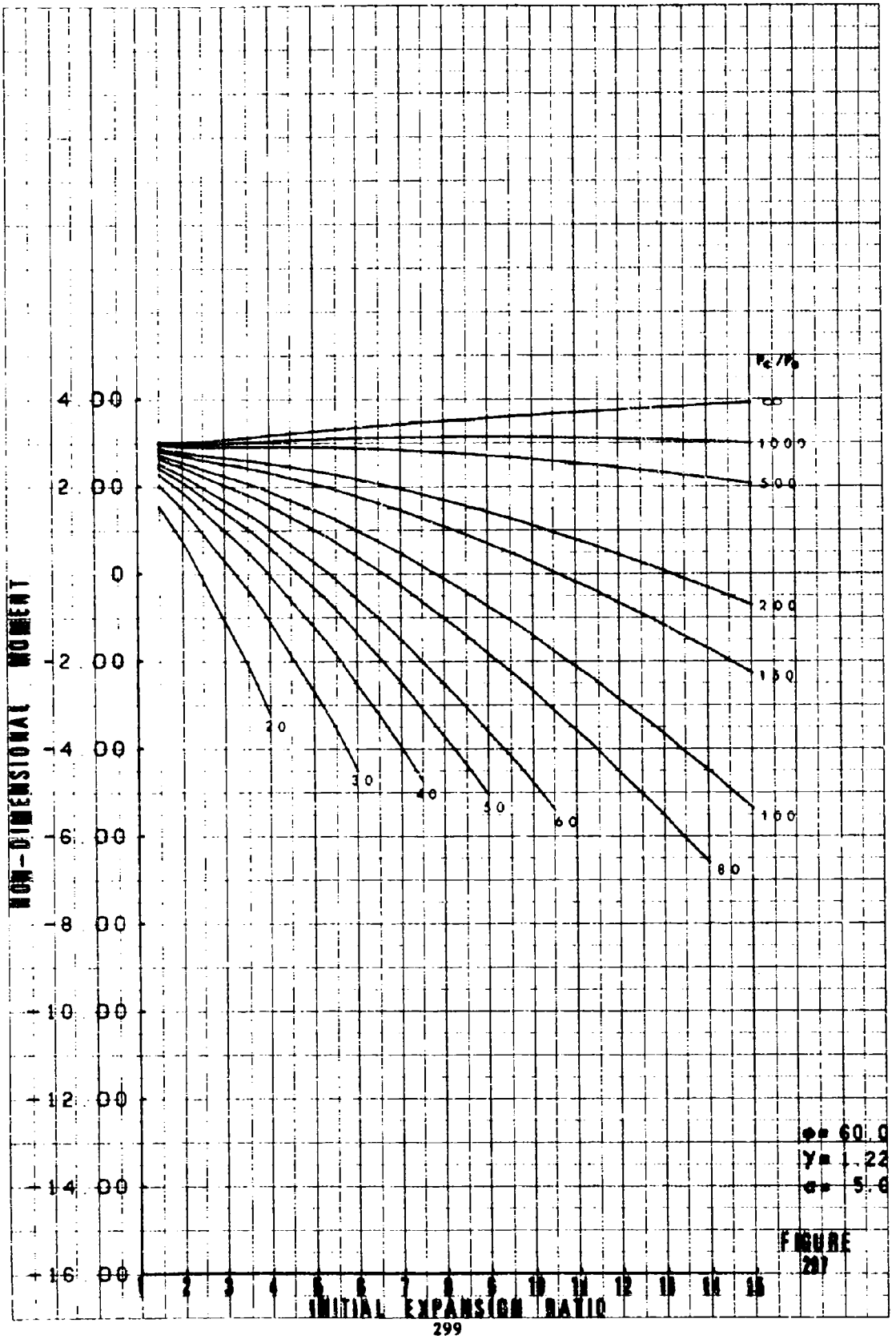
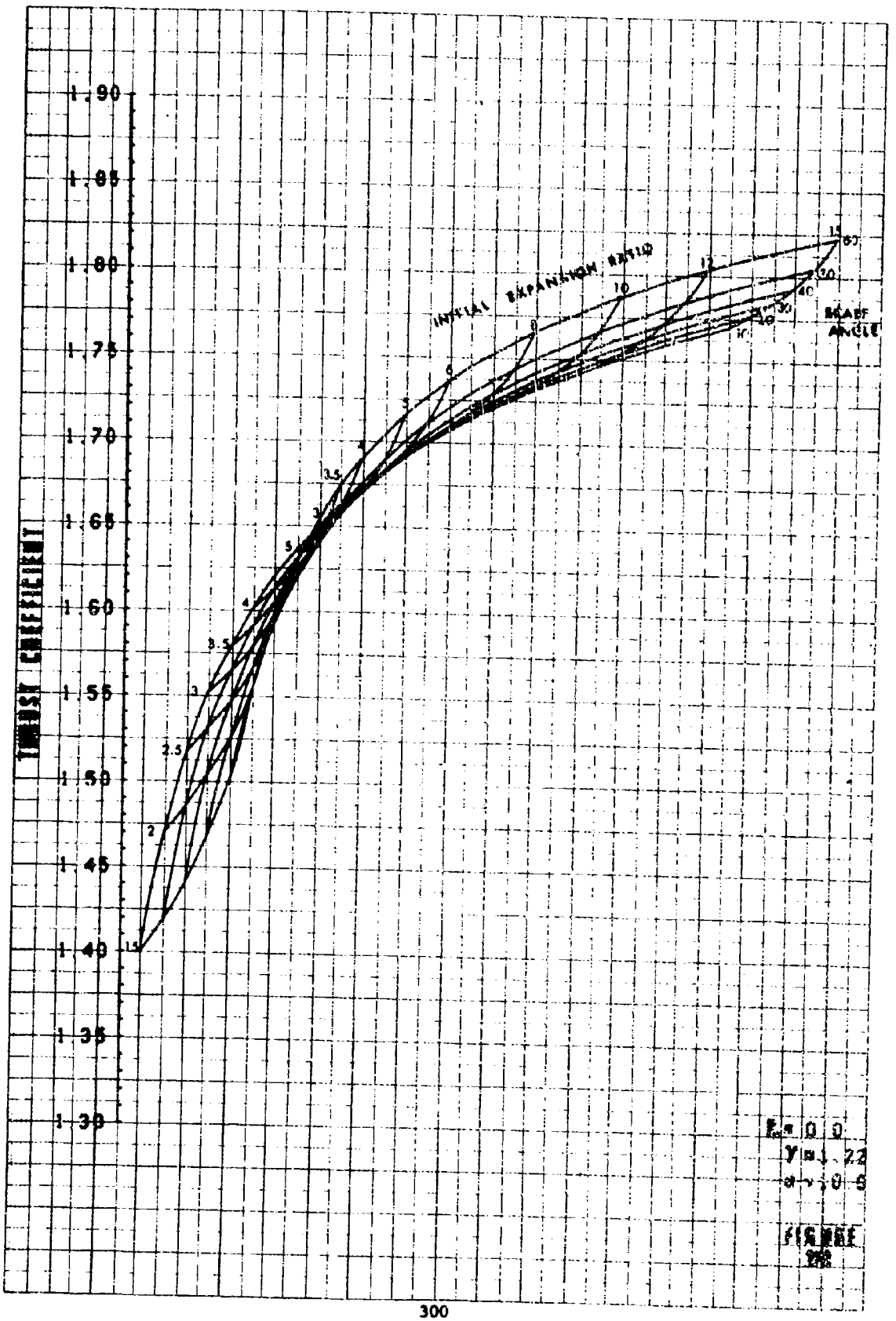

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
4.00
2.00
0
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
-16.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 60.0
γ= 1.22
σ= 5.6

FIGURE 201



THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE

FIGURE

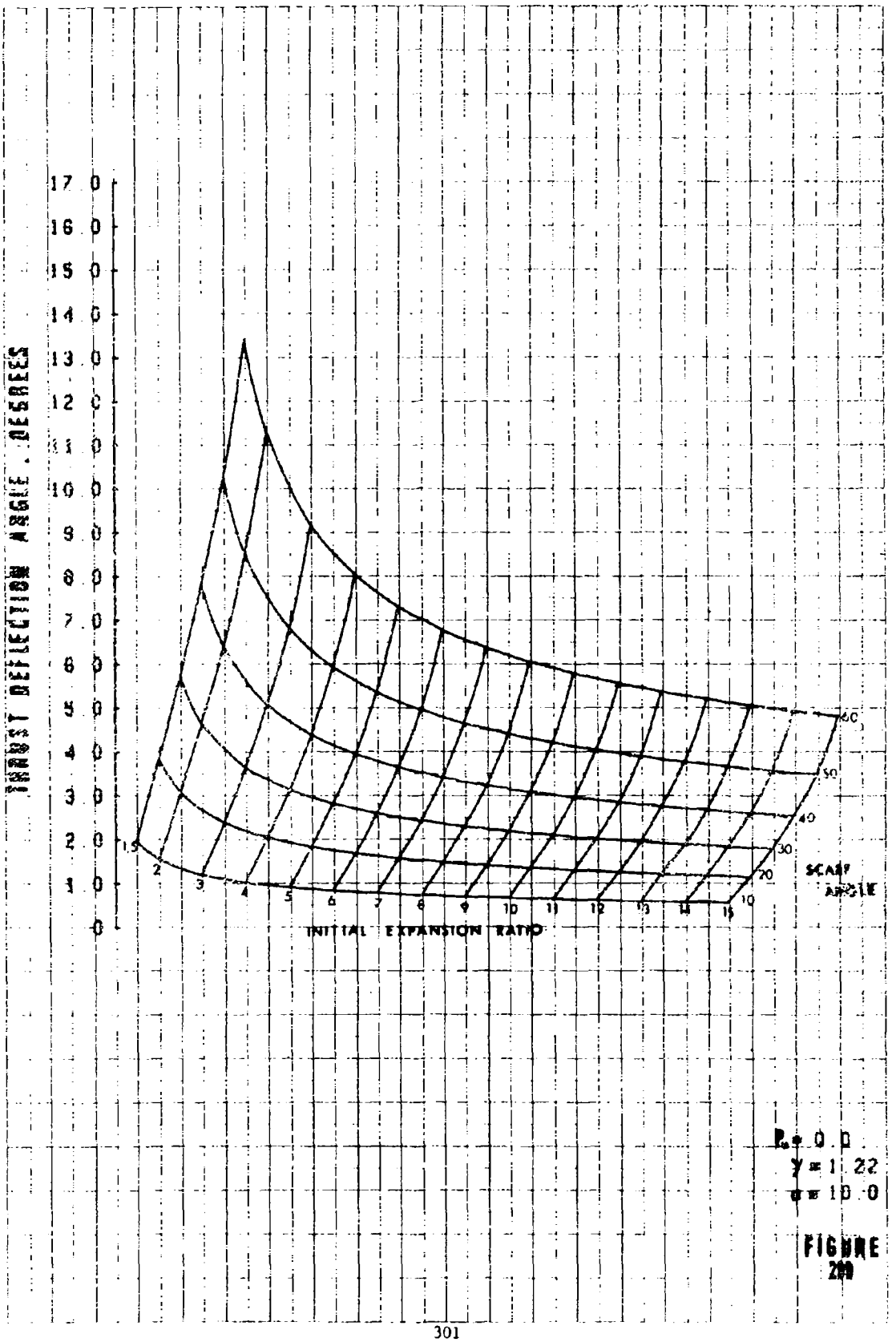
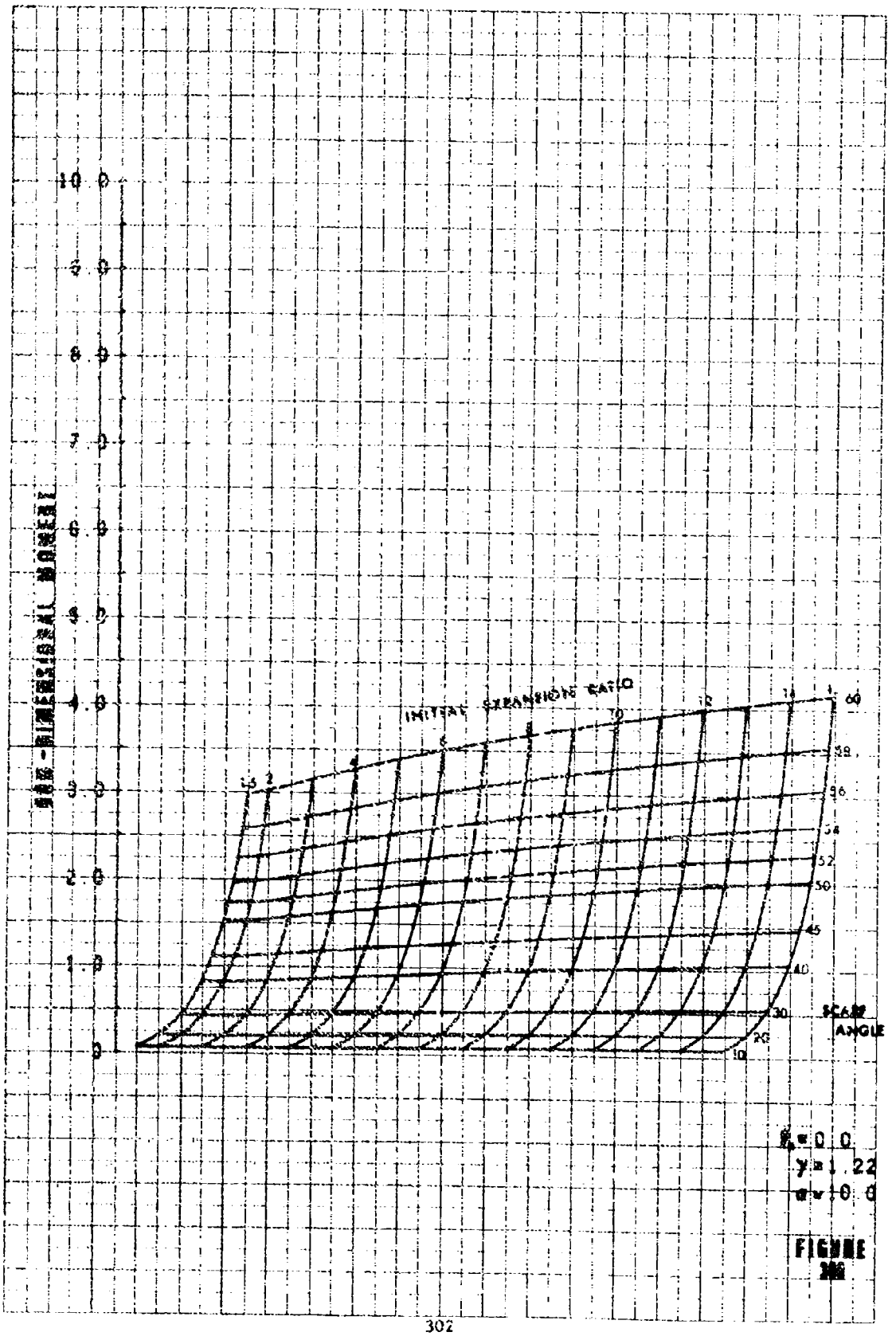
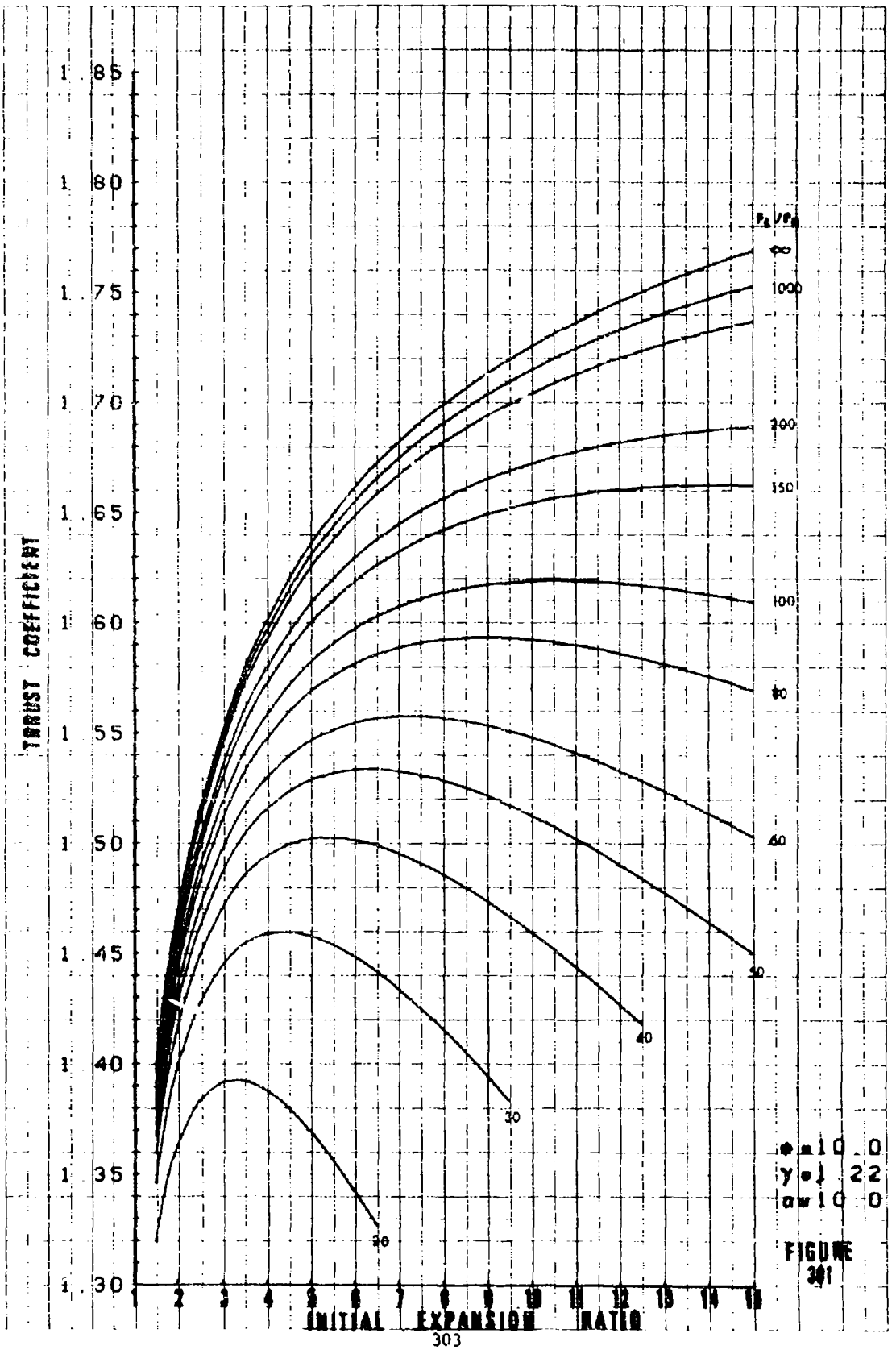

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
60
50
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.22
α = 10.0

FIGURE 200


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
γ = 1.22

FIGURE



TRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.22
α = 10.0

FIGURE 301

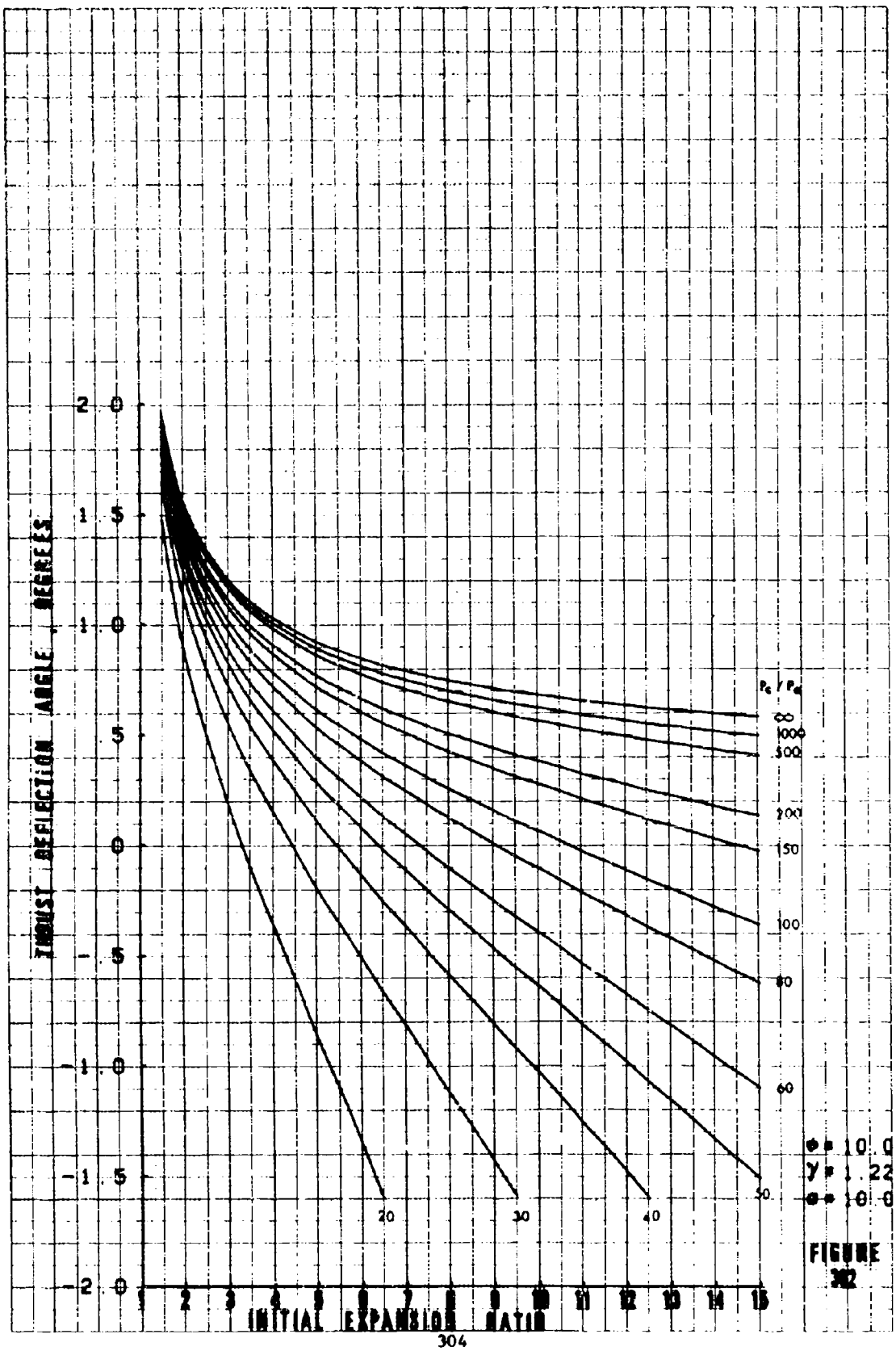

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
200
150
100
80
60
50
20
30
40
γ = 1.22

FIGURE 302

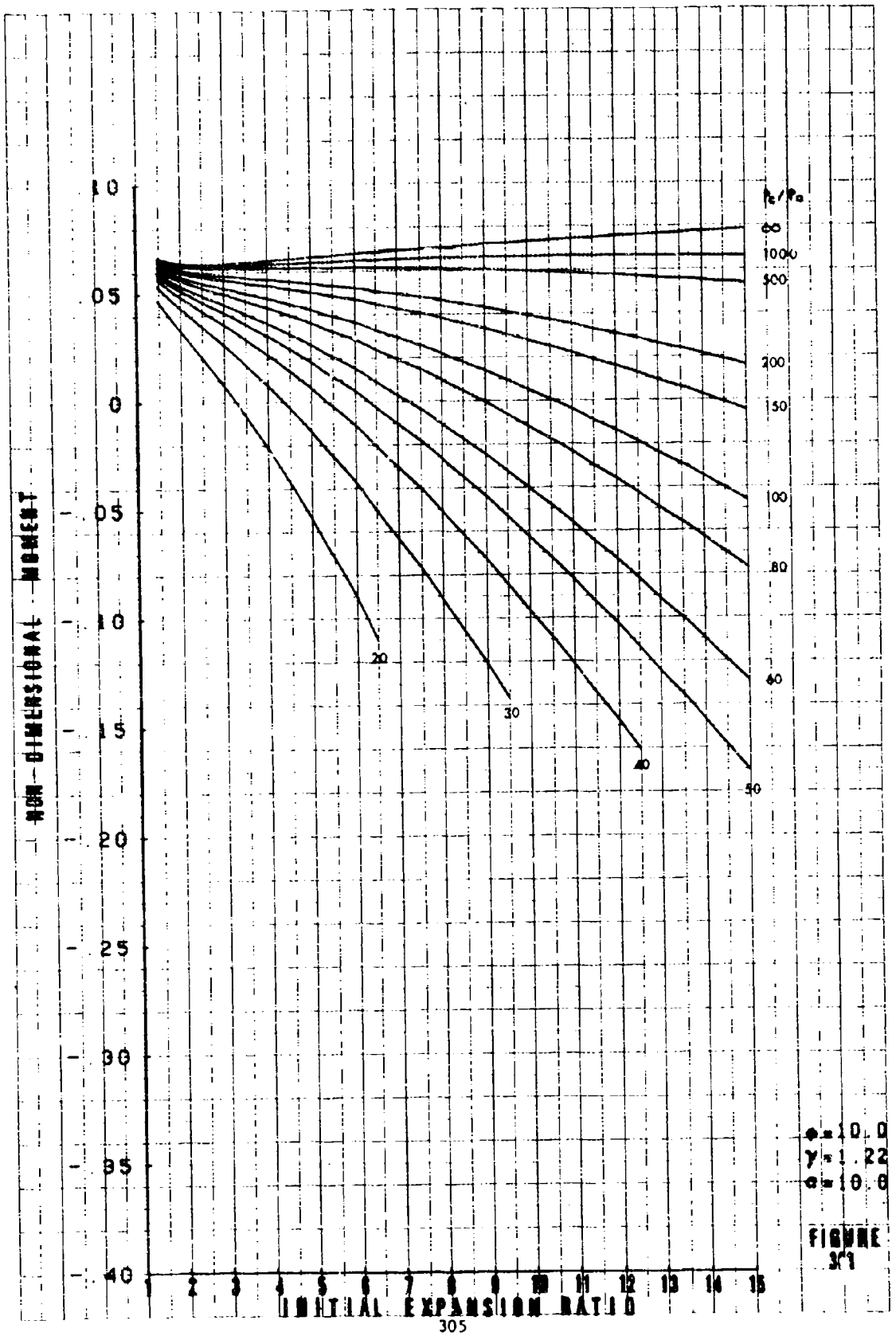

NON-DIMENSIONAL INERTIA MOMENT
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=10.0
γ=1.22
α=10.0

FIGURE 3C1

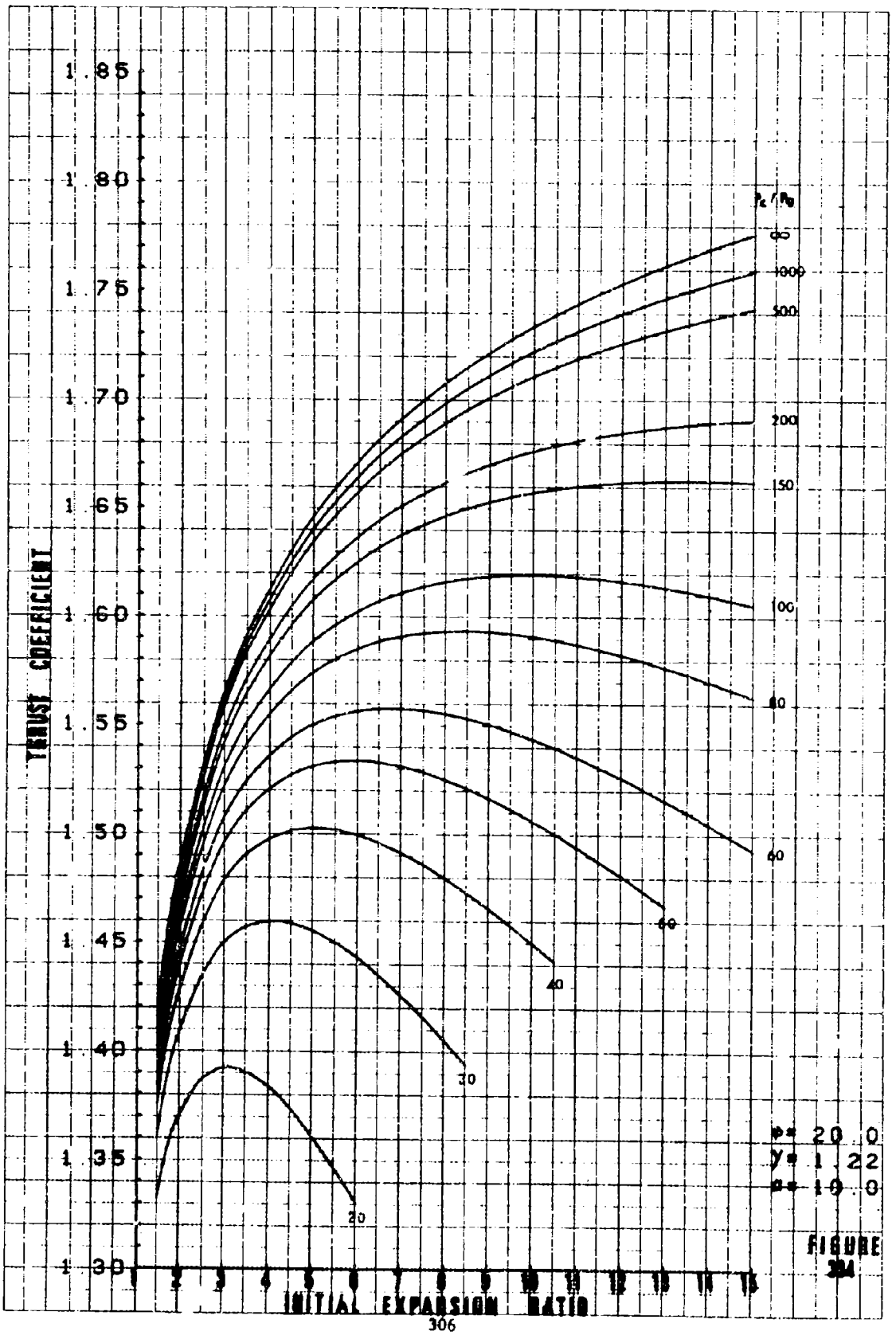

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 20.0
γ= 1.22
α= 10.0

FIGURE 3A

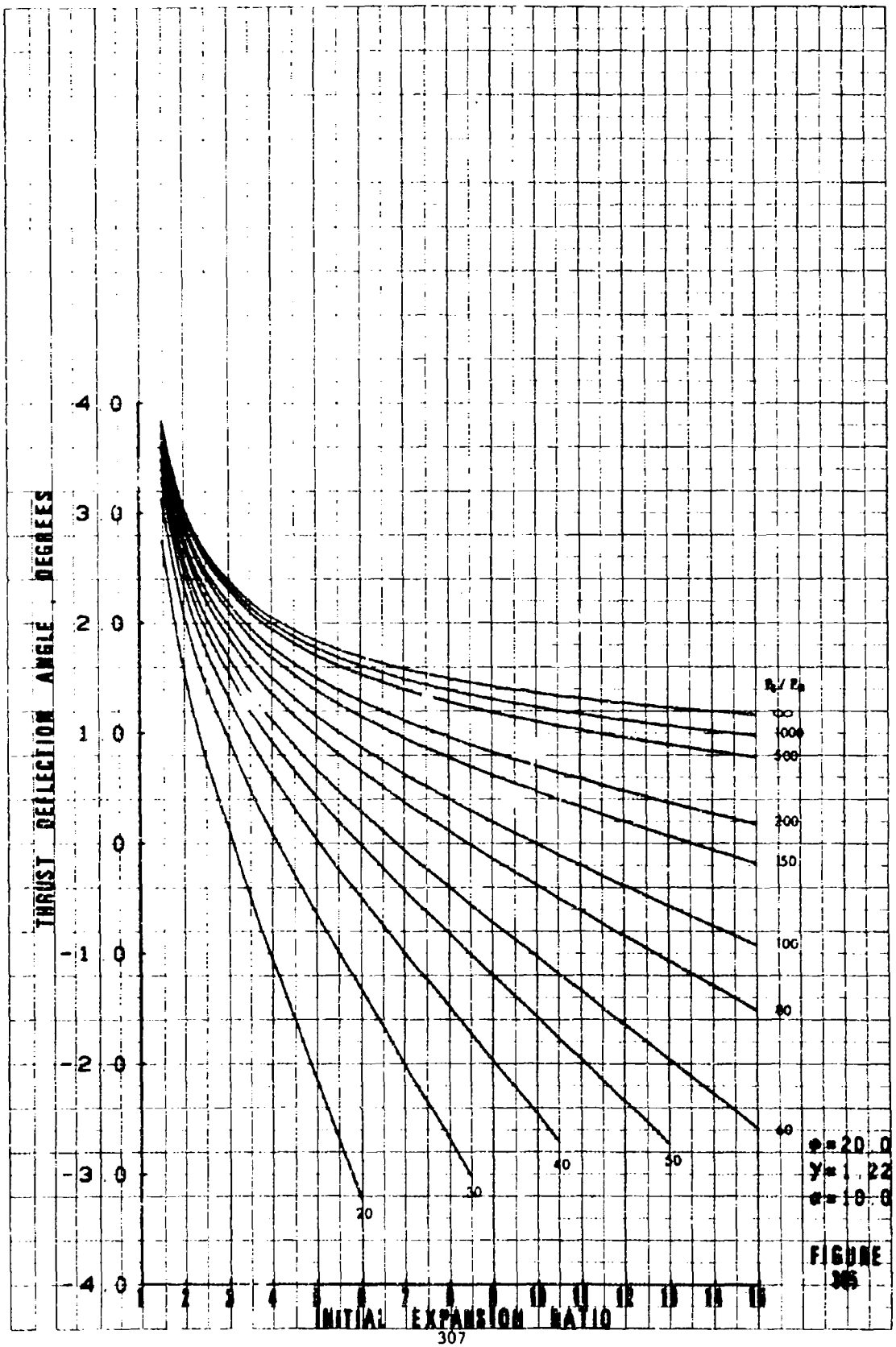

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
R_2/R_1
∞
1000
500
200
150
100
80
60
40
30
20
φ = 20.0
γ = 1.22
ε = 10.0

FIGURE 36

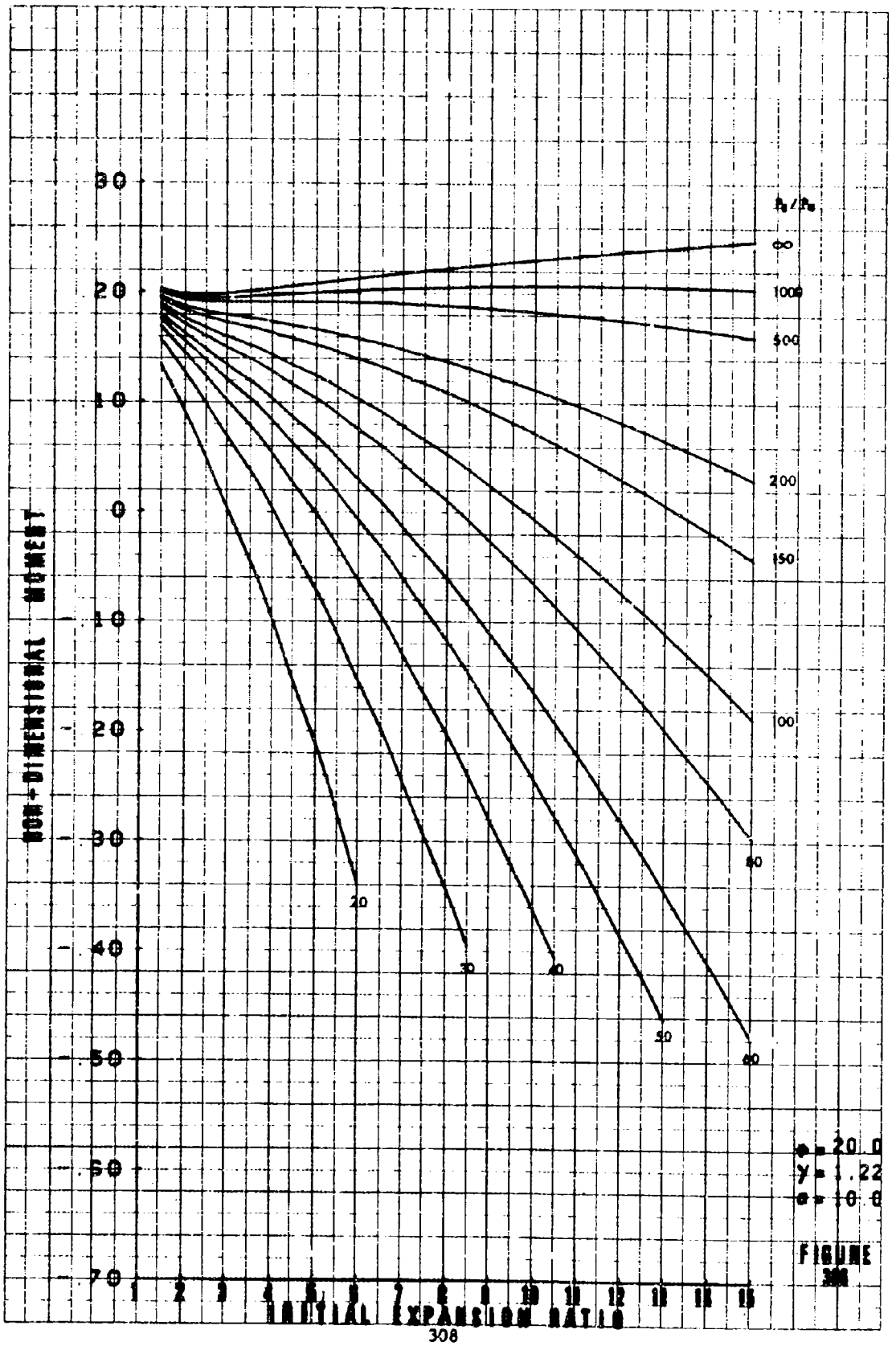

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
γ = 1.22

FIGURE 308

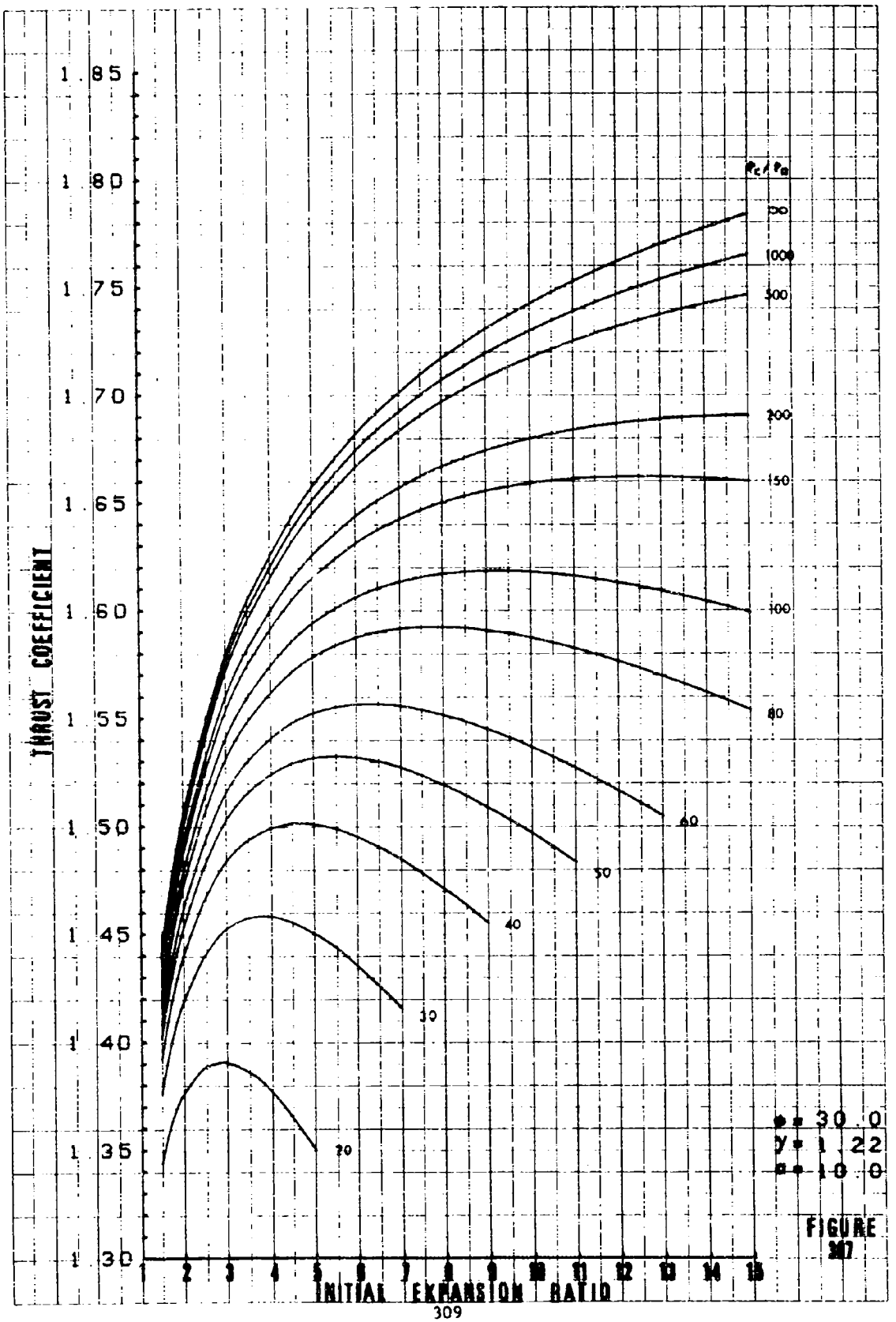
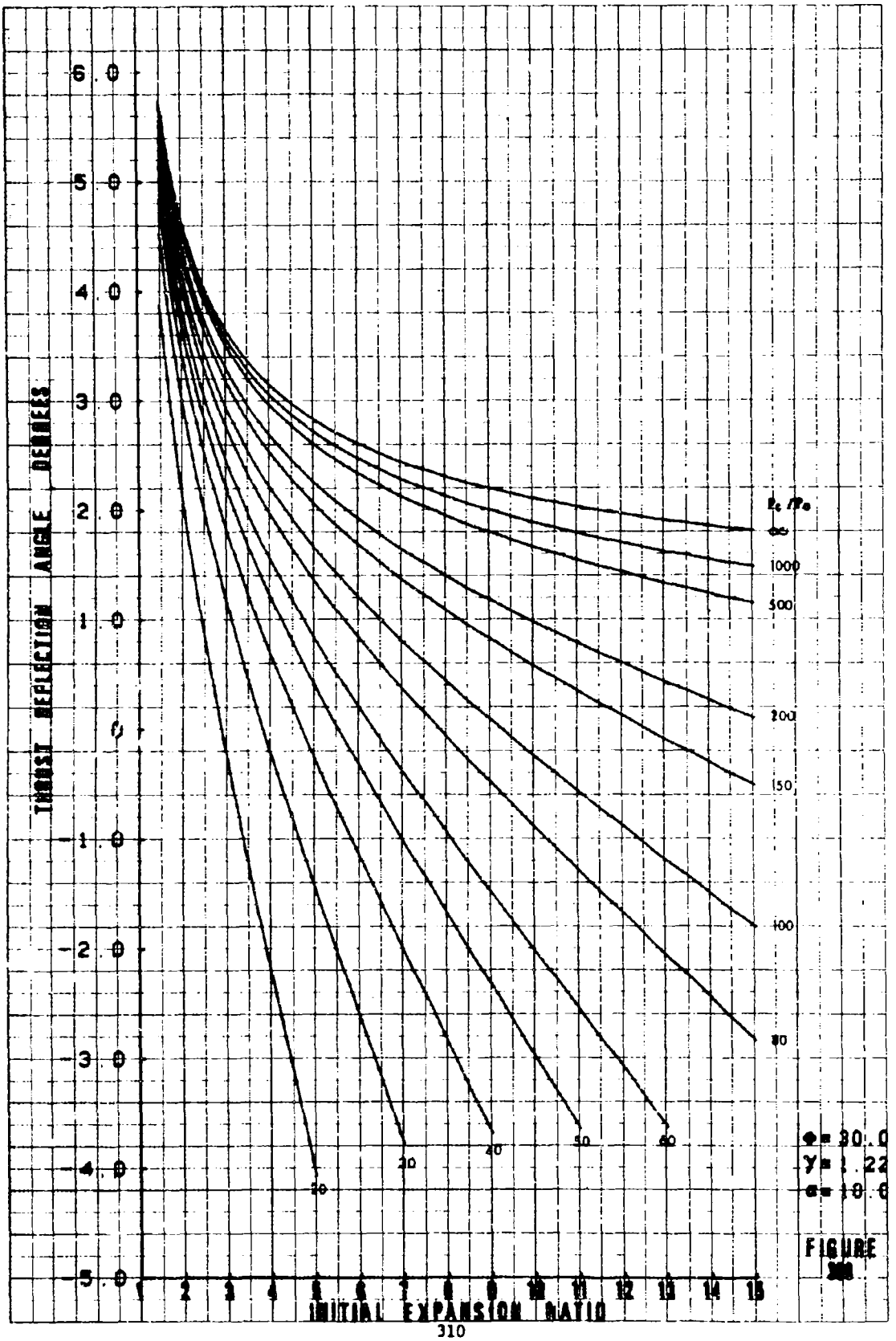
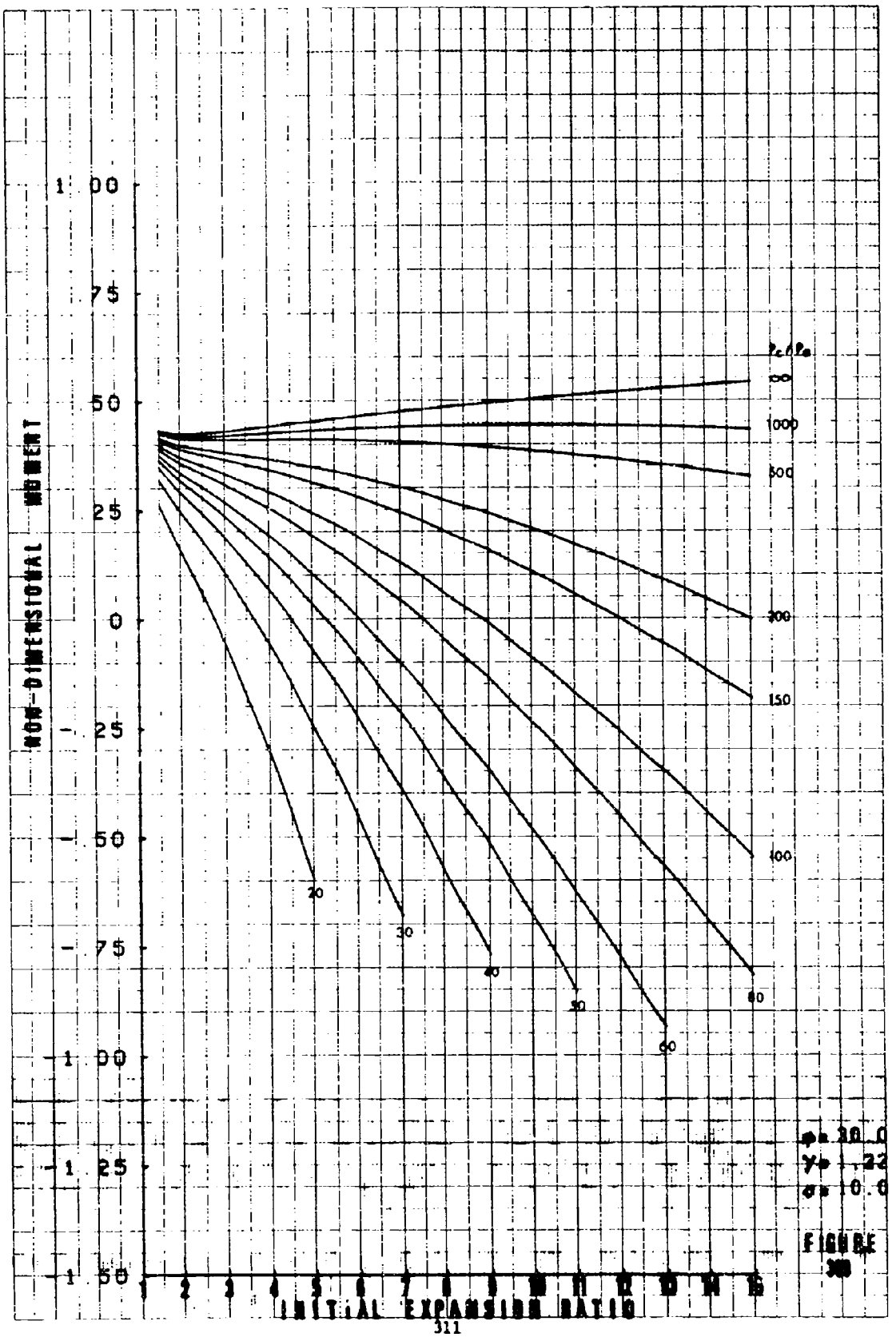
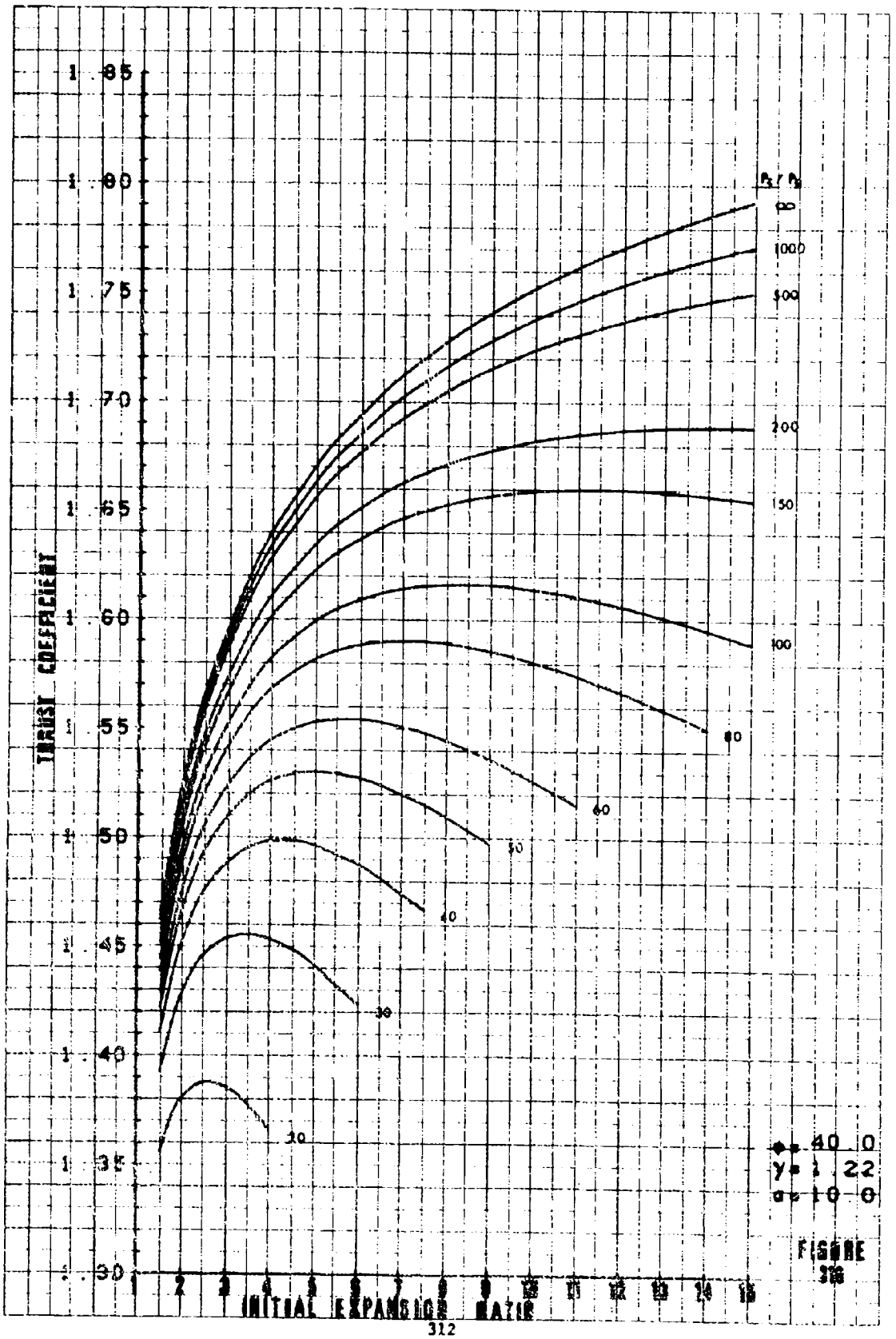

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
= 30.0
γ = 1.22
= 10.0

FIGURE 307


THRUST DEFLECTION ANGLE DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c MPa
∞
1000
500
200
150
100
80
10
20
40
50
60
φ= 30.0
γ= 1.22
α= 10.6

FIGURE


NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
300
150
100
80
60
50
40
30
20
FIGURE



THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.22
α = 10.0

FIGURE 316

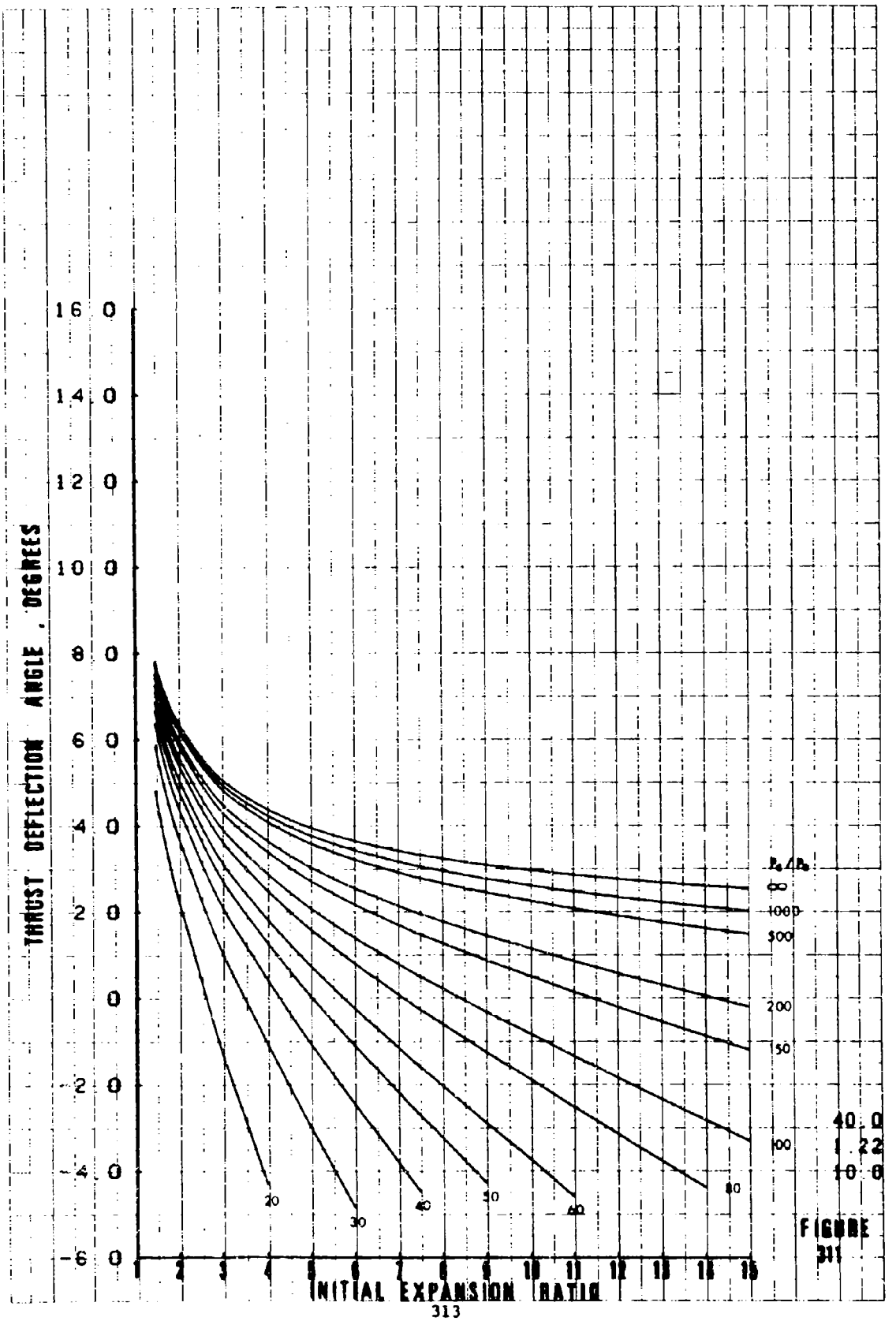

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
200
500
1000
∞
40.0
1.22
10.0

FIGURE 311

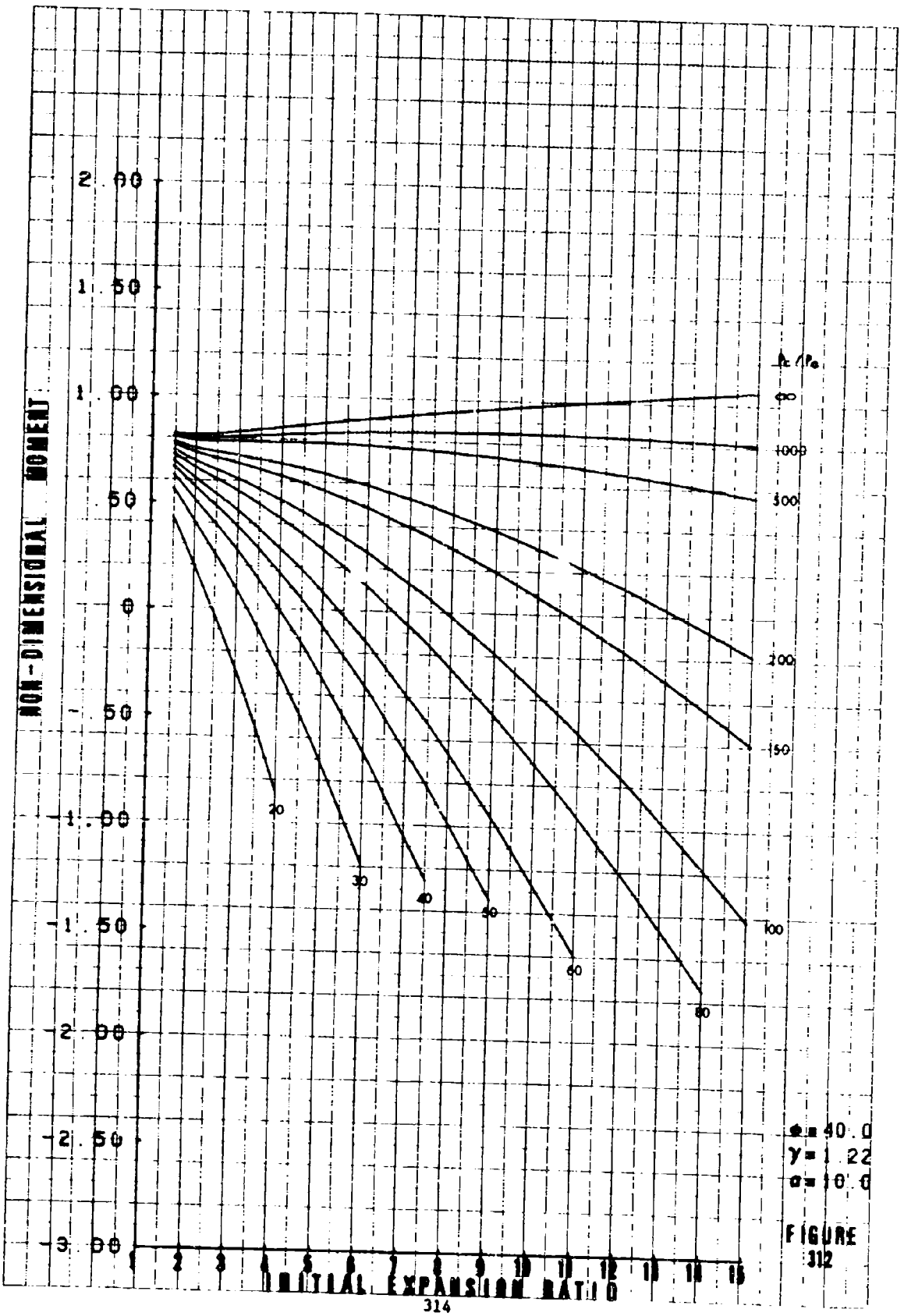

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
20
30
40
50
60
80
ϕ= 40.0
γ= 1.22
α= 10.0

FIGURE 312

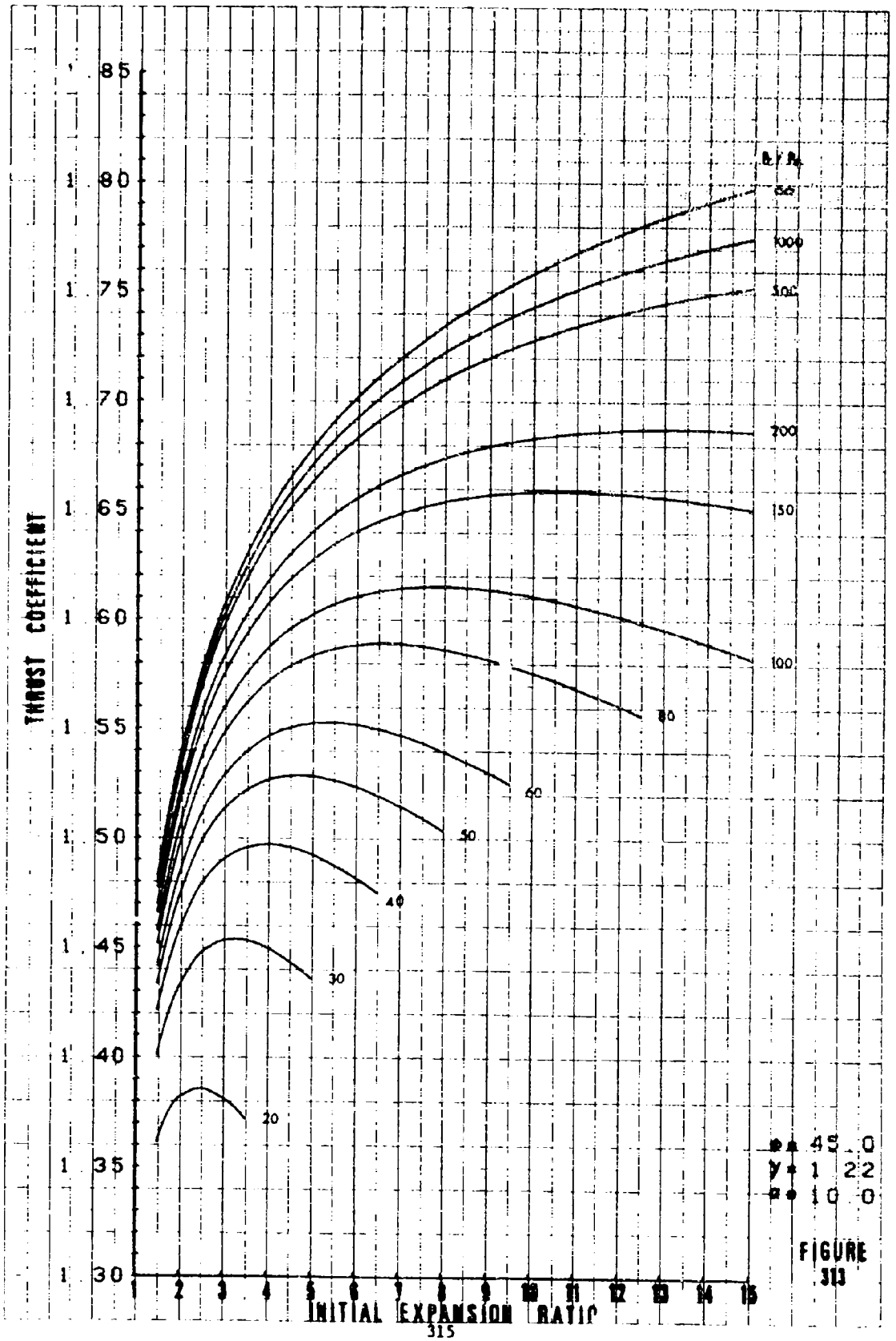

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
300
200
150
100
80
60
50
40
30
20
45.0
1.22
10.0

FIGURE 313

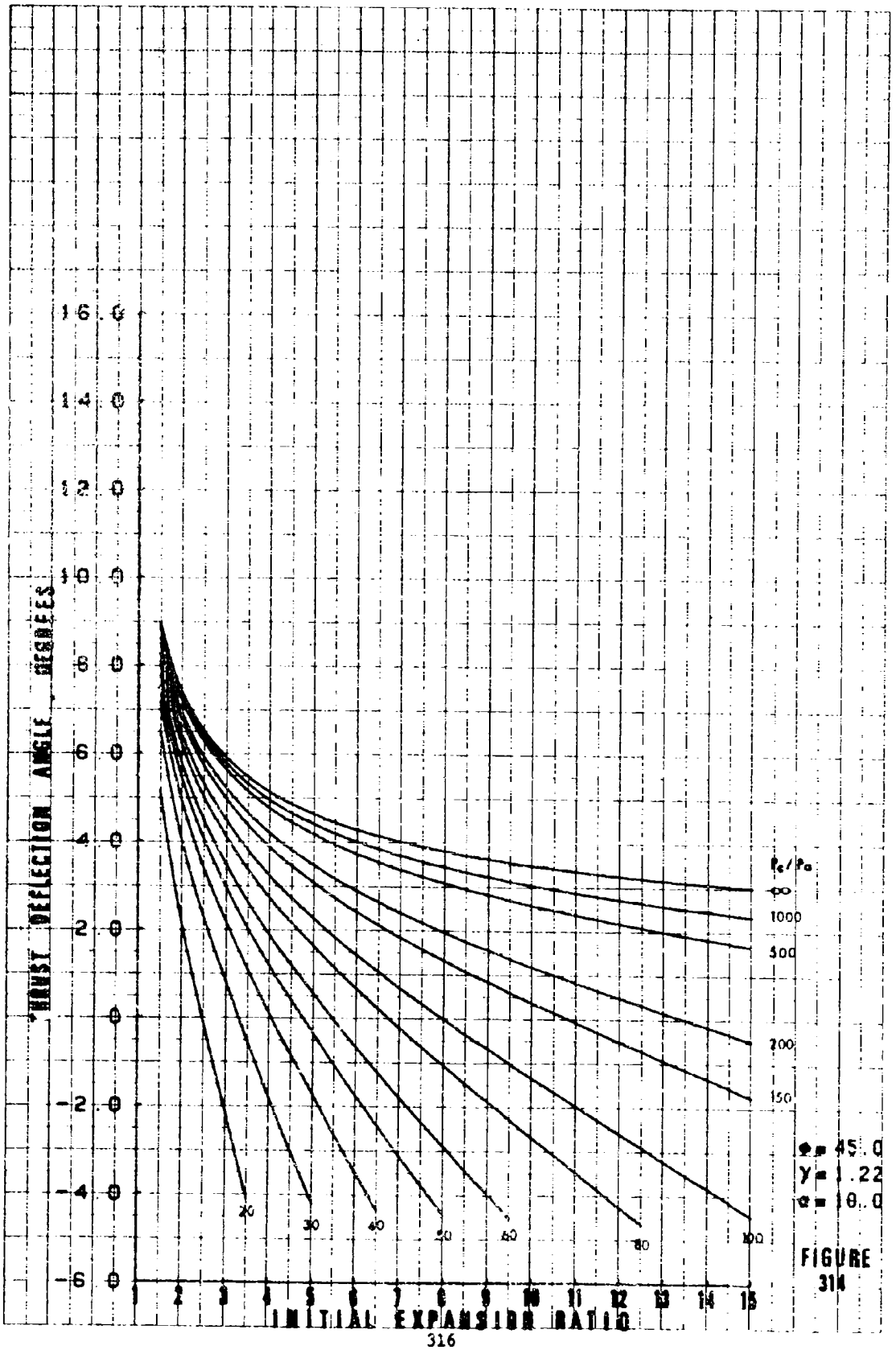

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.22
α = 10.0

FIGURE 314

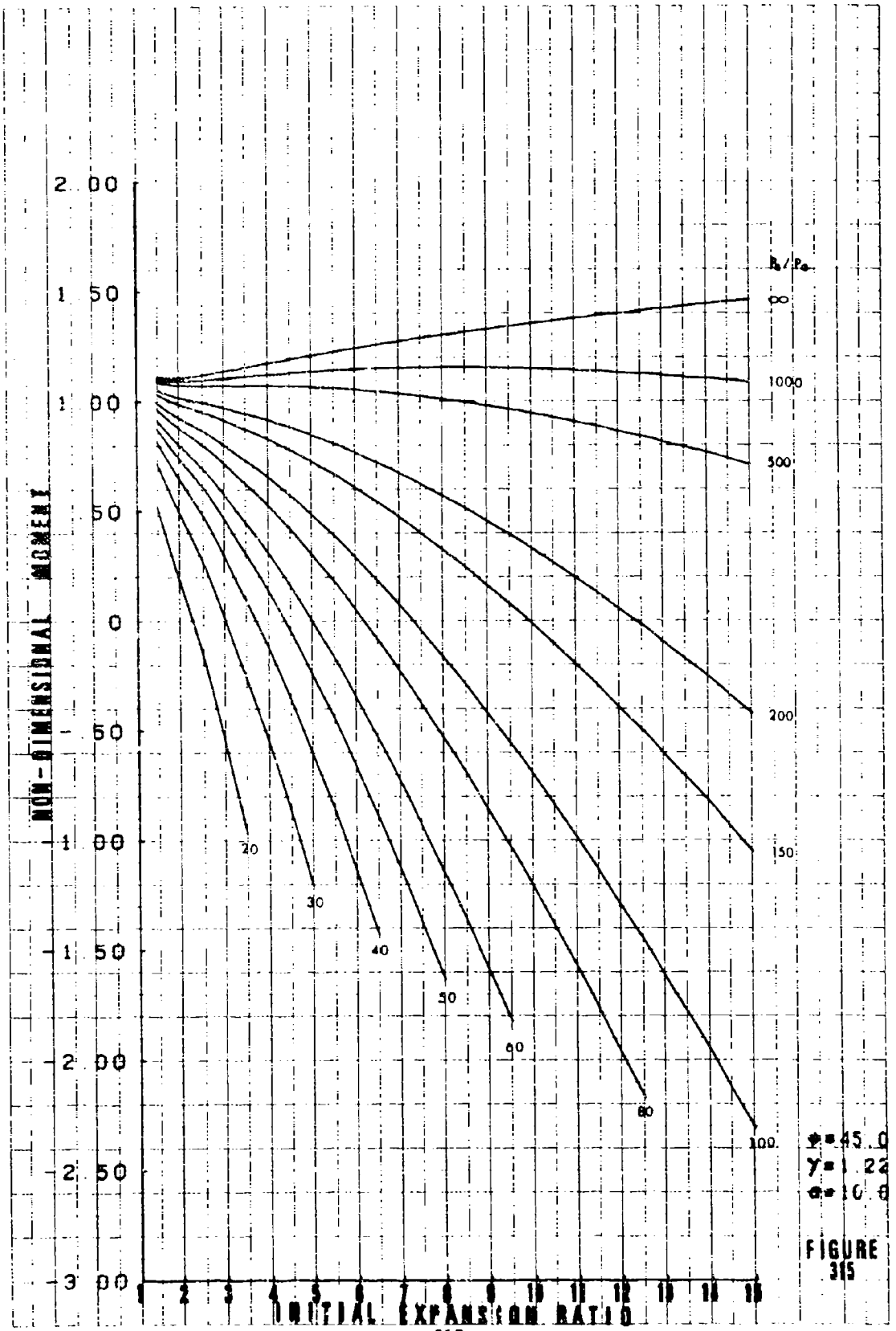

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_b/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=45.0
γ=1.22
α=10.0

FIGURE 315

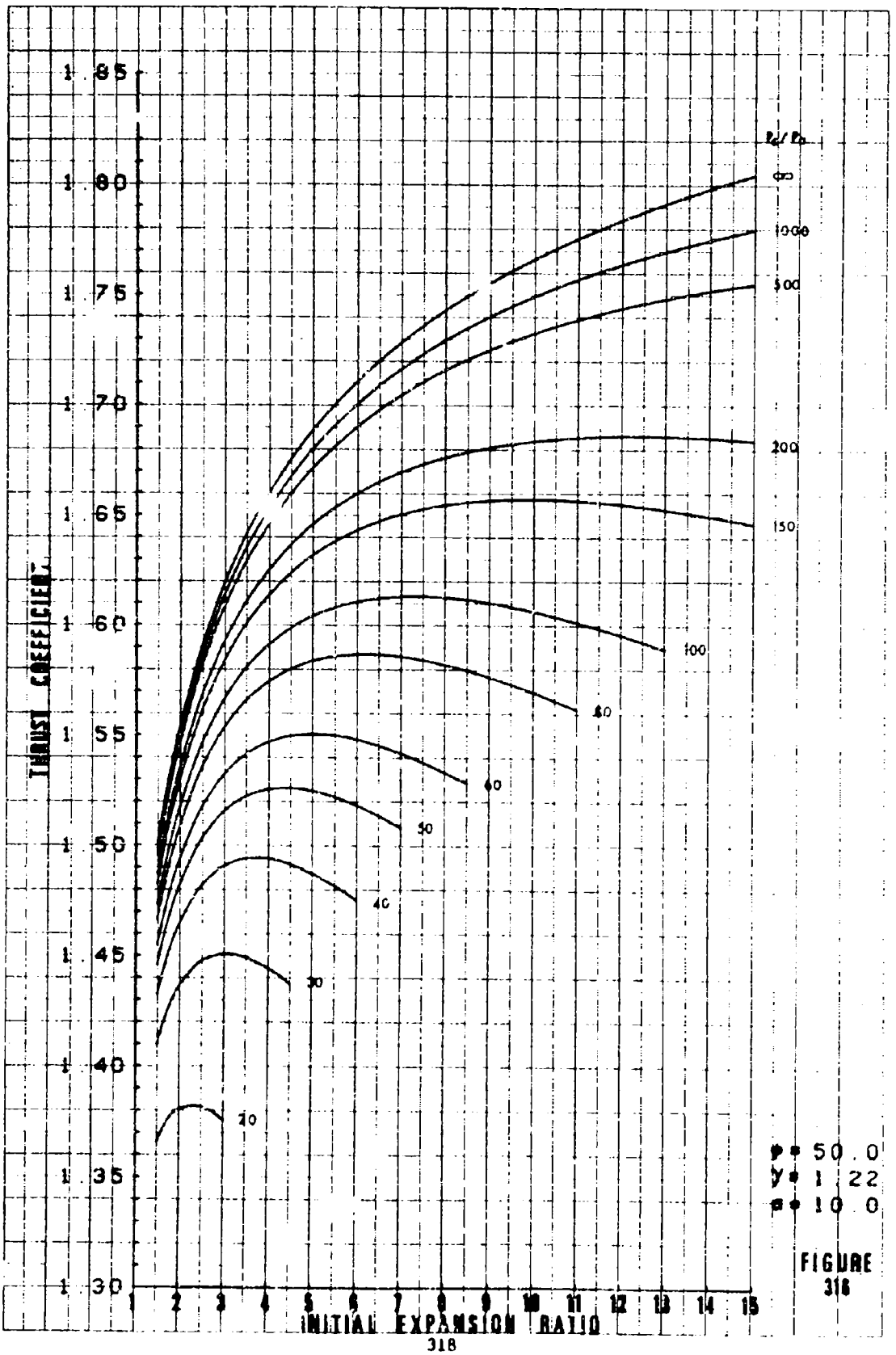

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
P = 50.0
γ = 1.22
ε = 10.0

FIGURE 318

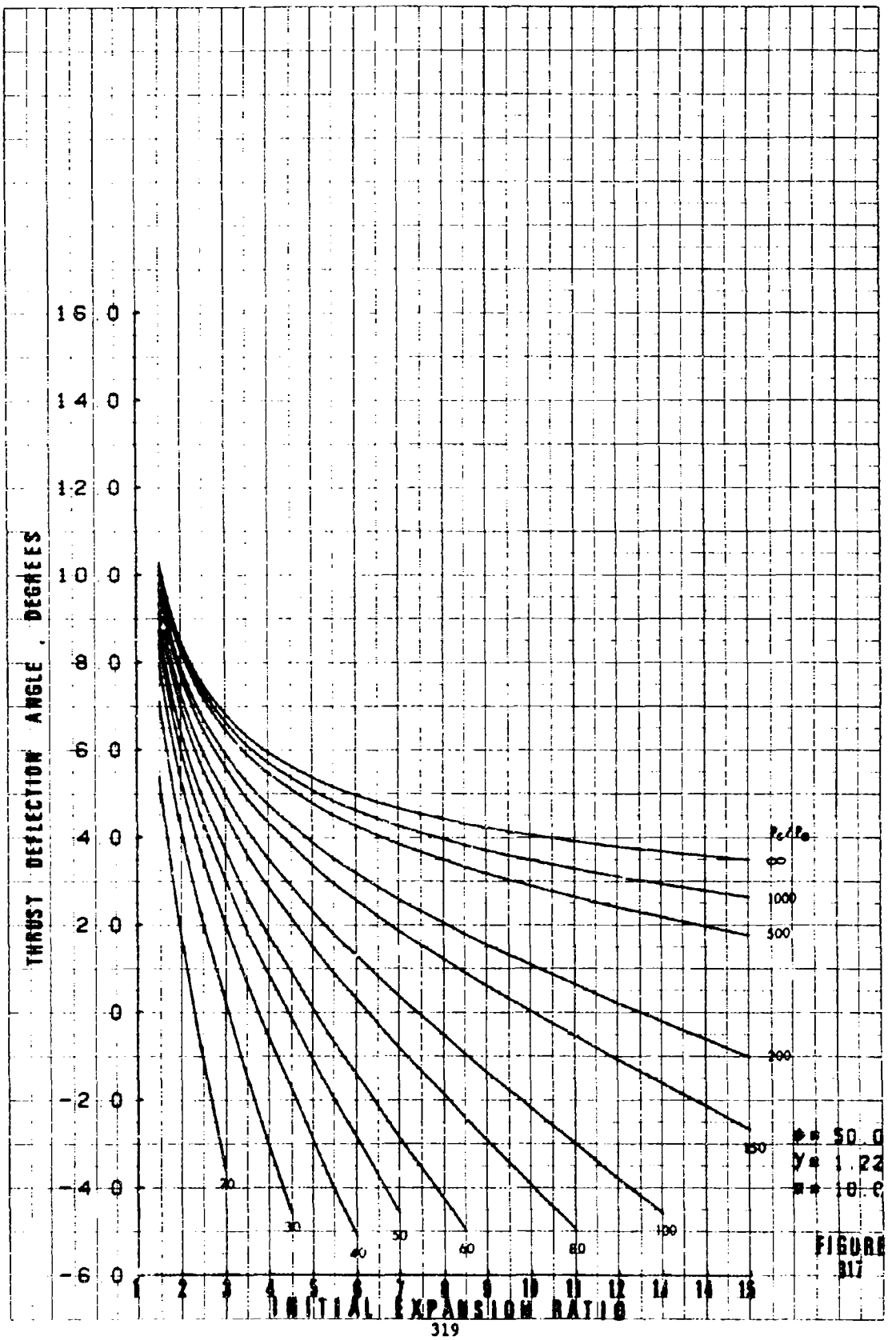

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.22

FIGURE 317

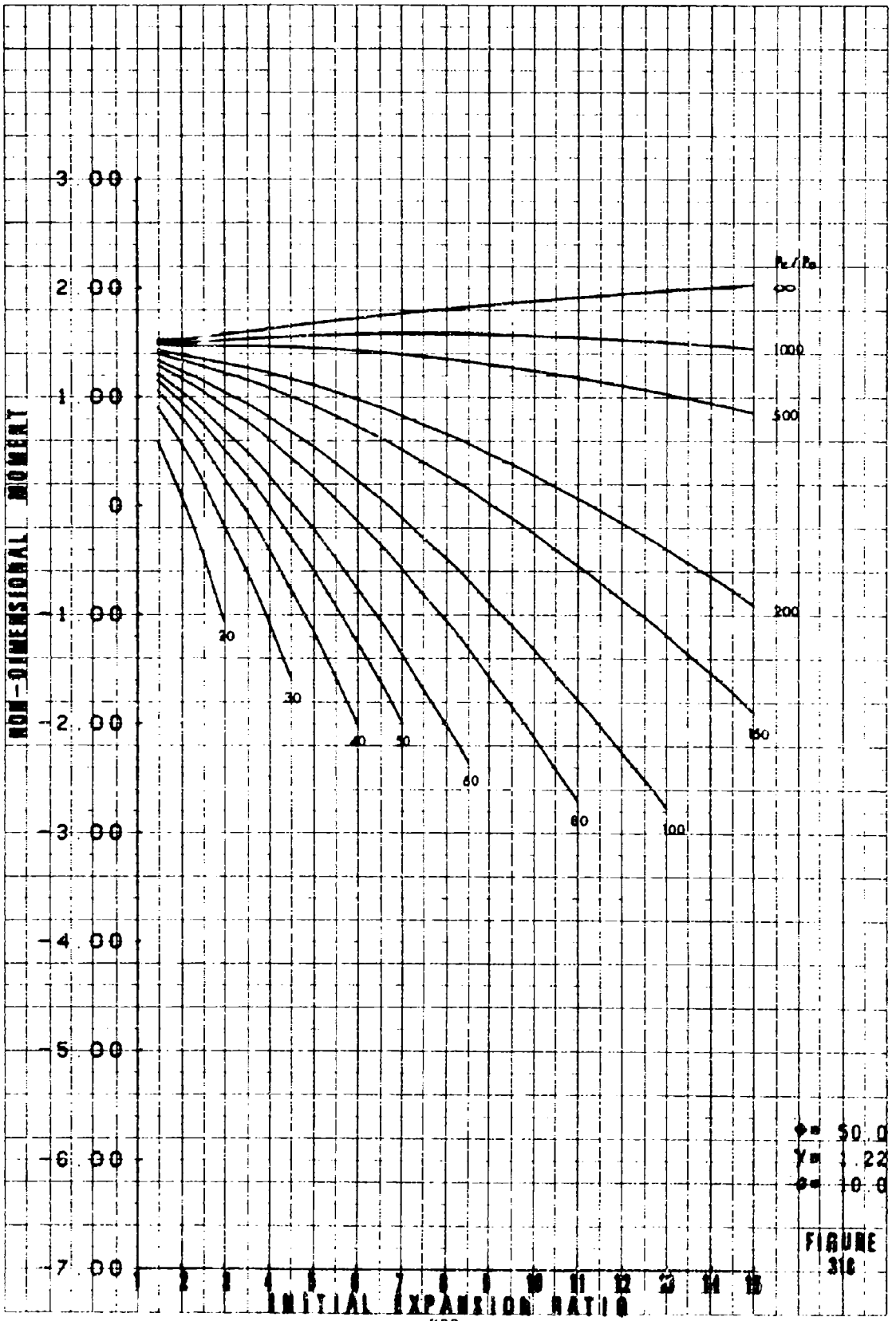

NON-DIMENSIONAL MOMENT
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ= 50.0
γ= 1.22
θ= 10.0

FIGURE 31C

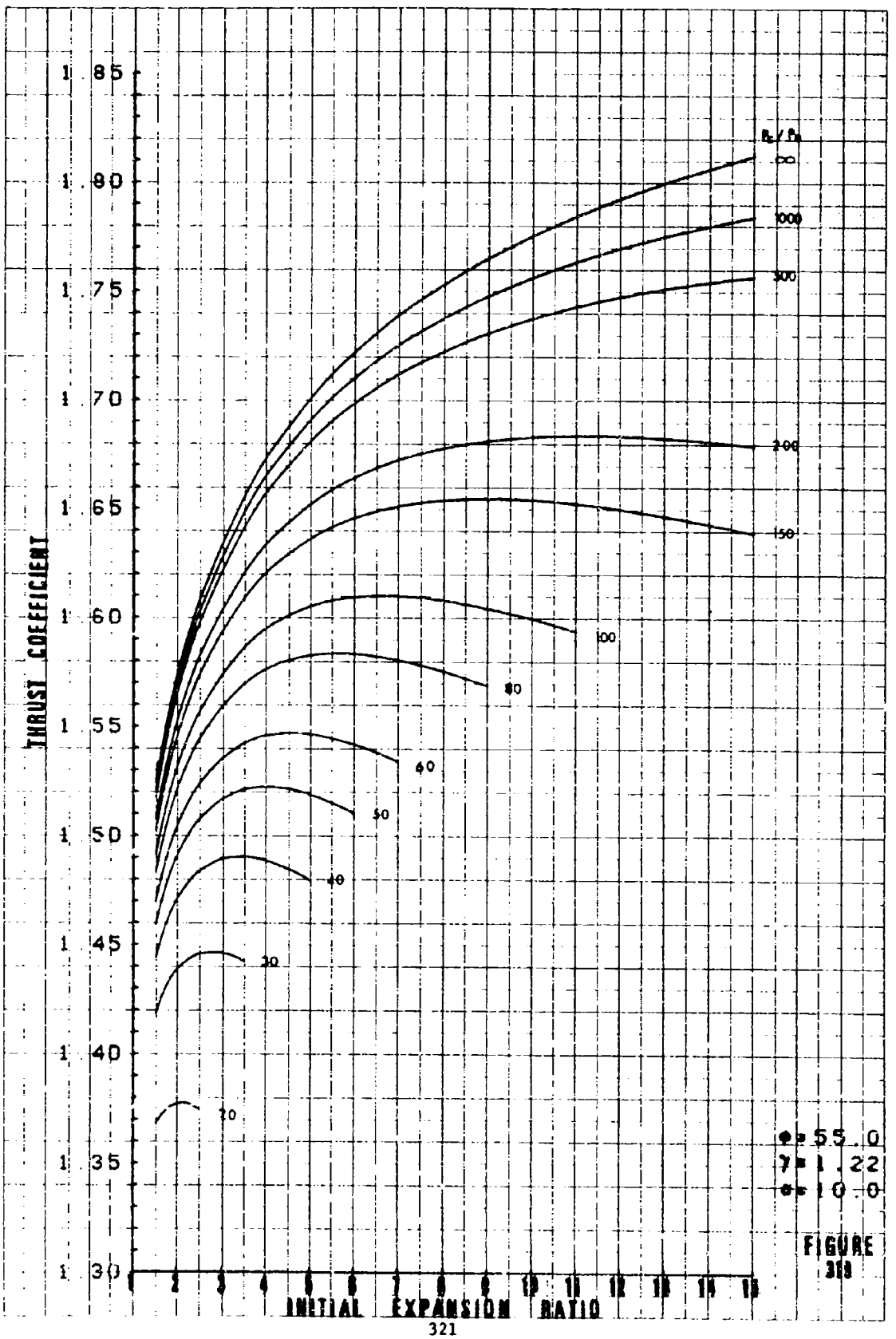

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
20
10
φ = 55.0
γ = 1.22
θ = 10.0

FIGURE 318

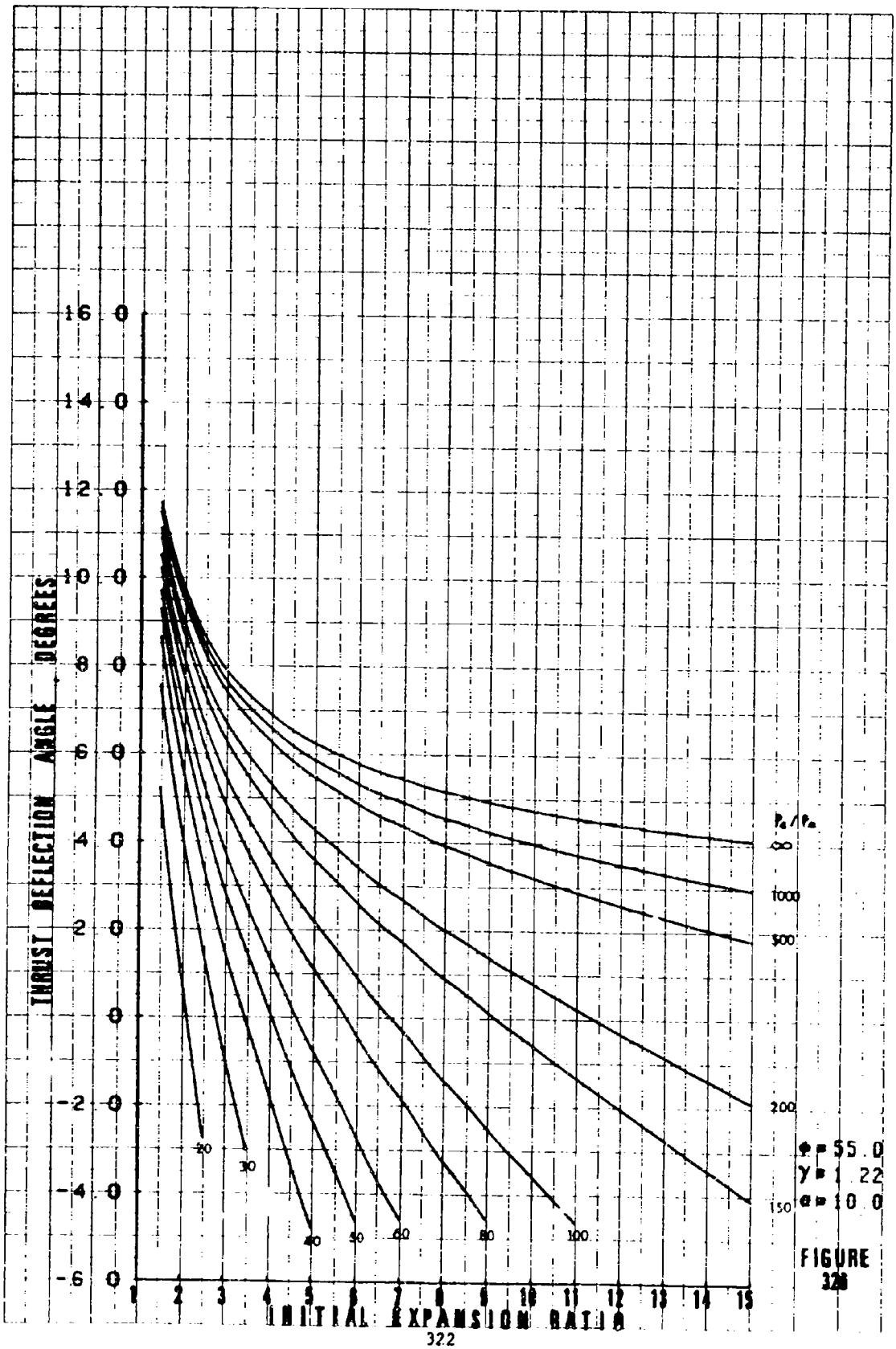

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
P_a/P_e
∞
1000
500
200
150
φ = 55.0
γ = 1.22
α = 10.0

FIGURE 326

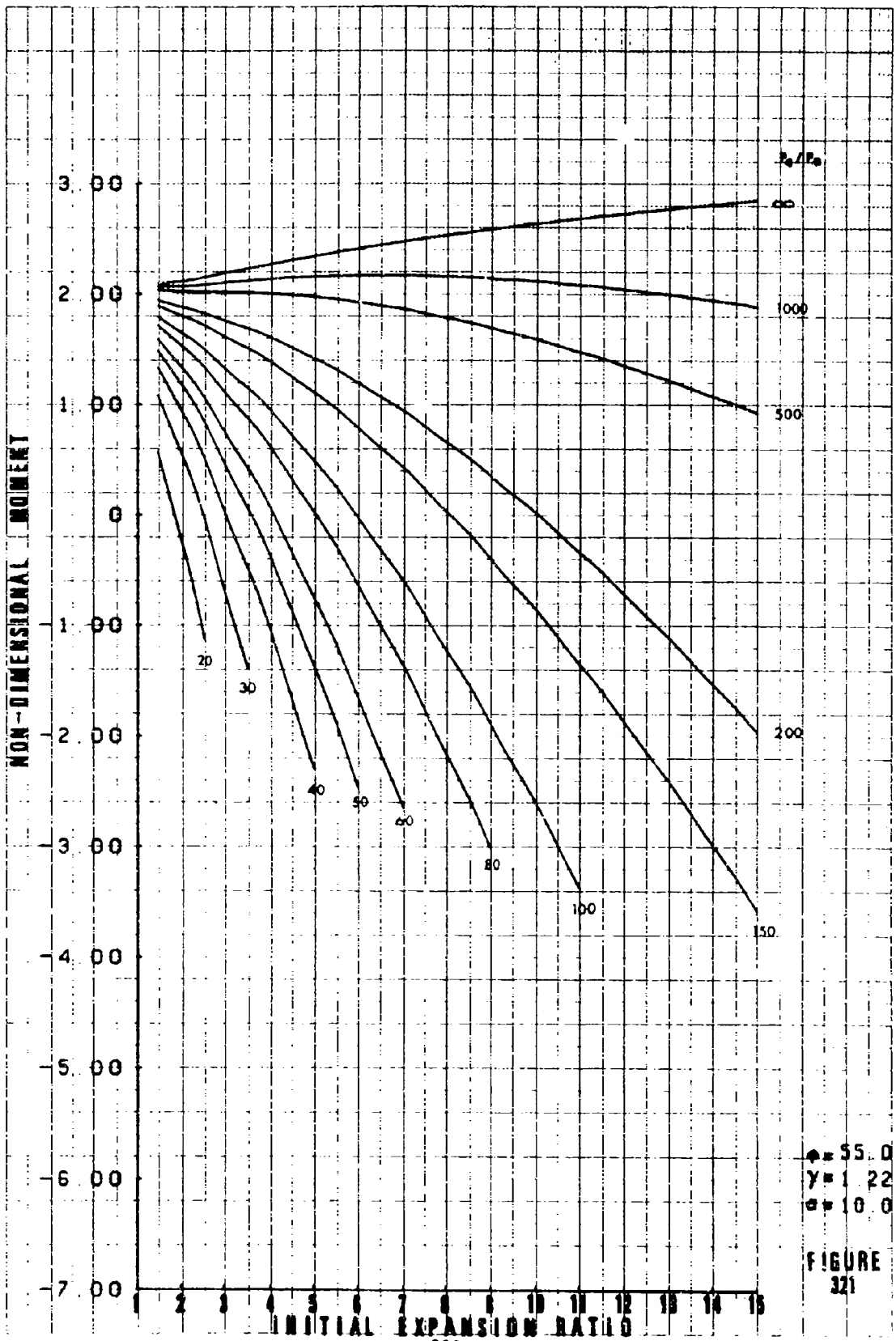

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 55.0
γ = 1.22
σ = 10.0

FIGURE 321

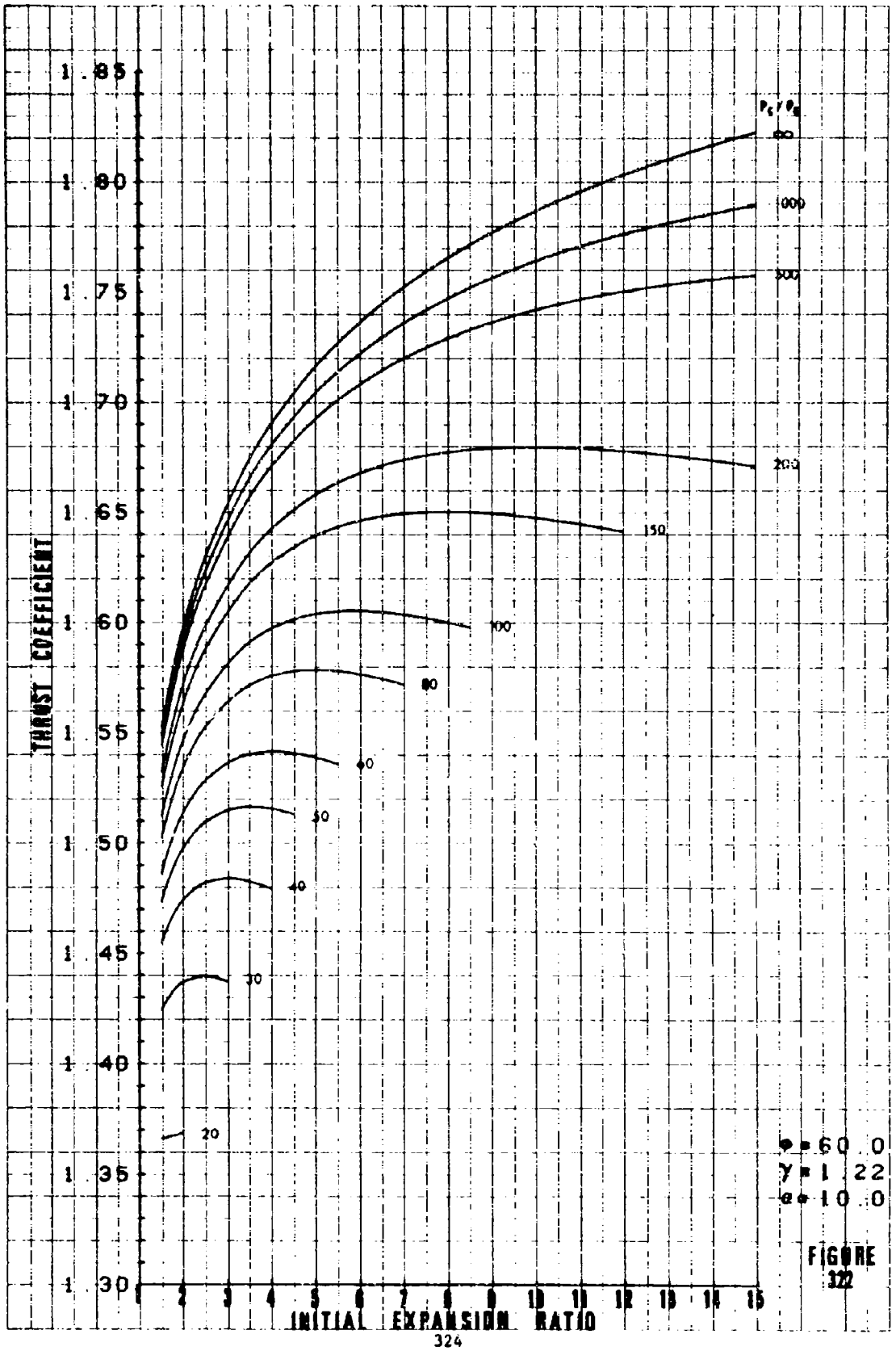

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.22
ε = 10.0

FIGURE 322

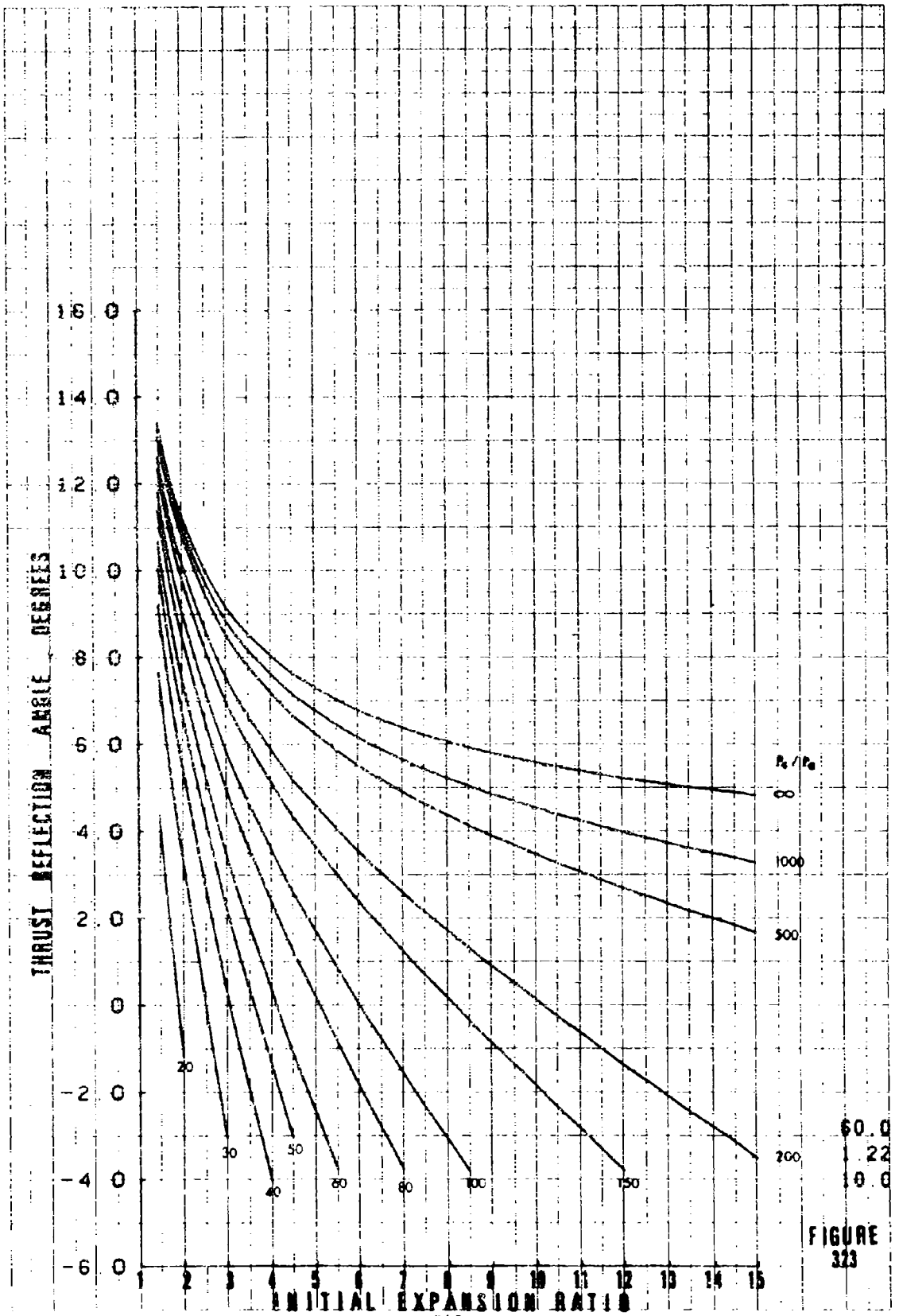

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
20
30
40
50
60
80
100
150
60.0
1.22
10.0

FIGURE 323

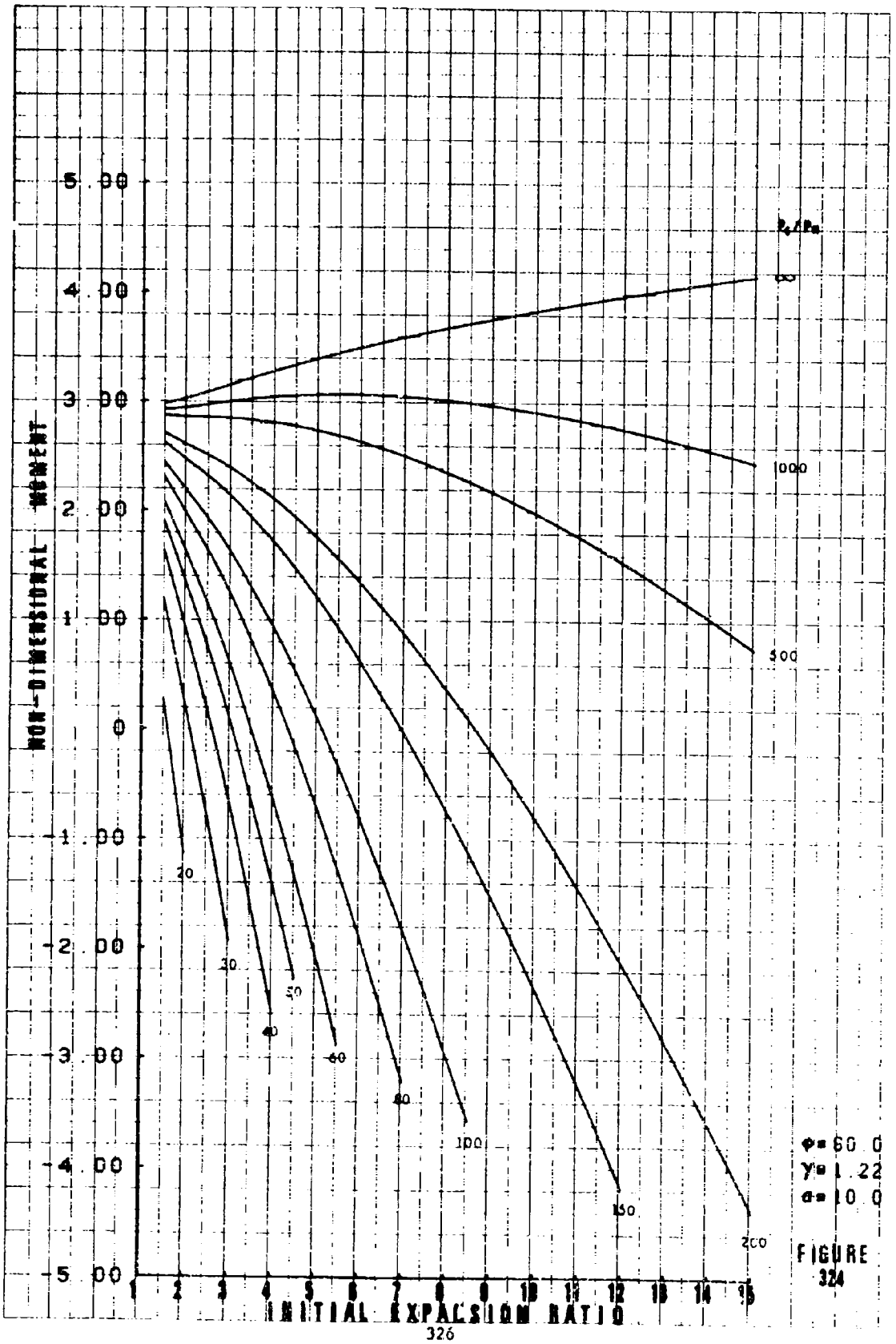

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_0/P_a
∞
1000
500
20
30
50
40
60
80
100
150
200
φ= 60.0
γ= 1.22
α= 10.0

FIGURE 324

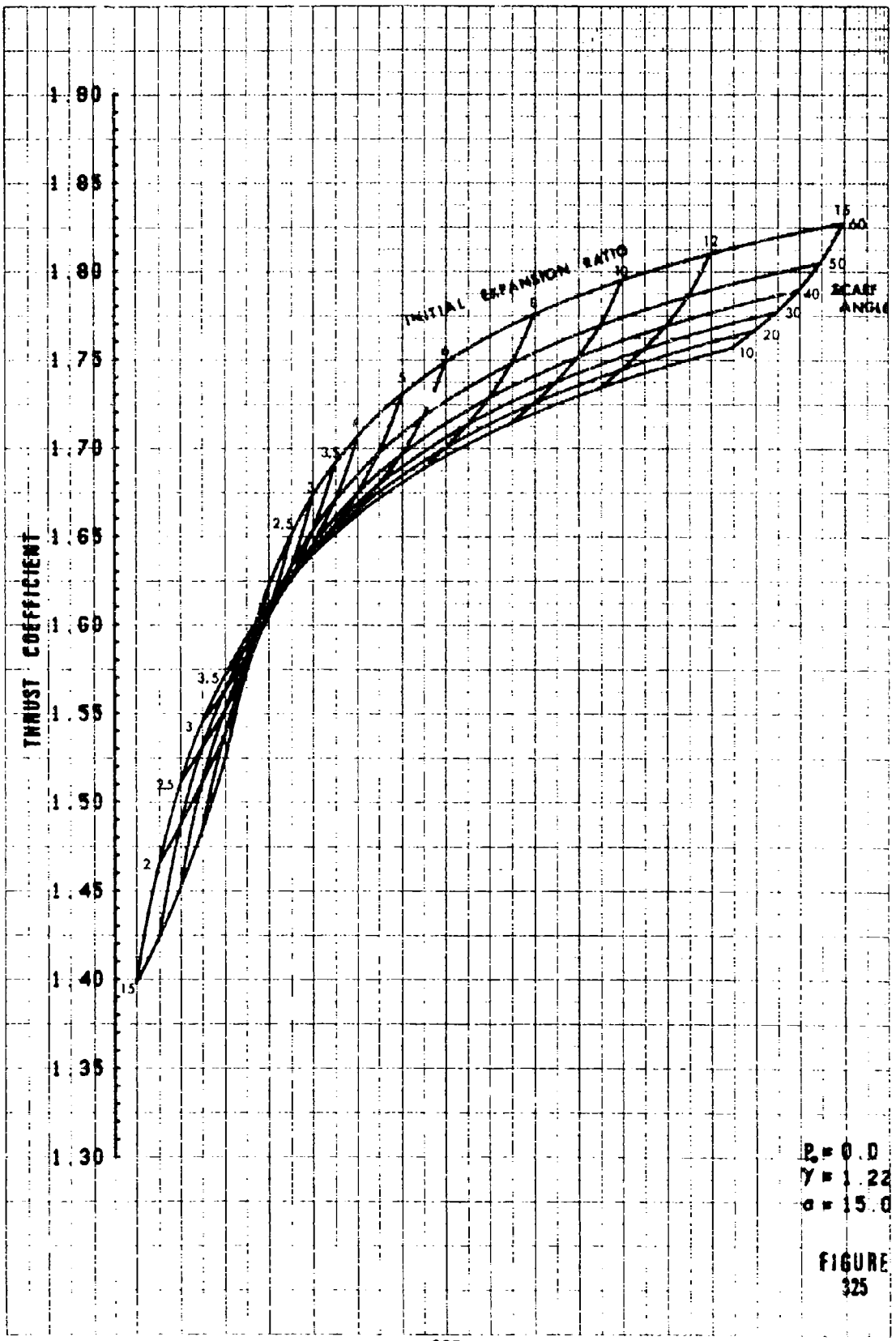

THRUST COEFFICIENT
1.80
1.85
1.90
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
15
12
10
8
6
5
4
3.5
3
2.5
2
60
50
40
30
20
10
SCARF ANGLE
P_o = 0.0
γ = 1.22
α = 15.0

FIGURE 325

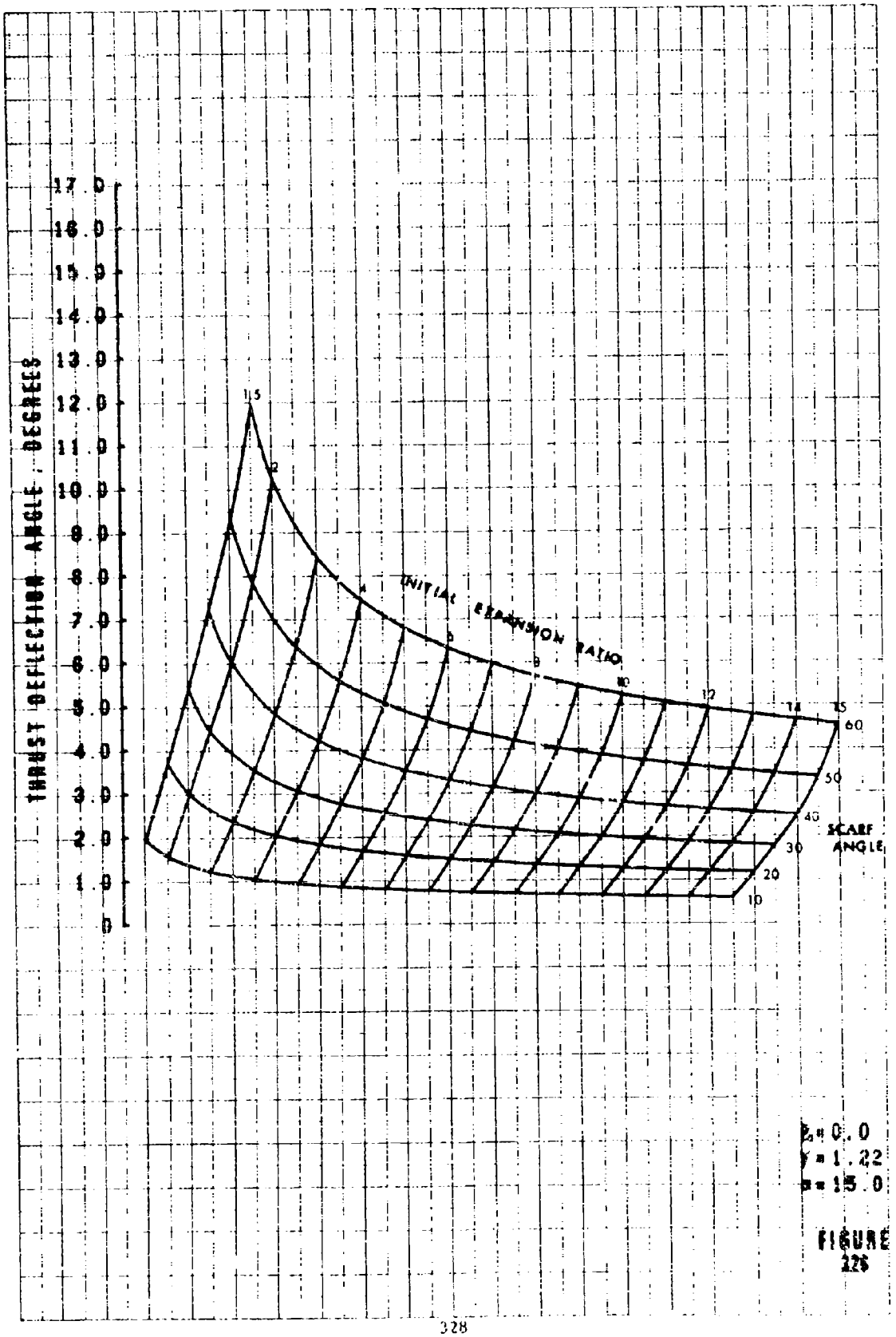

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
15
SCARF ANGLE
60
50
40
30
20
10
= 0.0
= 1.22
= 15.0

FIGURE 226

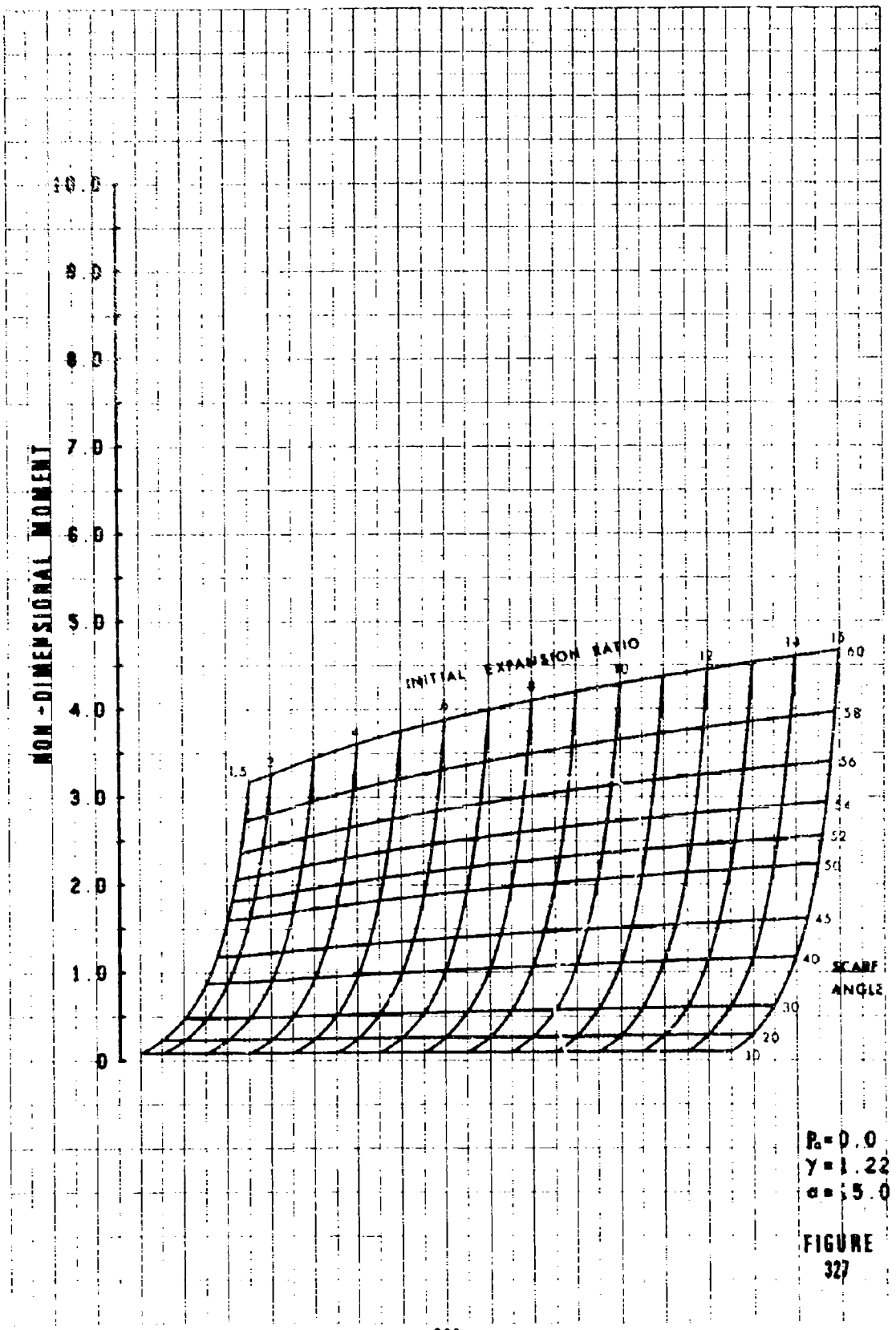

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
16
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
$P_a = 0.0$
$\gamma = 1.22$
$\alpha = 5.0$

FIGURE 327

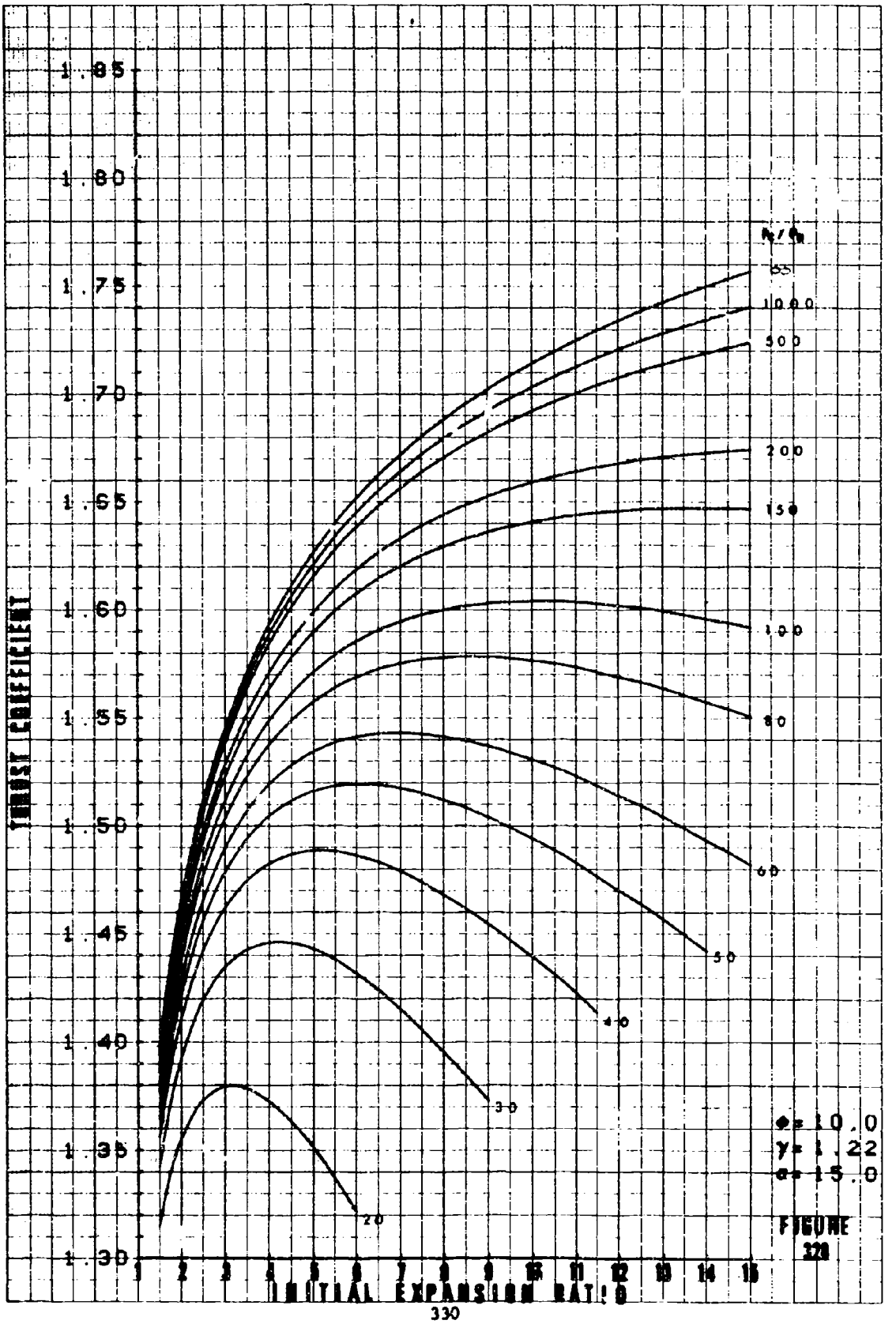

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
65
1000
500
200
150
100
80
60
50
40
30
20
ϕ= 10.0
γ= 1.22
α= 15.0

FIGURE 328

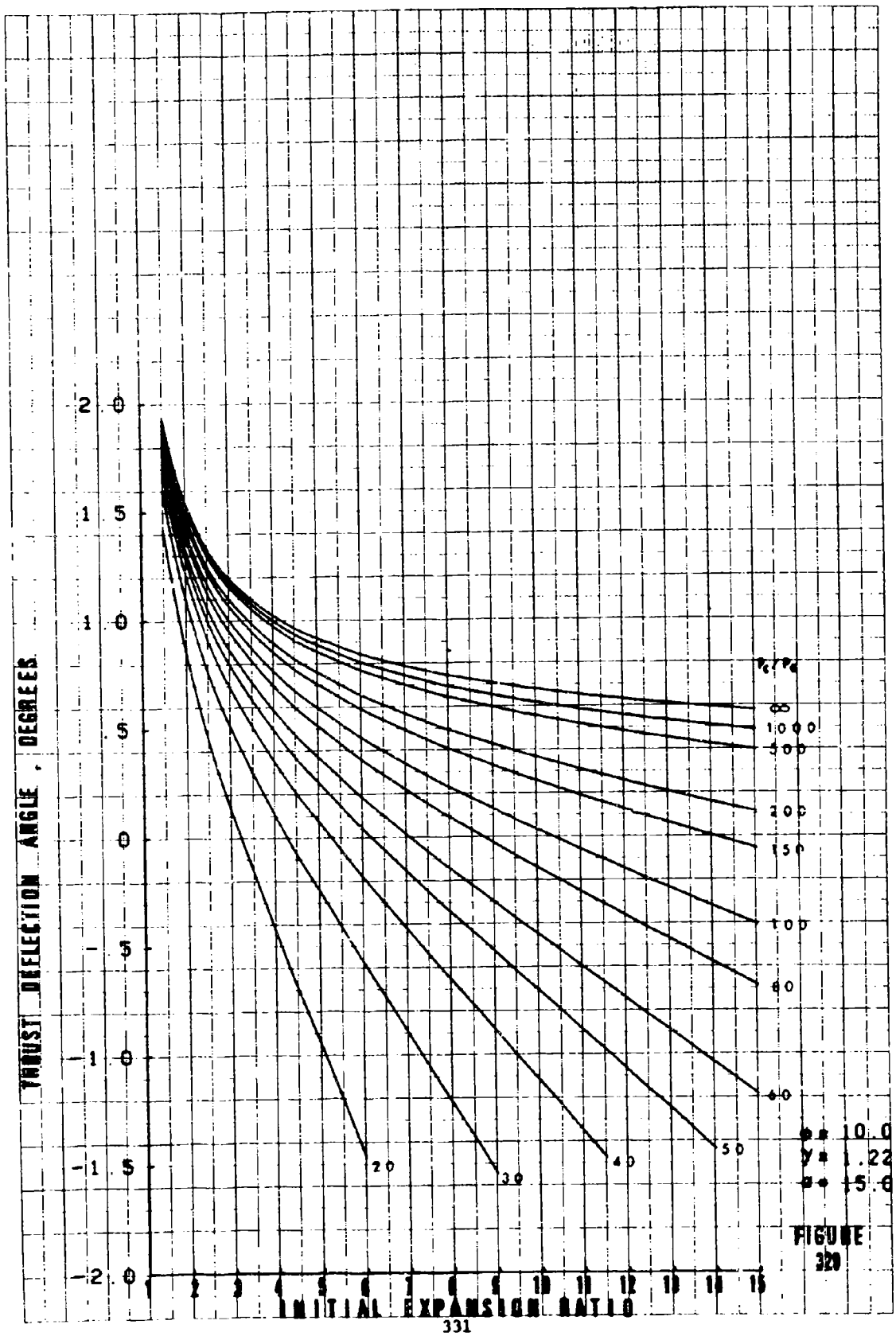
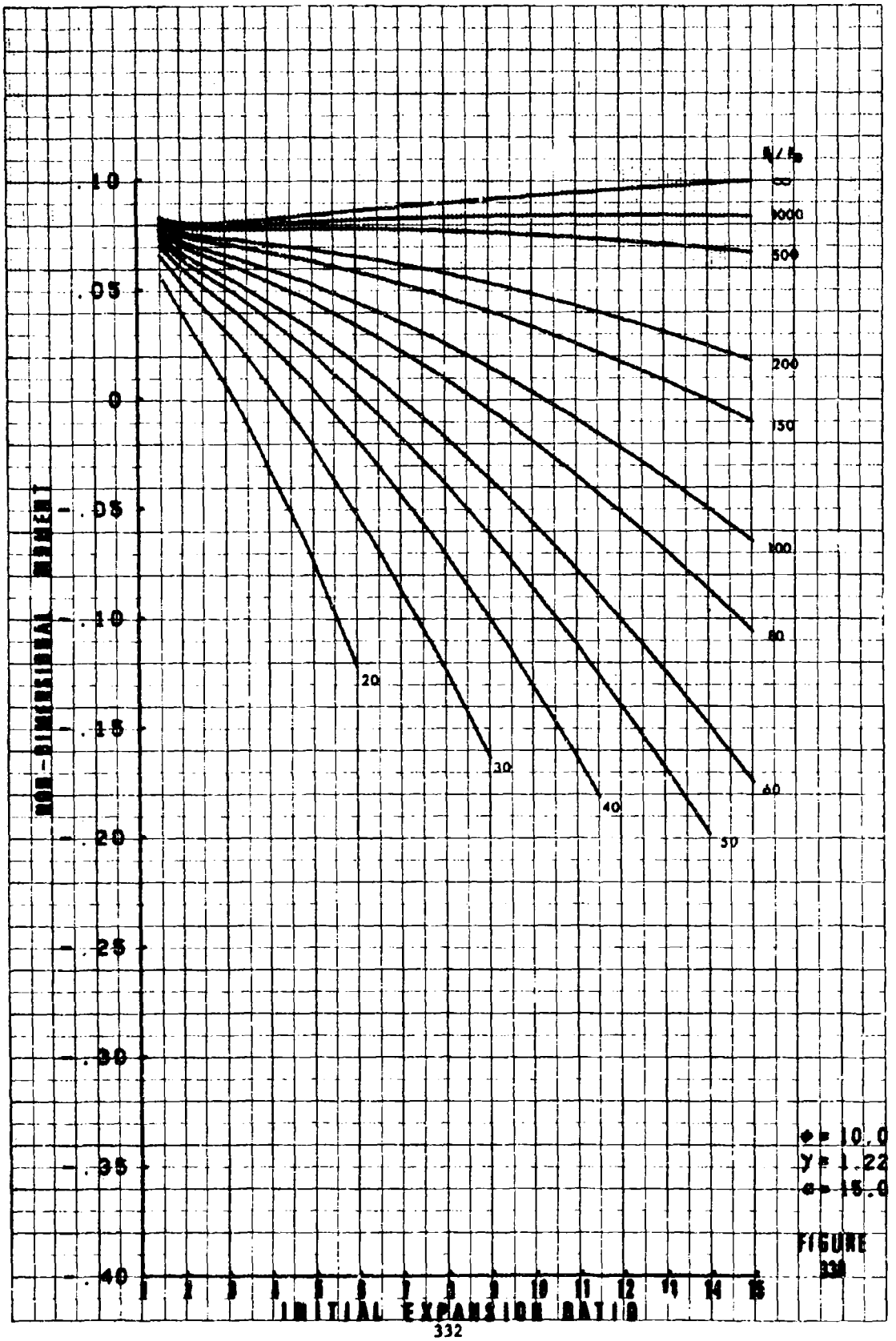

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.22

FIGURE 320



NON-DIMENSIONAL MOMENT
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
-.35
-.40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.22
α = 15.0

FIGURE 33[illegible]

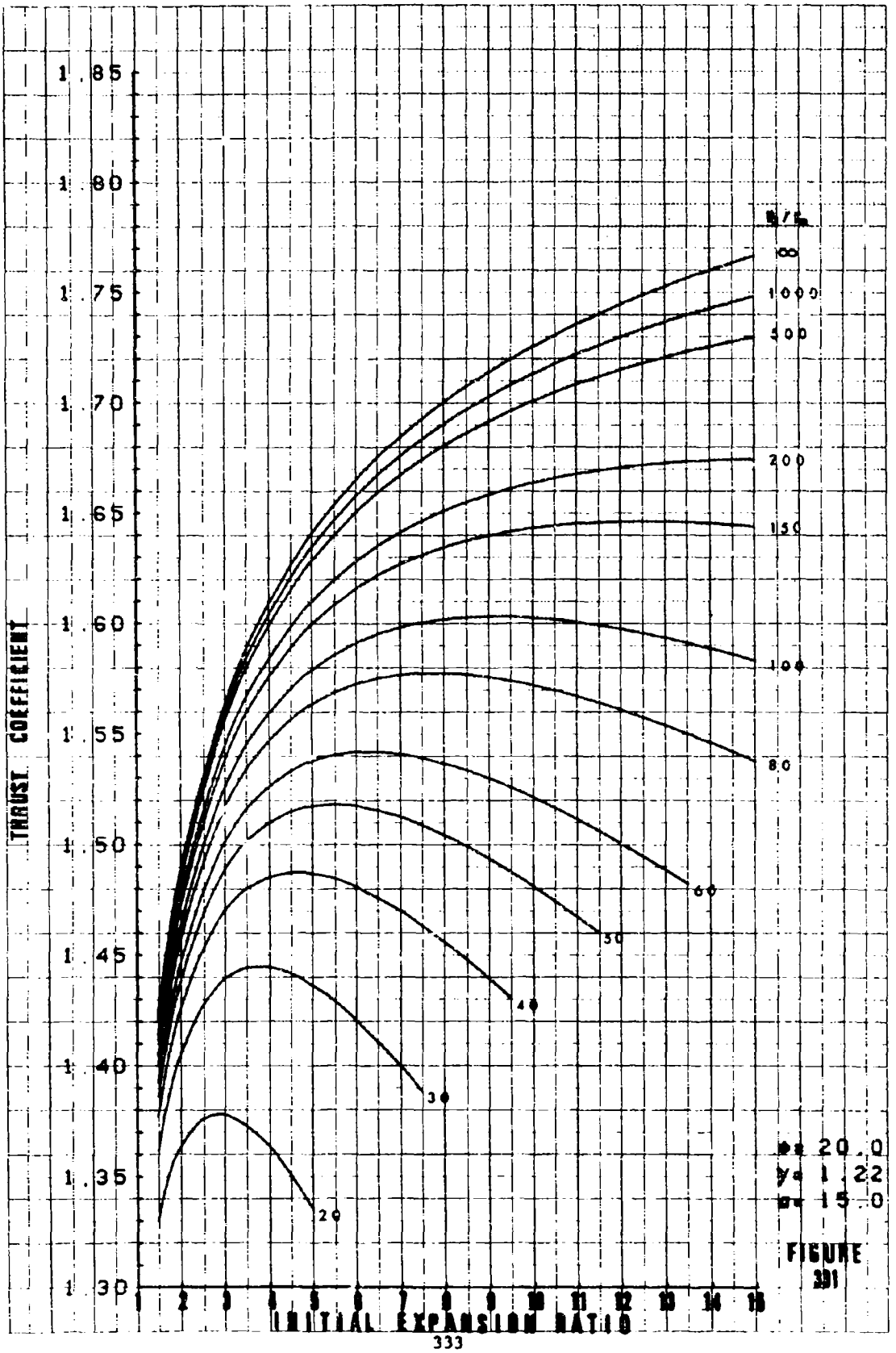
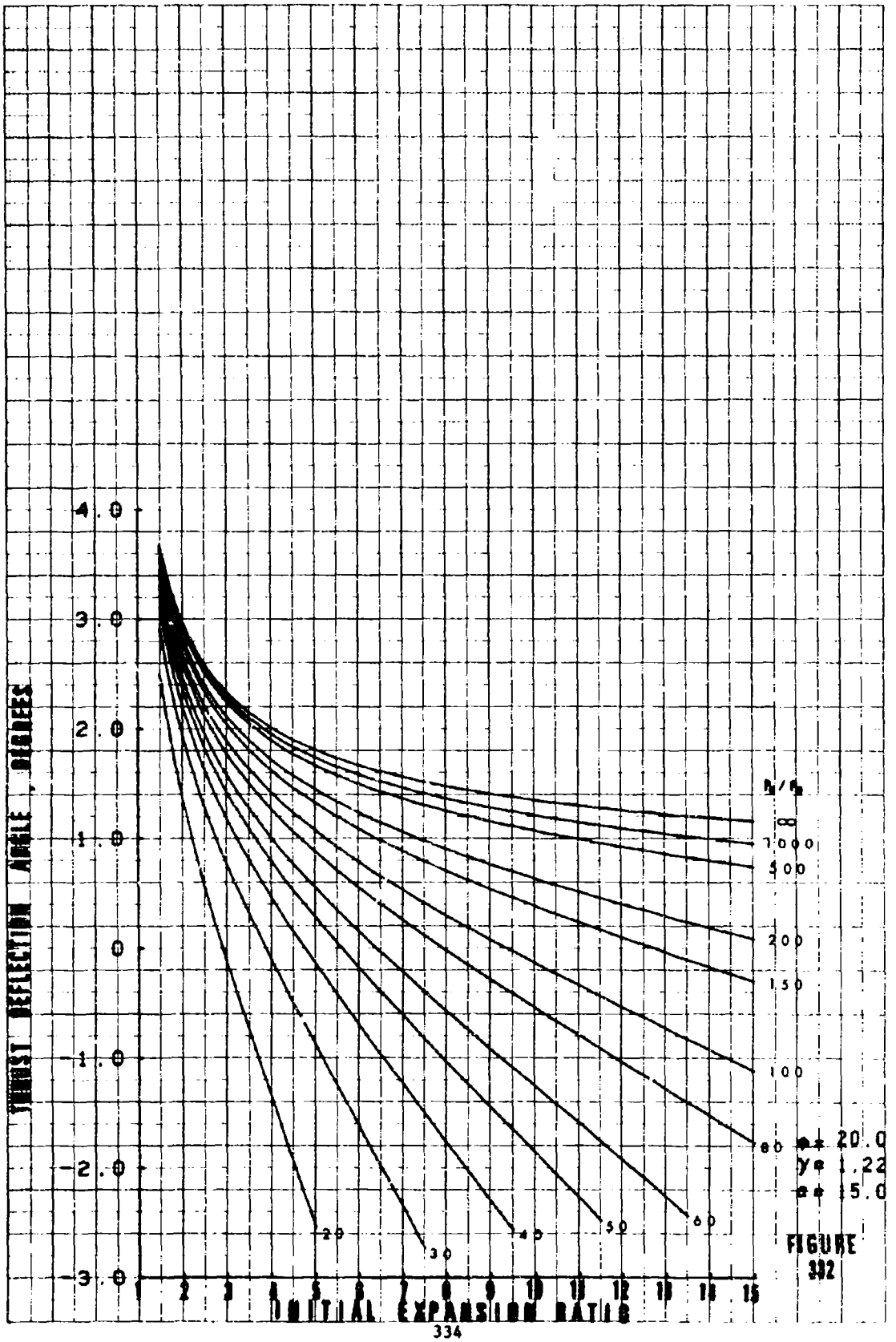

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
= 20.0
γ = 1.22
= 15.0

FIGURE 331



4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
THRUST DEFLECTION ANGLE, DEGREES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
α = 15.0

FIGURE 332

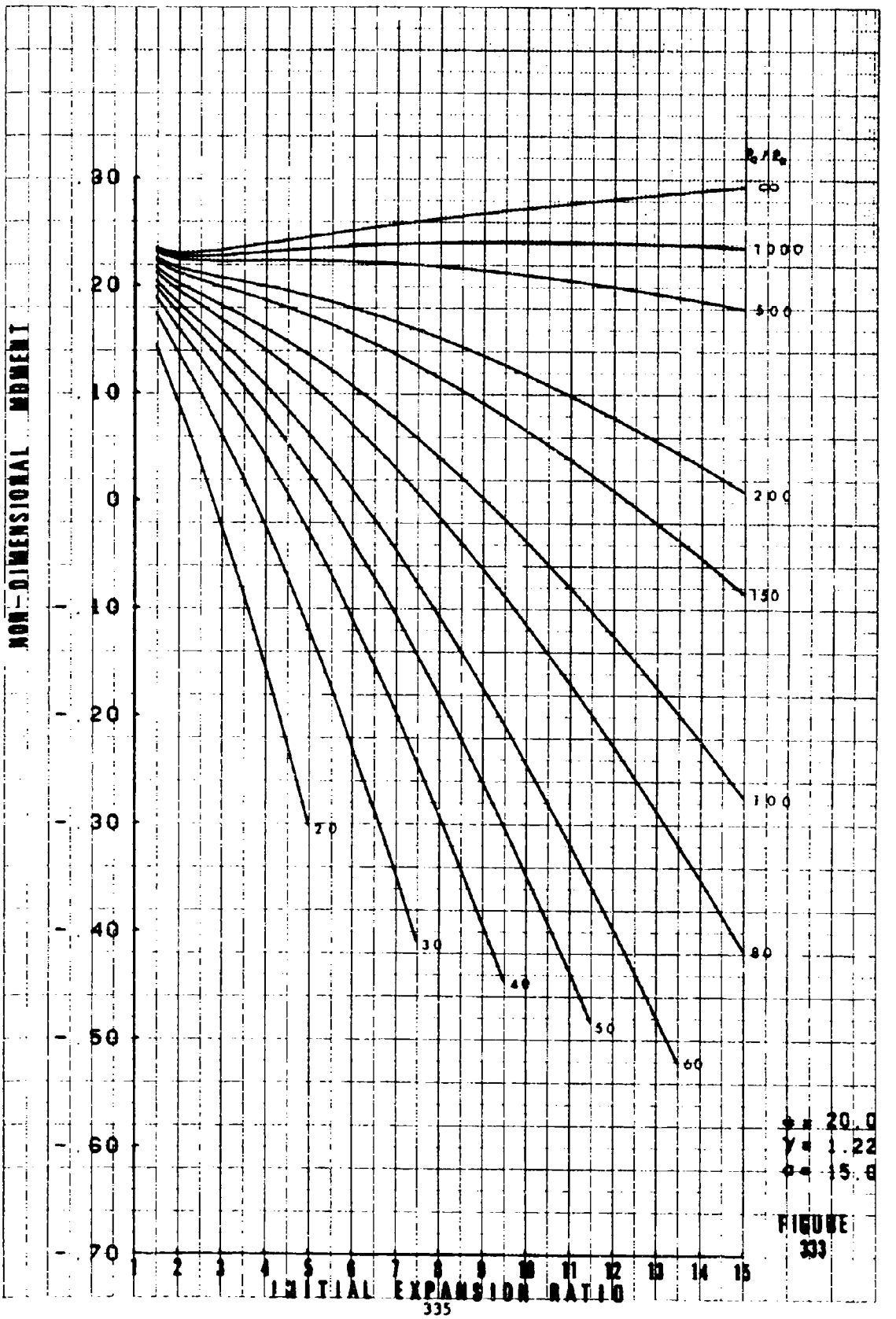

NON-DIMENSIONAL MOMENT
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 20.0
γ = 1.22
θ = 15.6

FIGURE 333

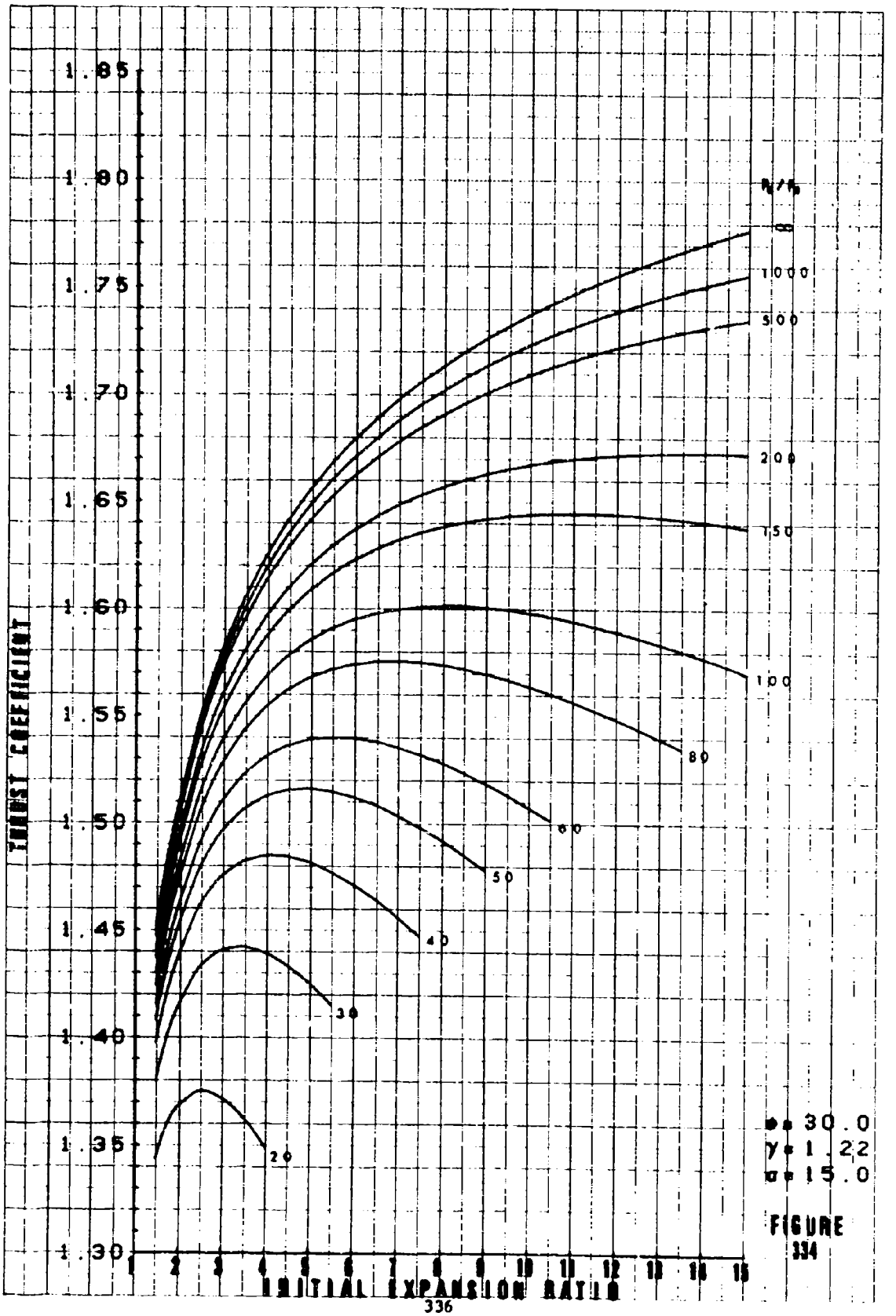

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R_1/R_0
∞
1000
500
200
150
100
80
60
50
40
30
20
= 30.0
γ = 1.22
= 15.0

FIGURE 334

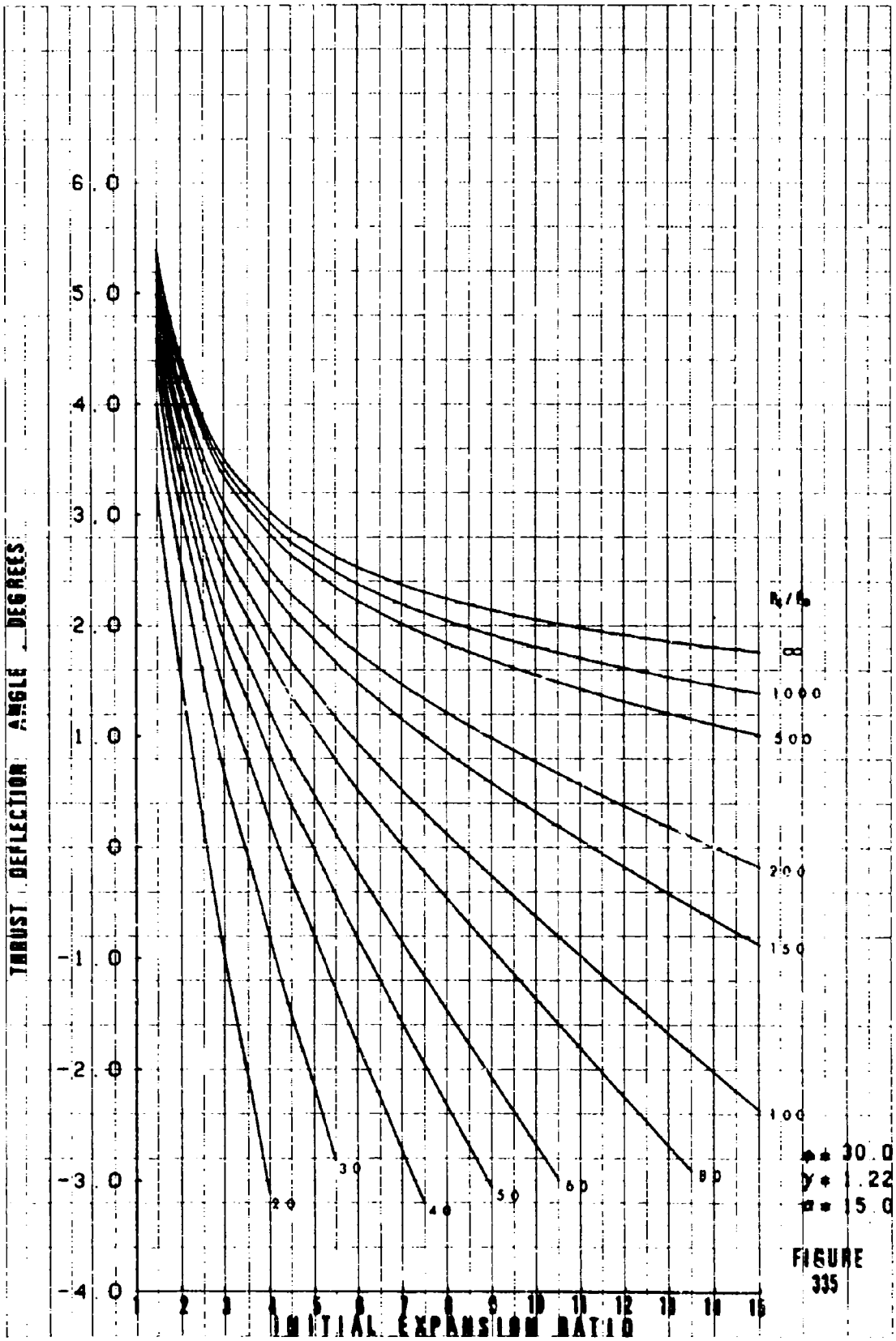
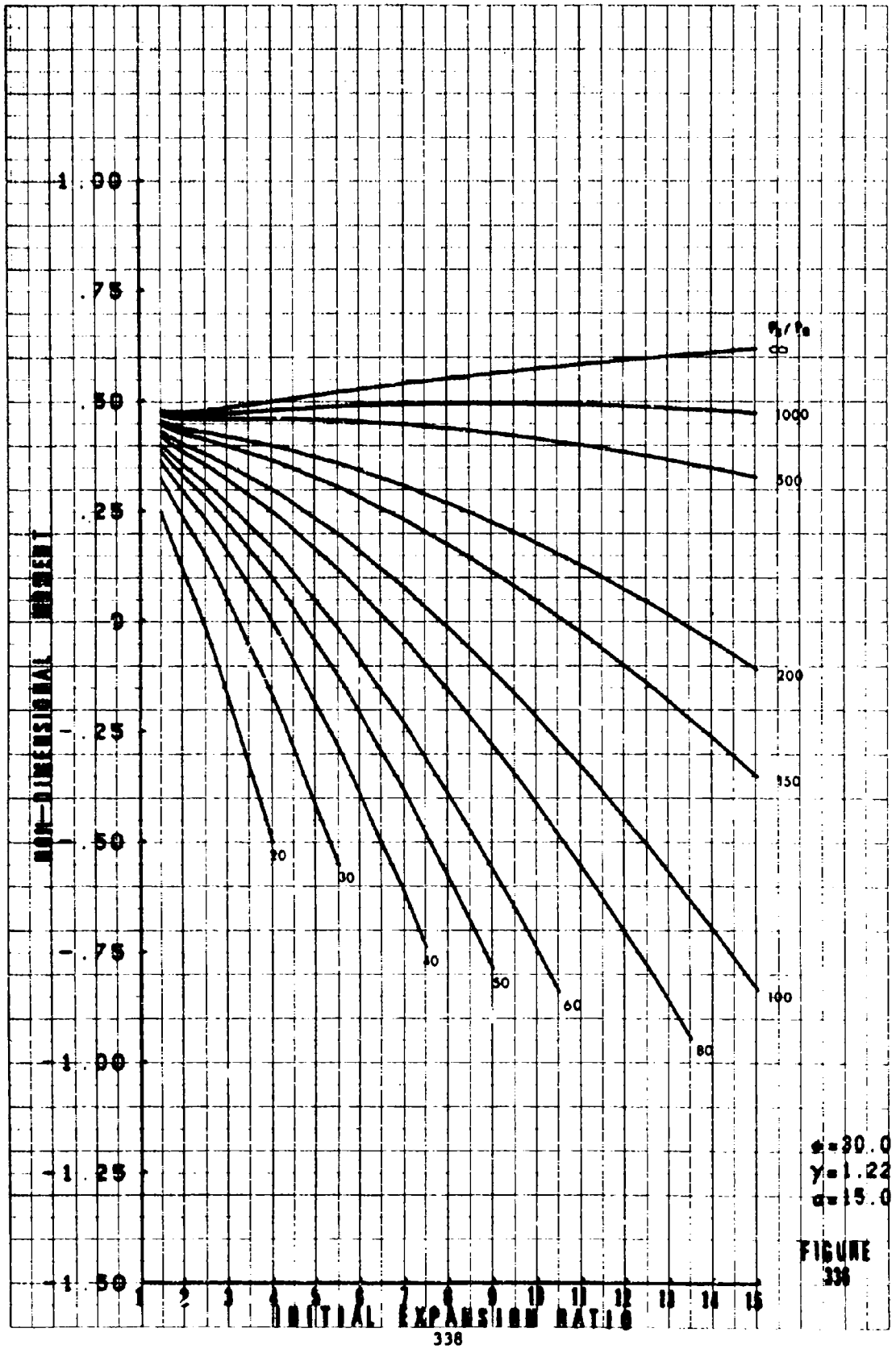

THRUST DEFLECTION ANGLE DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R_t/R_b
∞
1000
500
200
150
100
80
60
50
40
30
20
= 30.0
γ = 1.22
= 15.0

FIGURE 335



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_s/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=30.0
γ=1.22
α=15.0

FIGURE 336

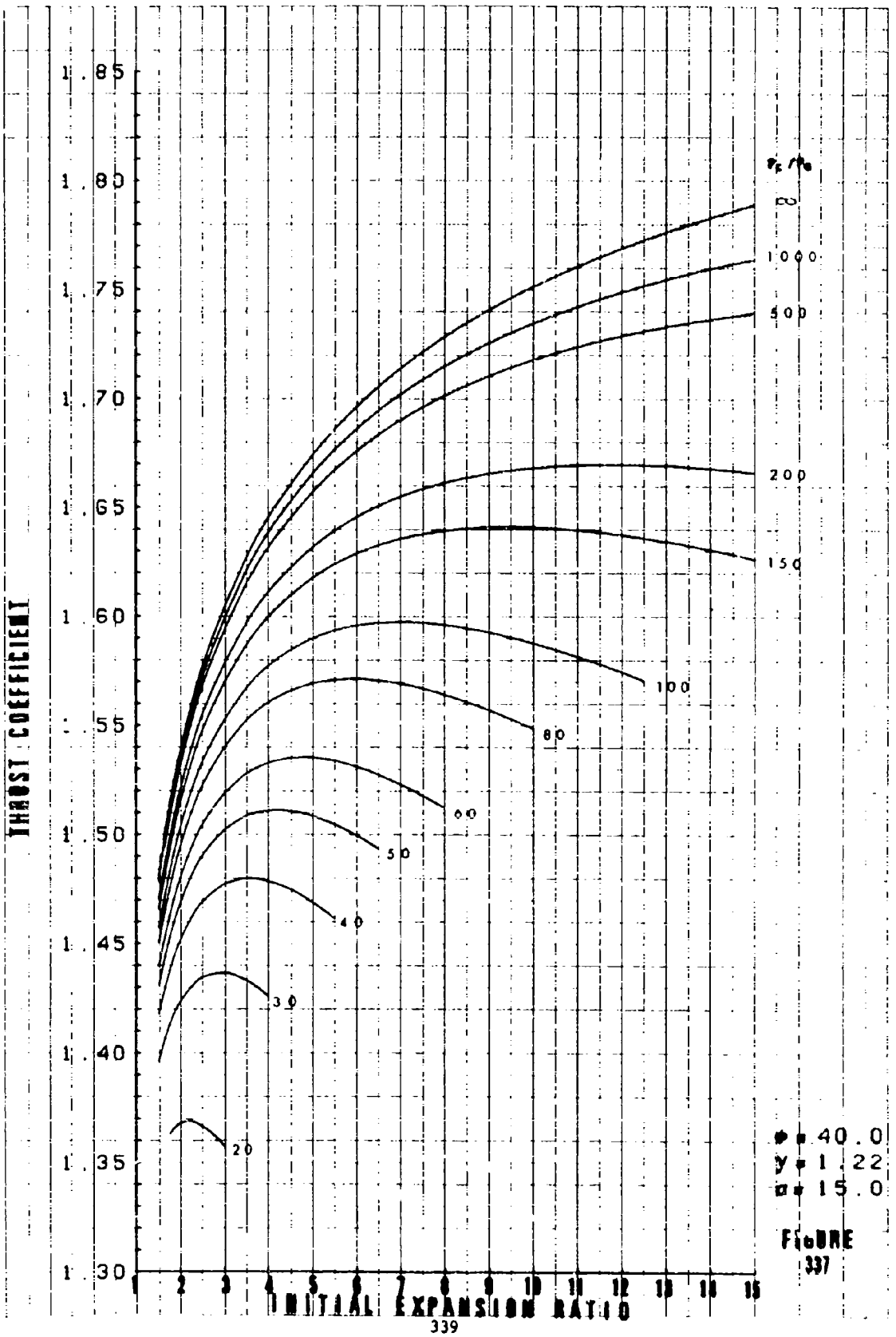

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
= 40.0
y = 1.22
= 15.0

FIGURE 337

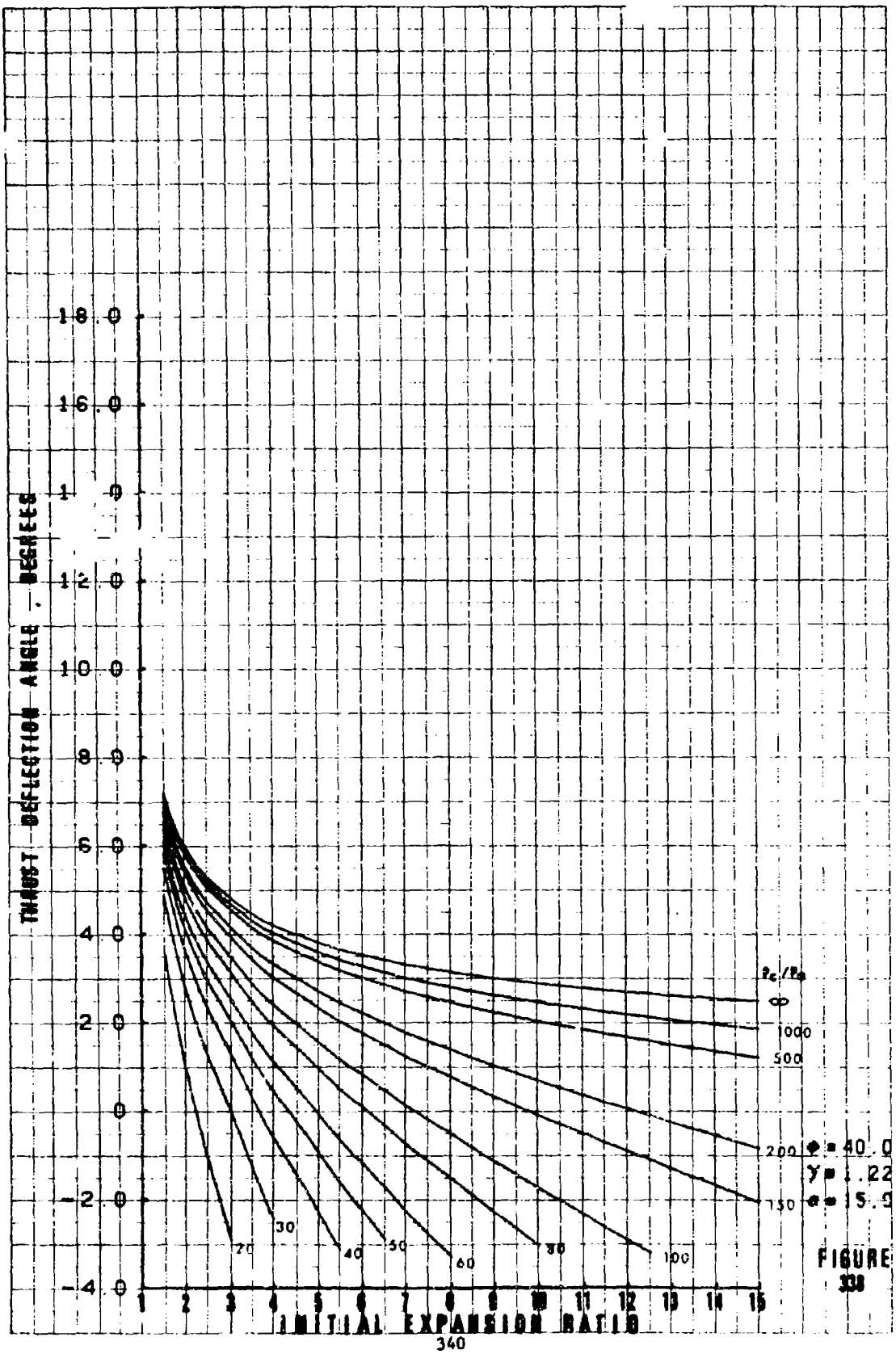

THRUST DEFLECTION ANGLE - DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
200
150
70
30
40
50
60
80
100
ϕ = 40.0
γ = 1.22
α = 15.9

FIGURE 338

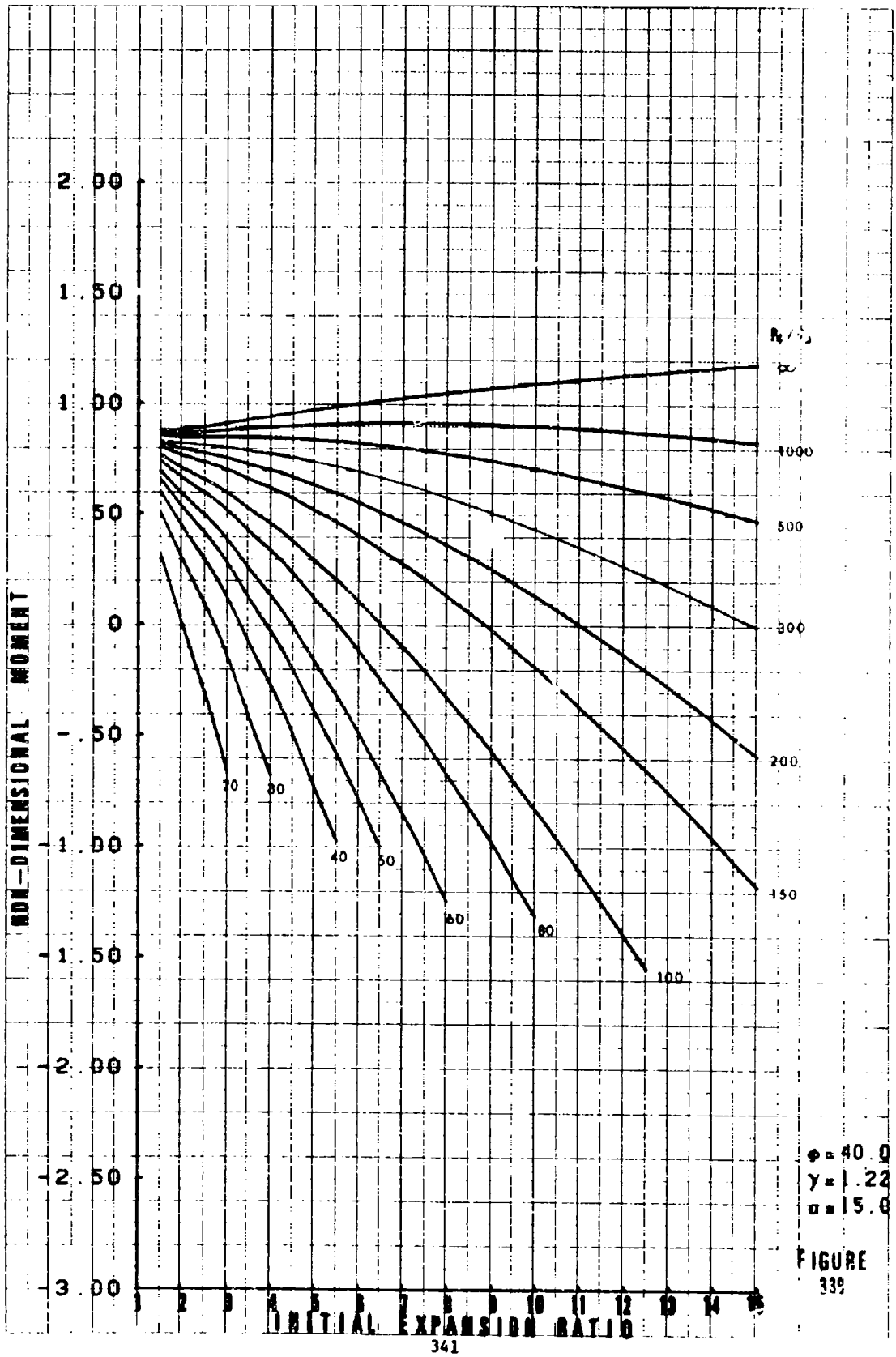

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.22
α = 15.6

FIGURE 339

THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
q/p∞
∞
1000
500
200
150
100
80
60
50
40
30
20
θ= 45.0
γ= 1.22
α= 15.0

FIGURE 340

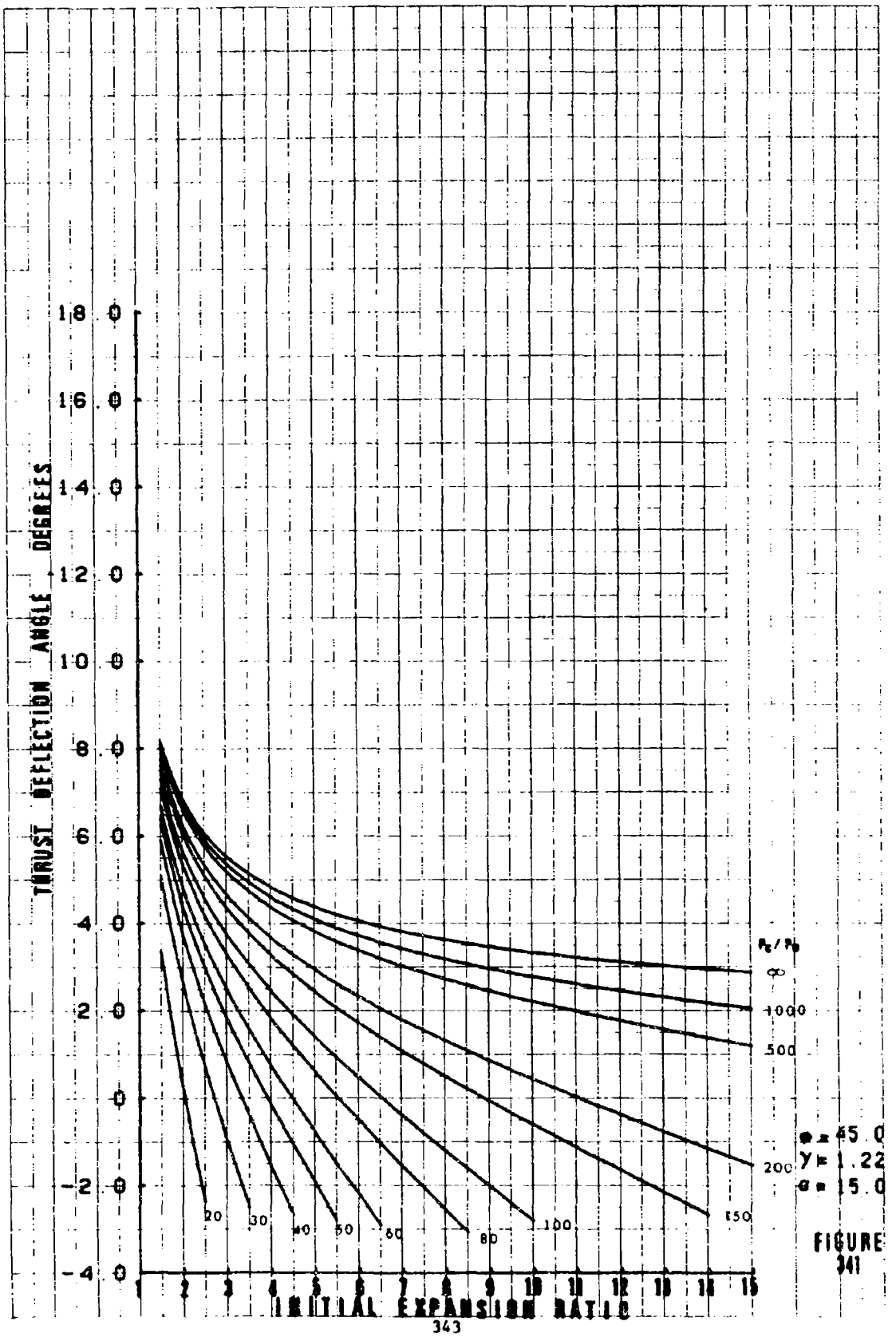
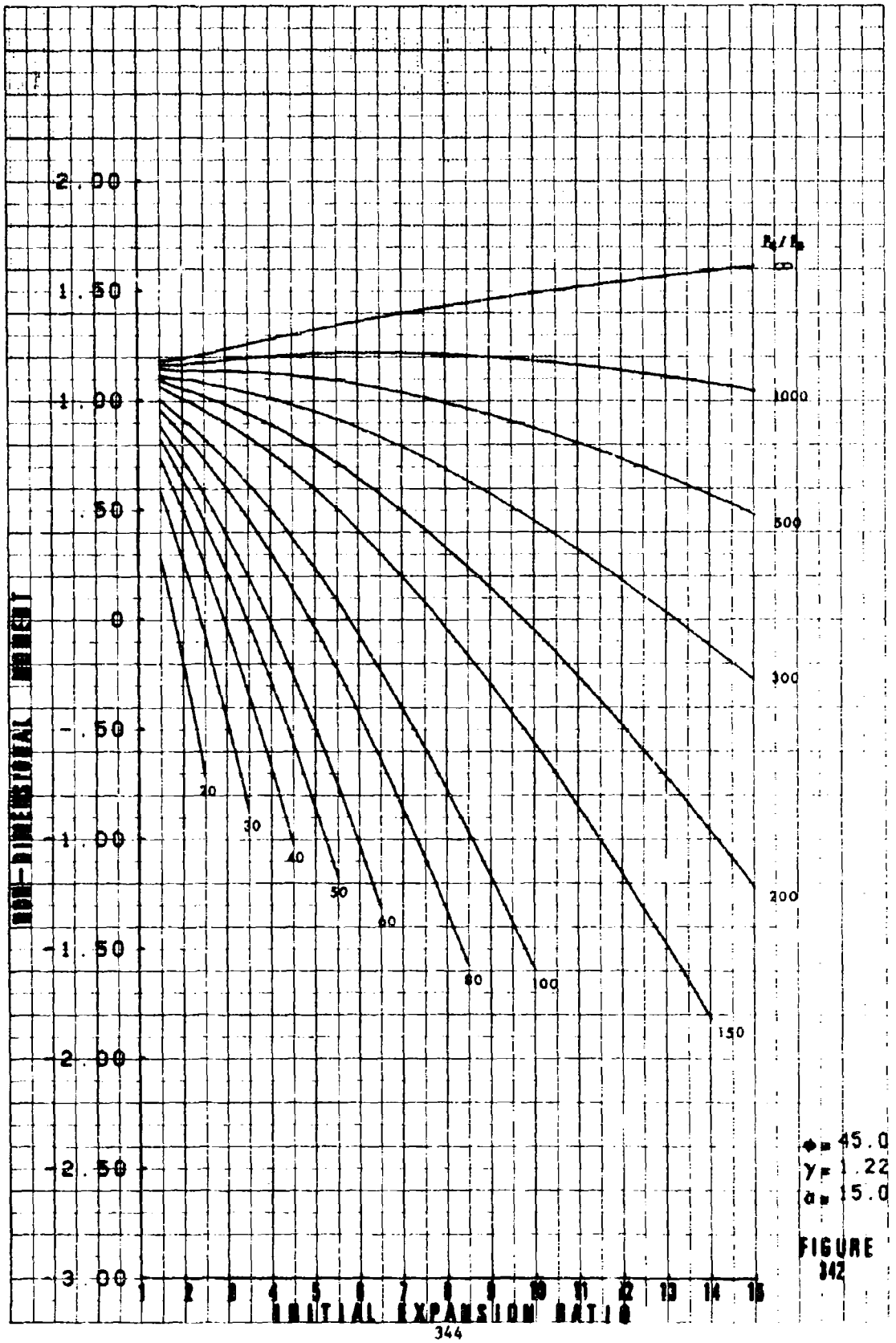
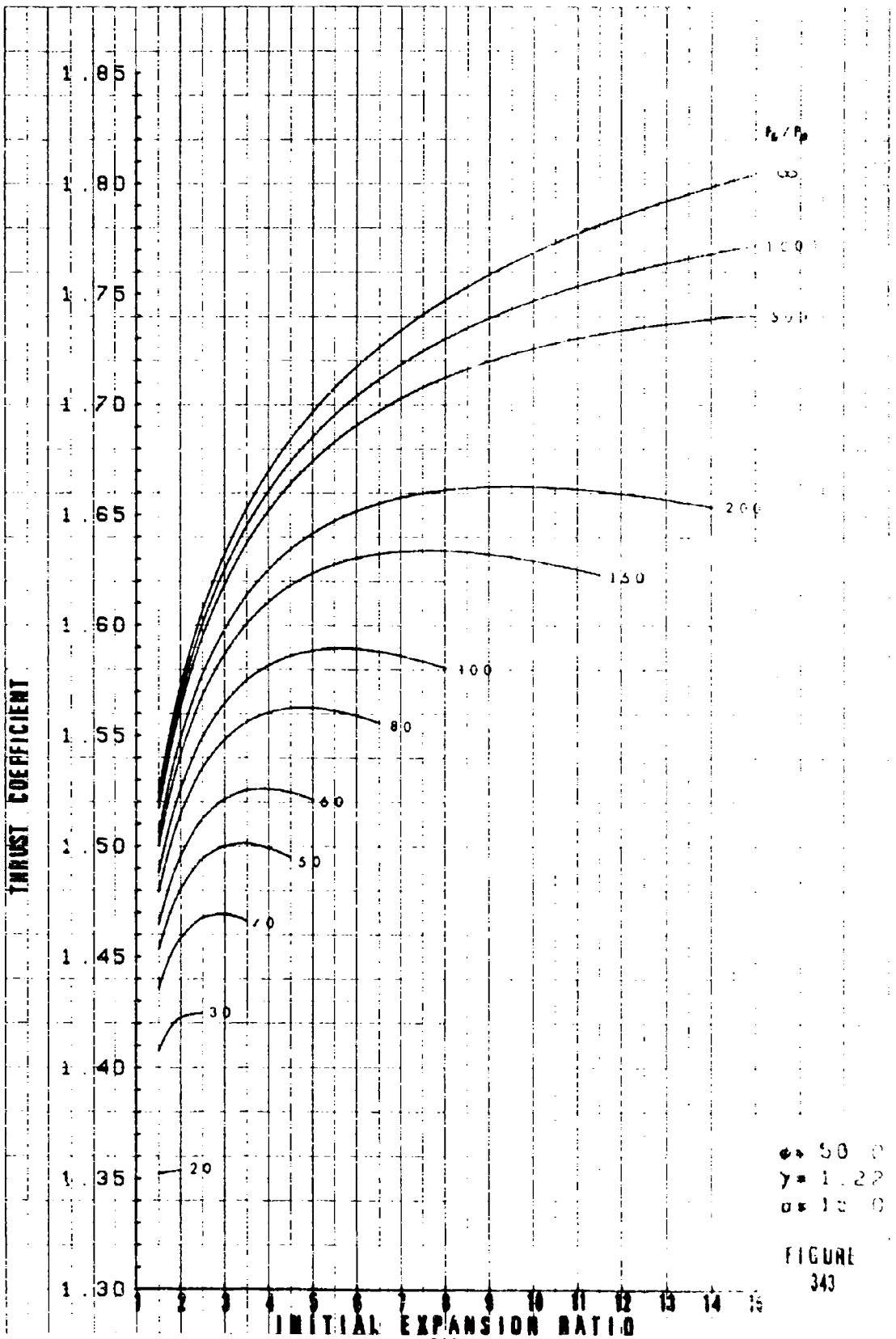

THRUST DEFLECTION ANGLE DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.22
α = 15.0

FIGURE 341



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_a/P_b
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.22
α = 15.0

FIGURE 342



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_p
∞
100
500
200
150
100
80
60
50
40
30
20

FIGURE 343

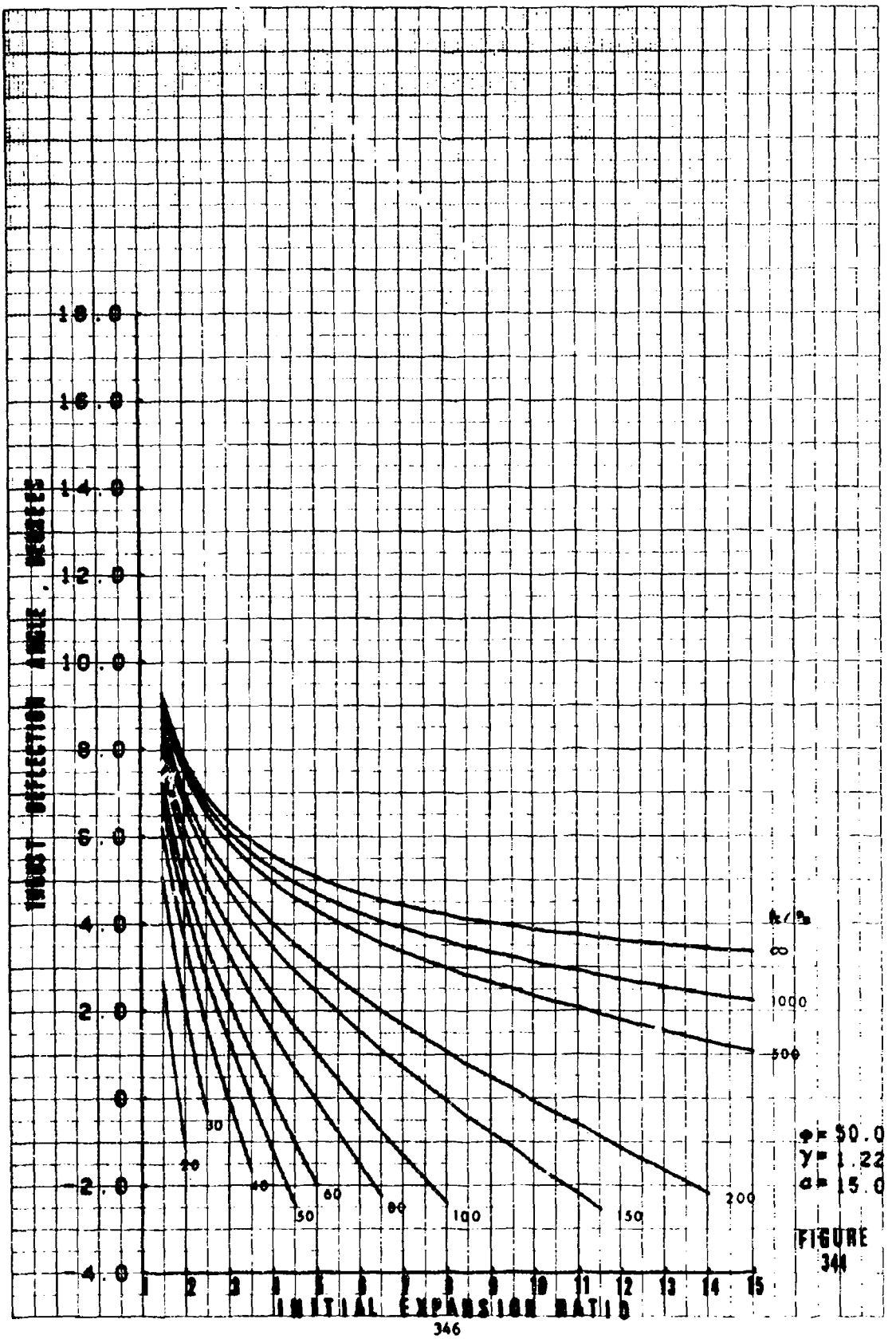

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
k/p
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 50.0
γ = 1.22
α = 15.0

FIGURE 34A

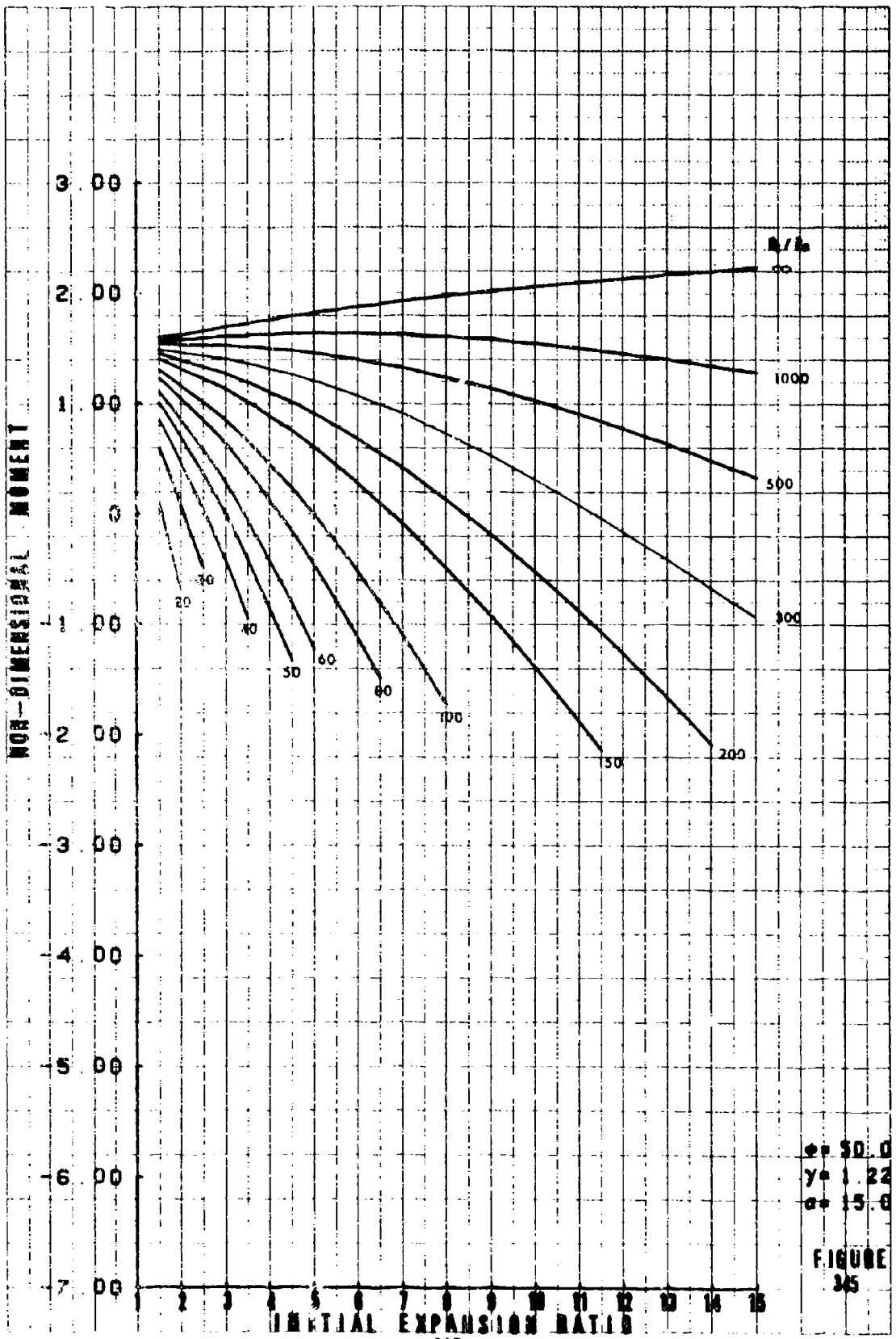

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.22
α= 15.0

FIGURE 345

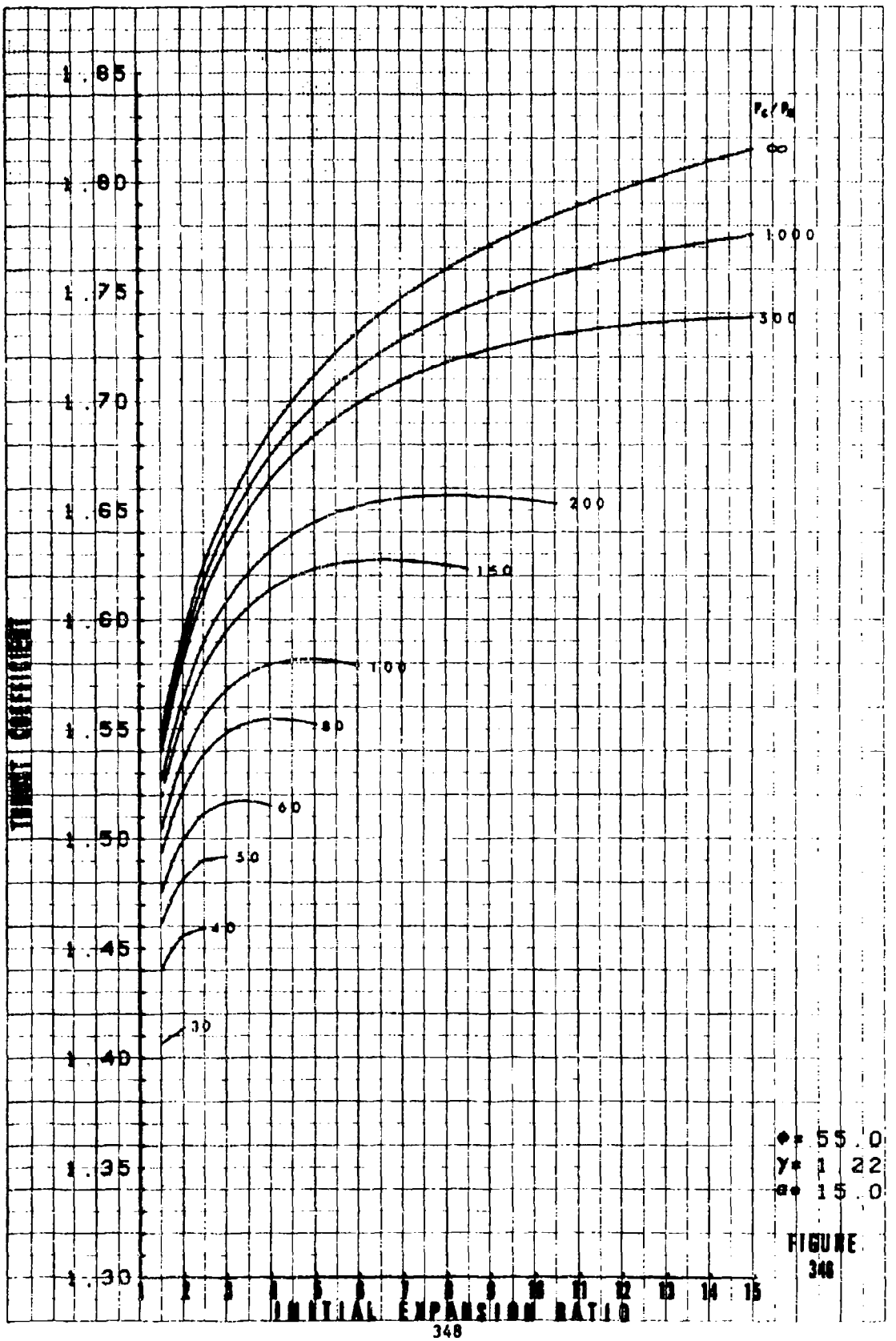

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
300
200
150
100
80
60
50
40
30
φ= 55.0
γ= 1.22
α= 15.0

FIGURE 348

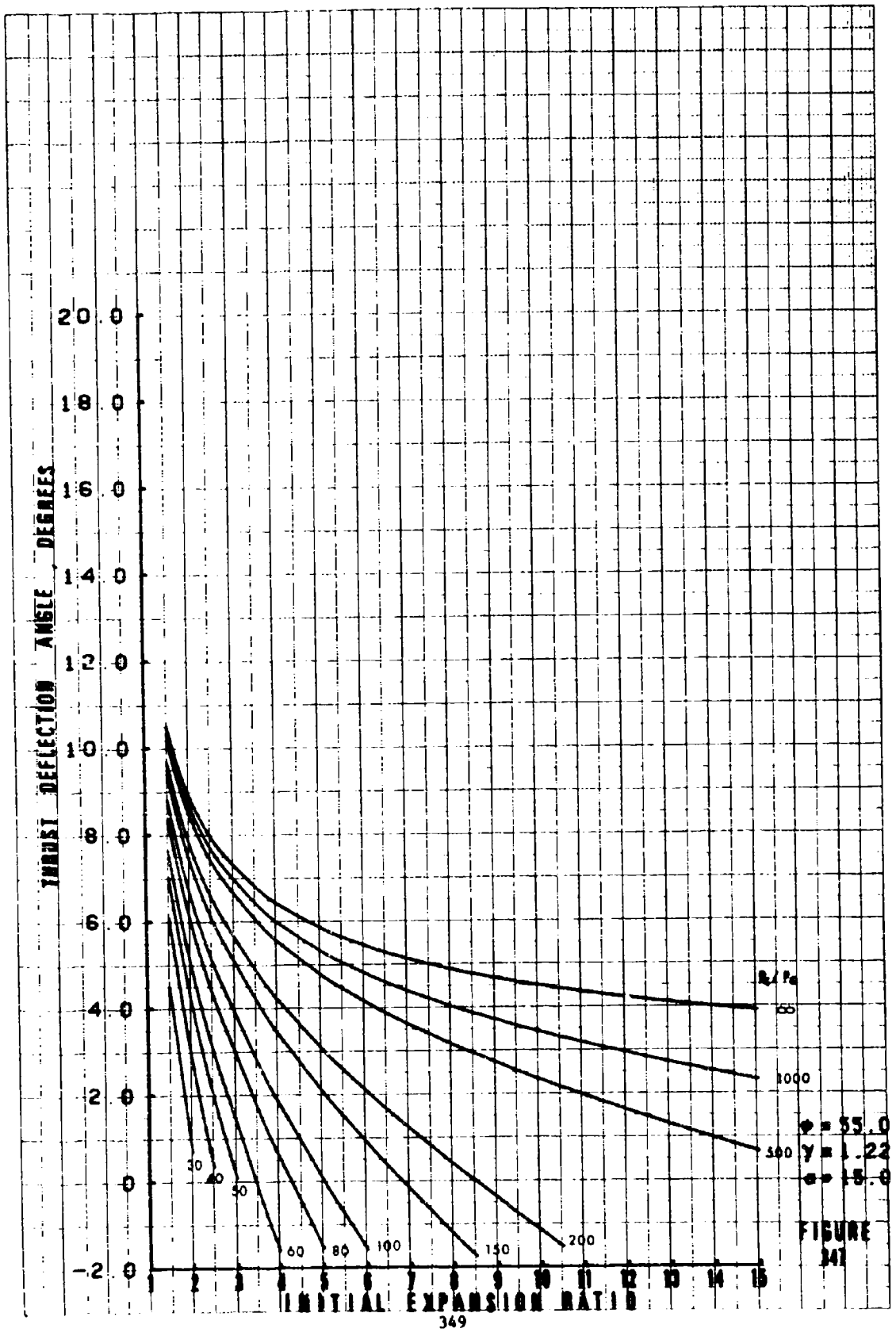

THRUST DEFLECTION ANGLE DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
500
1000
φ = 55.0
γ = 1.22
α = 15.0

FIGURE 347

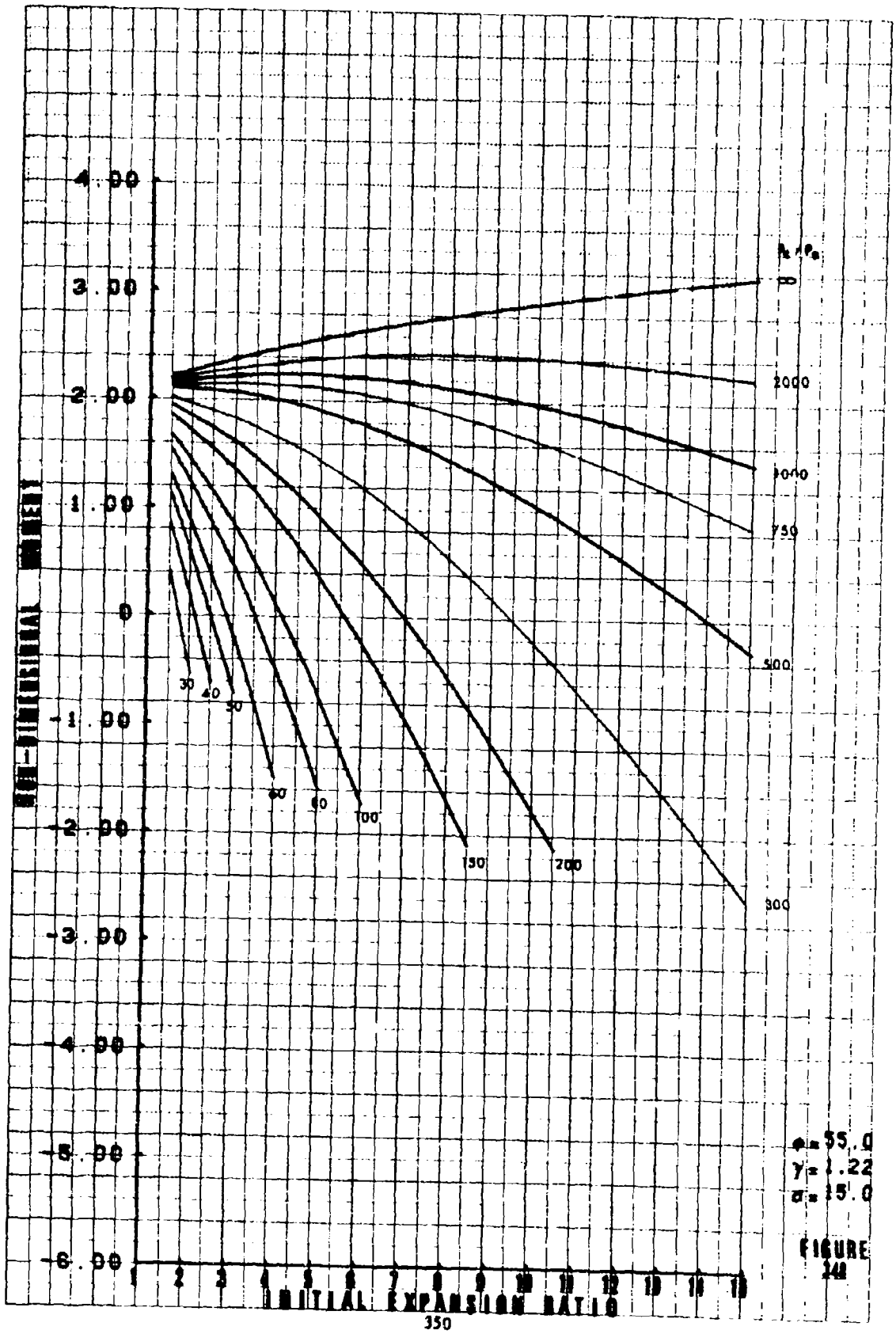
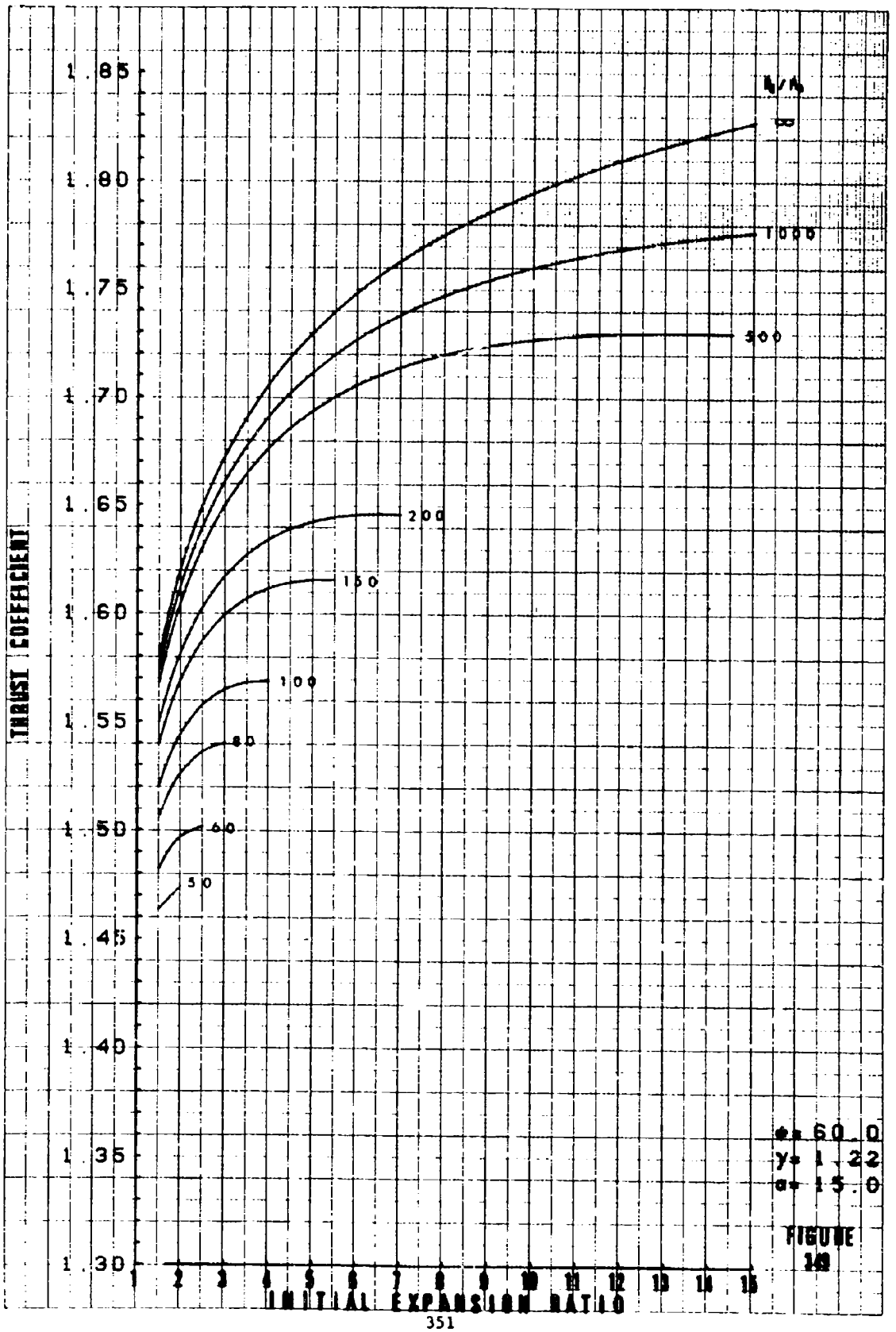

4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
30
φ = 55.0
γ = 1.22
σ = 15.0

FIGURE 248



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
φ= 60.0
γ= 1.22
α= 15.0

FIGURE 149

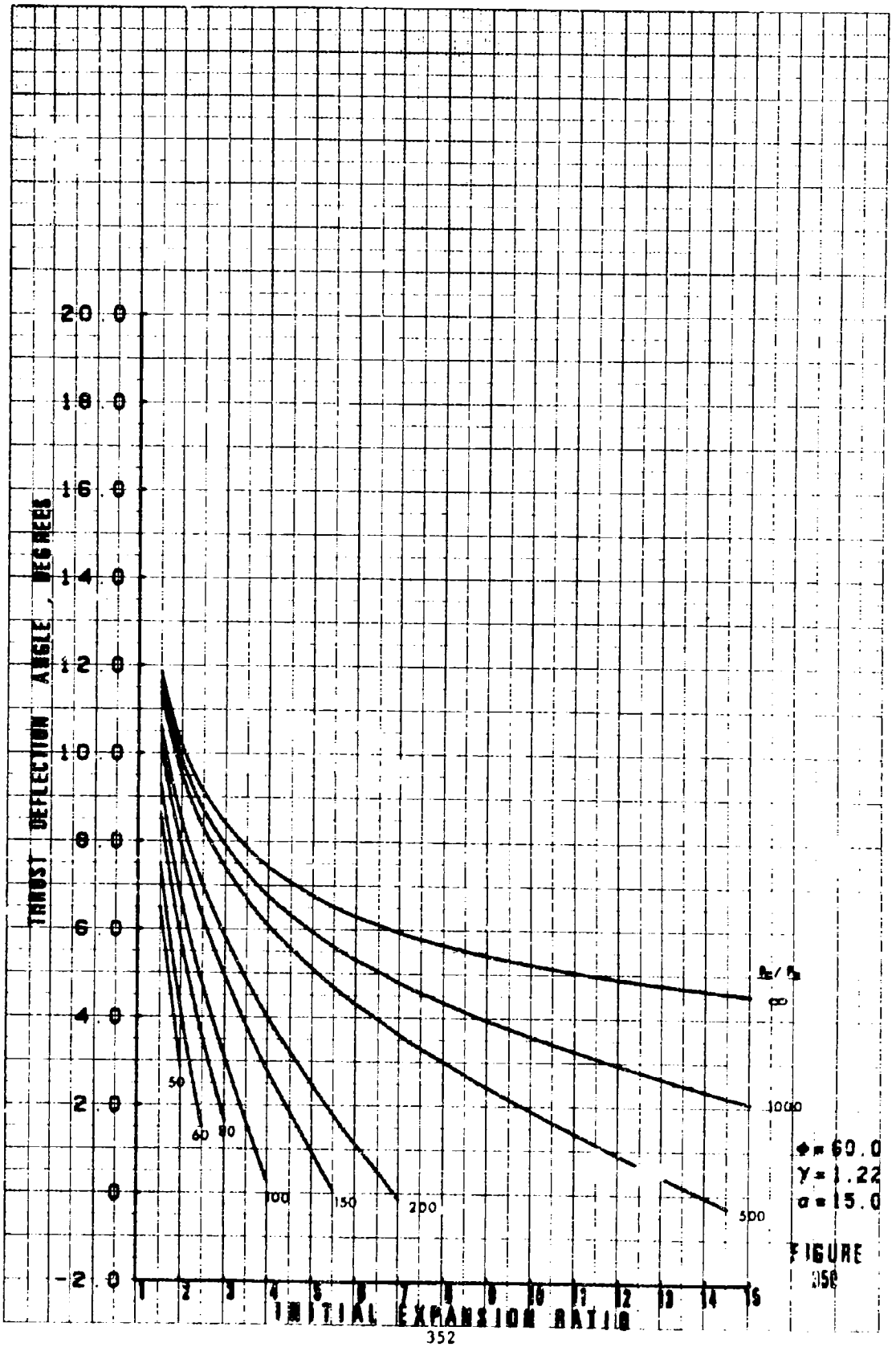
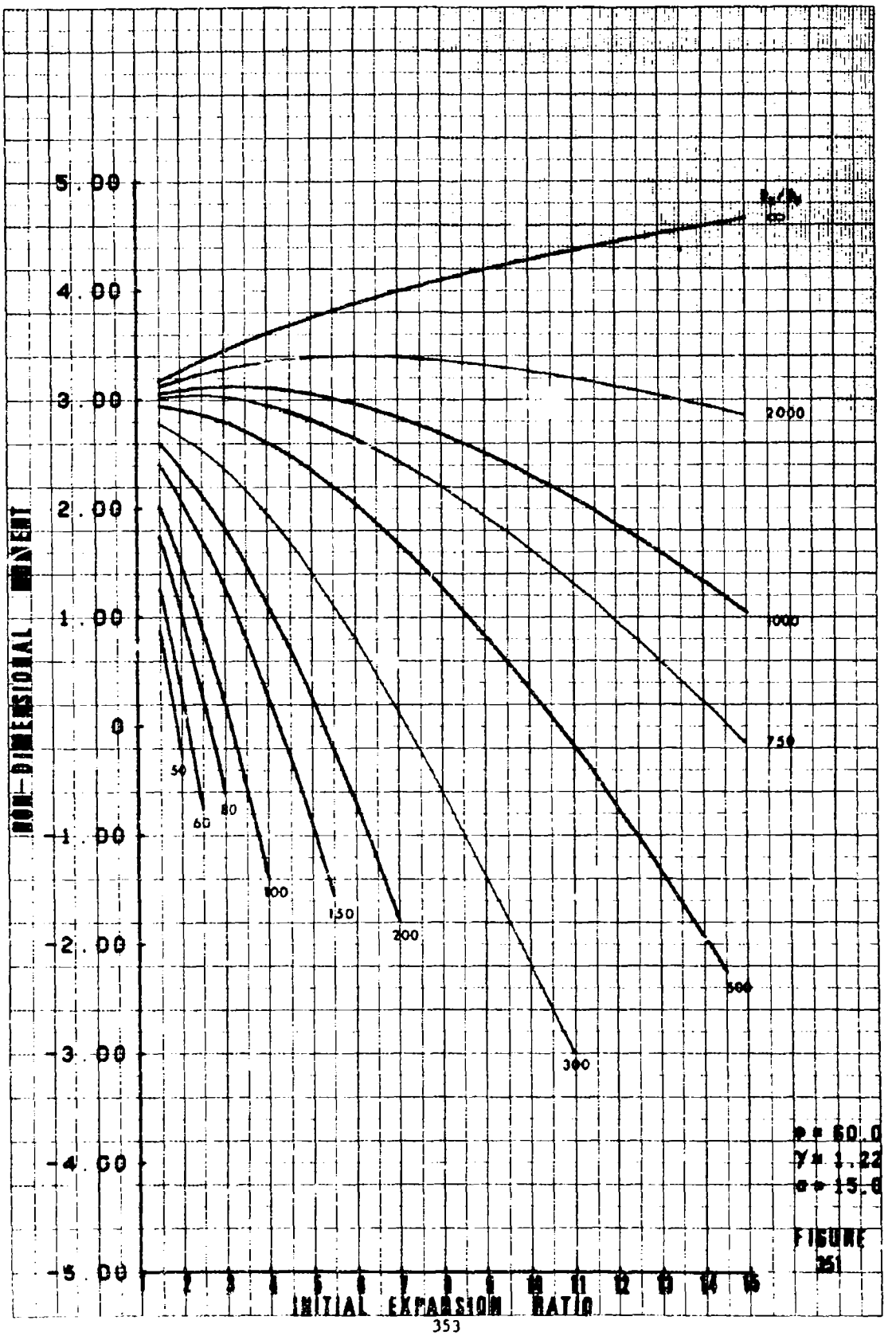

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
50
60
80
100
150
200
500
1000
$\phi = 60.0$
$\gamma = 1.22$
$\sigma = 15.0$

FIGURE 358


5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
2000
1000
750
500
300
200
150
100
80
60
50
FIGURE 251

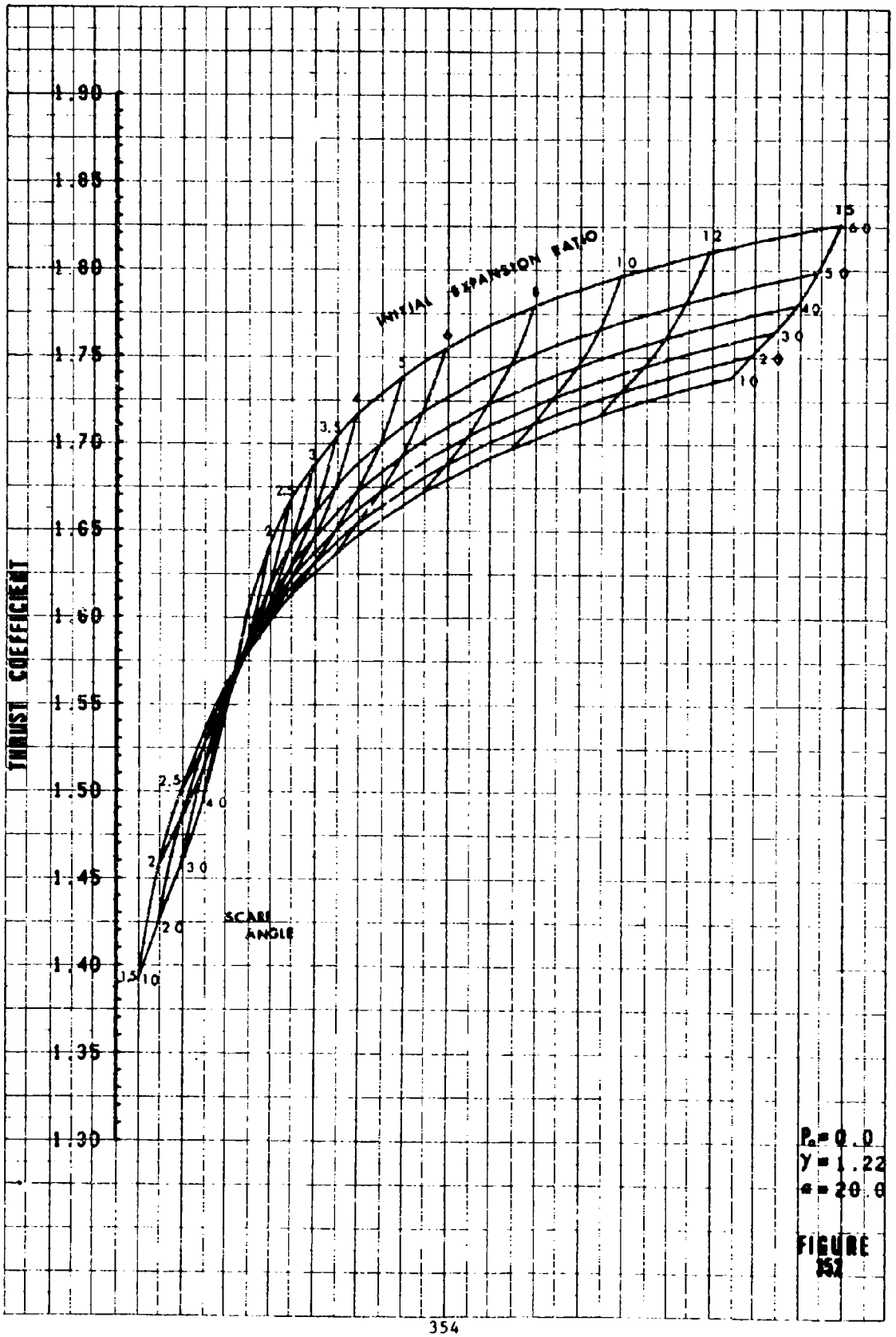

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
P_a = 0.0
γ = 1.22
α = 20.0

FIGURE 352

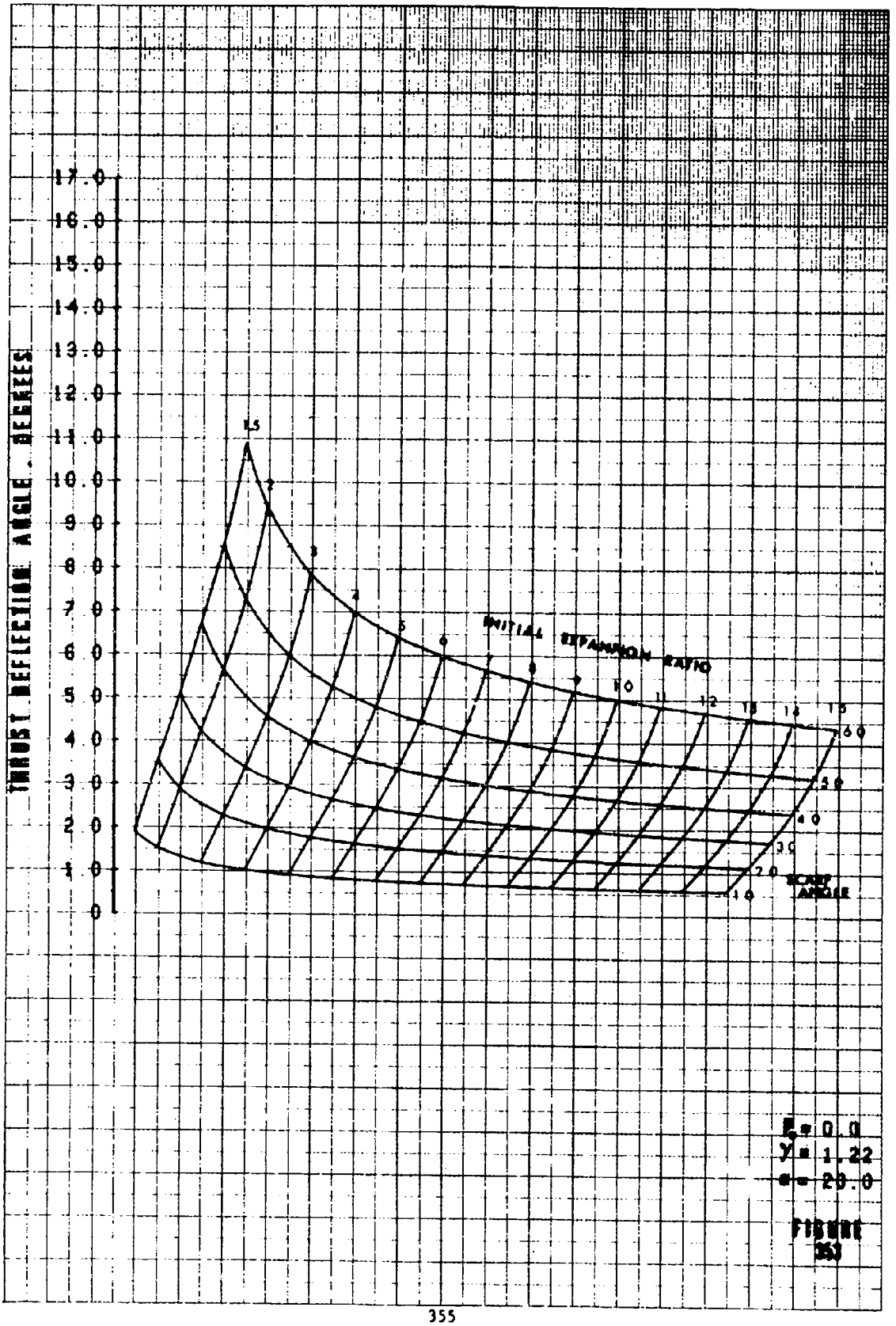

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
SCARF ANGLE
ξ = 0.0
γ = 1.22
α = 20.0

FIGURE 353

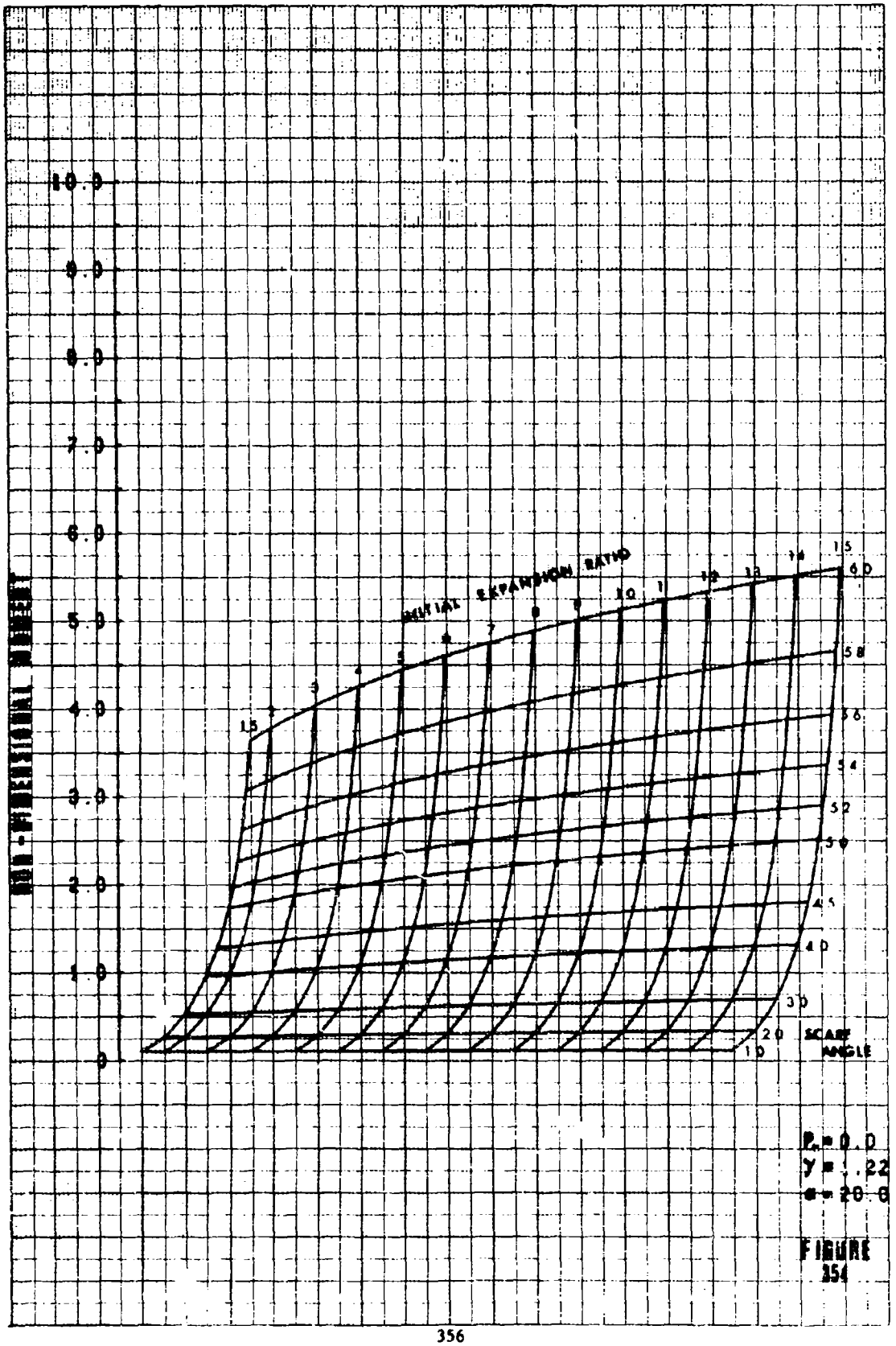
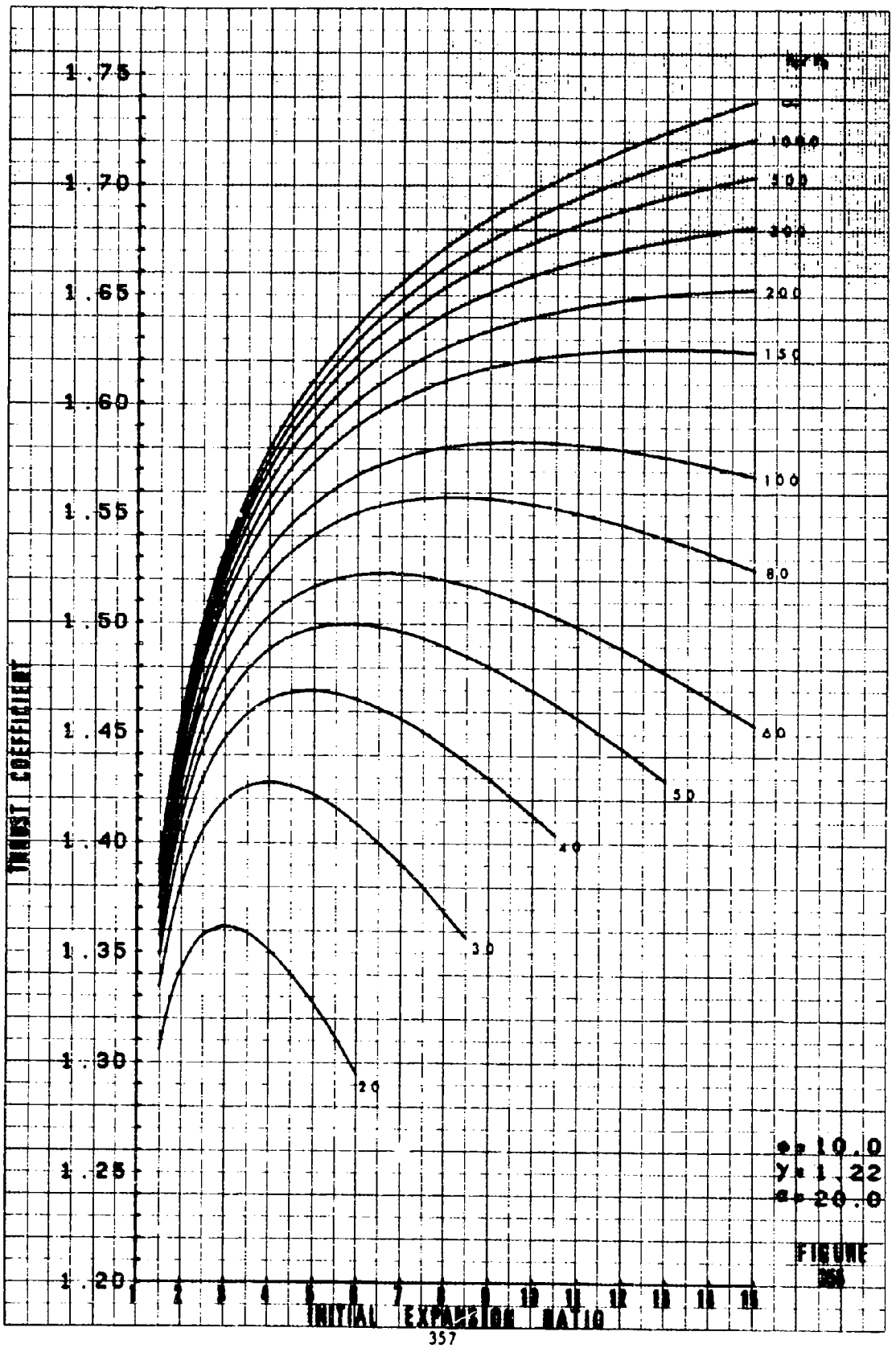

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
6.0
5.8
5.6
5.4
5.2
5.0
4.5
4.0
3.0
2.0
1.0
SCARF ANGLE
P_o = 0.0
γ = .22
α = 20.0

FIGURE 354



1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
THRUST COEFFICIENT
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.22
α = 20.0
FIGURE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

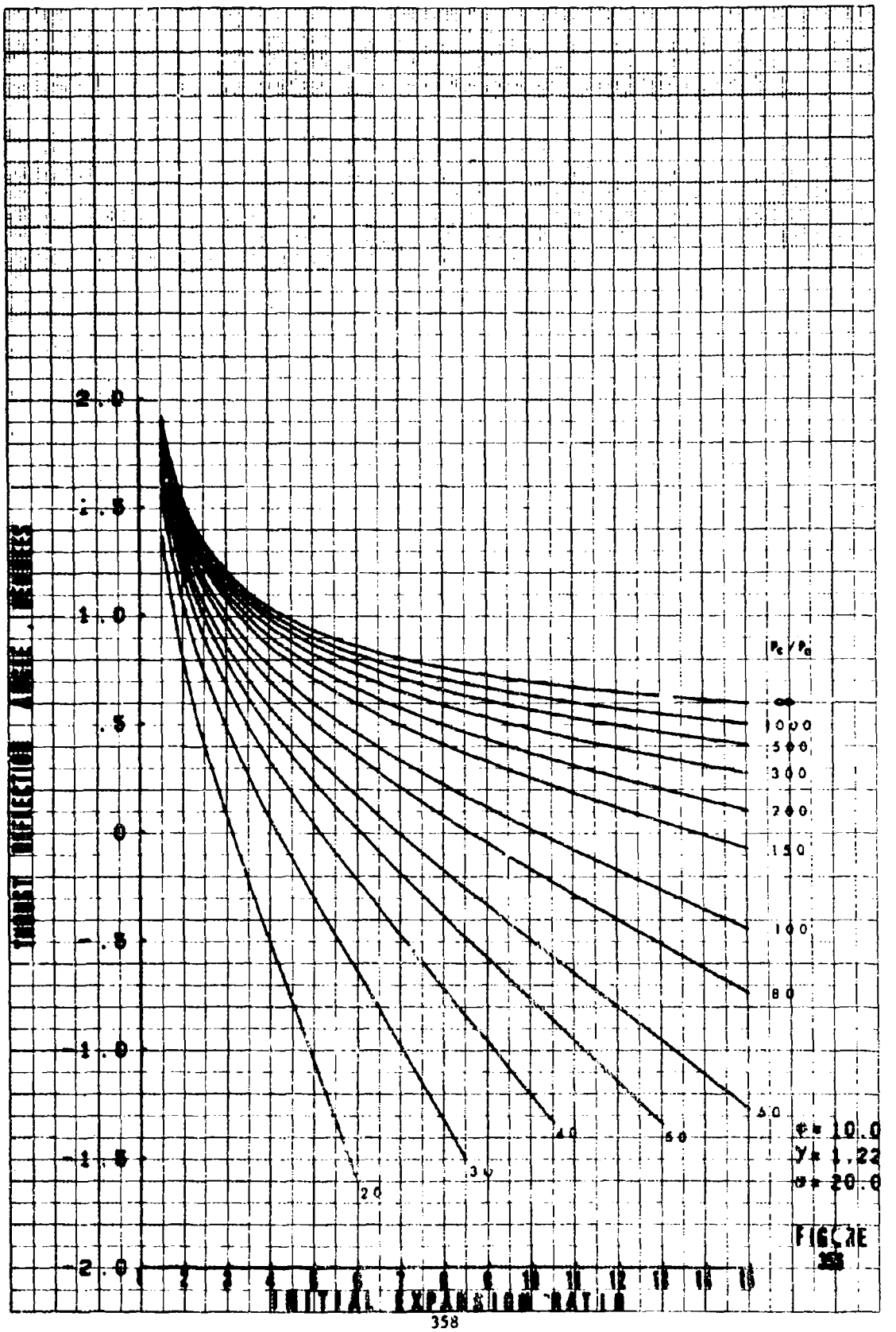

2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
40
30
20
ϵ = 10.0
γ = 1.22
θ = 20.0

FIGURE 358

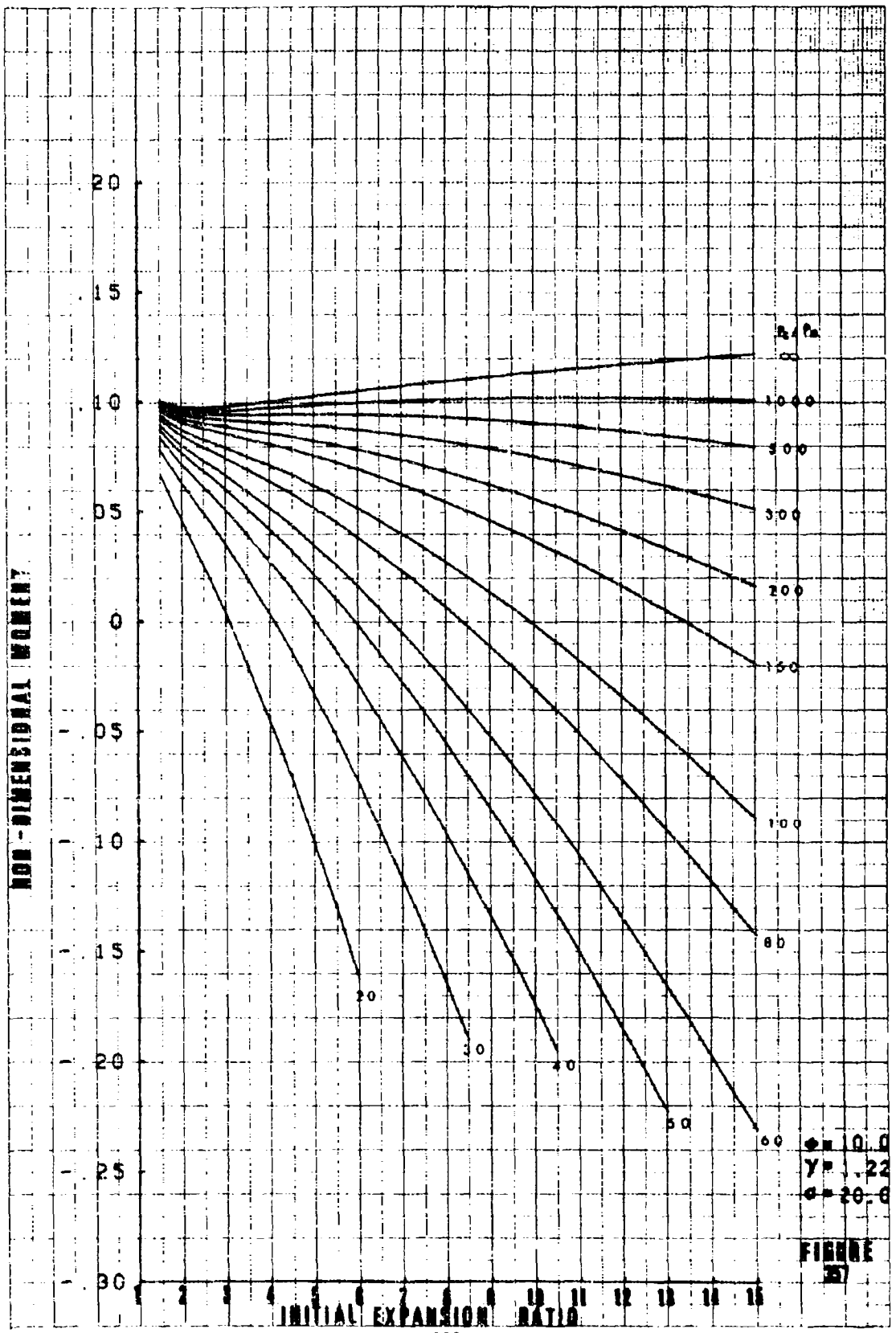

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_2/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = .22
α = 20.0

FIGURE 35

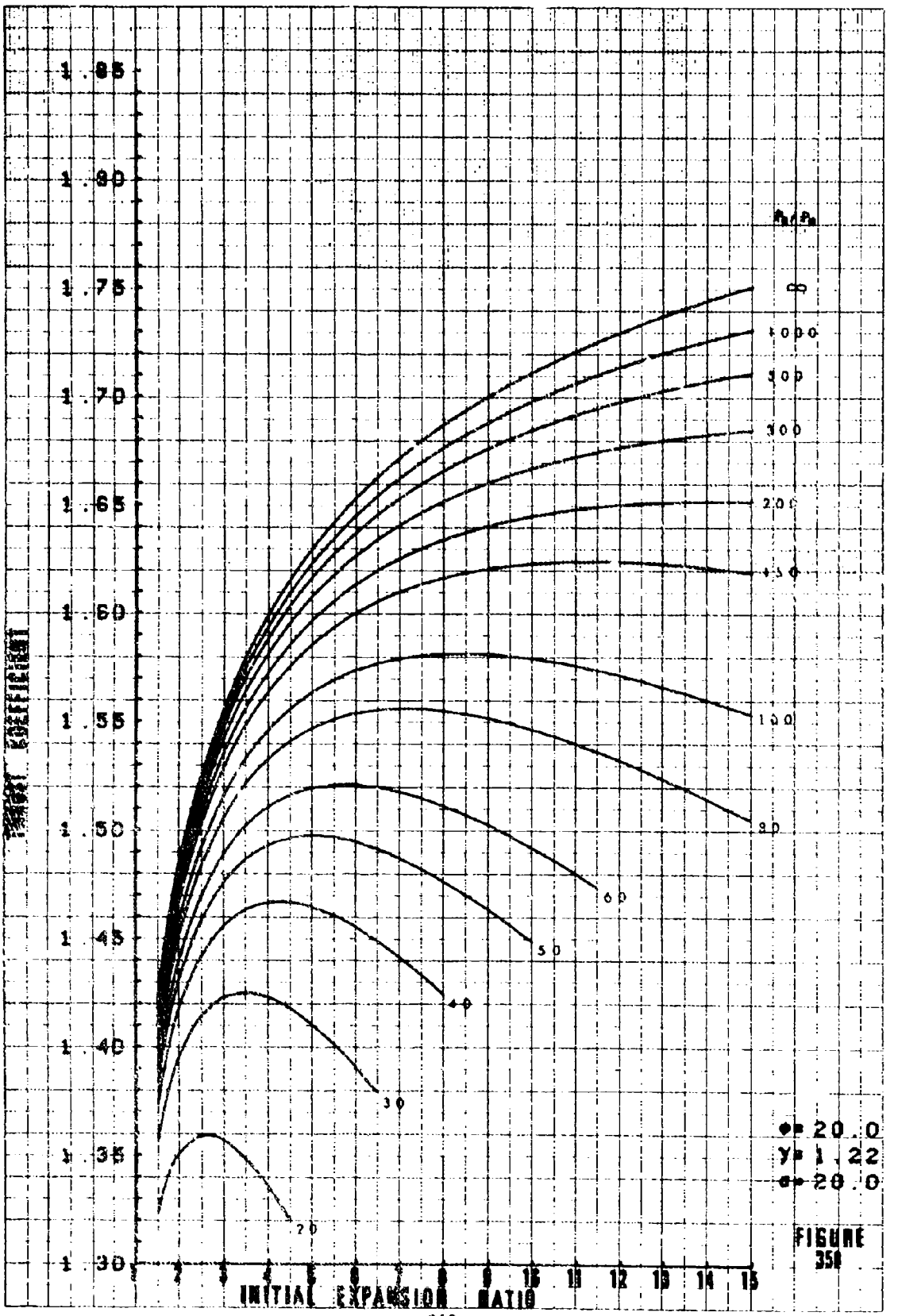

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 20.0
γ= 1.22
α= 20.0

FIGURE 350

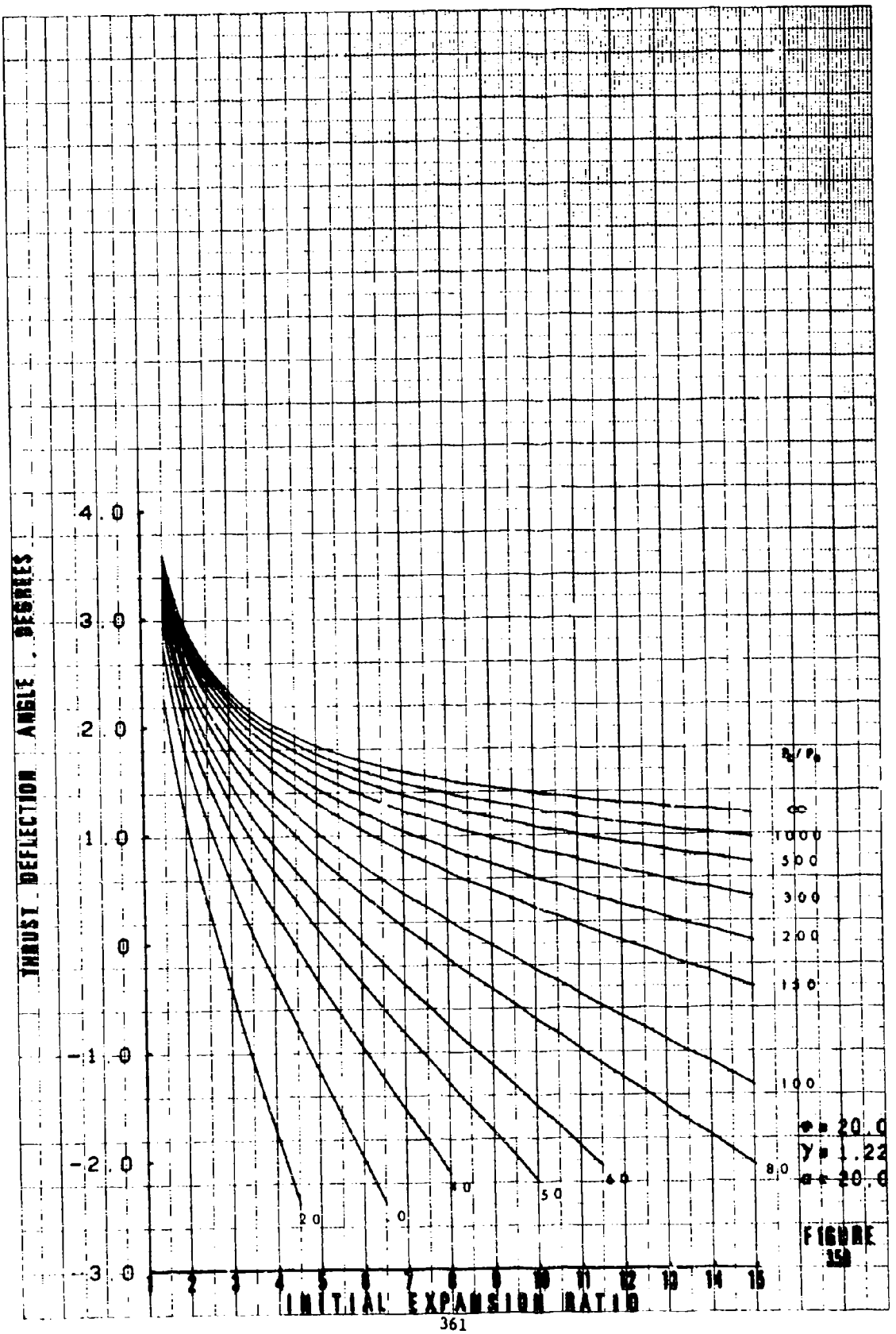
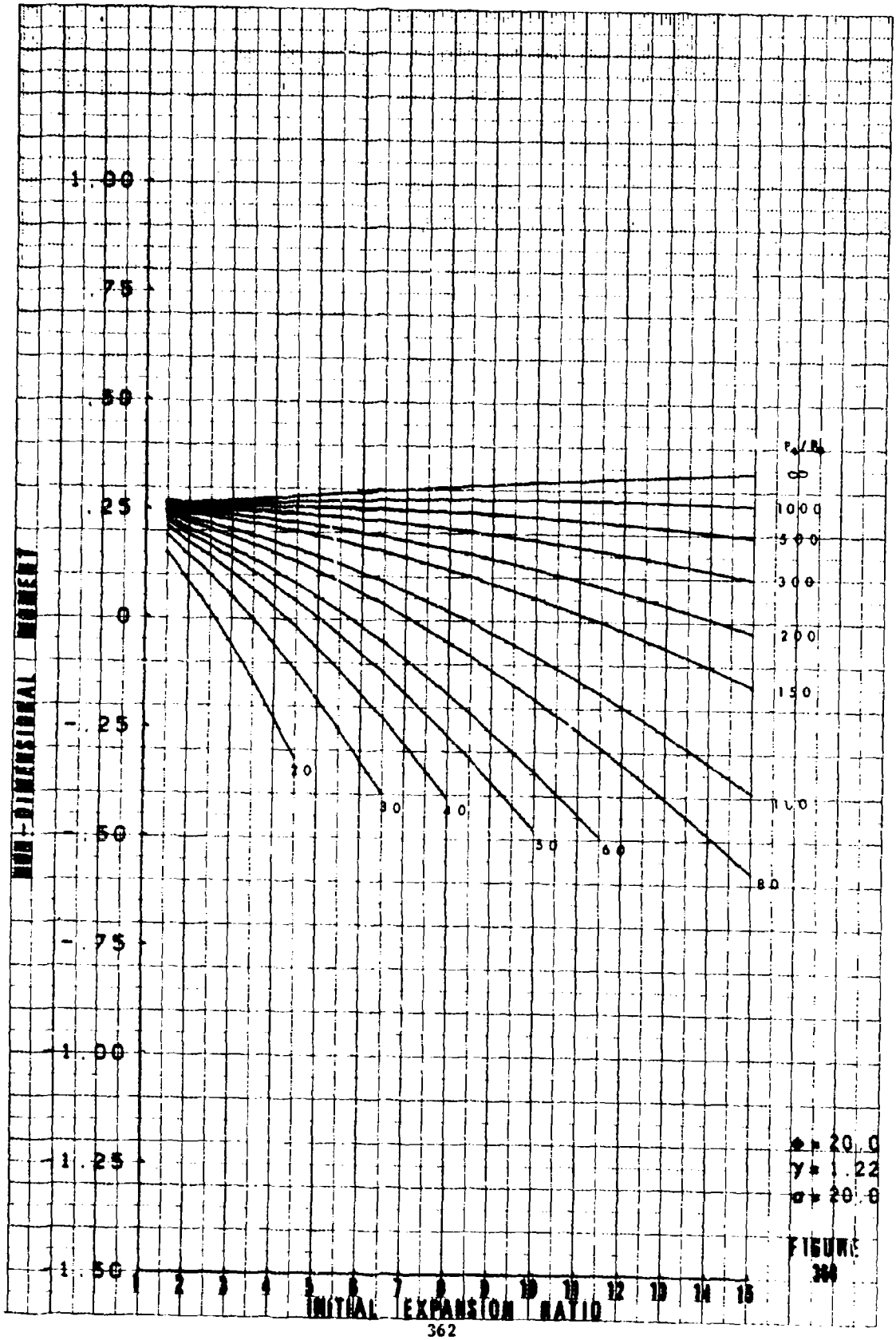

THRUST DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_b
∞
1000
500
300
200
150
100
80
20
0
10
50
40
γ = 1.22

FIGURE 15



1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_a/P_0
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.22
α = 20.0

FIGURE 360

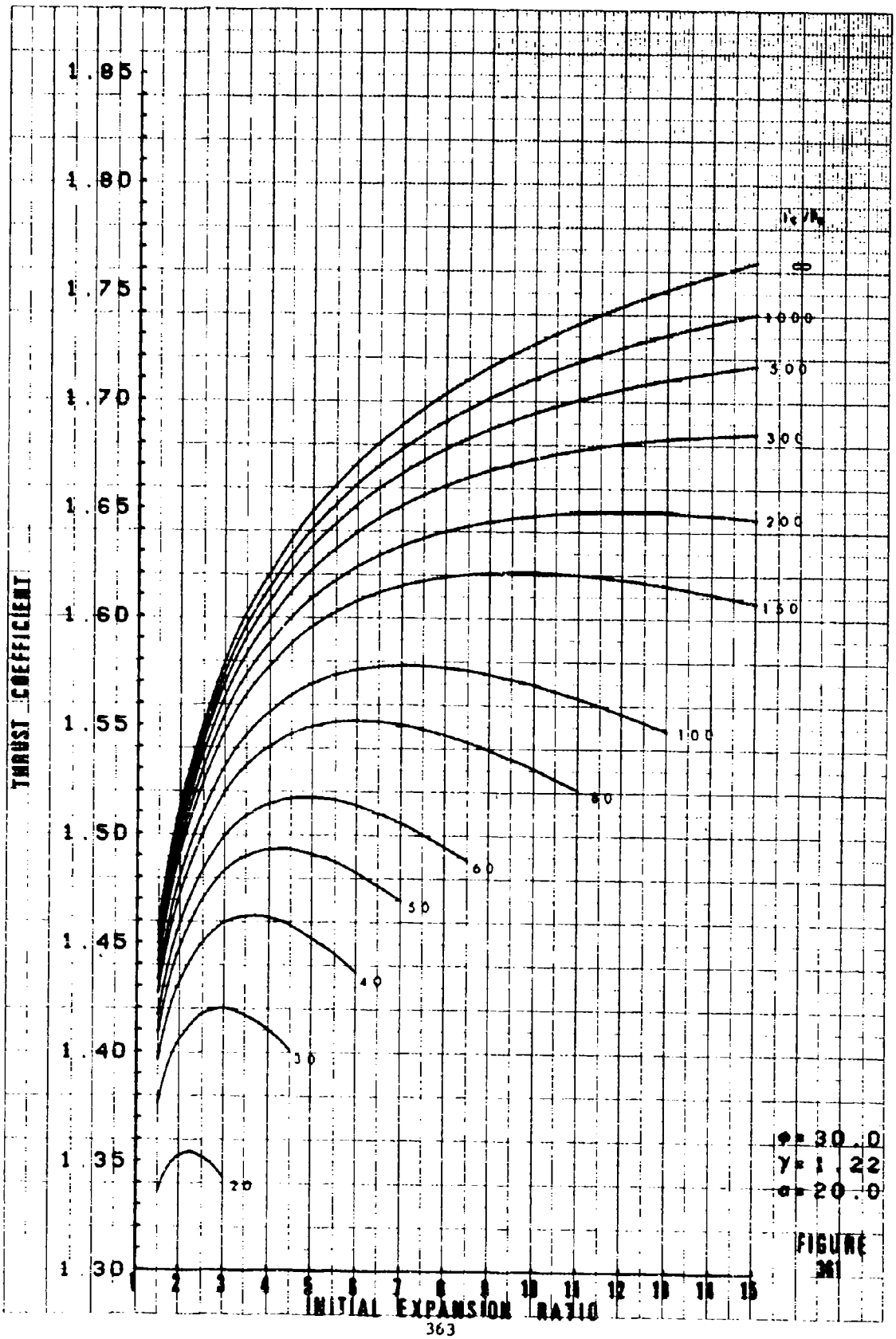

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.22
α= 20.0

FIGURE 31

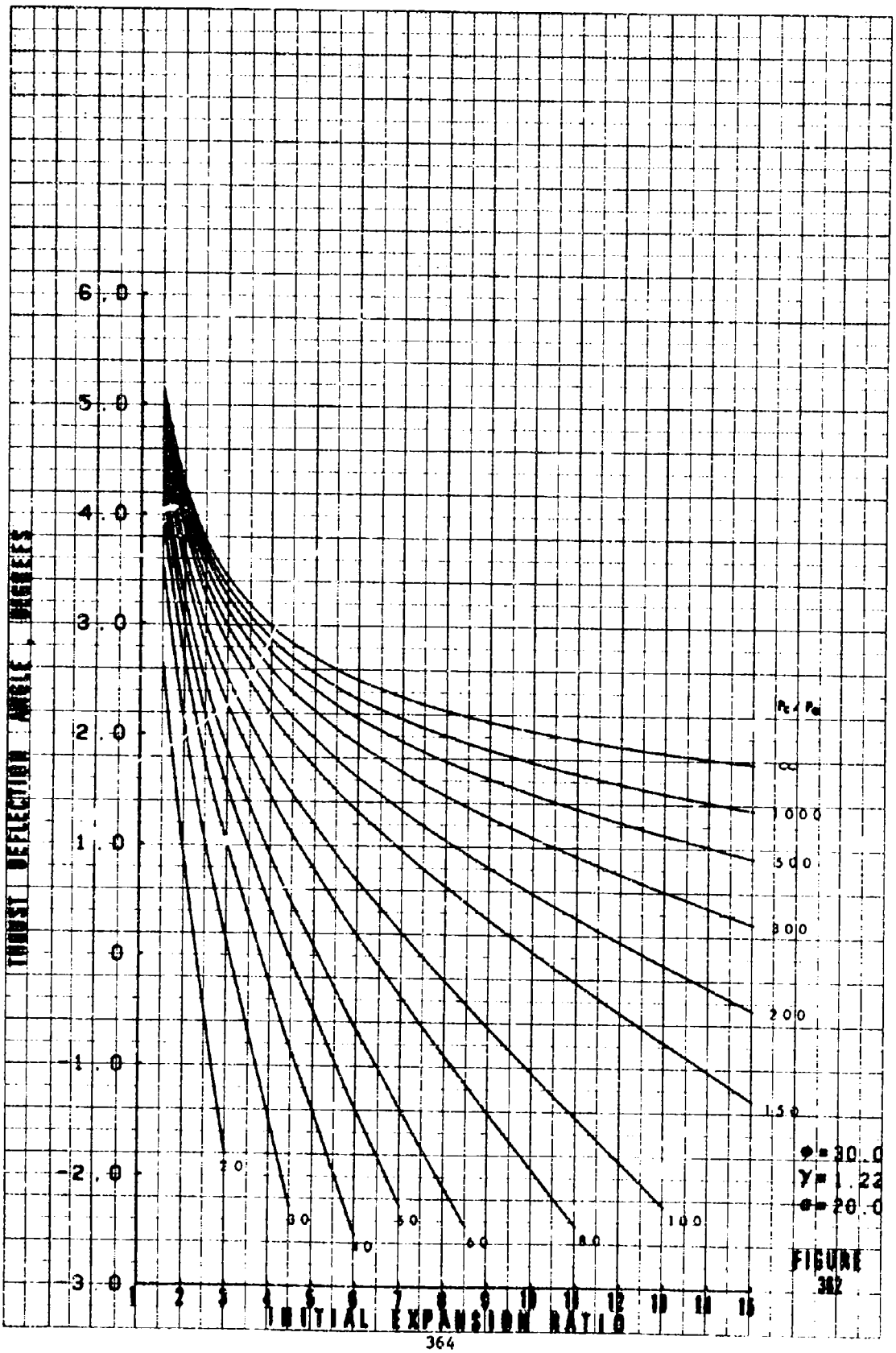
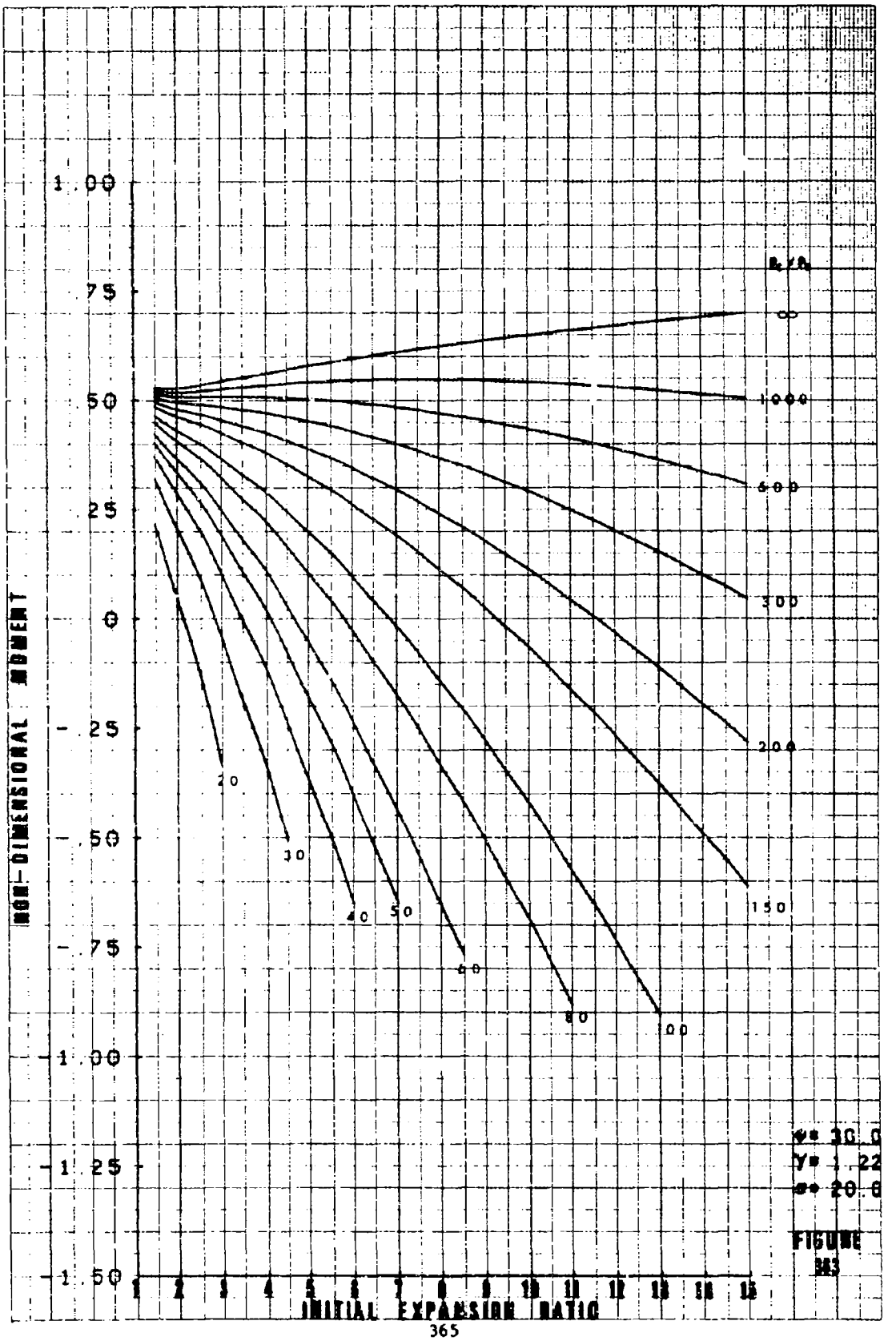

THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c / P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.22
θ = 20.0

FIGURE 382



NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
600
300
200
150
100
80
60
50
40
30
20

FIGURE 363

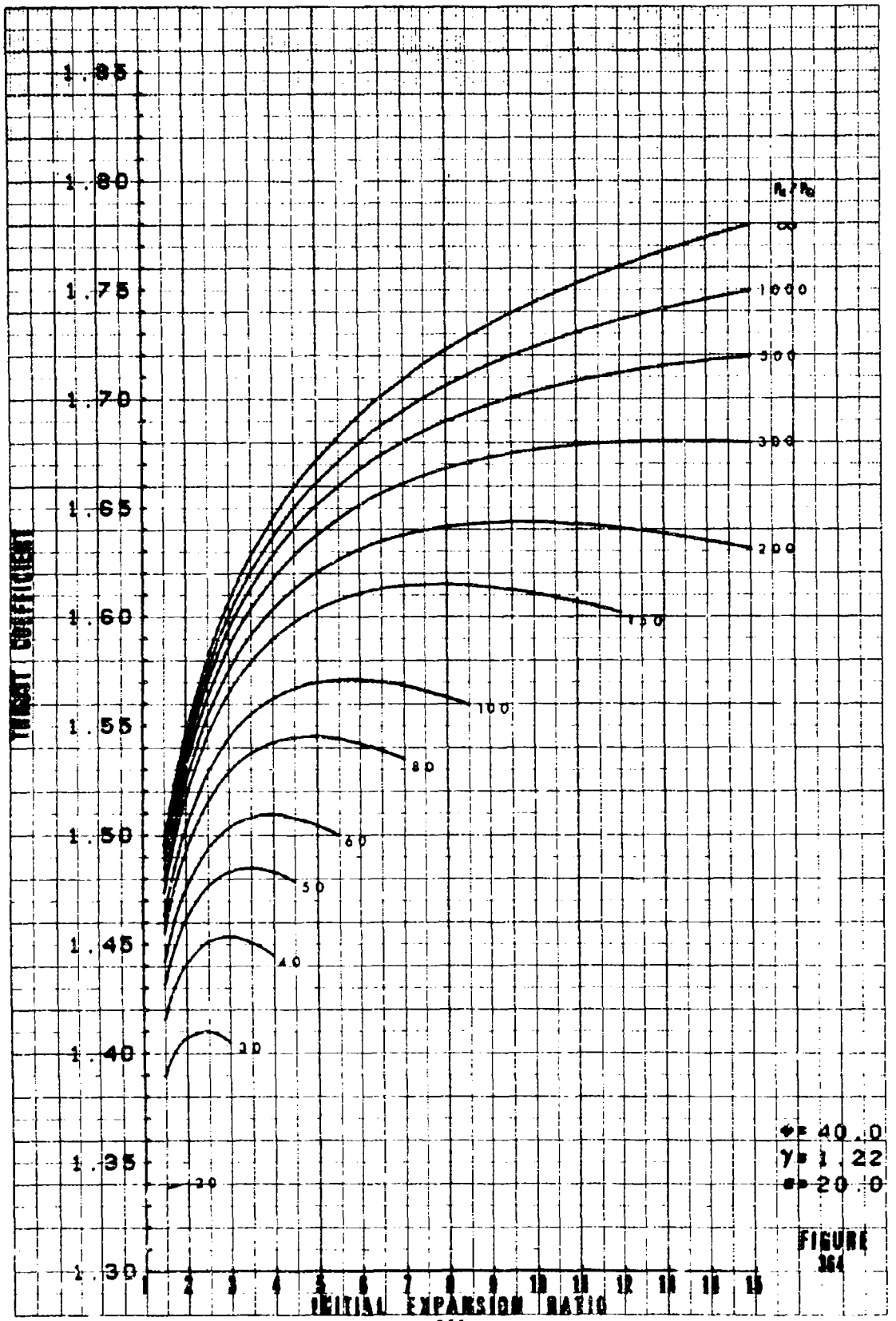

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 40.0
γ= 1.22
α= 20.0

FIGURE 364

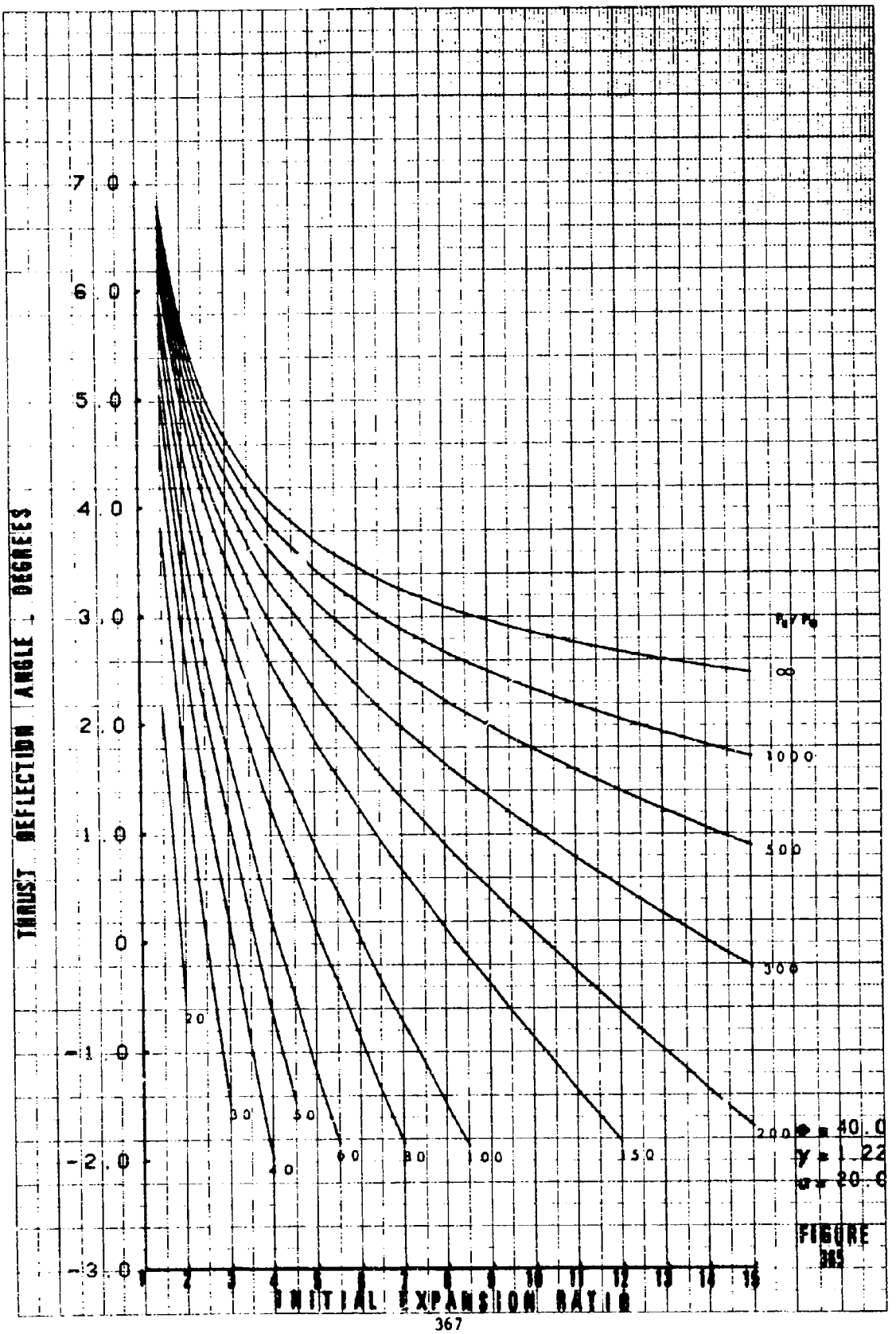

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_a/P_0
∞
1000
500
300
200
20
30
40
50
60
80
100
150
ϕ = 40.0
γ = 1.22
α = 20.0

FIGURE 365

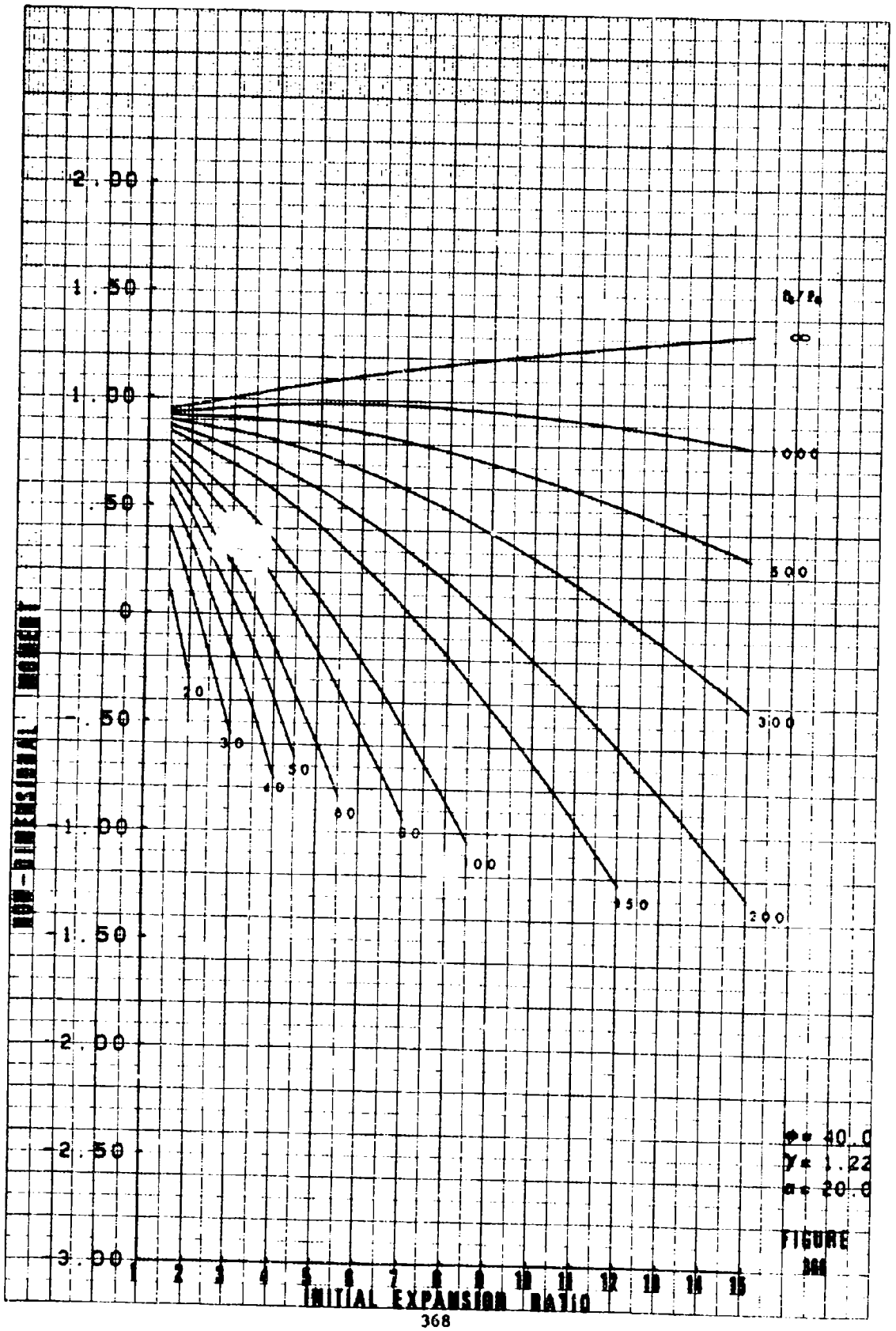

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.22
α = 20.0

FIGURE 366

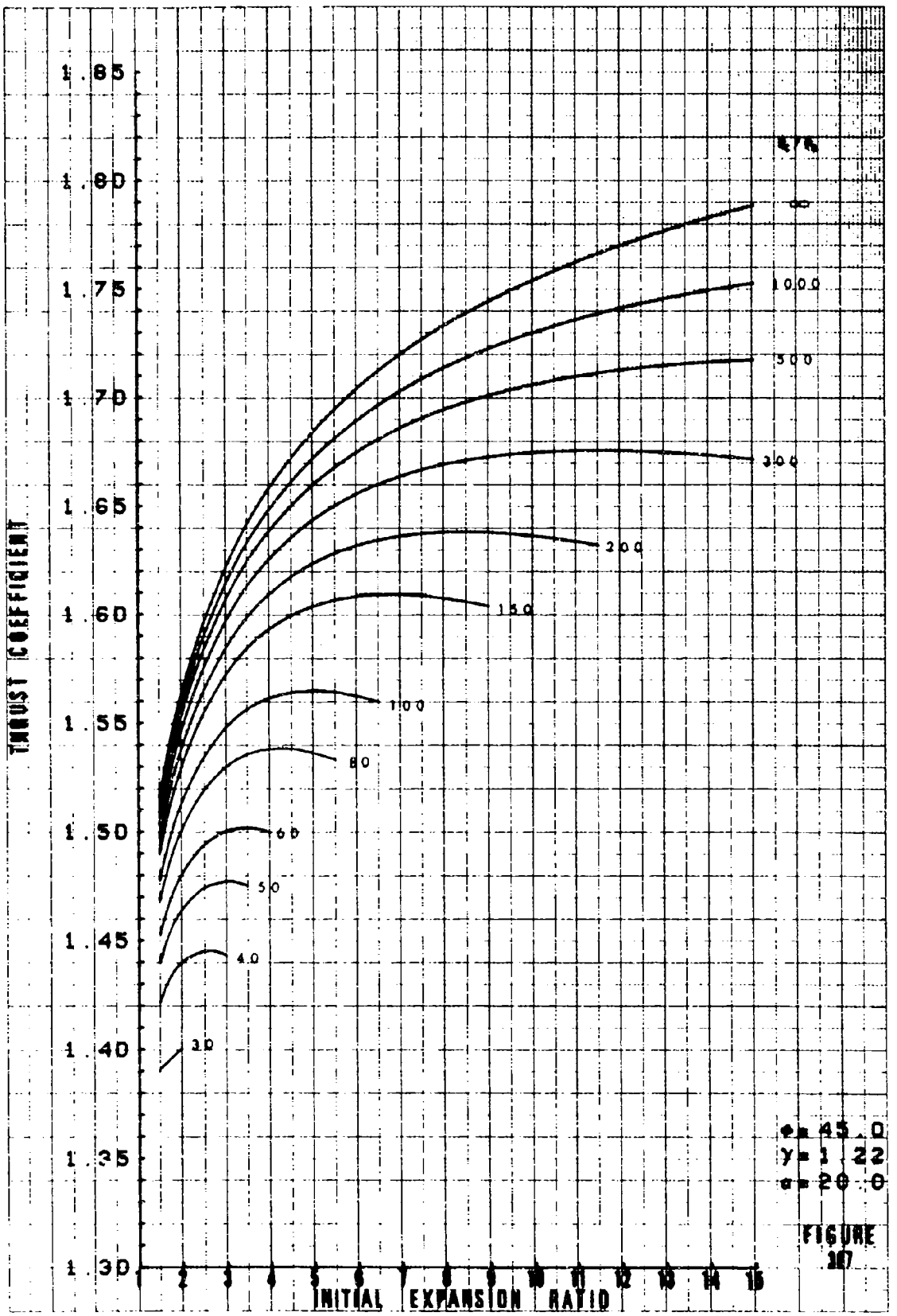

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
φ= 45.0
γ= 1.22
α= 20.0

FIGURE 107

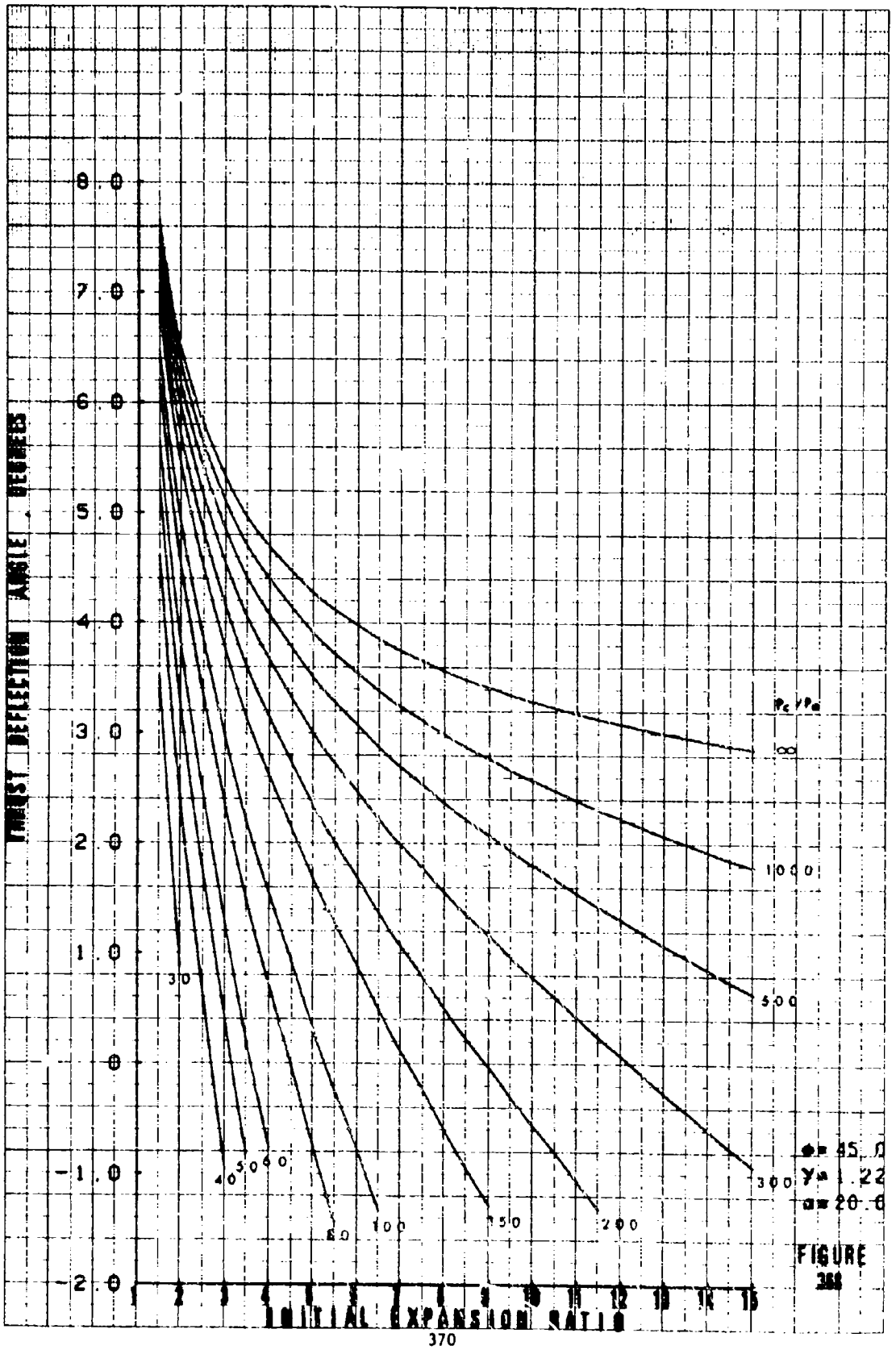

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
φ = 45.0
γ = 1.22
α = 20.6

FIGURE 368

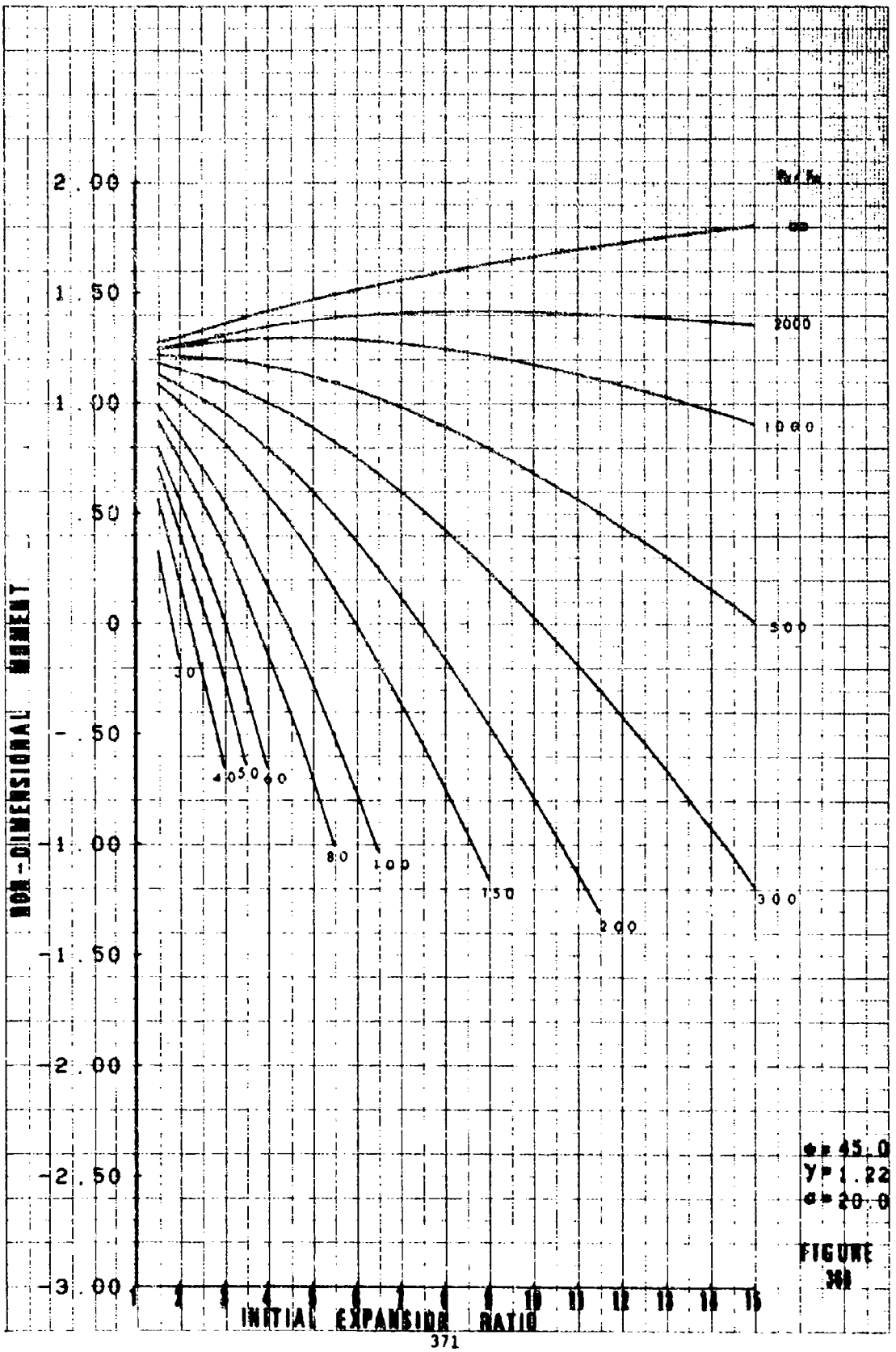

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1000
500
300
200
150
100
80
40
50
60
30
φ = 45.0
γ = 1.22
α = 20.0

FIGURE 36

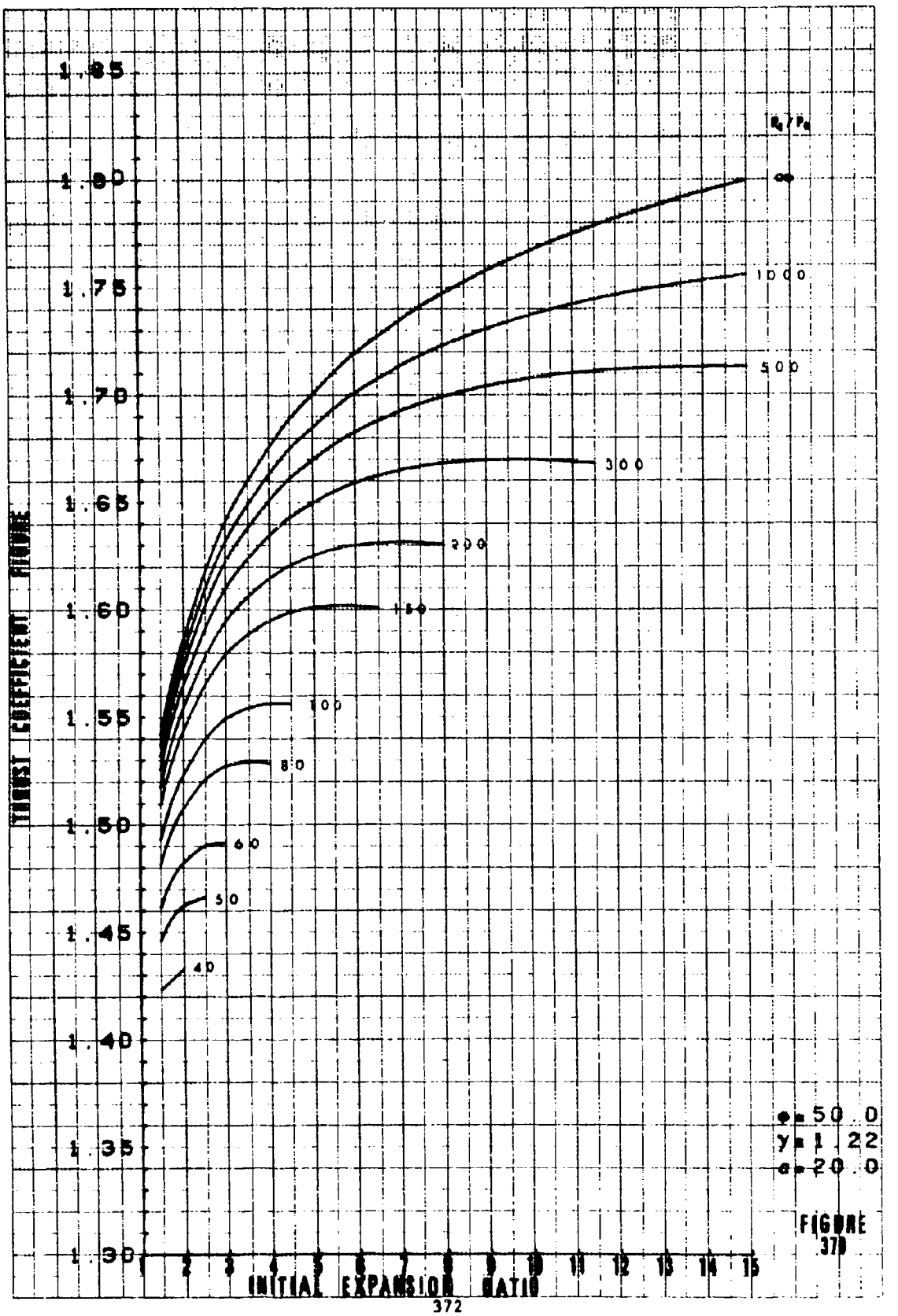

THRUST COEFFICIENT FINDRE
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_a/P_a
∞
1000
500
300
200
150
100
80
60
50
40
φ = 50.0
γ = 1.22
α = 20.0

FIGURE 37D

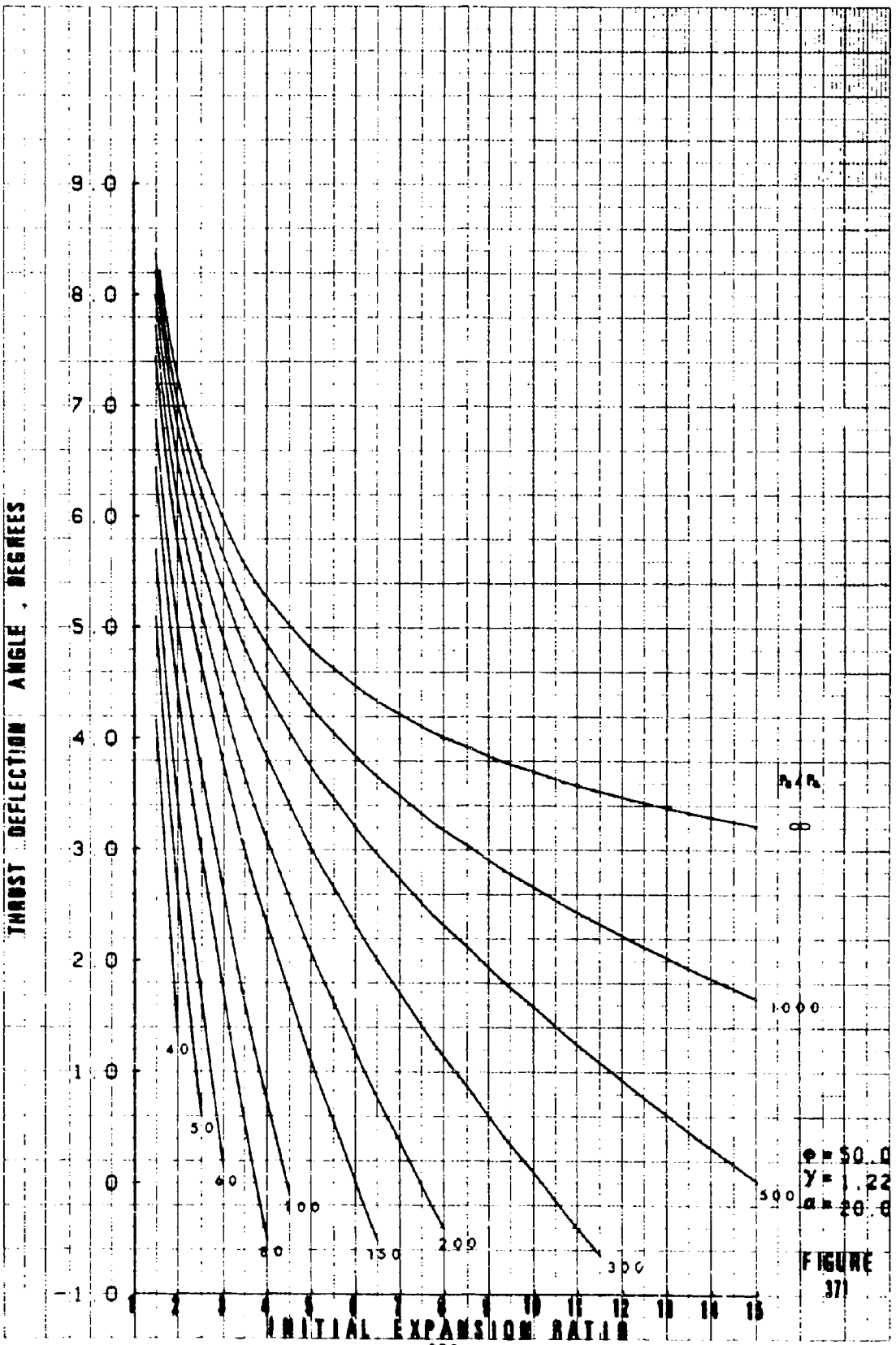
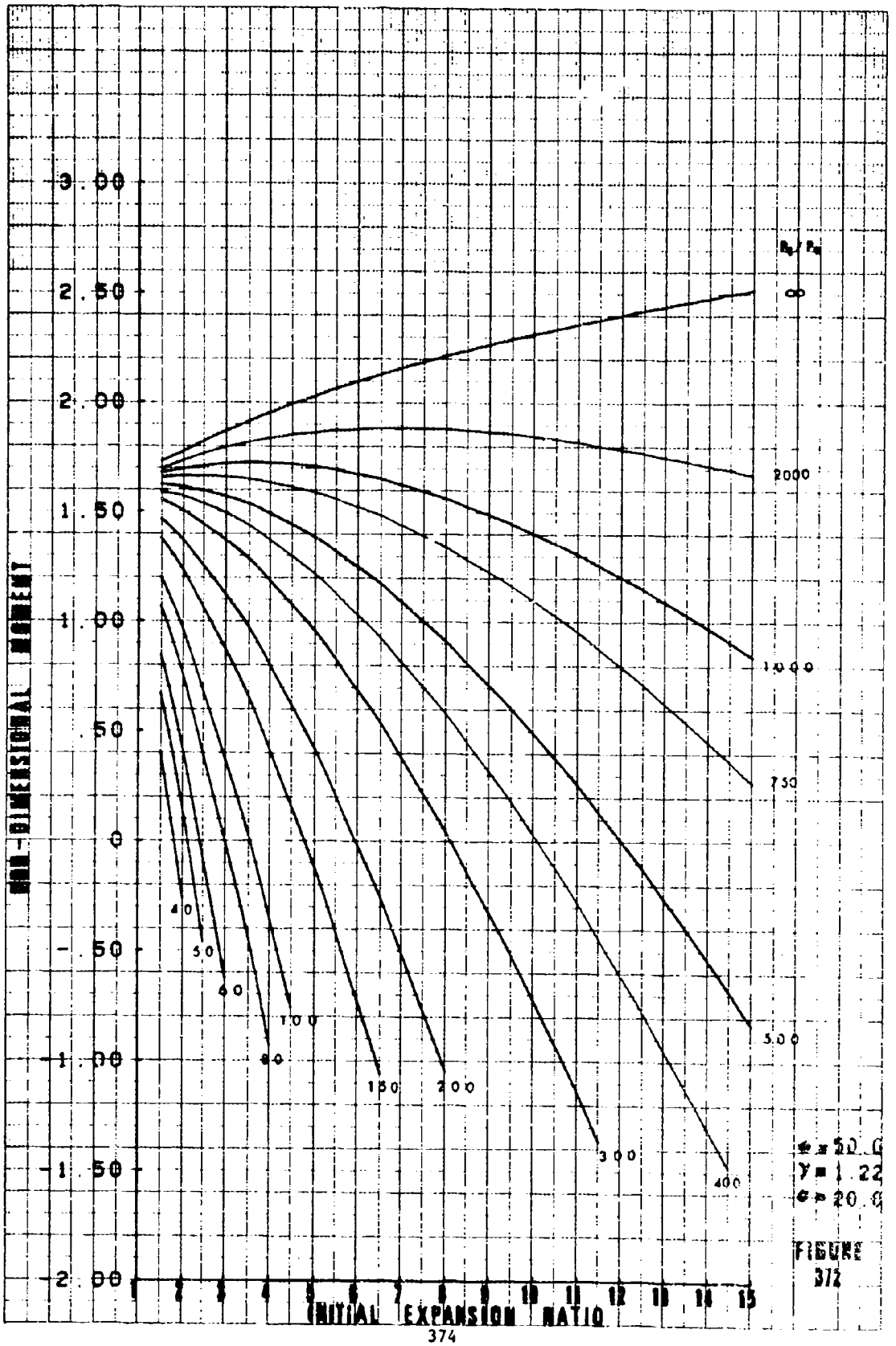

THRUST DEFLECTION ANGLE, DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
40
50
60
80
100
150
200
300
500
1000
∞
φ = 50.0
γ = 1.22
α = 20.0

FIGURE 371



3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
400
300
200
150
100
80
60
50
40

FIGURE 372

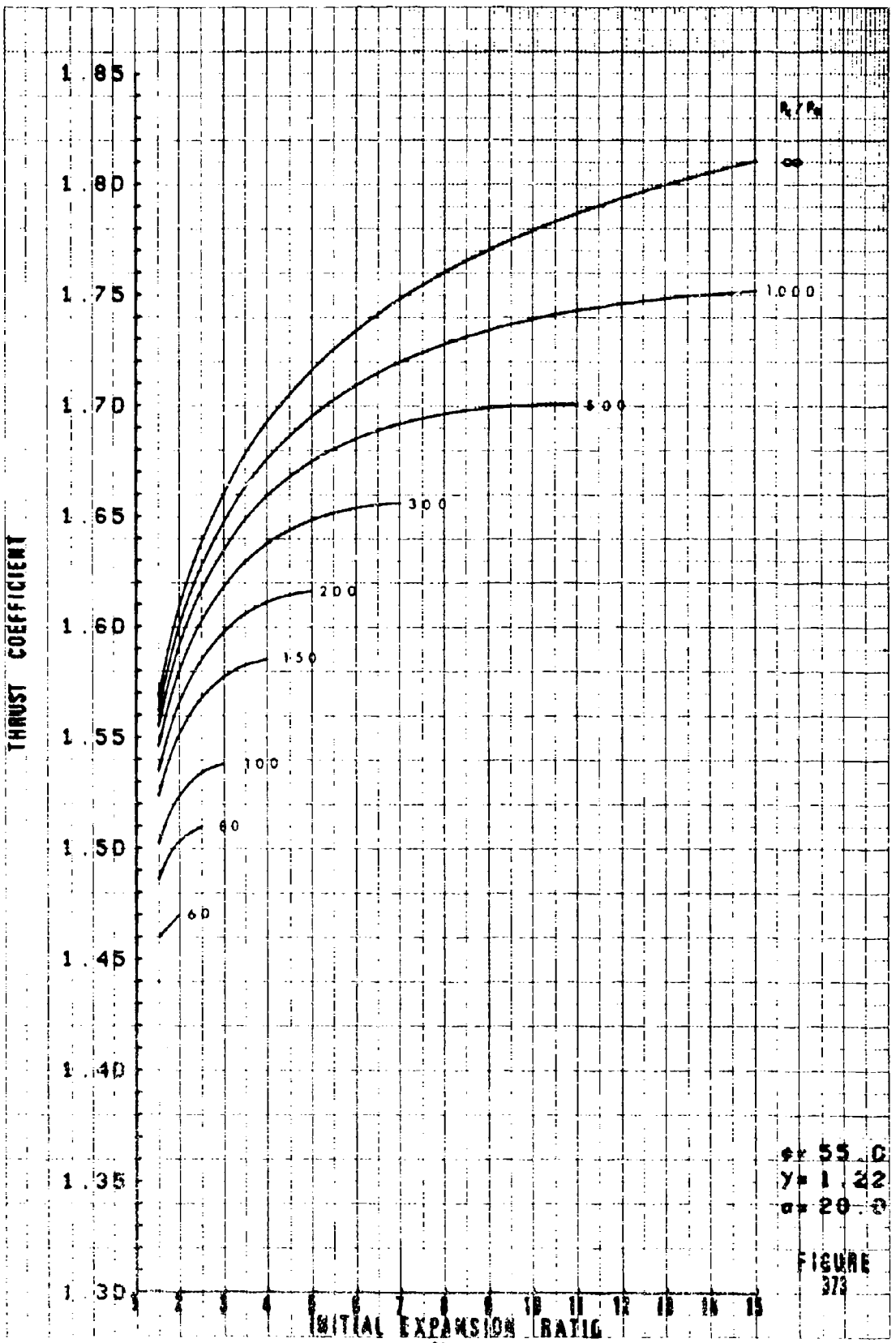
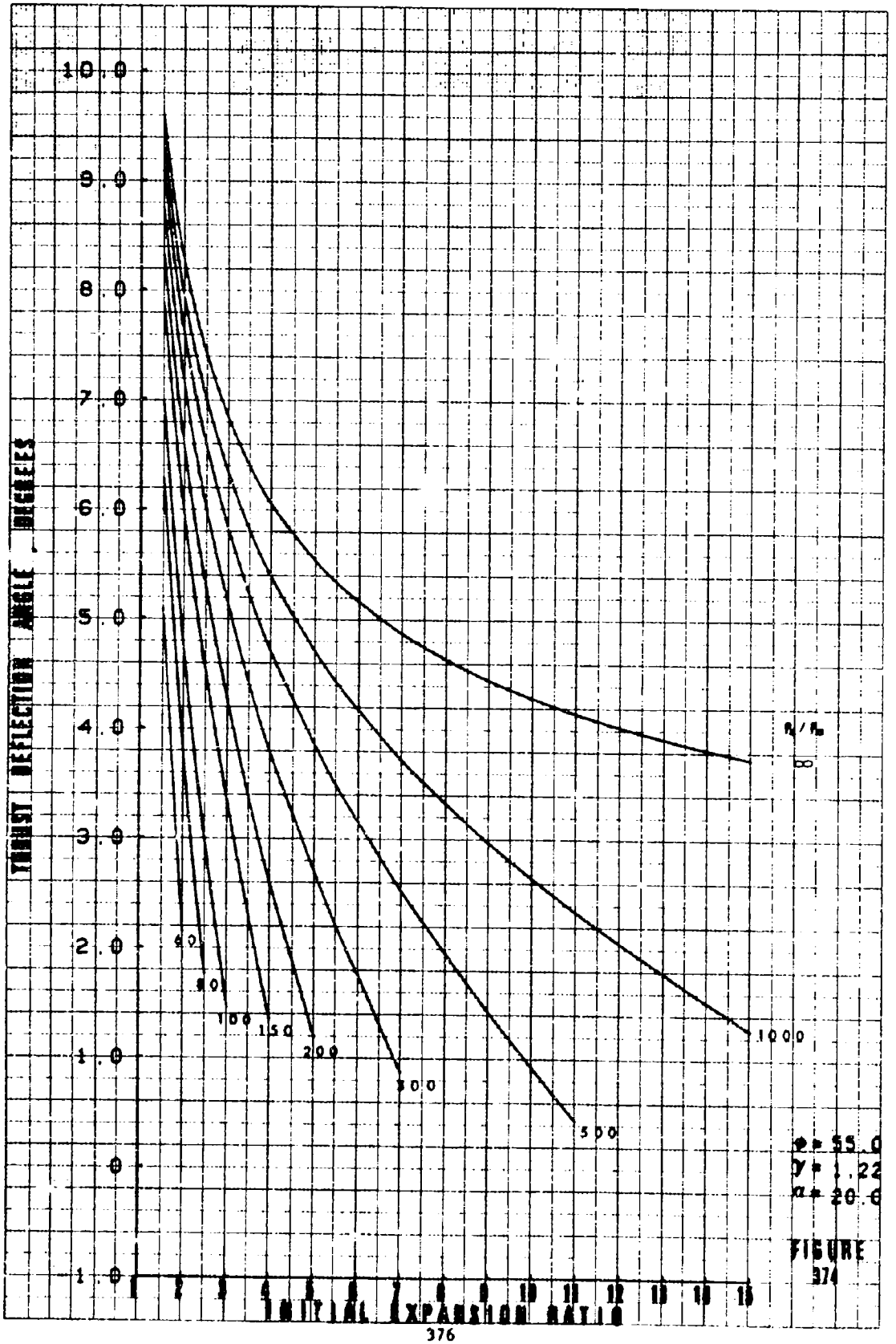

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
300
200
150
100
80
60
φ= 55.0
γ= 1.22
α= 20.0

FIGURE 373



THRUST DEFLECTION ANGLE, DEGREES
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.0
60
80
100
150
200
300
500
1000
∞
φ = 55.0
γ = 1.22
α = 20.6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 374

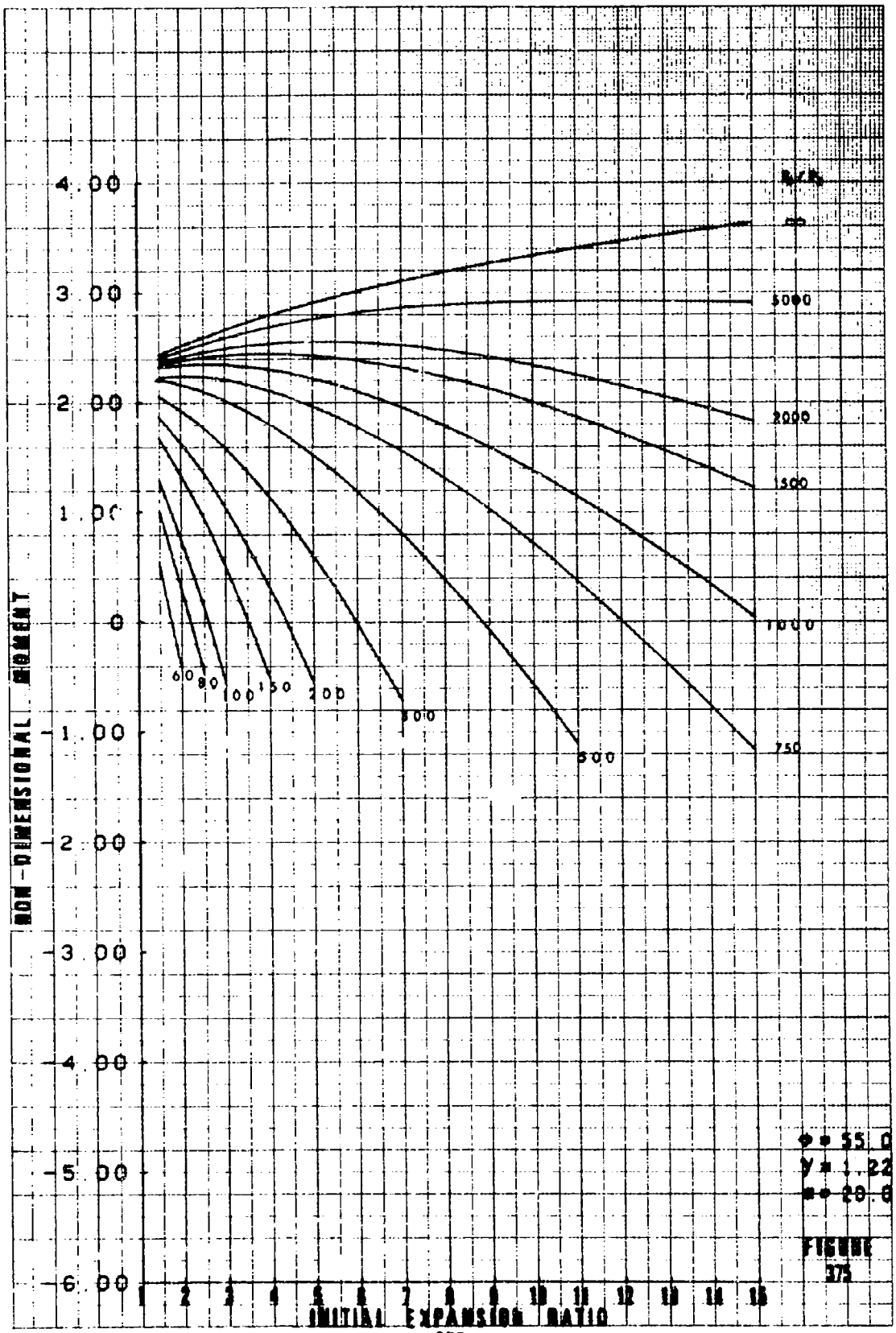

NON-DIMENSIONAL MOMENT
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
5000
2000
1500
1000
750
500
300
200
150
100
80
60
φ = 55.0
γ = 1.22
α = 20.0

FIGURE 375

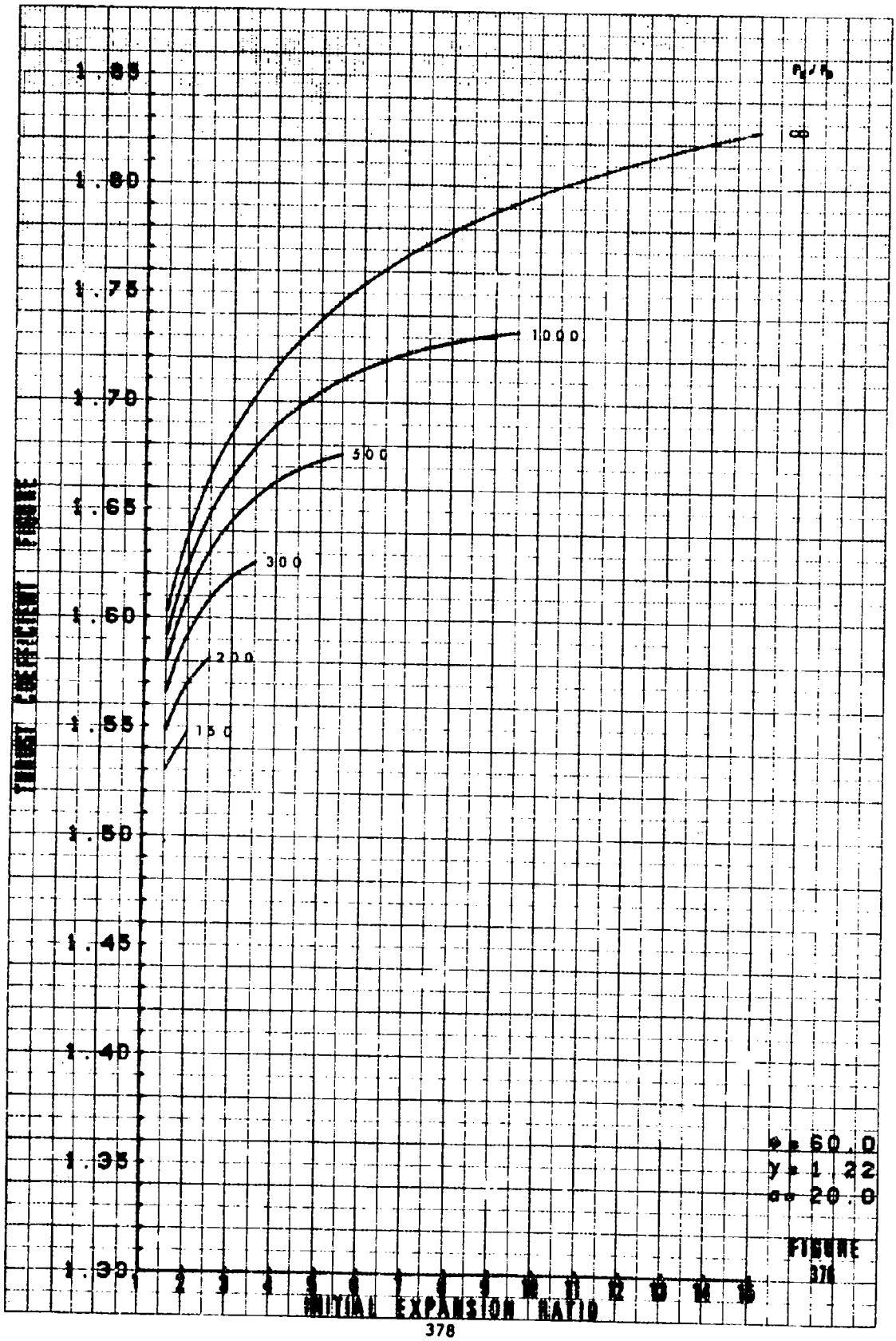

THRUST COEFFICIENT FIGURE
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_b
∞
1000
500
300
200
150
φ = 60.0
γ = 1.22
α = 20.0

FIGURE 376

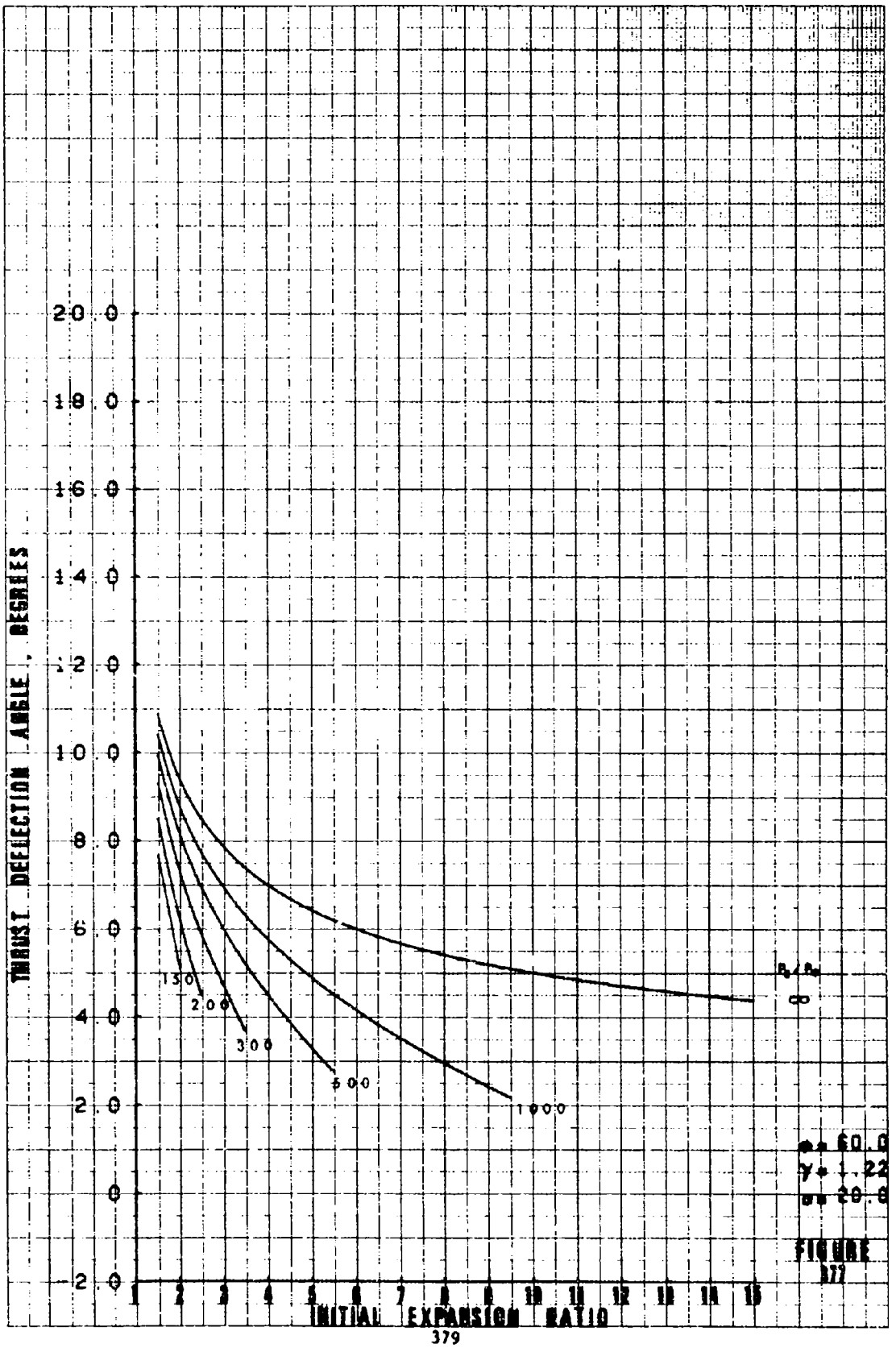

THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
150
200
300
500
1000
∞
φ = 60.0
γ = 1.22
σ = 20.0

FIGURE 377

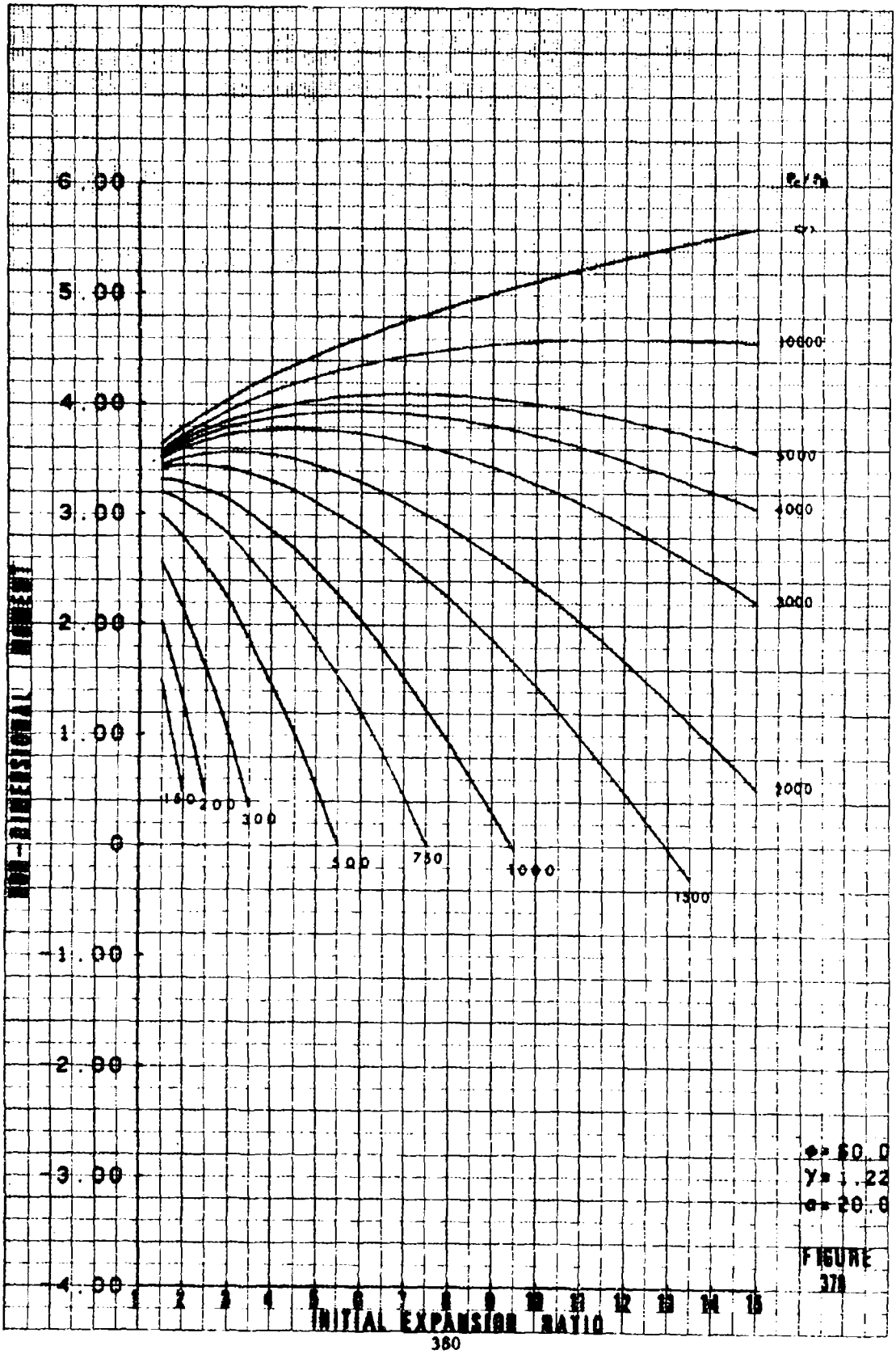

6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
φ= 60.0
γ= 1.22
α= 20.0

FIGURE 37B

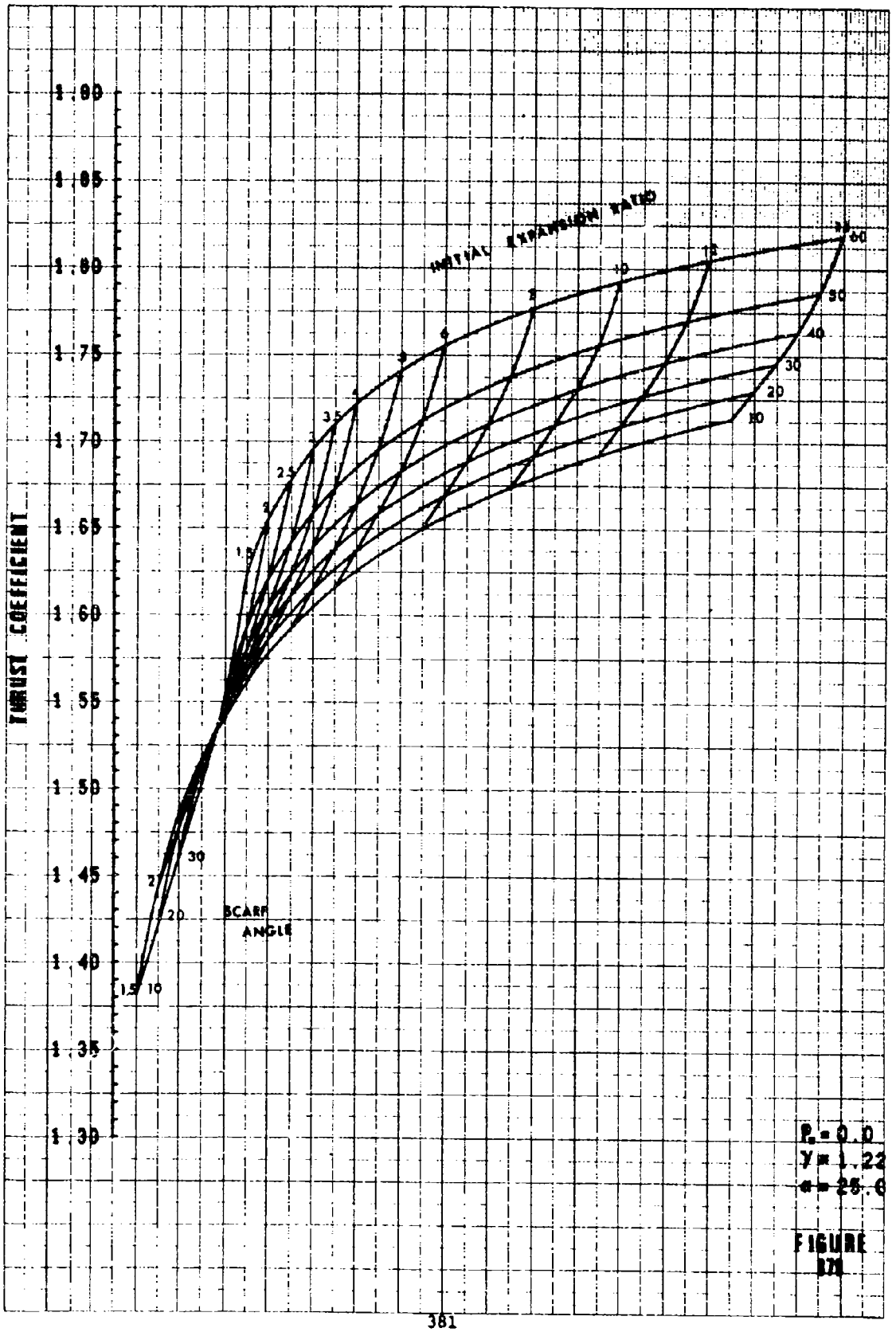

THRUST COEFFICIENT
1.80
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
P = 0.0
γ = 1.22
α = 25.0

FIGURE B74

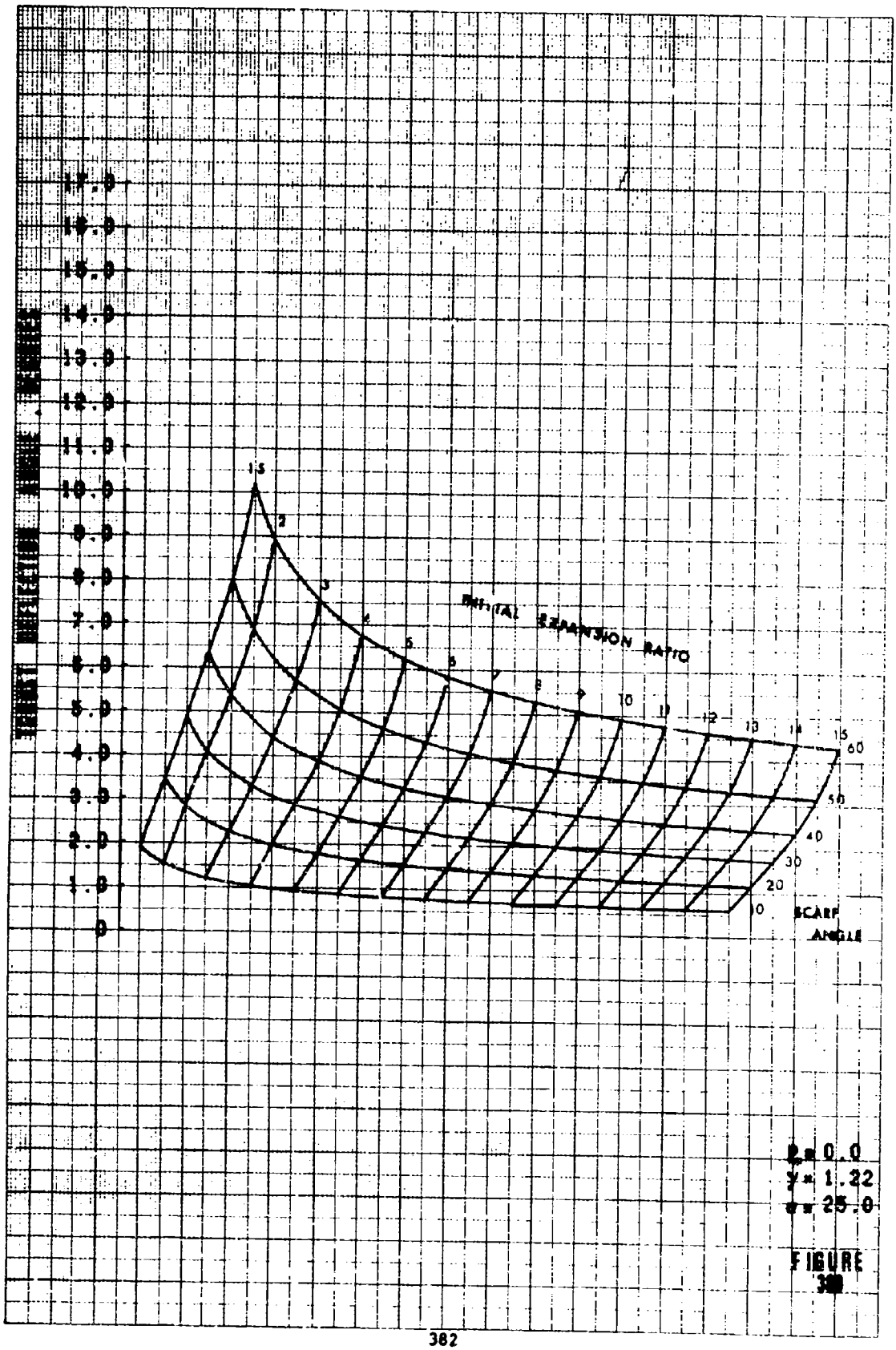

17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
60
50
40
30
20
10
SCARF ANGLE
= 0.0
= 1.22
= 25.0

FIGURE 3[illegible]

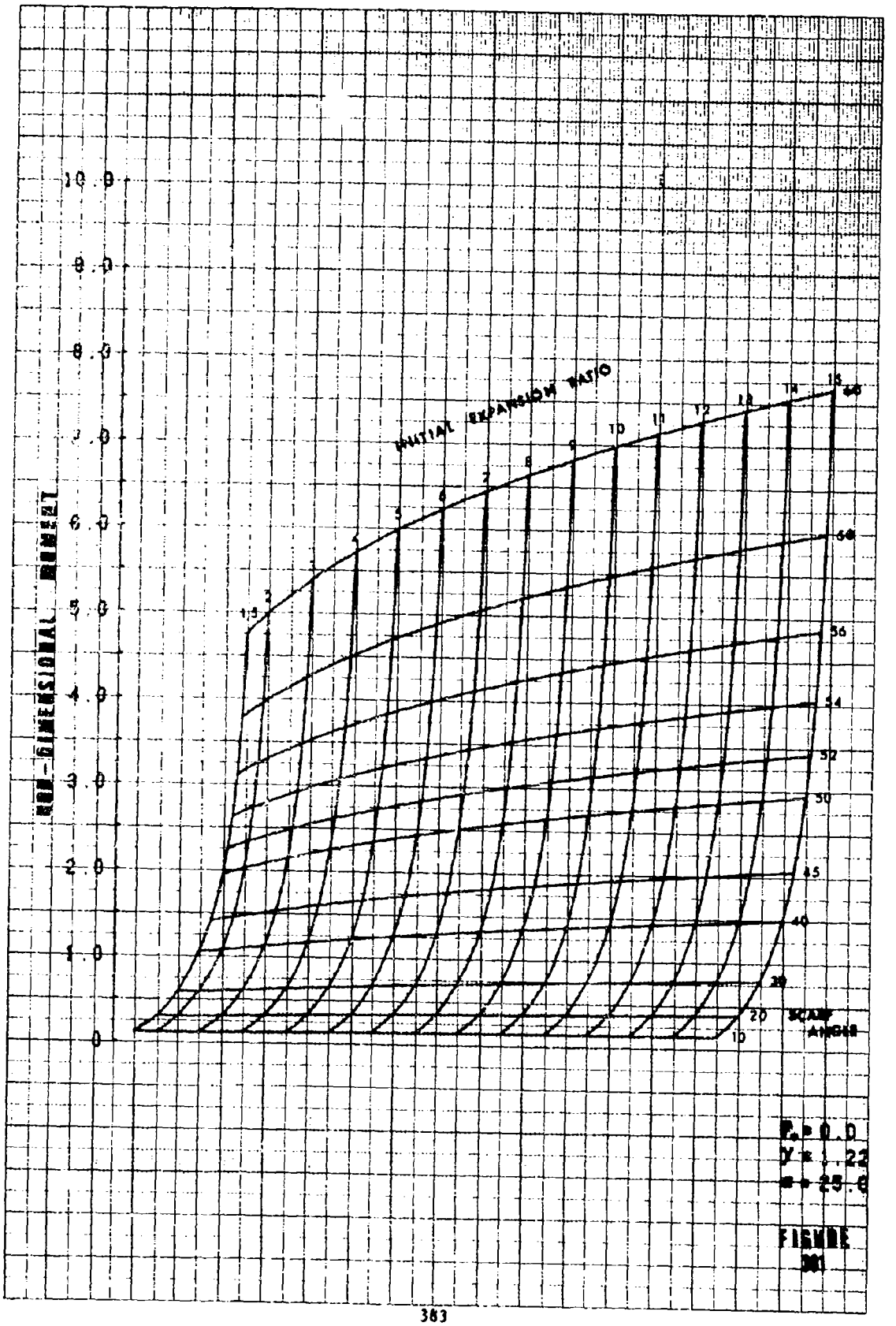

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P_o = 0.0
γ = 1.22
α = 25.0

FIGURE 381

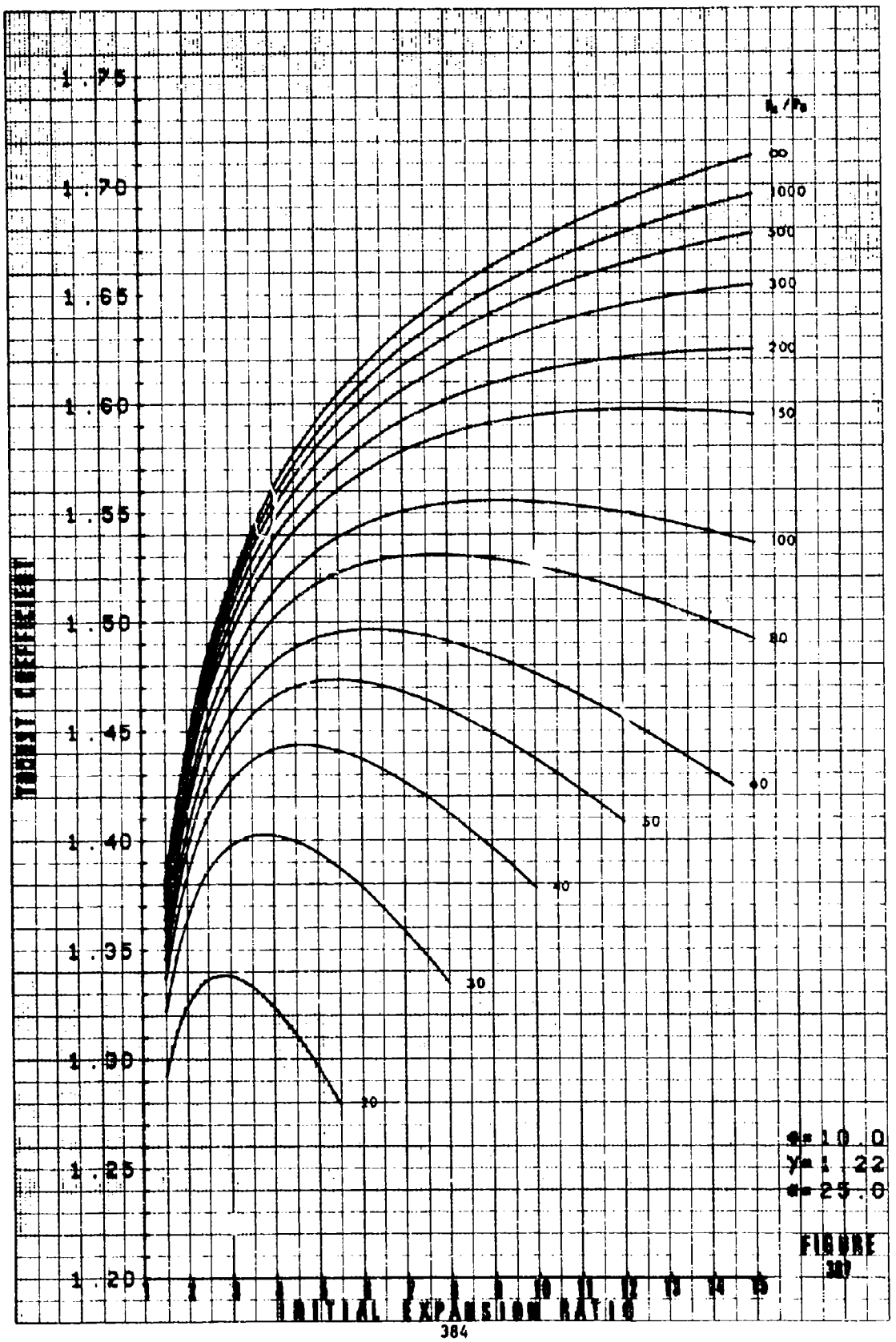

1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_1/P_0
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ϵ= 10.0
γ= 1.22
α= 25.0

FIGURE 30

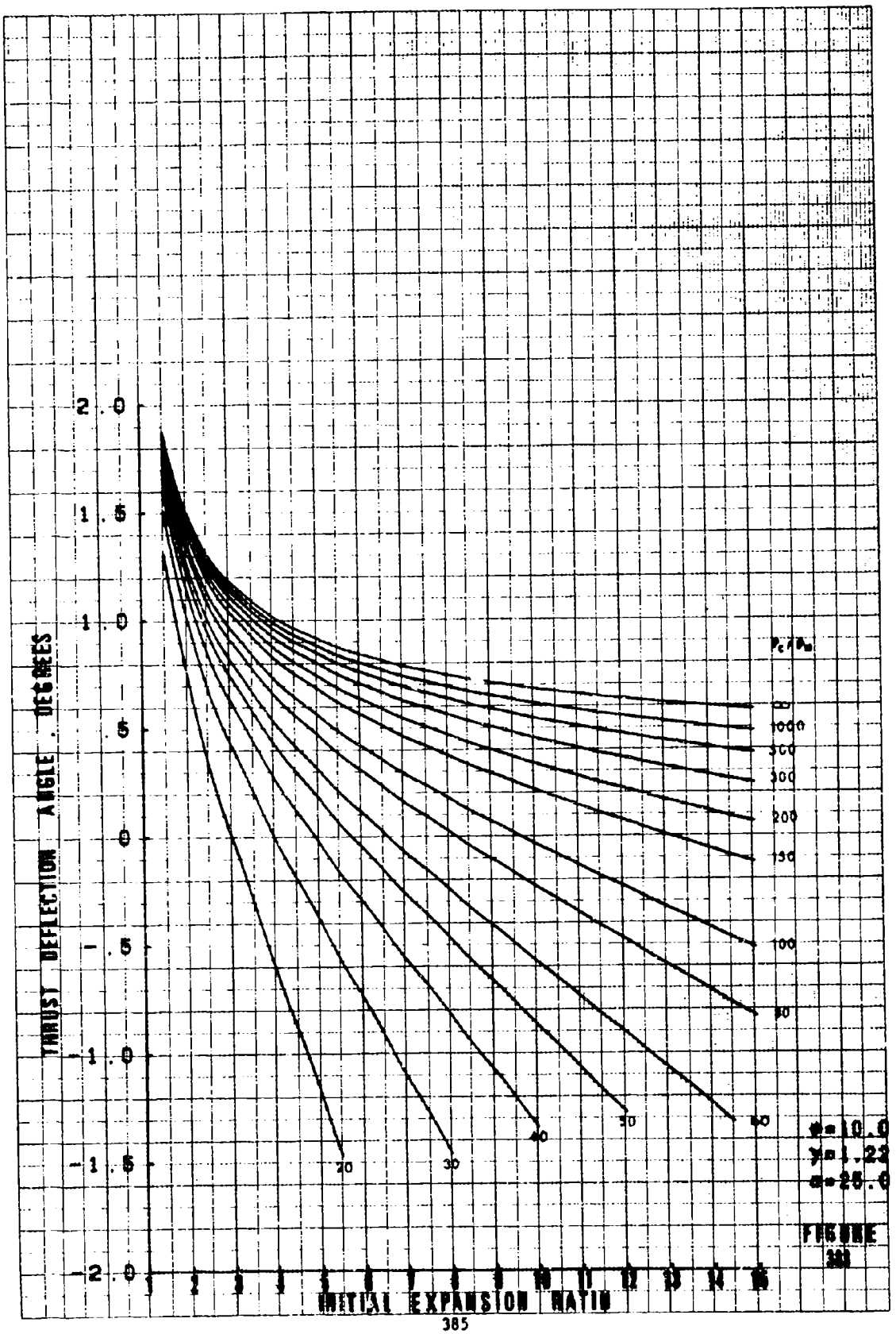

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
300
500
1000
∞
γ=1.22

FIGURE 38

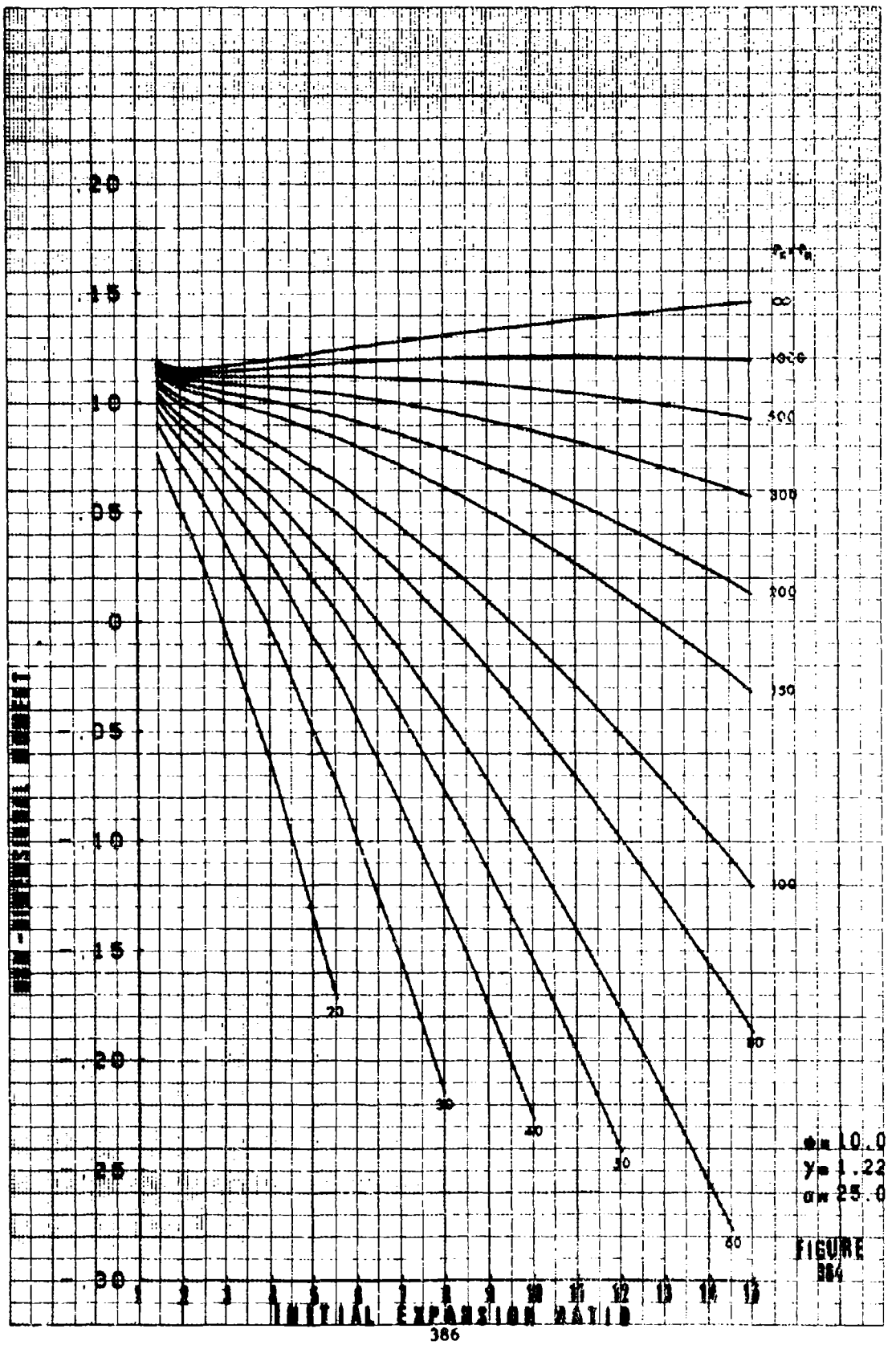

.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.22
α = 25.0

FIGURE 384

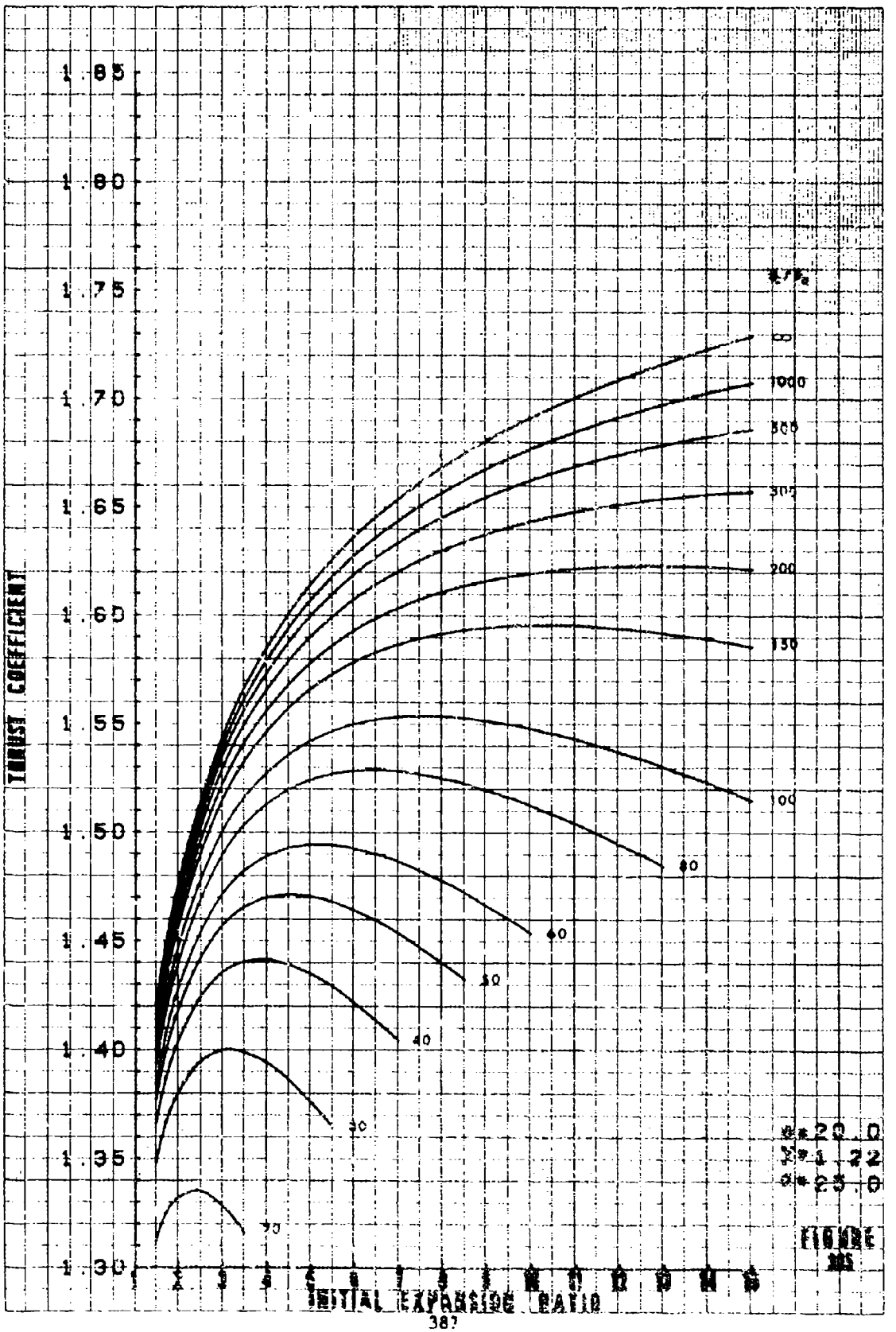

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
θ=20.0
γ=1.22
α=25.0

FIGURE 105

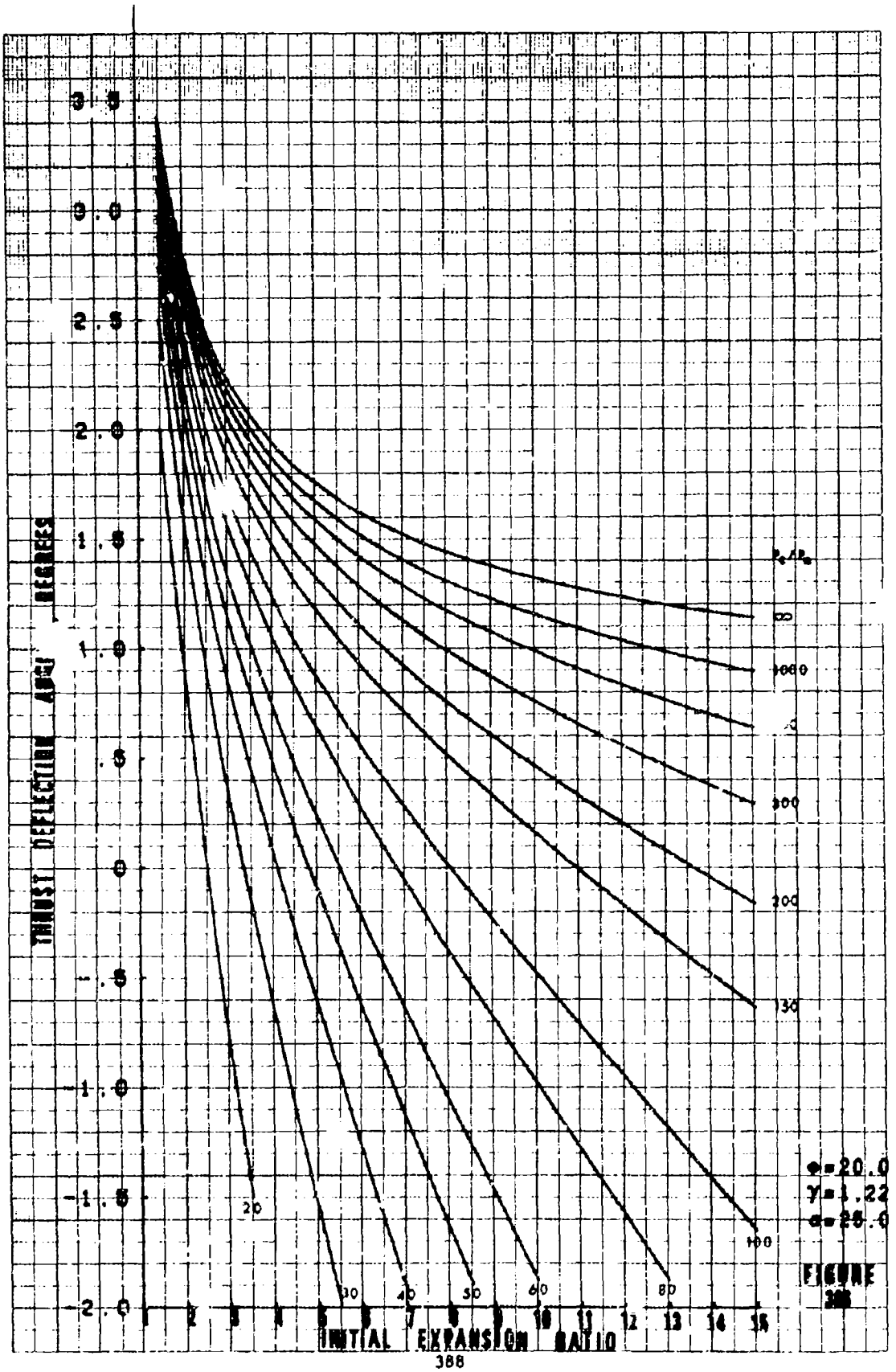

THRUST DEFLECTION ANGLE DEGREES
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.22
α=25.0

FIGURE 38

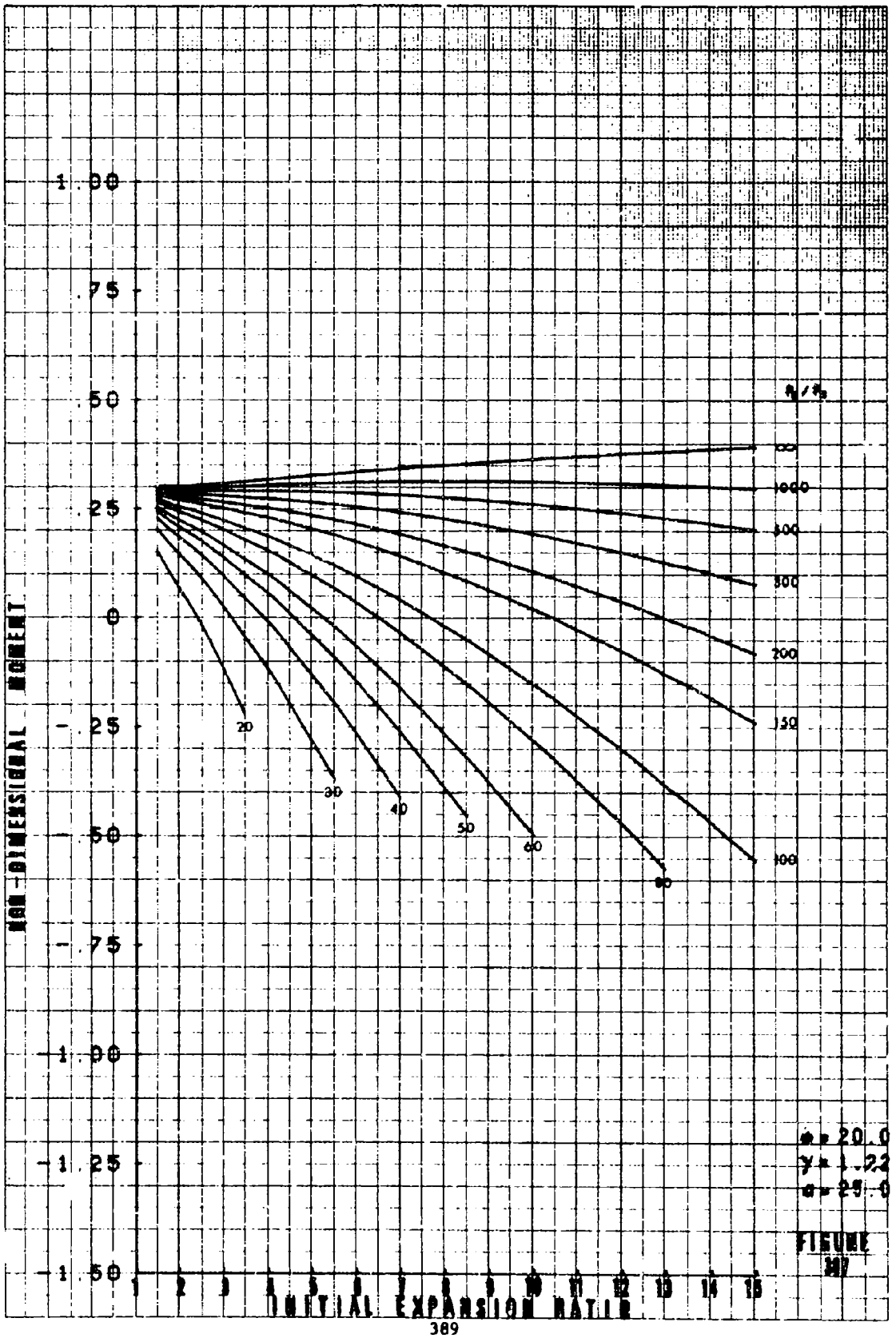
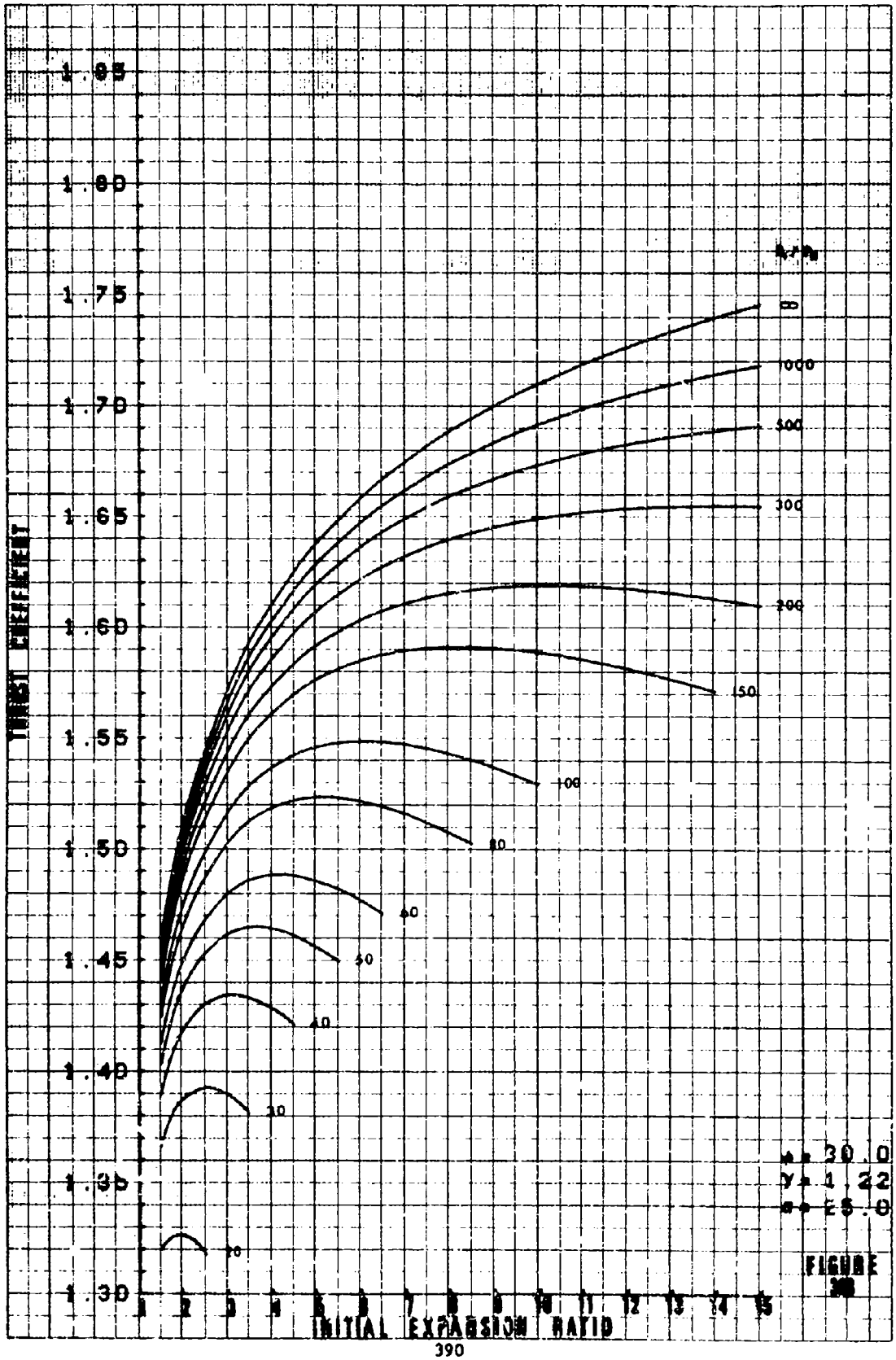
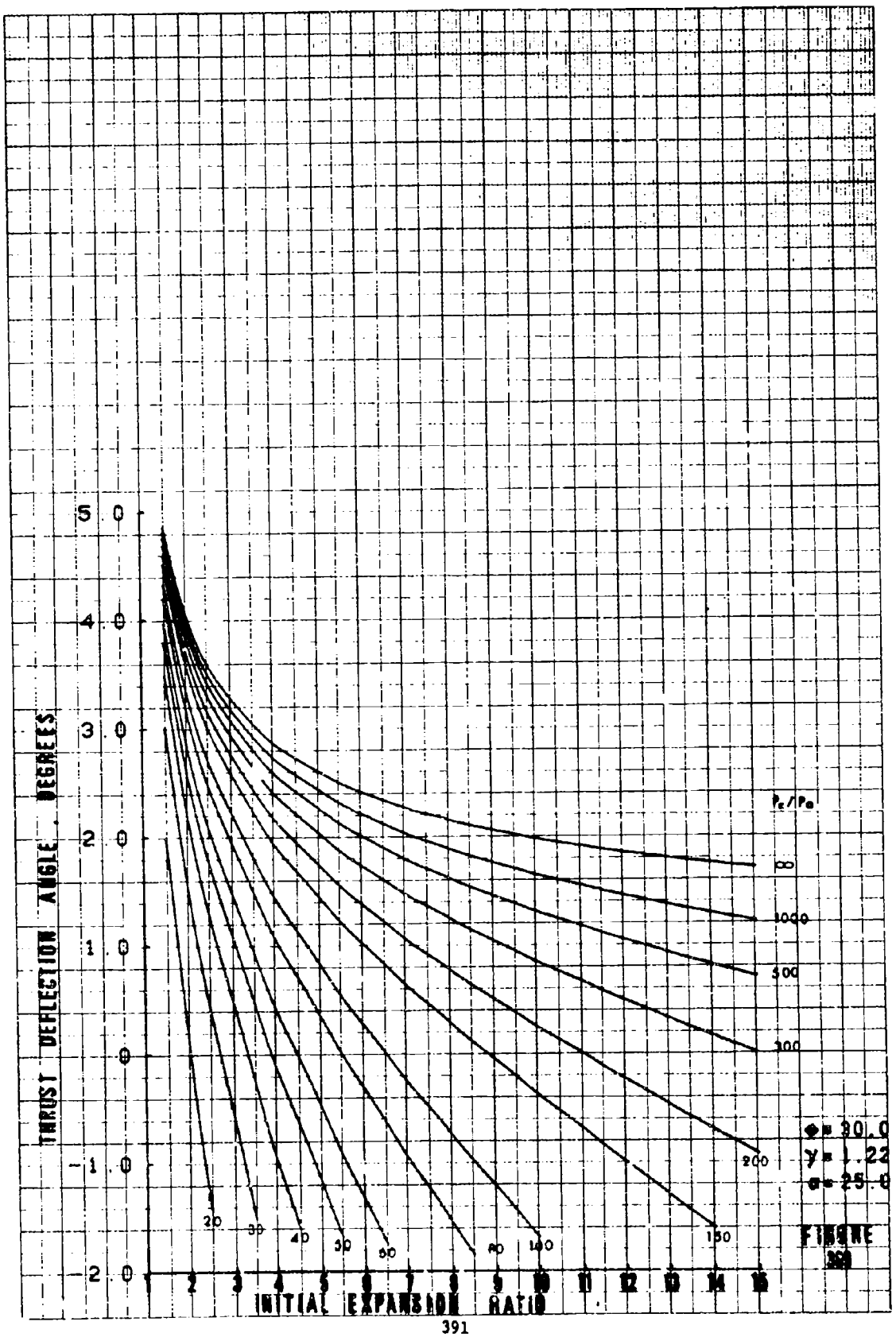
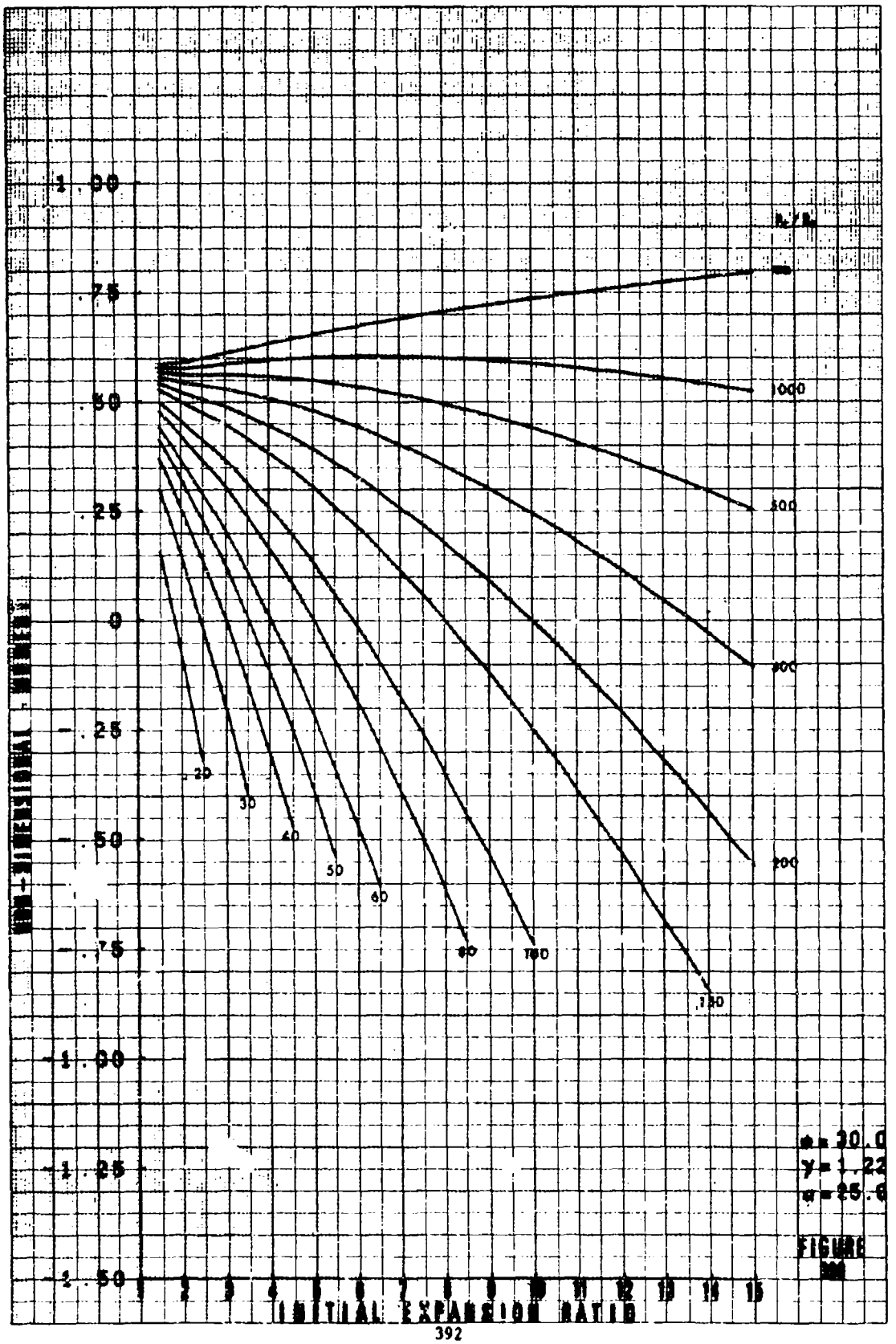

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R/R₀
∞
1000
500
300
200
150
100
20
30
40
50
60
80
φ = 20.0
γ = 1.22
α = 25.0

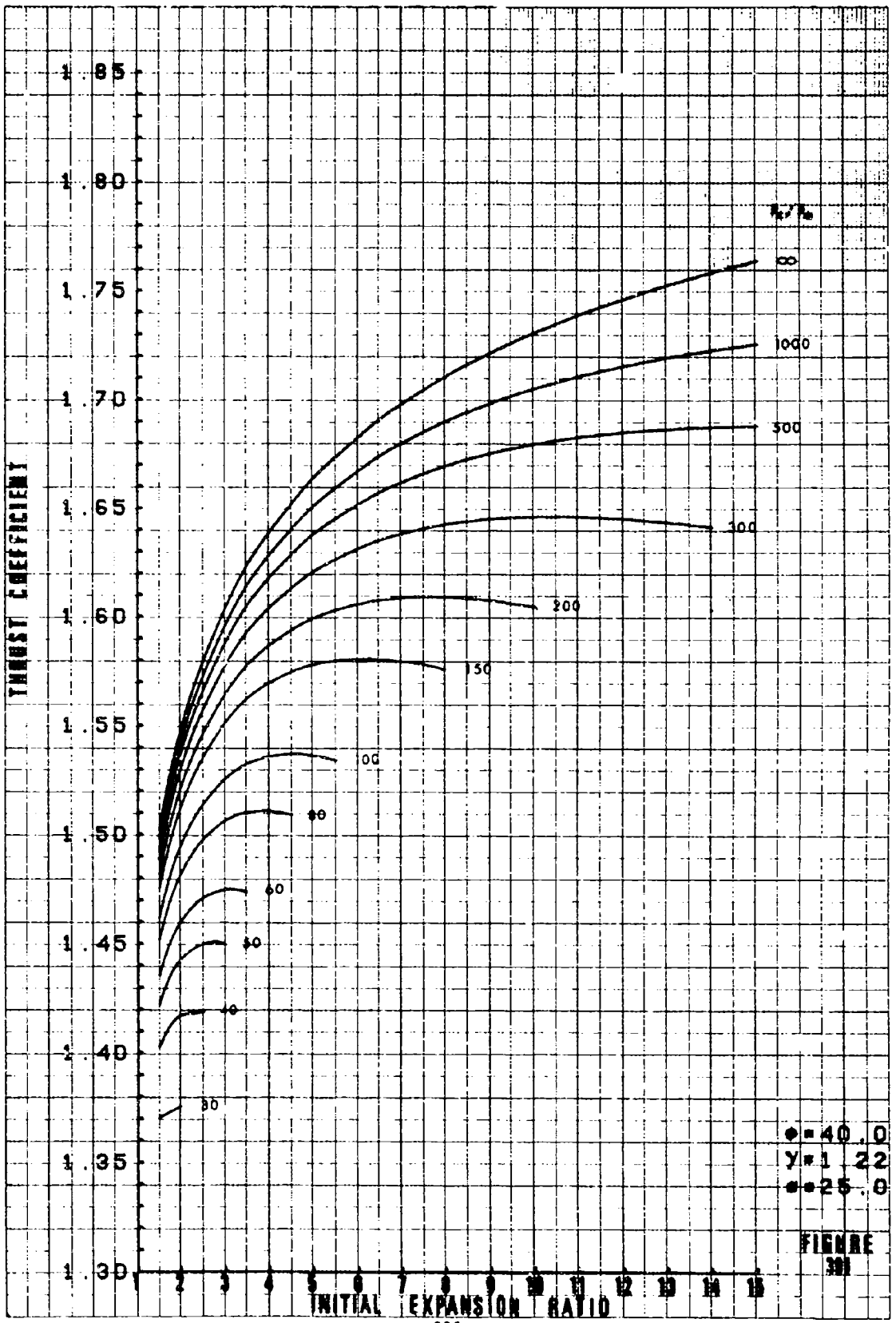
FIGURE 307


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
10
γ = 1.22

FIGURE


THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
Φ = 30.0
γ = 1.22
α = 25.0
FIGURE


1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1000
500
300
200
150
100
80
60
50
40
30
20
INITIAL EXPANSION RATIO
FIGURE



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
φ=40.0
γ=1.22
θ=25.0

FIGURE 391

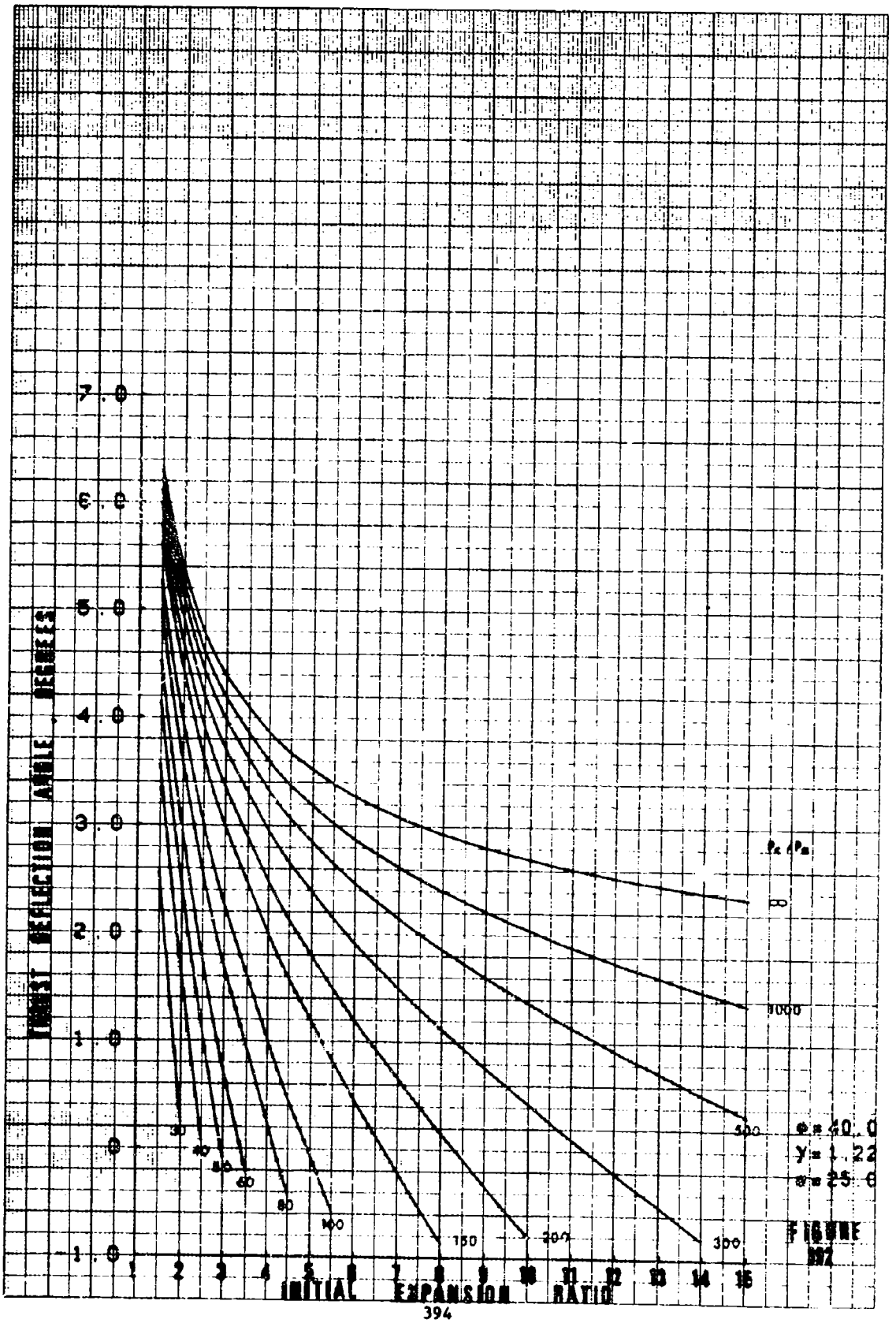

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
300
500
1000
∞
P_c/P_a
φ = 40.0
γ = 1.22
θ = 25.0

FIGURE 102

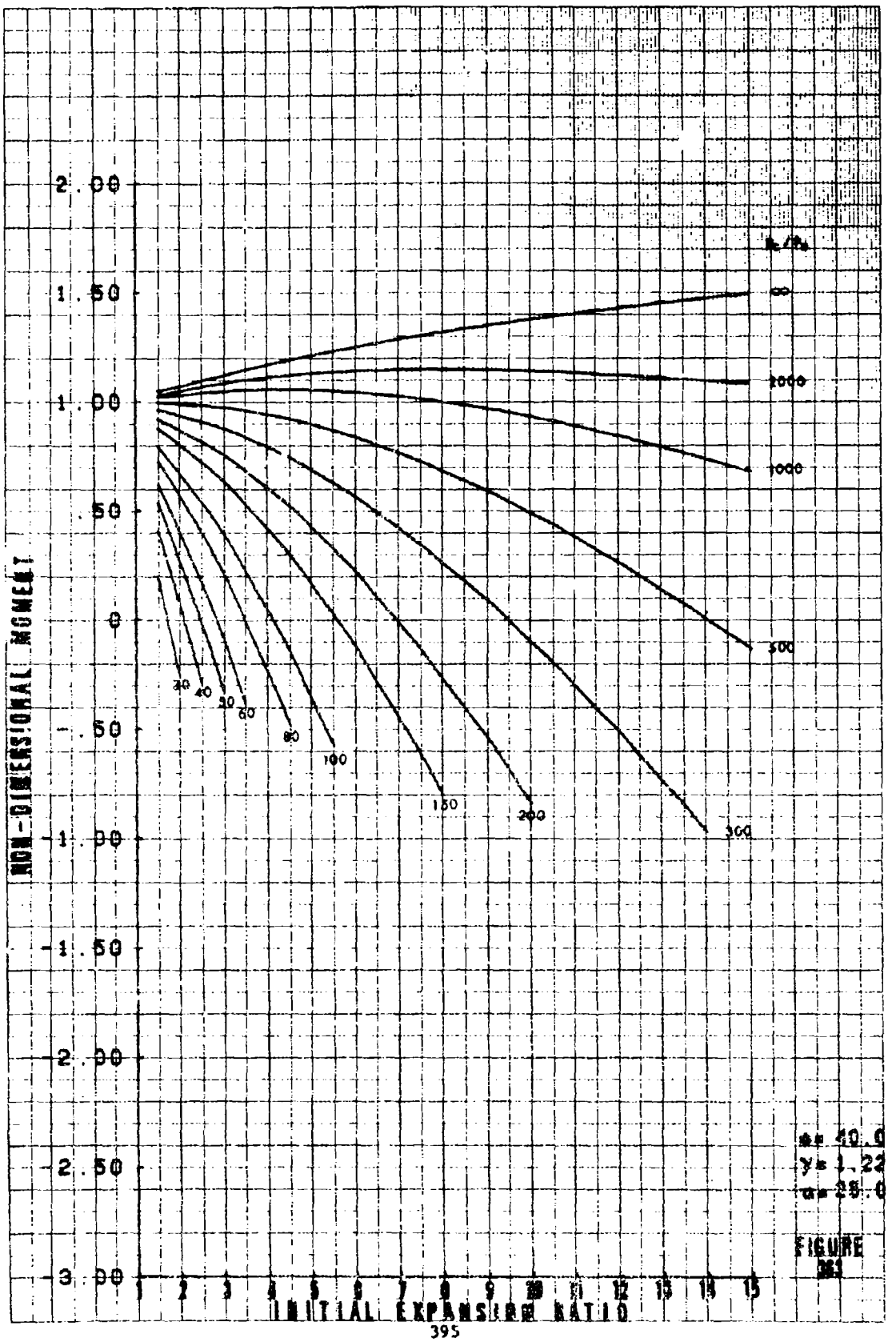

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
1000
500
300
20
40
30
60
80
100
150
200
φ= 40.0
γ= 1.22
α= 25.0

FIGURE 361

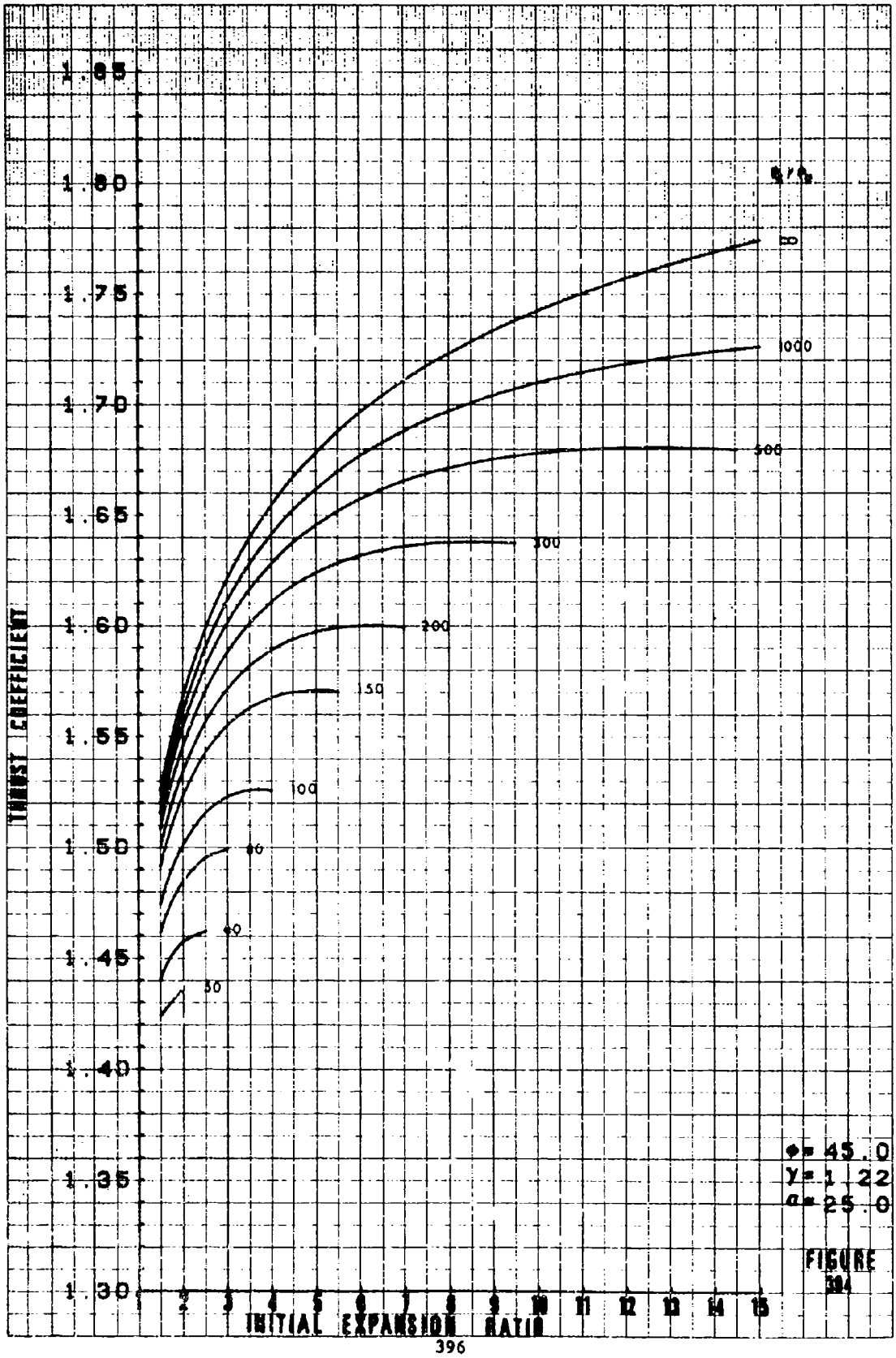

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
φ= 45.0
γ= 1.22
α= 25.0

FIGURE 394

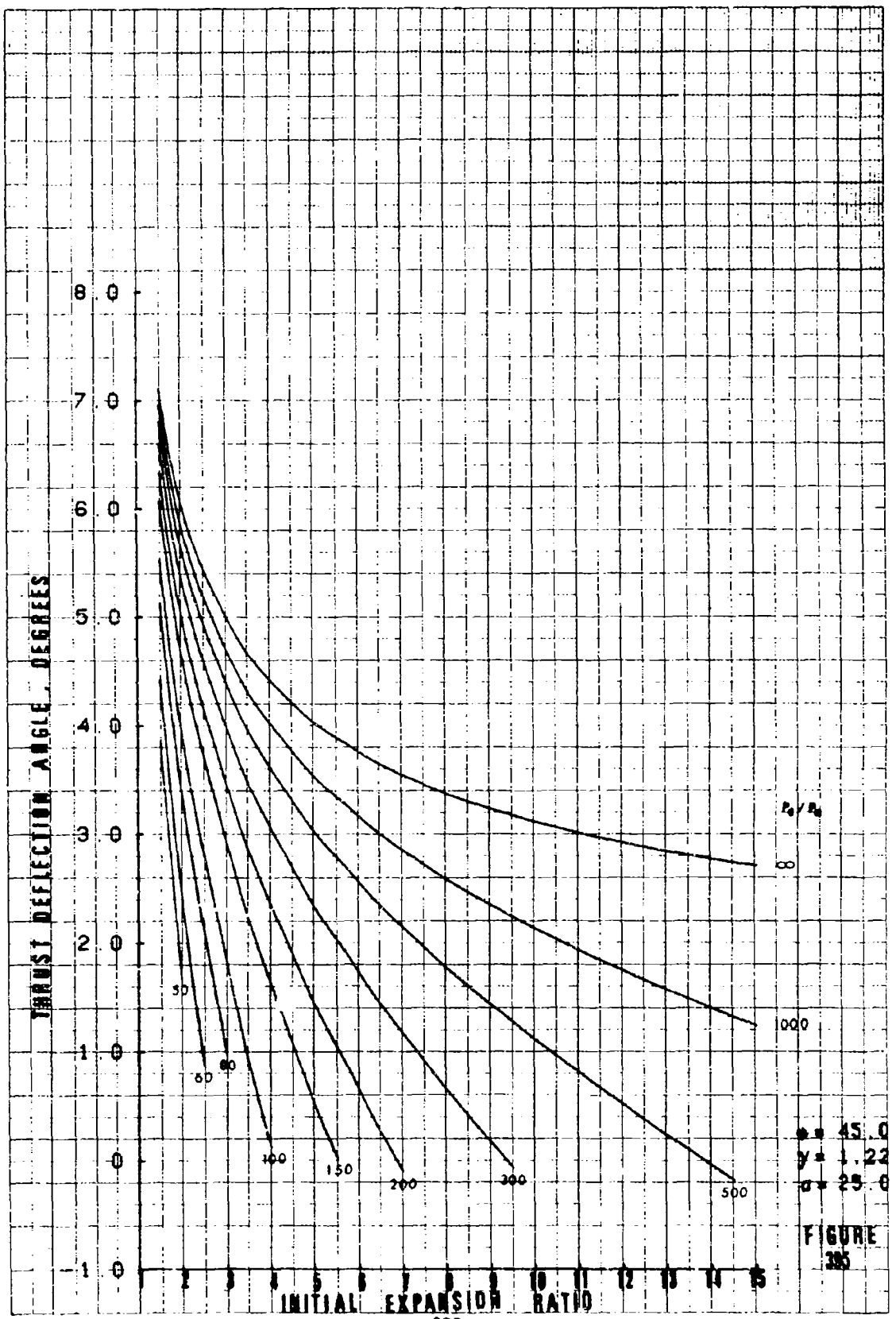

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_0/P_a
∞
1000
500
300
200
150
100
80
60
50
θ = 45.0
γ = 1.22
α = 25.0

FIGURE 385

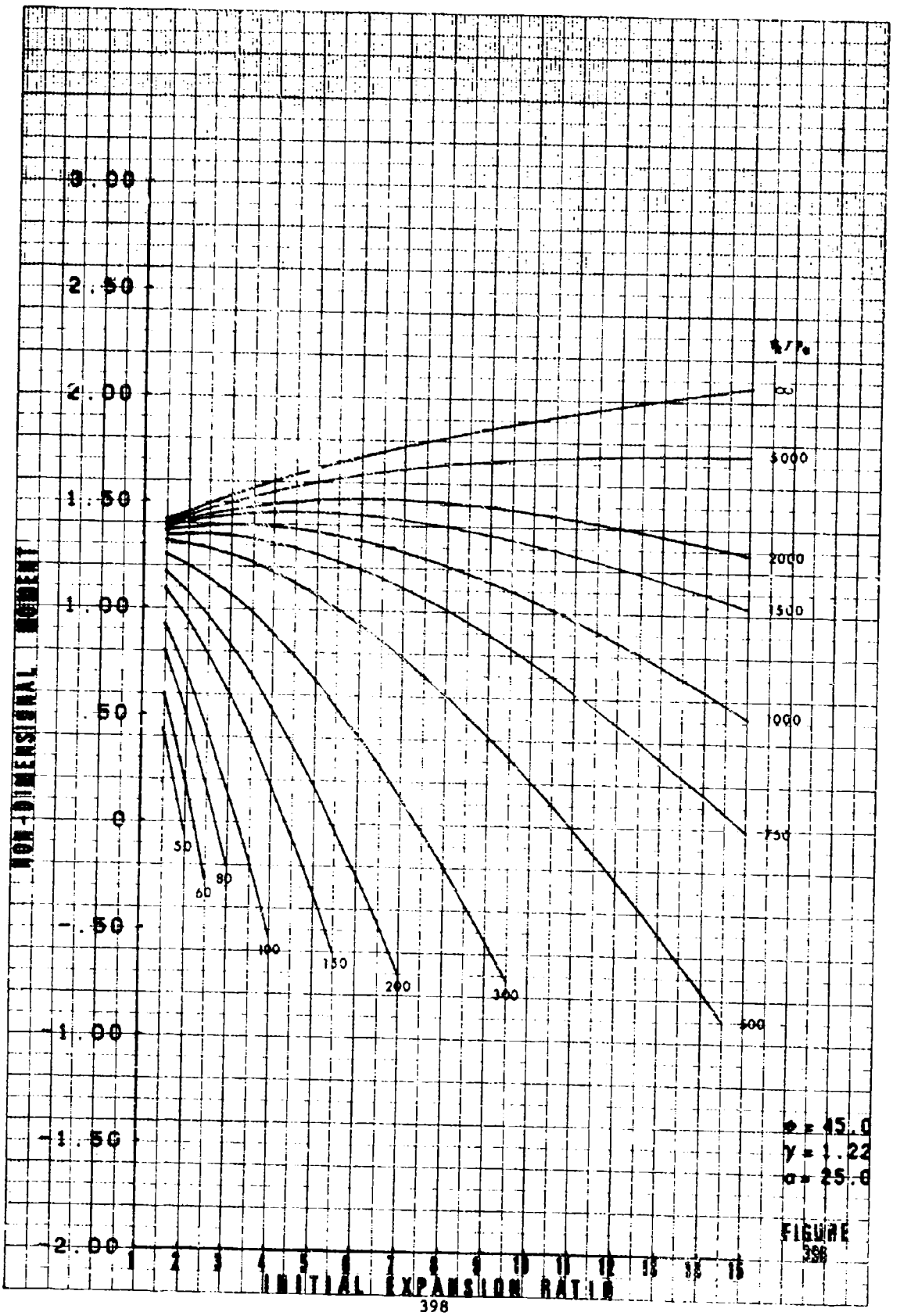
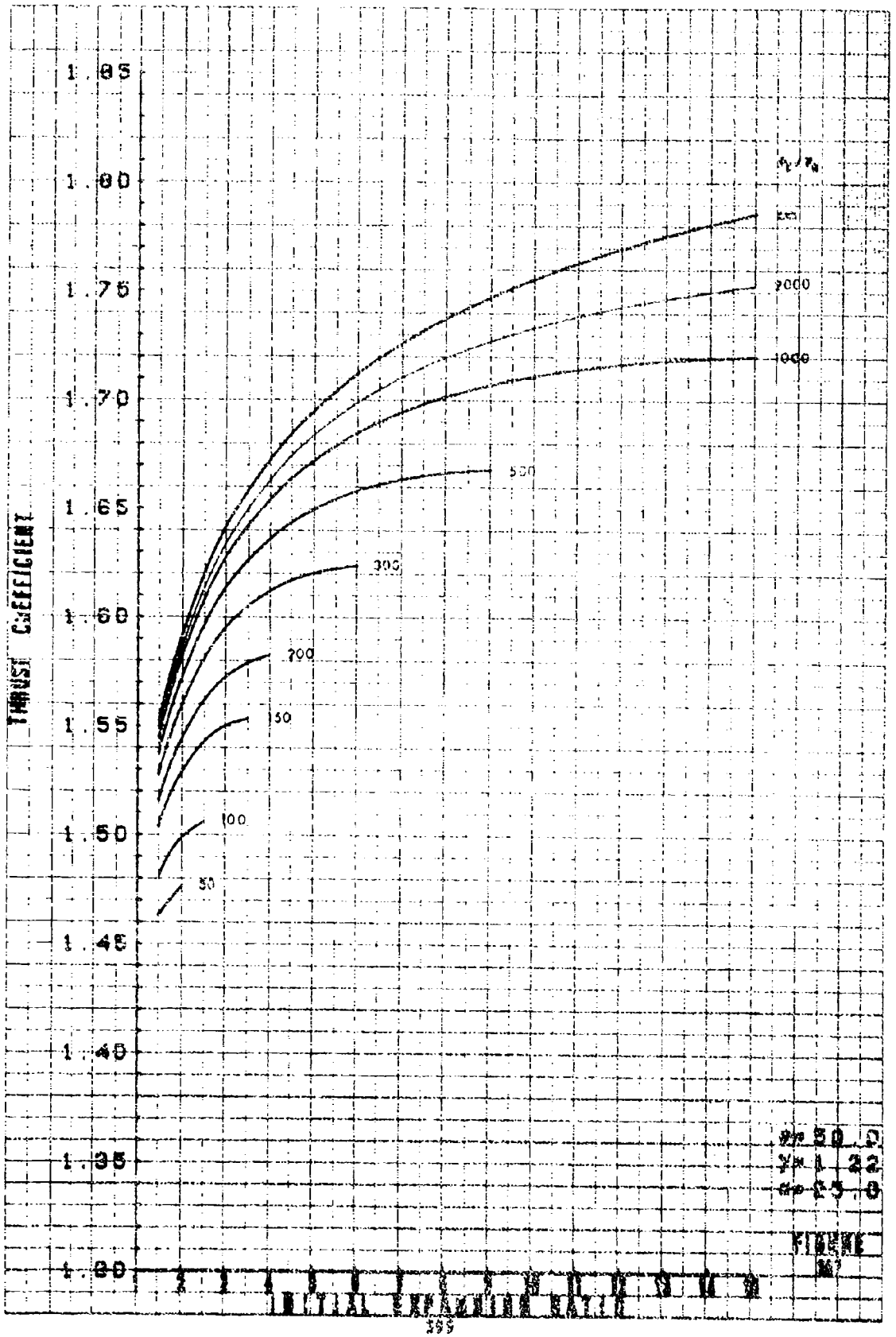
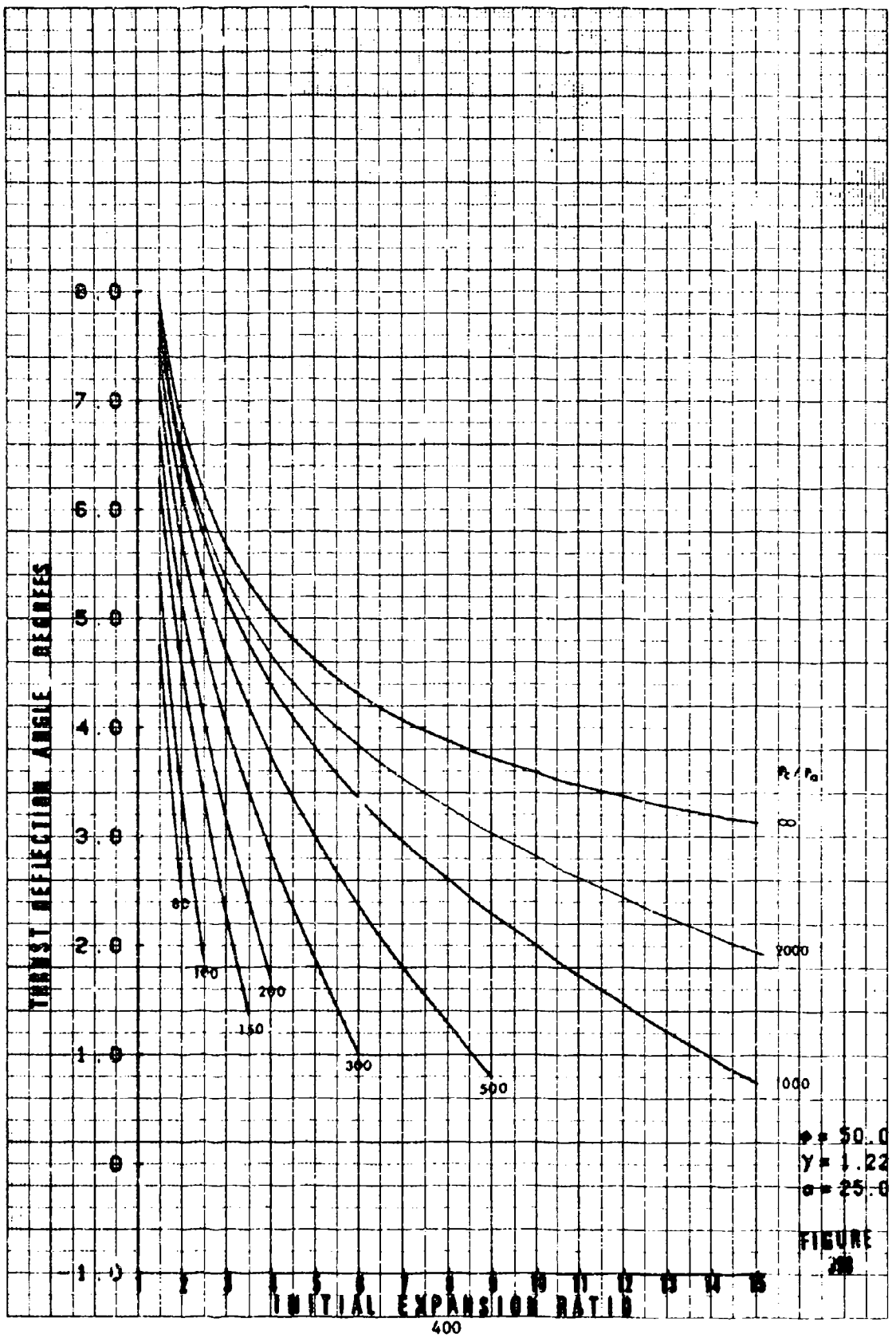
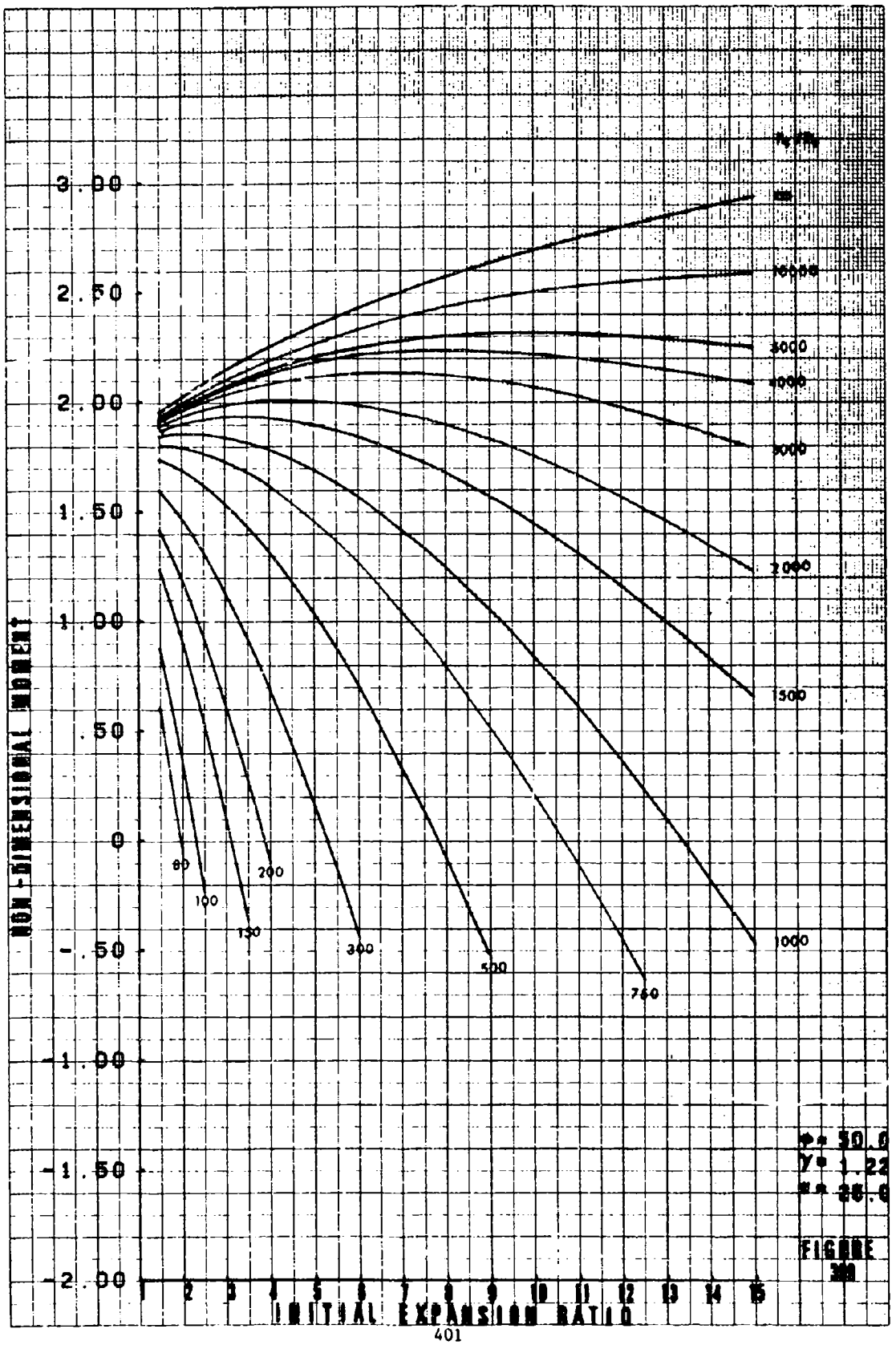

3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL THRUST
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_1/P_a
∞
5000
2000
1500
1000
750
500
50
60
80
100
150
200
300
φ = 45.0
γ = 1.22
α = 25.6

FIGURE 356


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2000
1000
500
300
200
150
100
50
INITIAL EXPANDING RATIO



THRUST DEFLECTION ANGLE DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
80
100
150
200
300
500
1000
2000
∞
P_c / P_a
φ = 50.0
γ = 1.22
α = 25.0
FIGURE



3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
10000
5000
4000
3000
2000
1500
1000
80
100
150
200
300
500
750
FIGURE

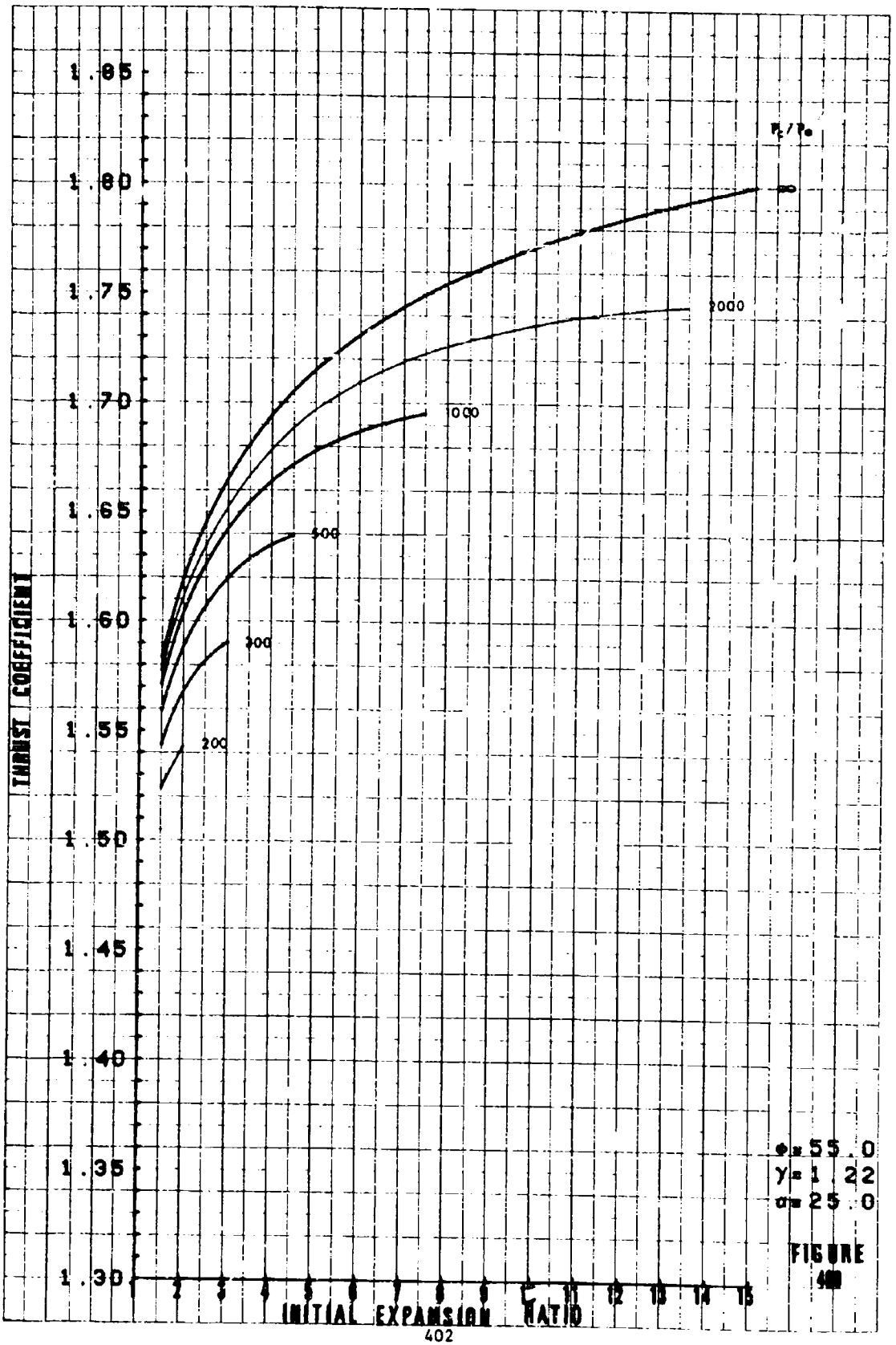

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
2000
1000
500
300
200
φ= 55.0
γ= 1.22
α= 25.0

FIGURE 4B

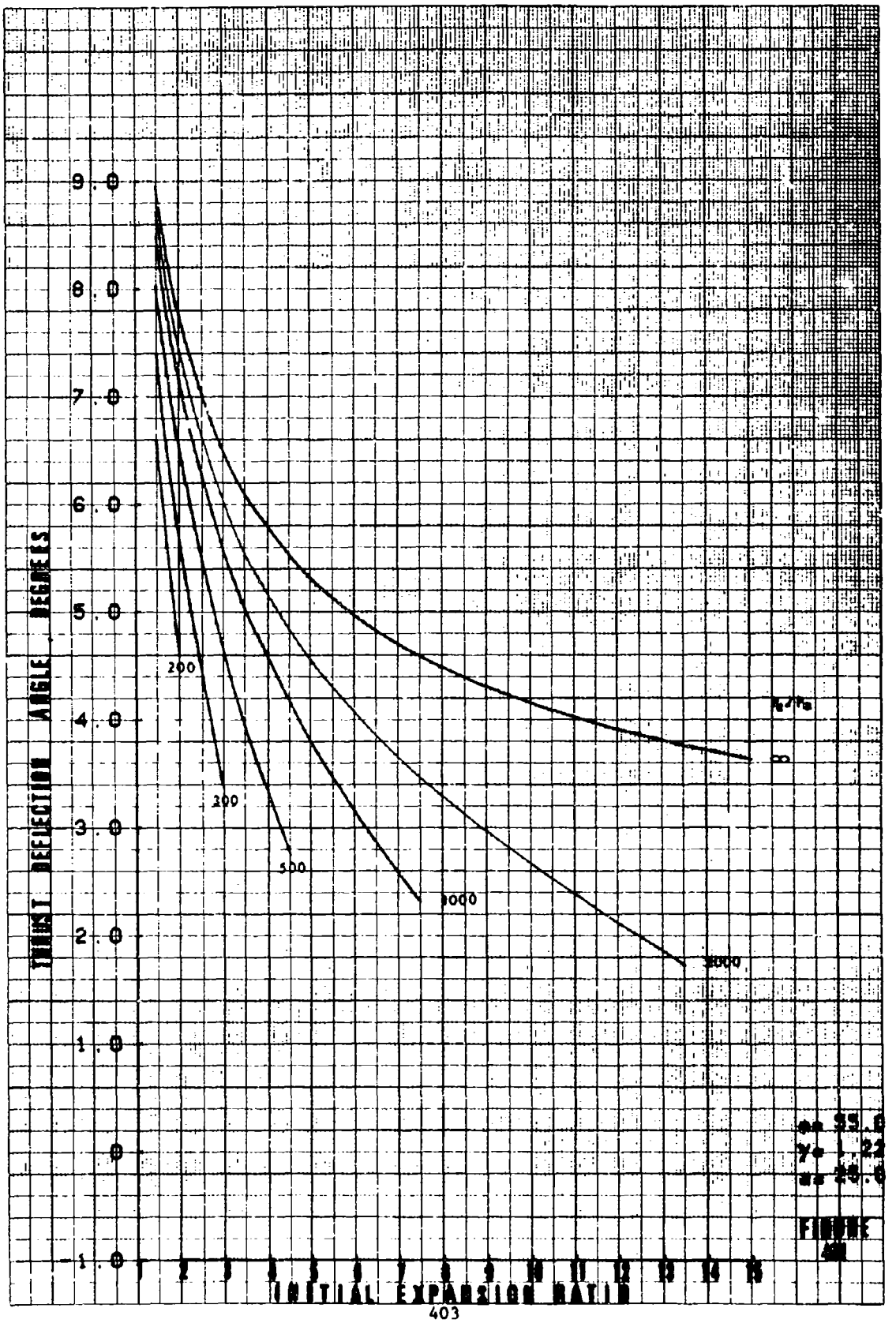

THRUST DEFLECTION ANGLE DEGREES
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
200
300
500
1000
3000
∞
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

FIGURE 4B

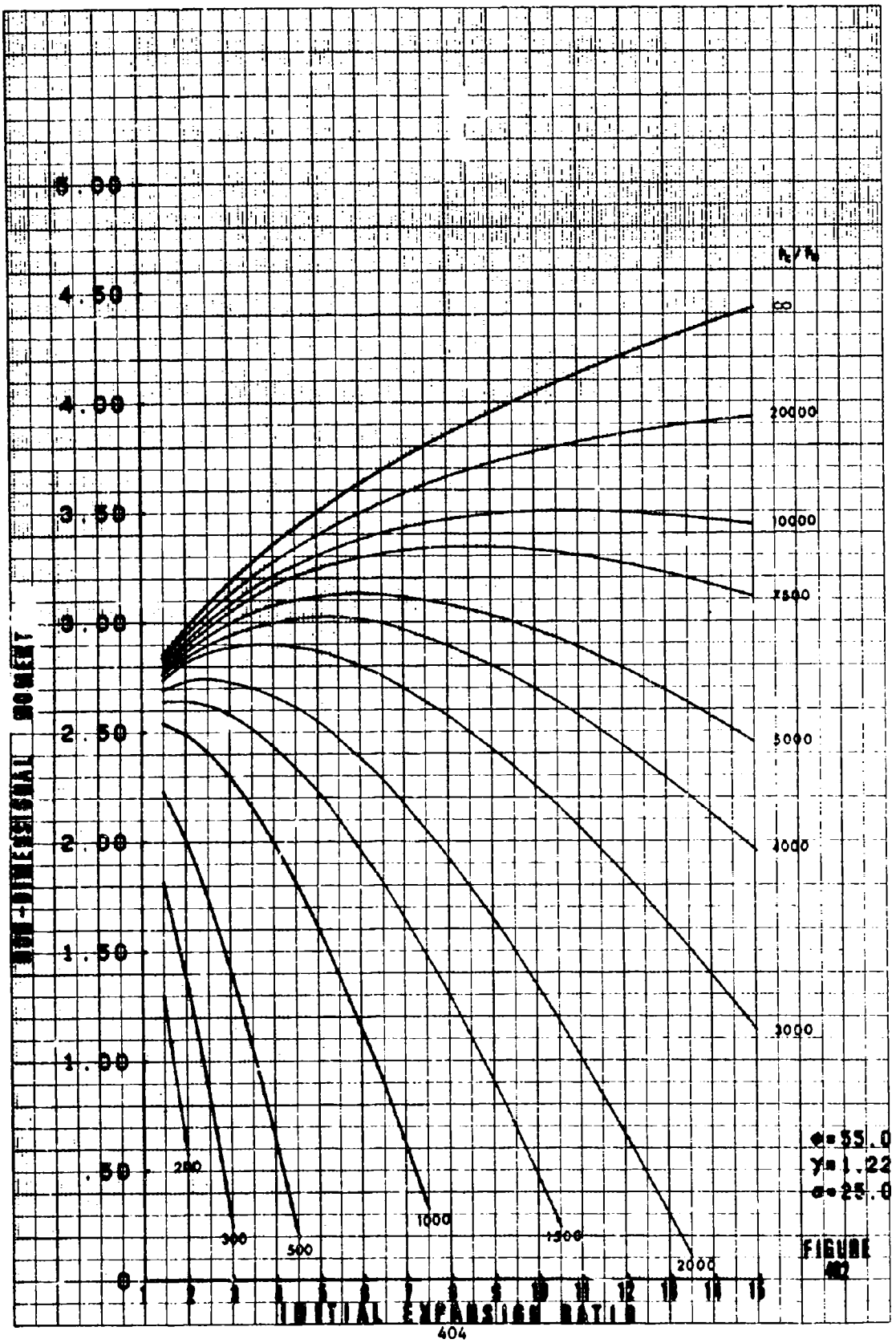

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
h_t/h_0
∞
20000
10000
7500
5000
4000
3000
2000
1500
1000
500
300
200
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
φ=55.0
γ=1.22
σ=25.0

FIGURE 402

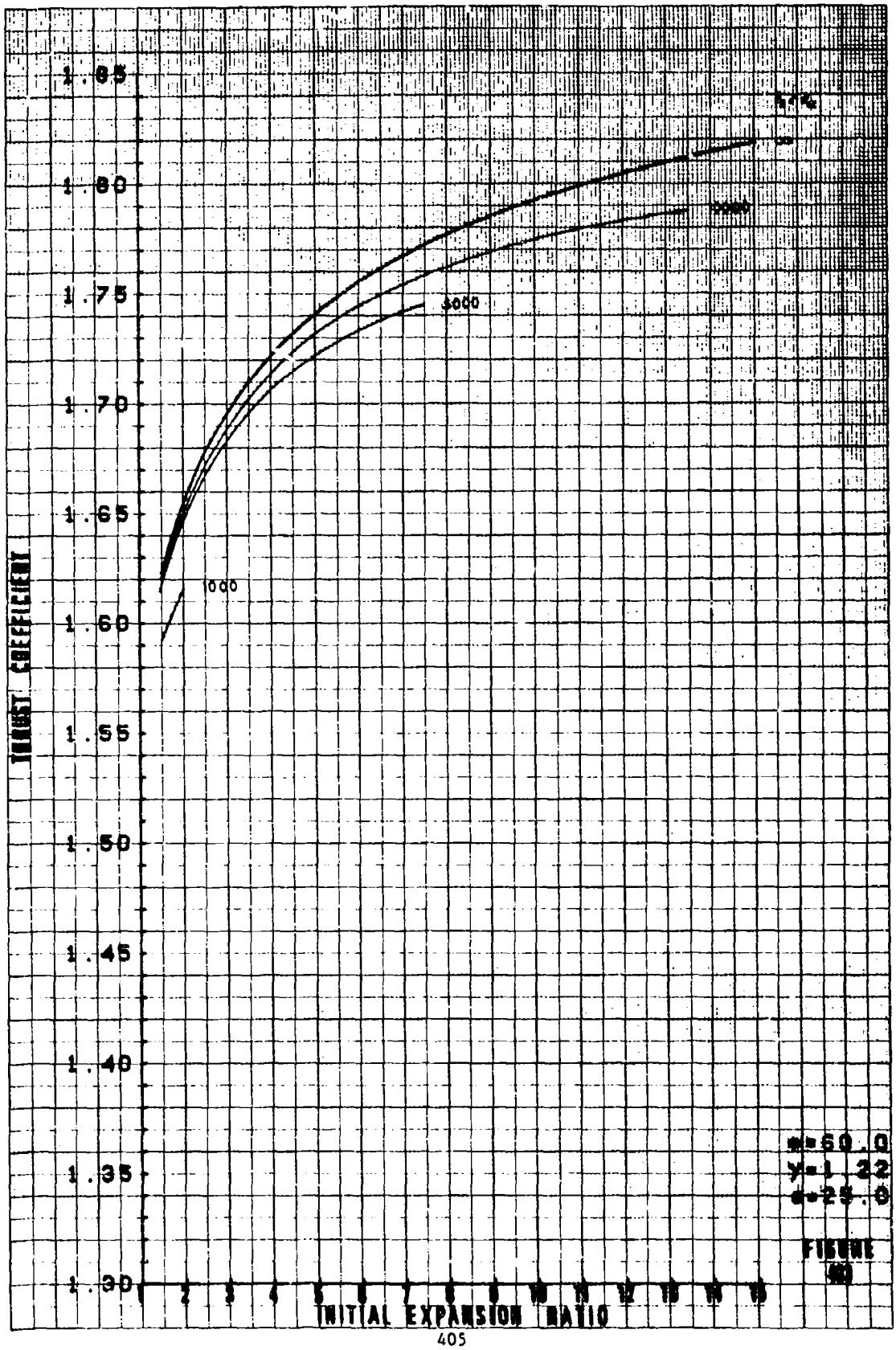

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1000
3000
INITIAL EXPANSION RATIO
w=50.0
y=1.22
d=25.0

FIGURE 40

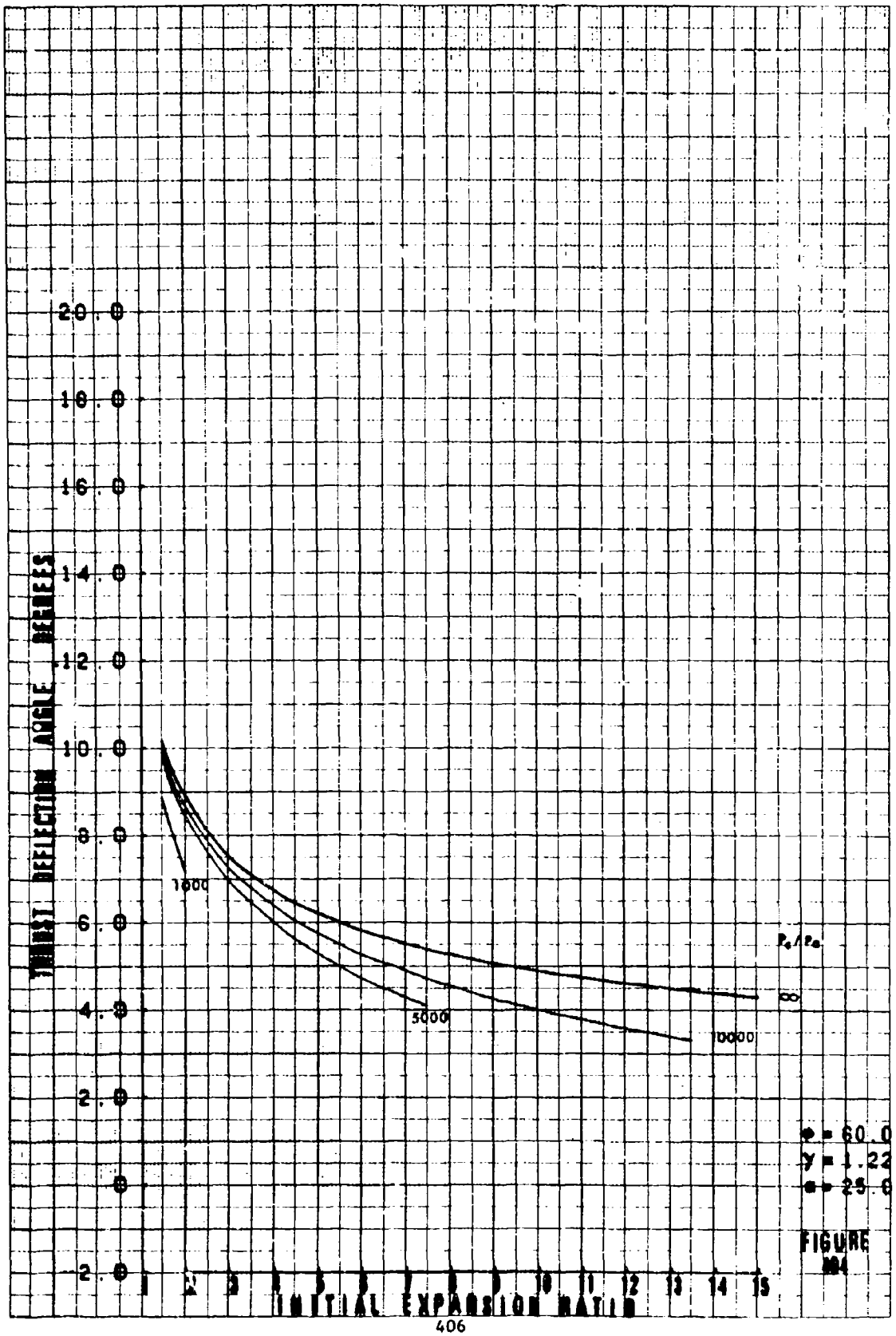
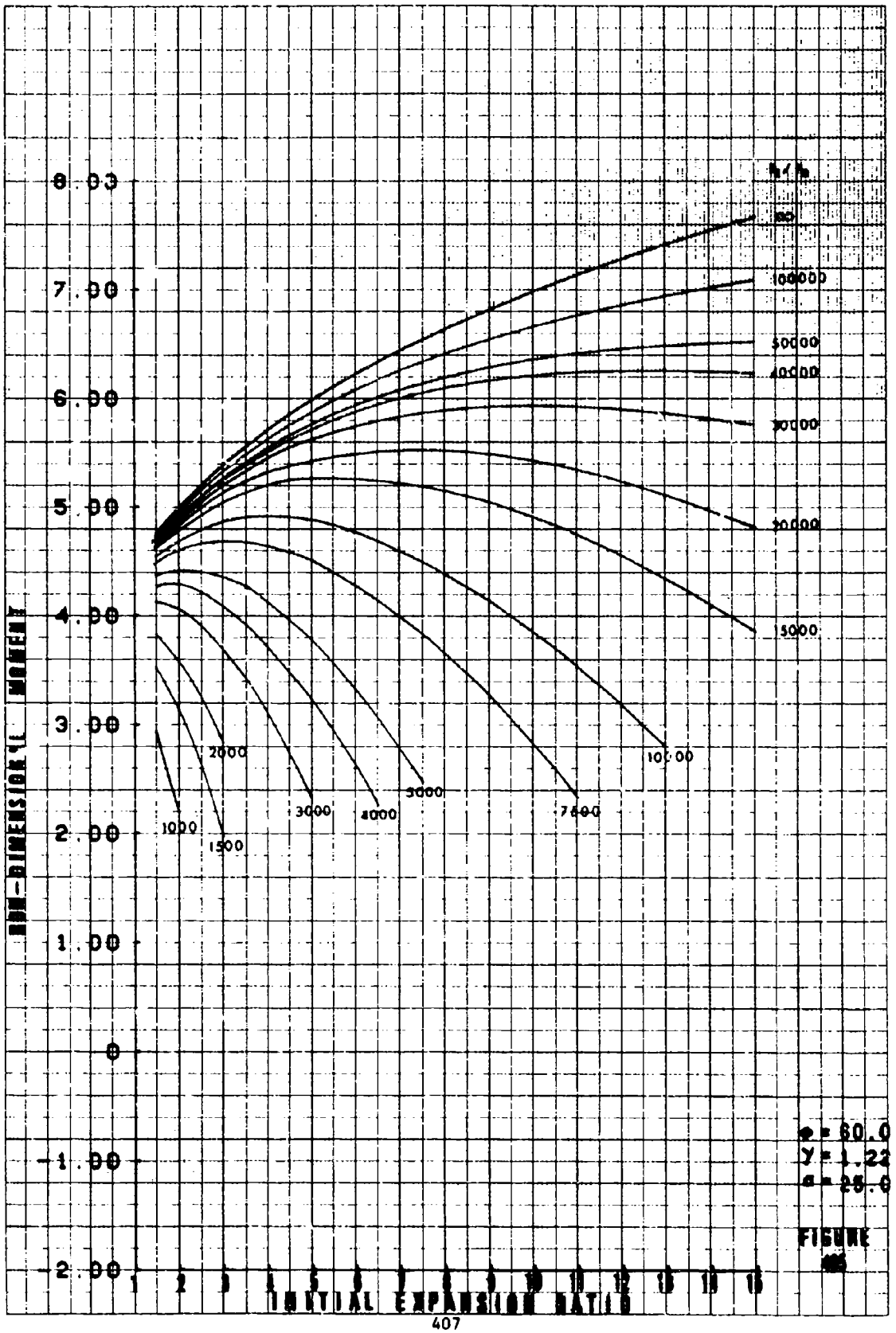

THRUST DEFLECTION ANGLE DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
1000
3000
10000
∞
P_e/P_a
φ = 60.0
γ = 1.22
α = 25.0

FIGURE
[illegible]



8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
100000
50000
40000
30000
20000
15000
10000
7500
5000
4000
3000
2000
1500
1000
φ = 60.0
γ = 1.22
α = 25.0
FIGURE

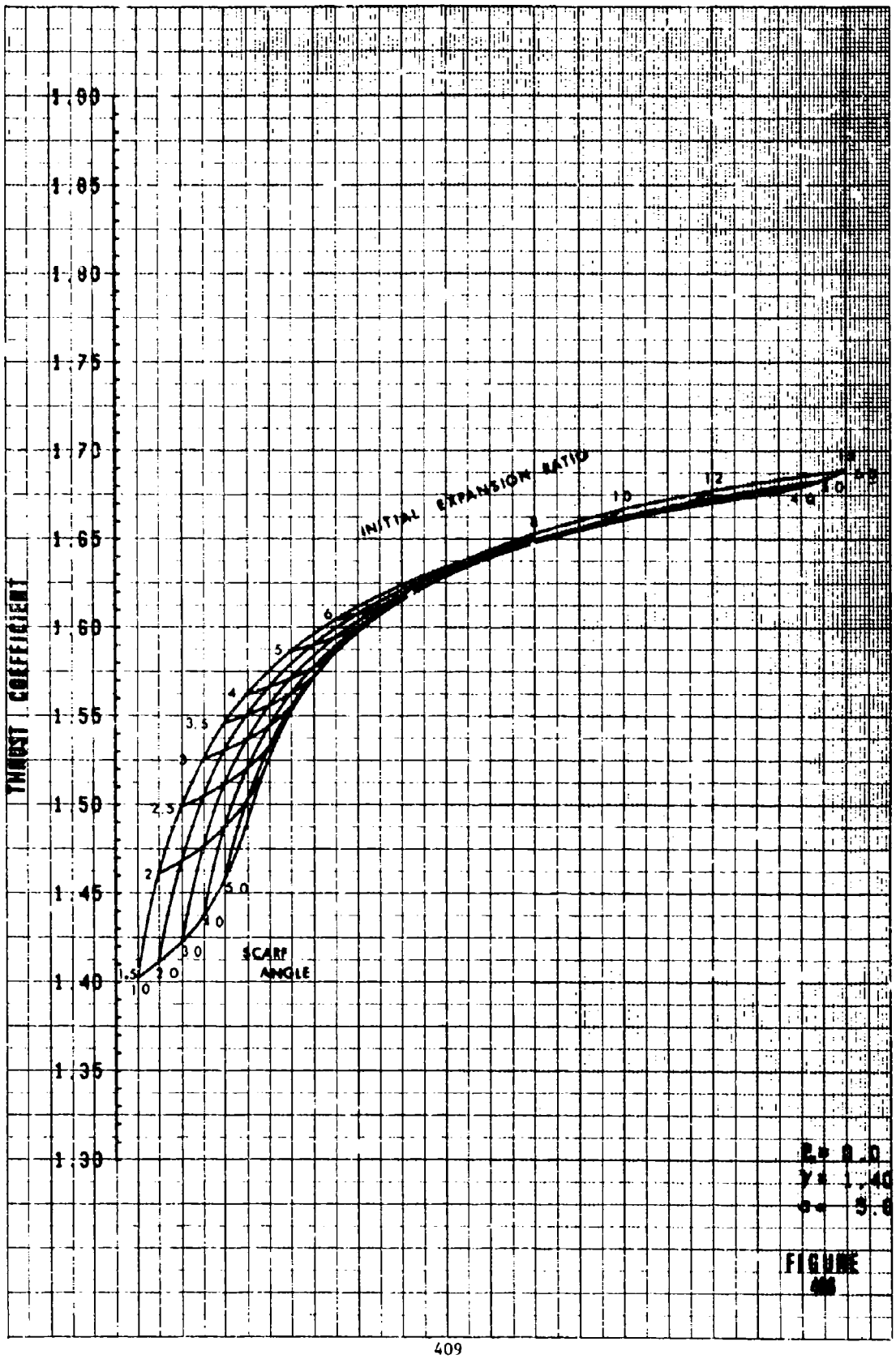

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
1.5
2
2.5
3
3.5
4
5
6
1.0
2.0
3.0
4.0
5.0
1.0
1.2
4.0
5.0
γ = 1.40

FIGURE 406

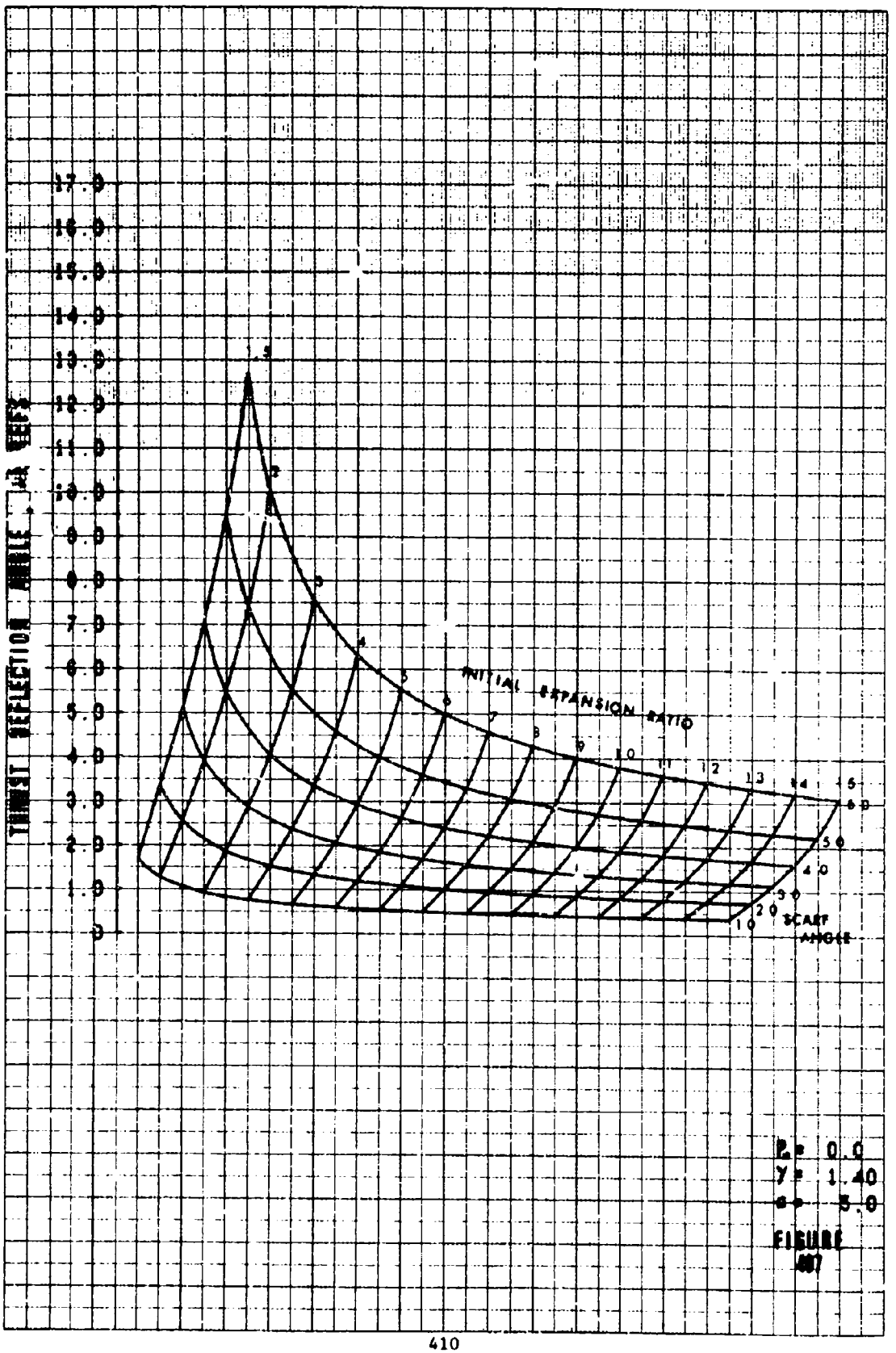
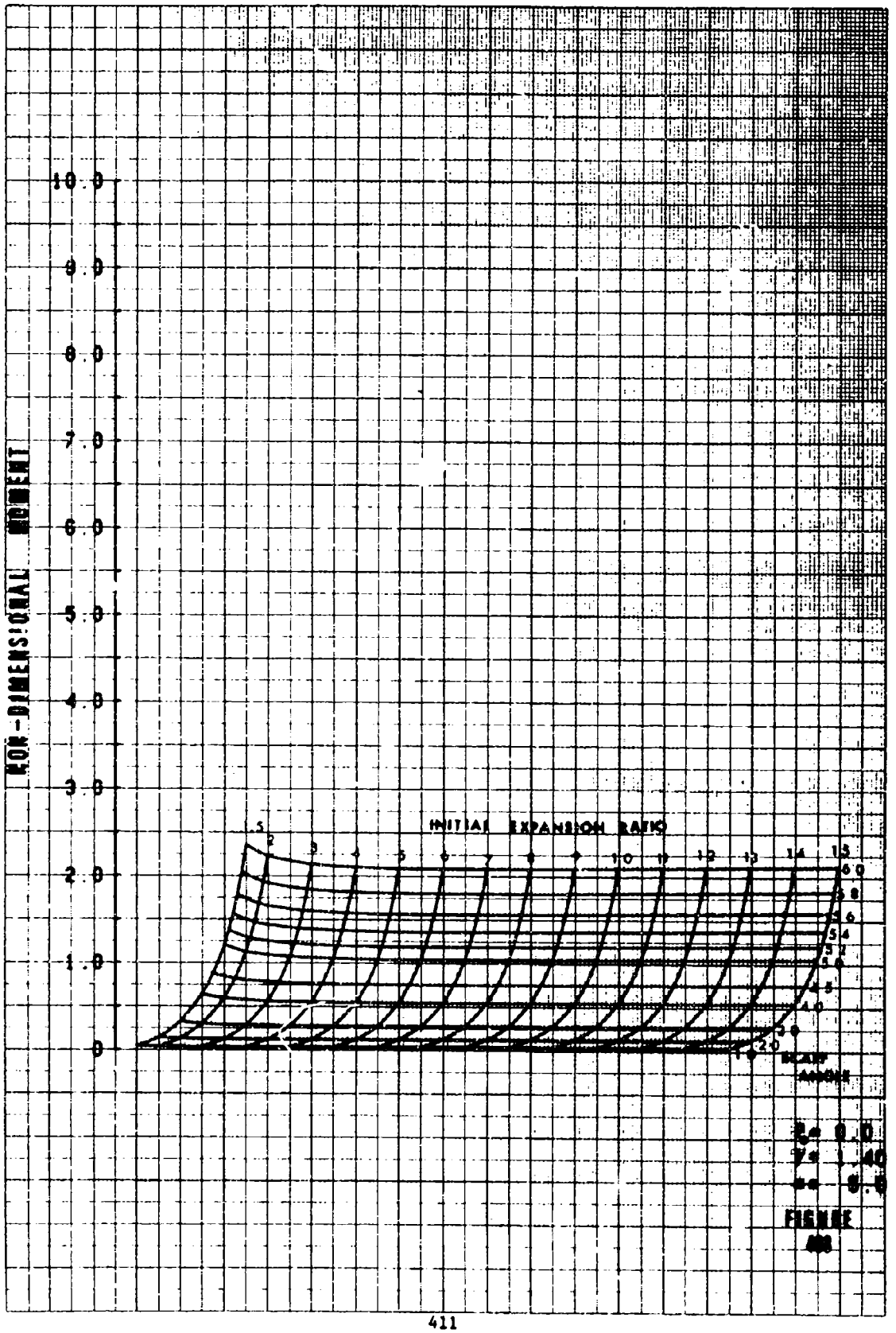
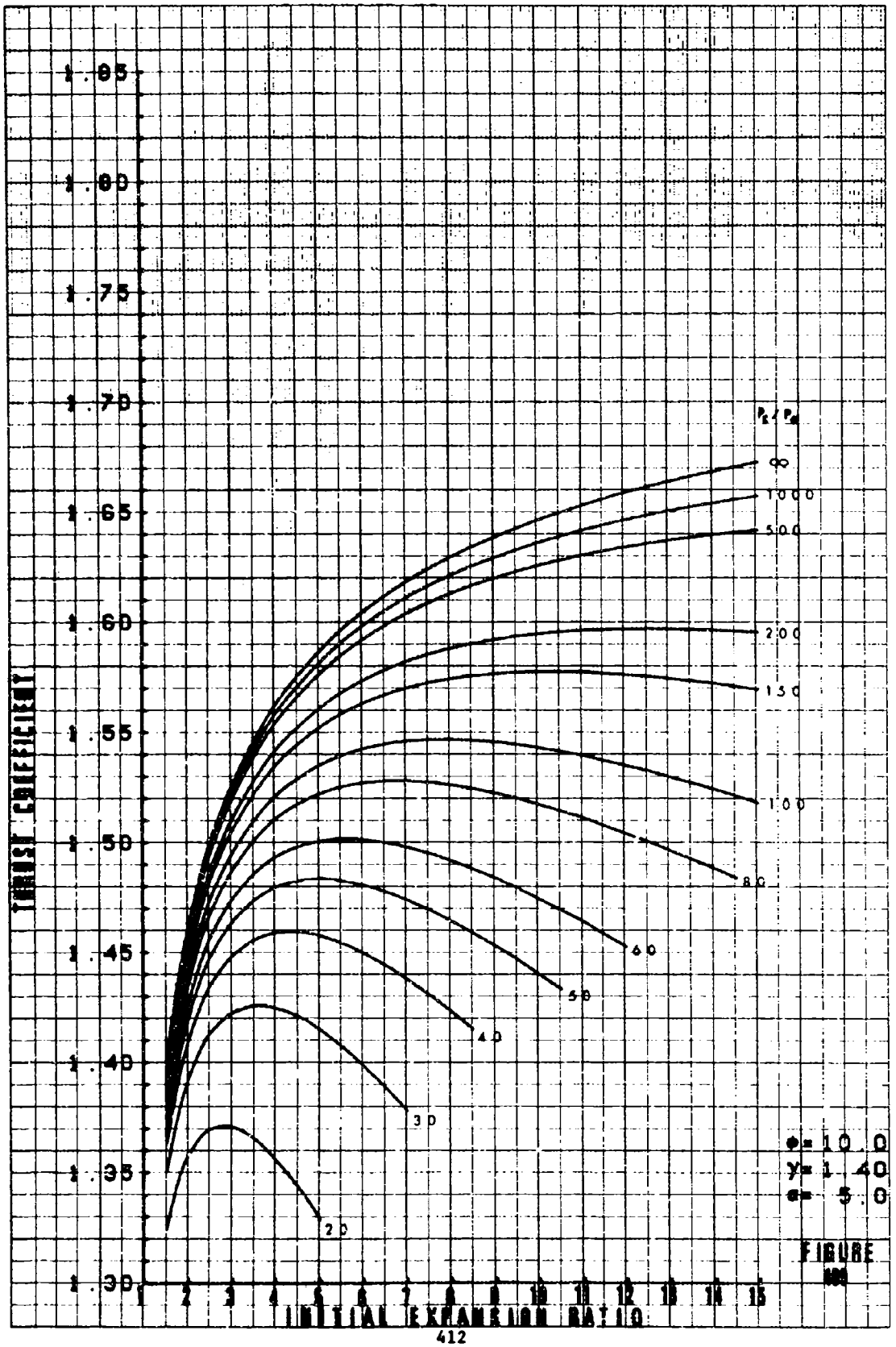

THRUST DEFLECTION ANGLE, μ, DEG
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.0
1.1
1.2
1.3
1.4
1.5
6.0
5.0
4.0
3.0
2.0
1.0
SCARF ANGLE
P = 0.0
γ = 1.40
α = 5.0

FIGURE 407


NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
6.0
5.8
5.6
5.4
5.2
5.0
4.5
4.0
3.0
2.0
1.0
SCARF ANGLE
FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_E/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.40
α= 5.0

FIGURE

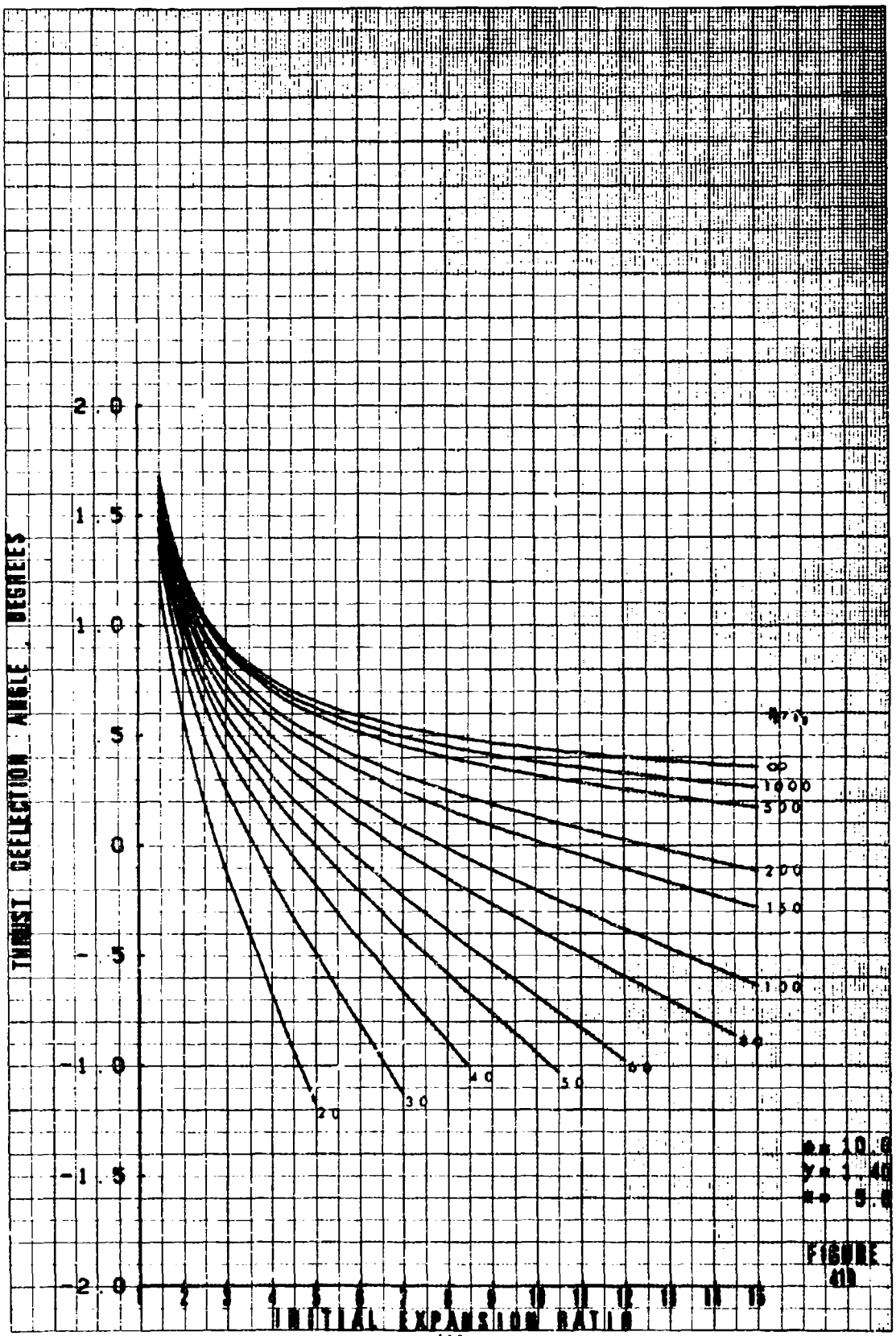

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

FIGURE 41b

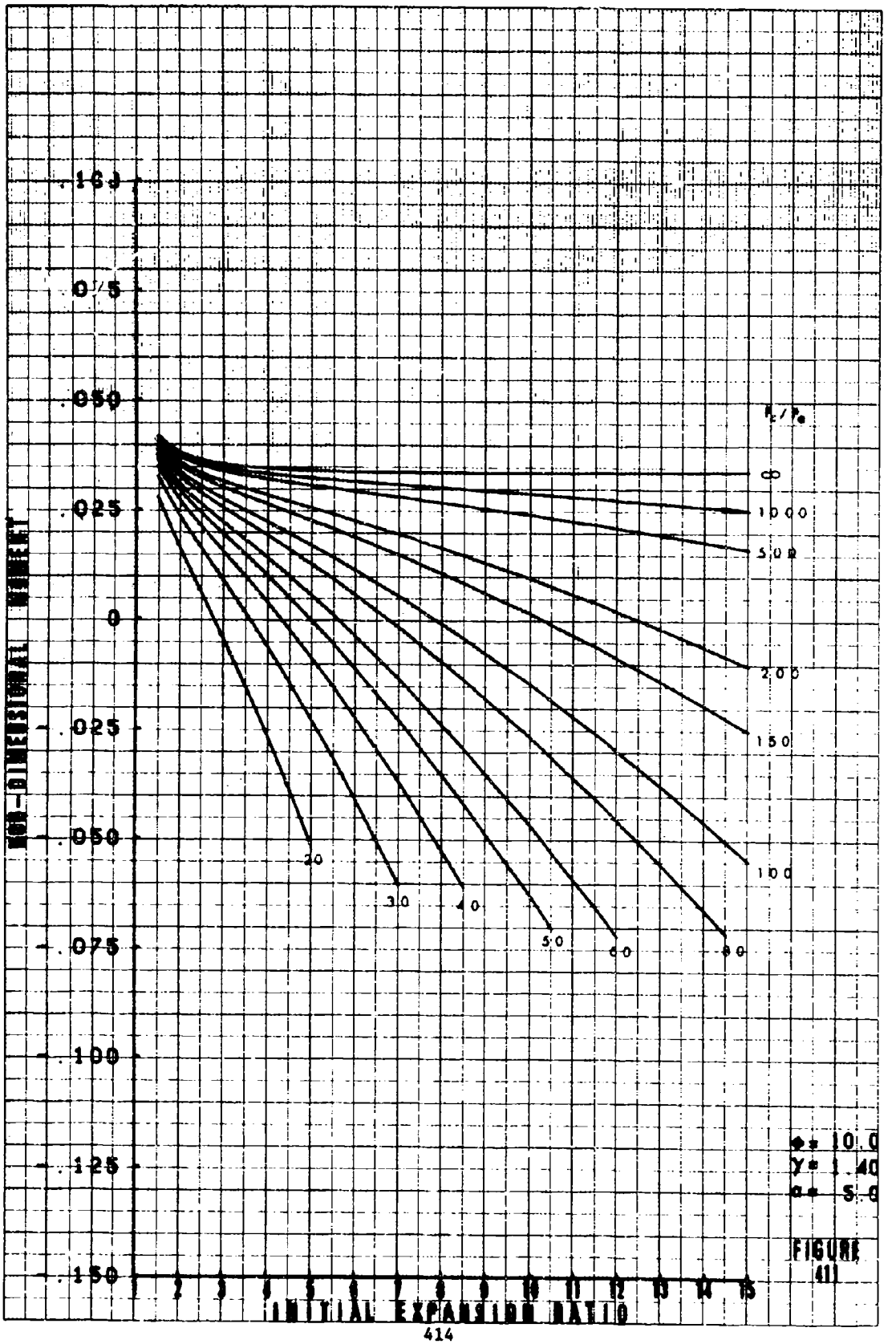

.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_2/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.40
α= 5.0

FIGURE 411

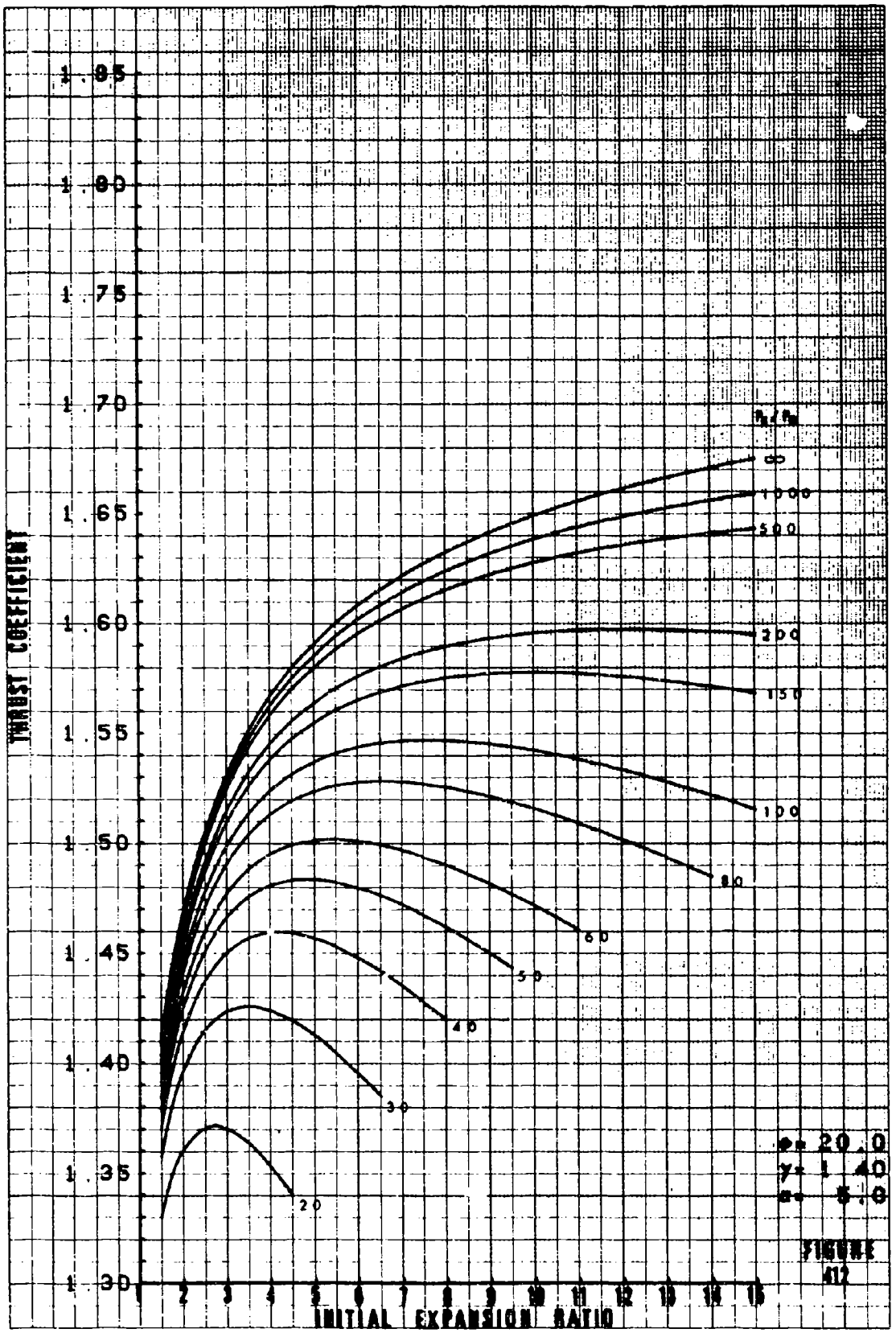

THRUST COEFFICIENT
1.95
1.90
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
p= 20.0
γ= 1.40
a= 5.0

FIGURE 412

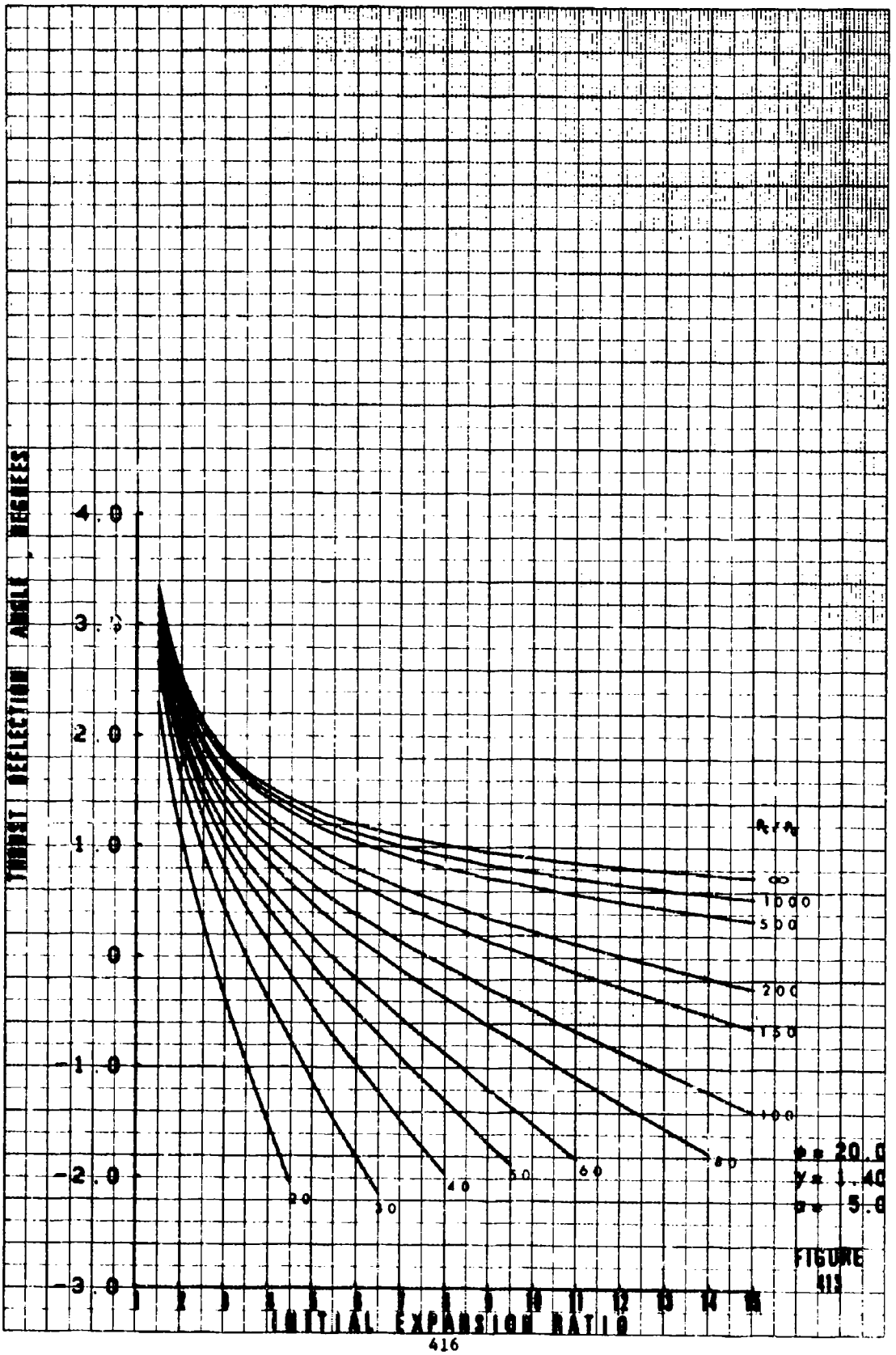
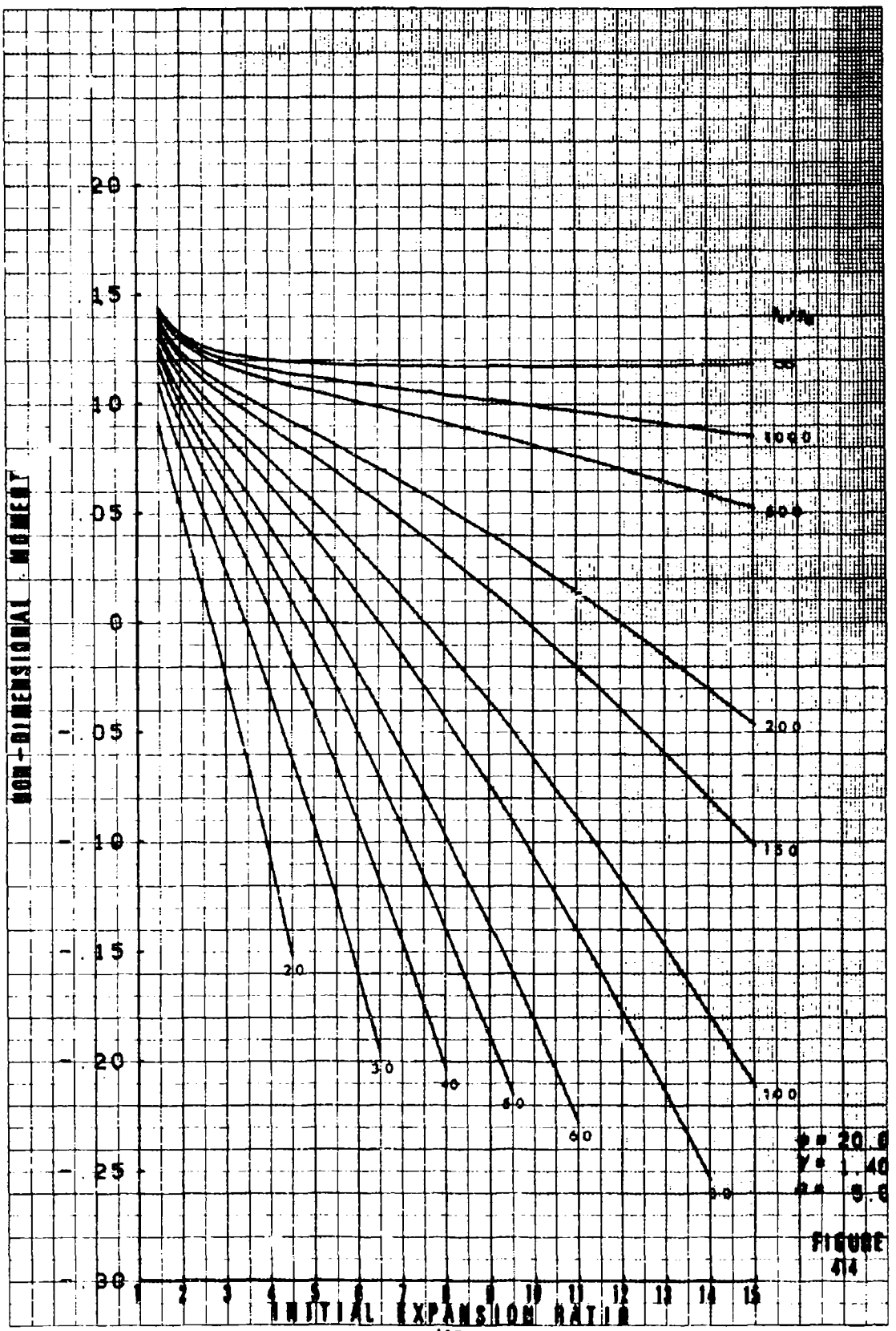

THROAT DEFLECTION ANGLE, DEGREES
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
R/R_t
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.40
σ = 5.0

FIGURE 413


NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
600
200
150
100
80
60
40
30
20
FIGURE 414

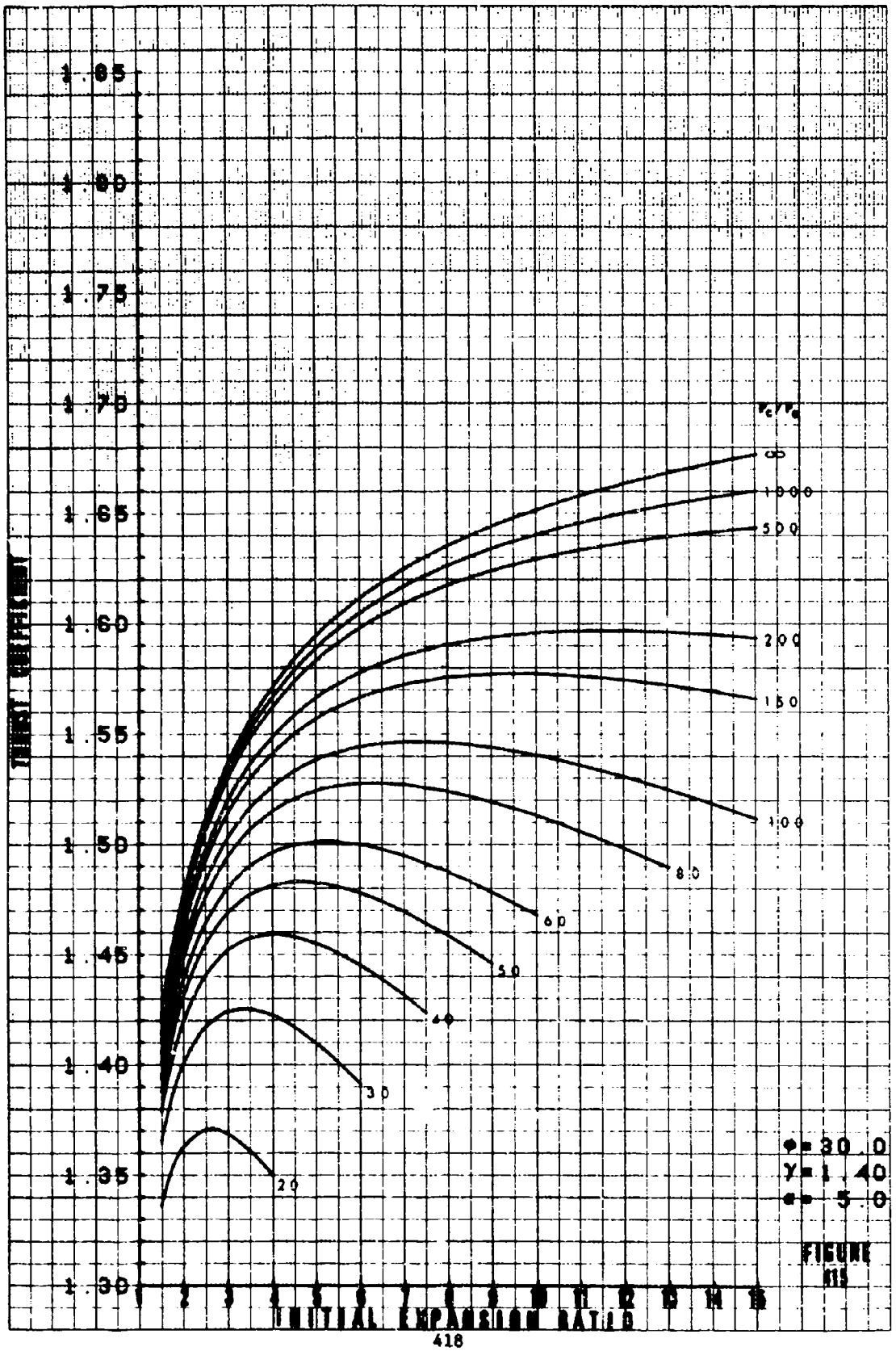

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 30.0
γ = 1.40
α = 5.0

FIGURE 115

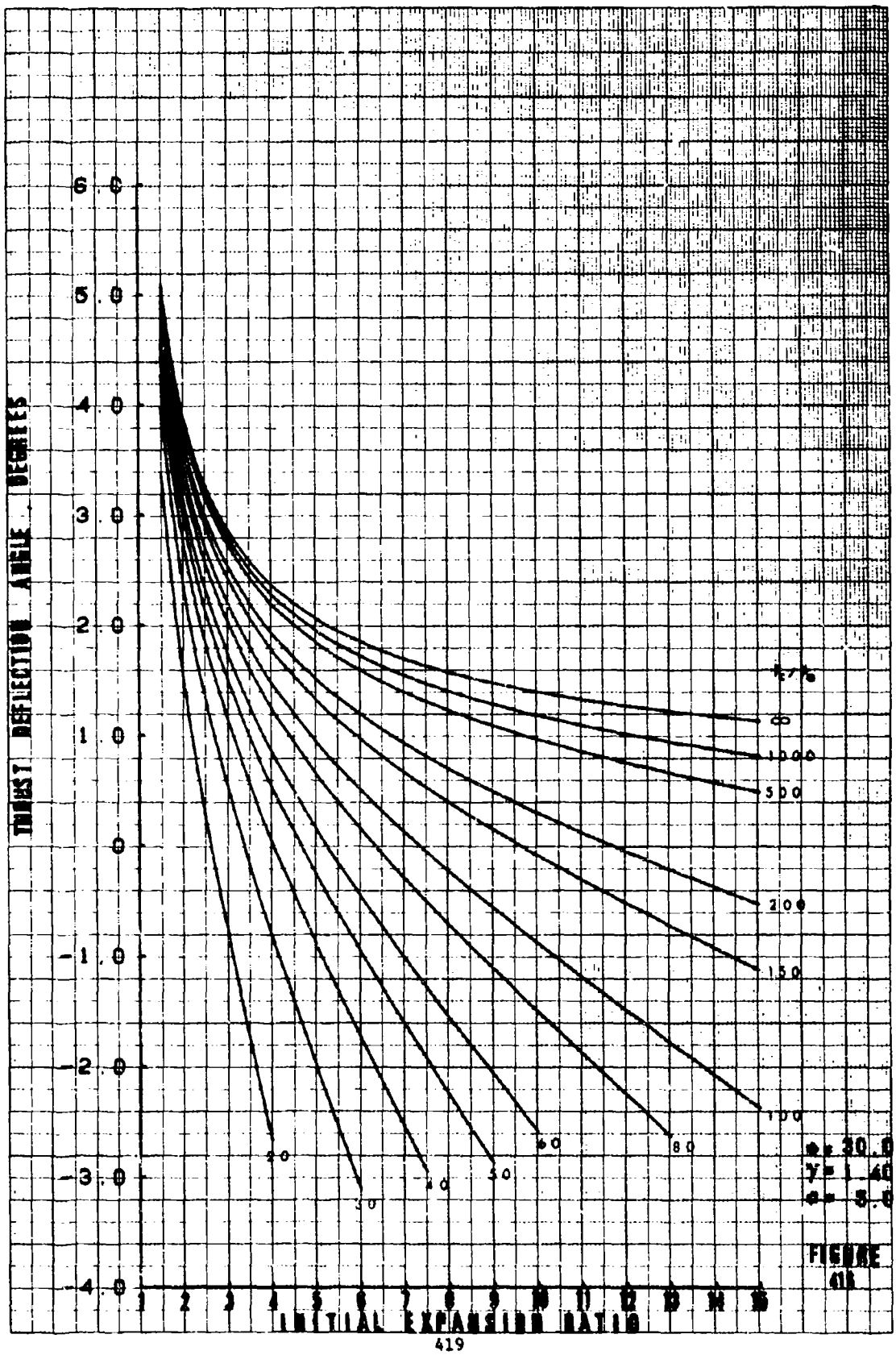

THRUST DEFLECTION ANGLE DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40

FIGURE 41b

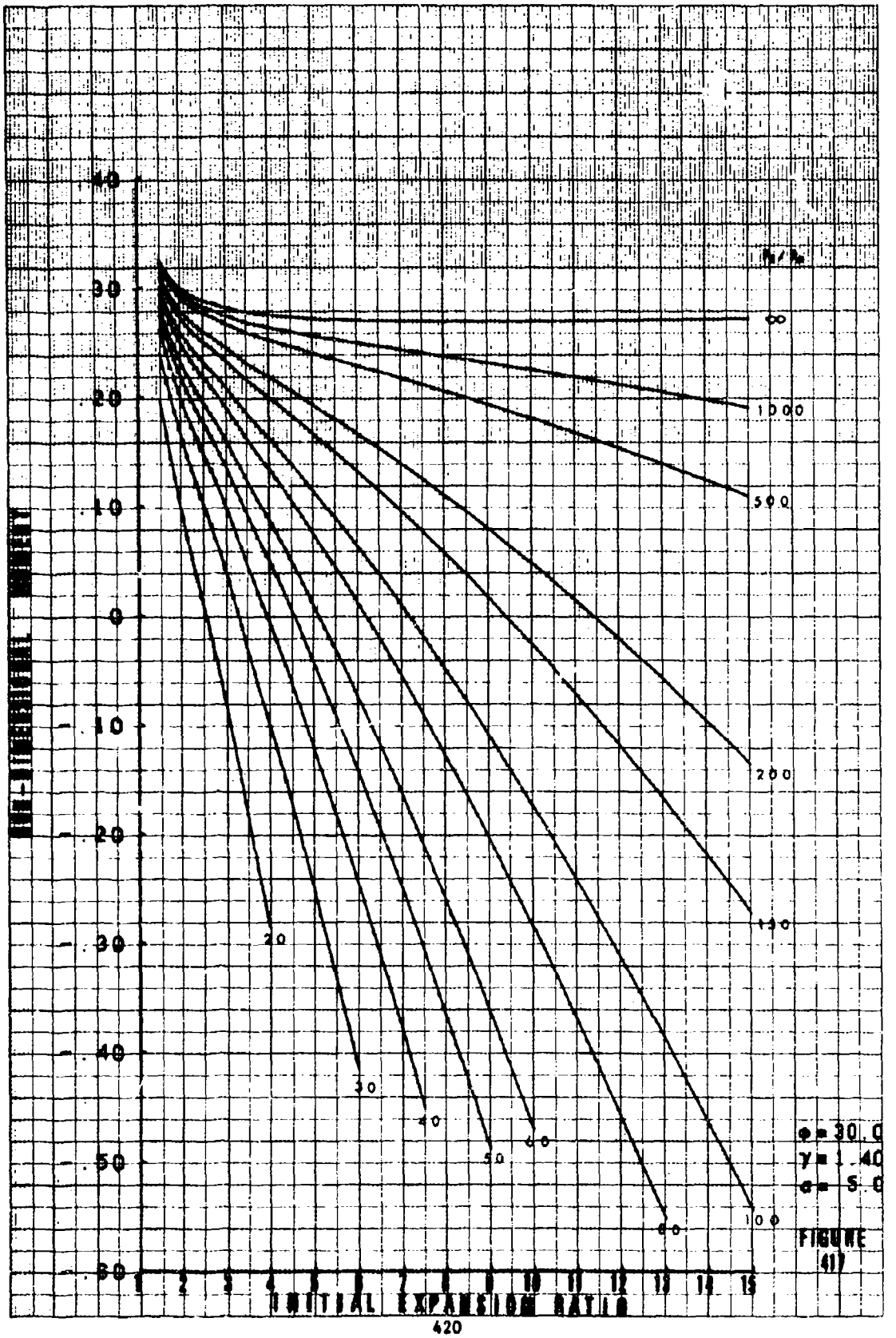
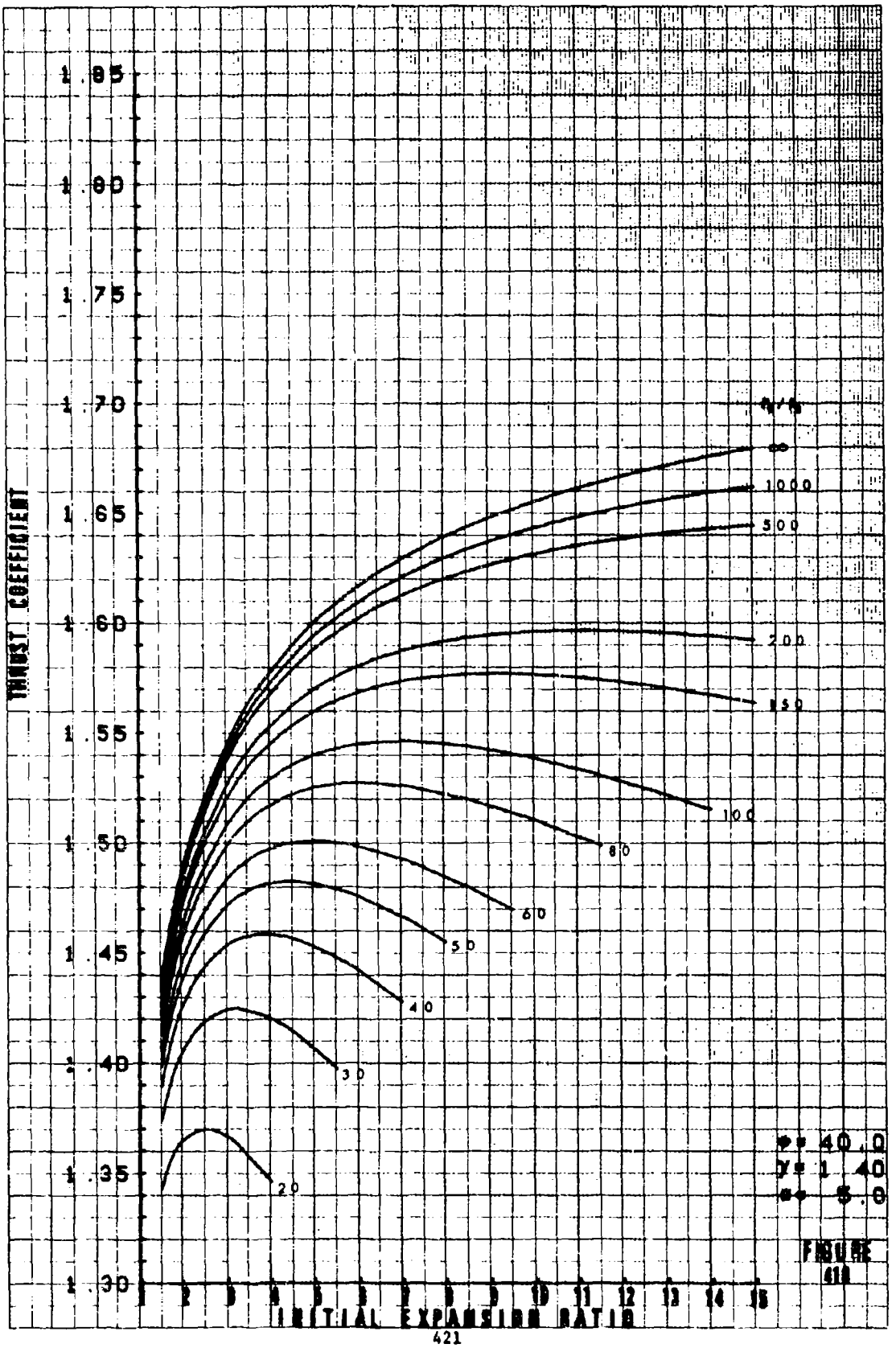

40
30
20
10
0
-10
-20
-30
-40
-50
-60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
h_1/h_2
∞
1000
500
200
100
20
30
40
50
60
100
φ = 30.0
γ = 1.40
α = 5.0

FIGURE 417


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40
FIGURE 41B

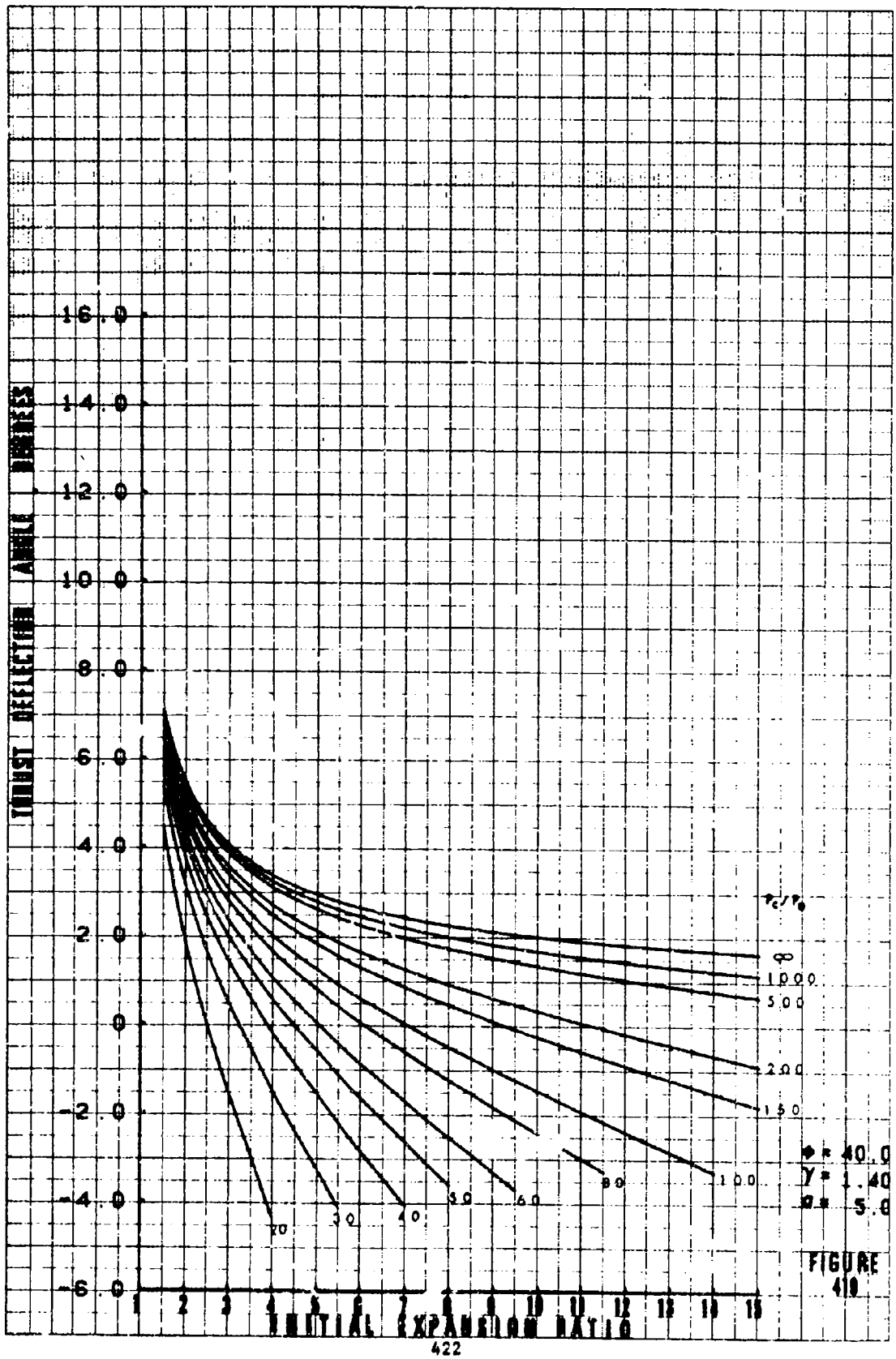
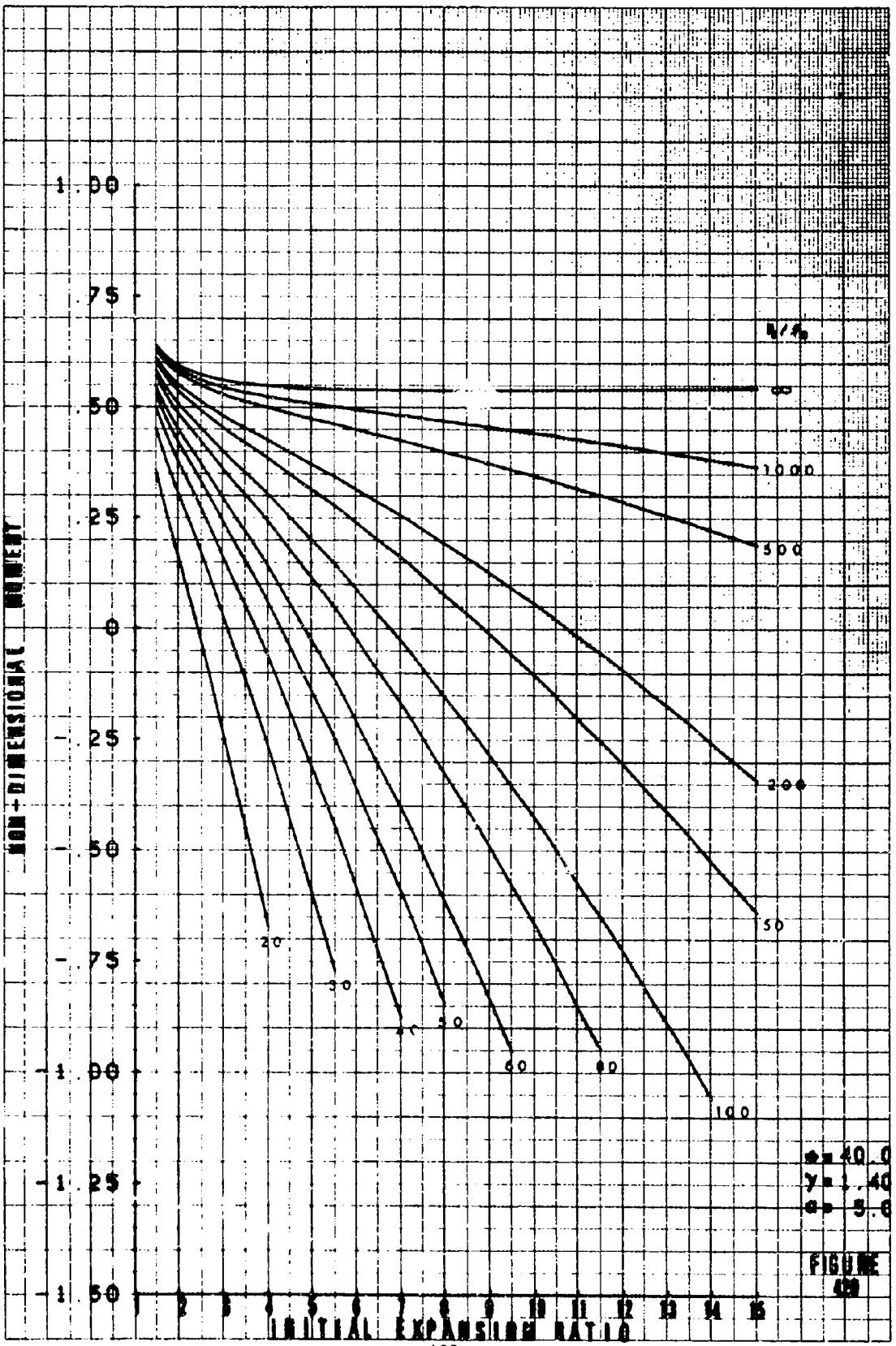
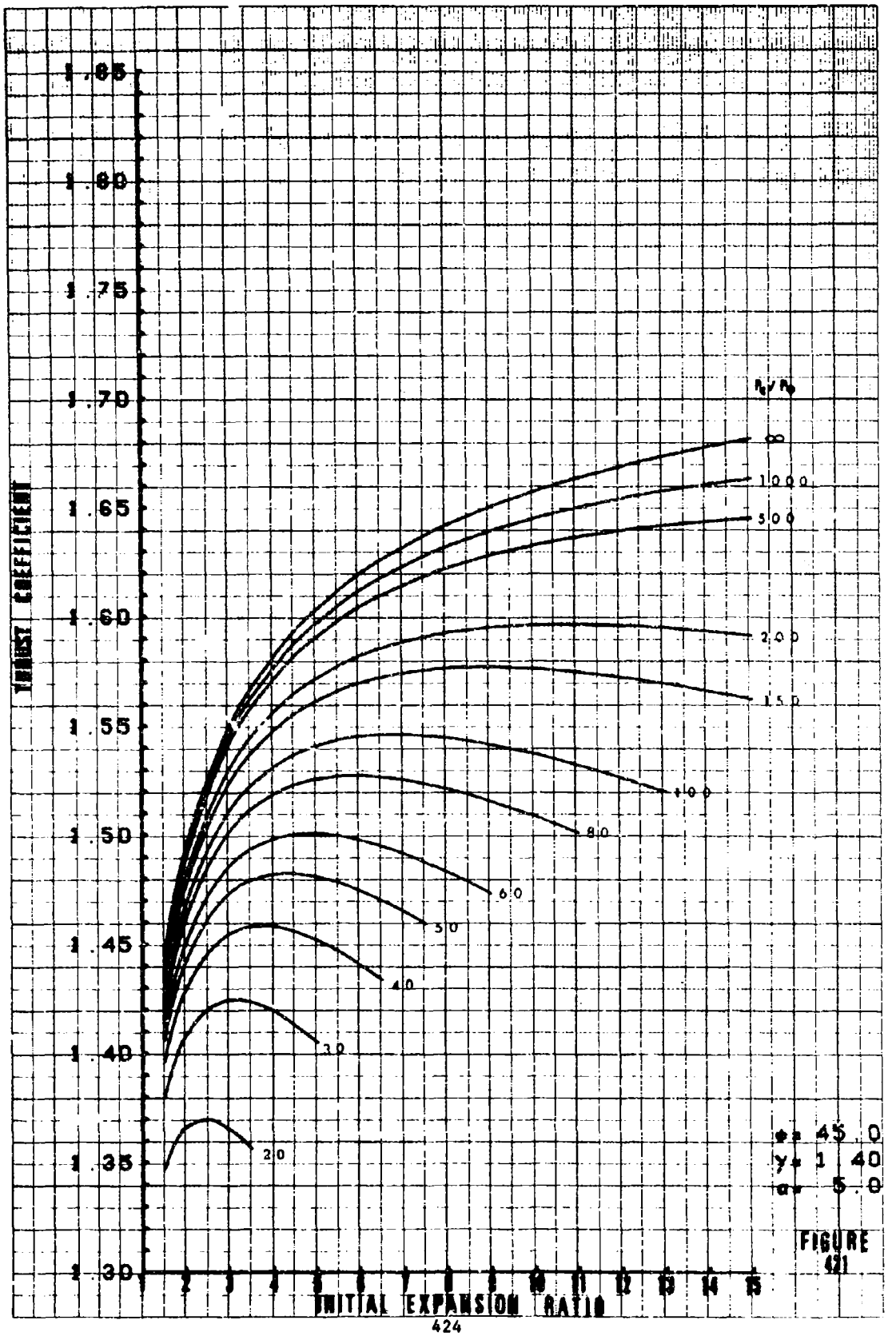

THRUST DEFLECTION ANGLE DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 40.0
γ = 1.40
α = 5.0

FIGURE 410



NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
50
100
20
30
40
50
60
80

FIGURE 420



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_e/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.40
α = 5.0

FIGURE 421

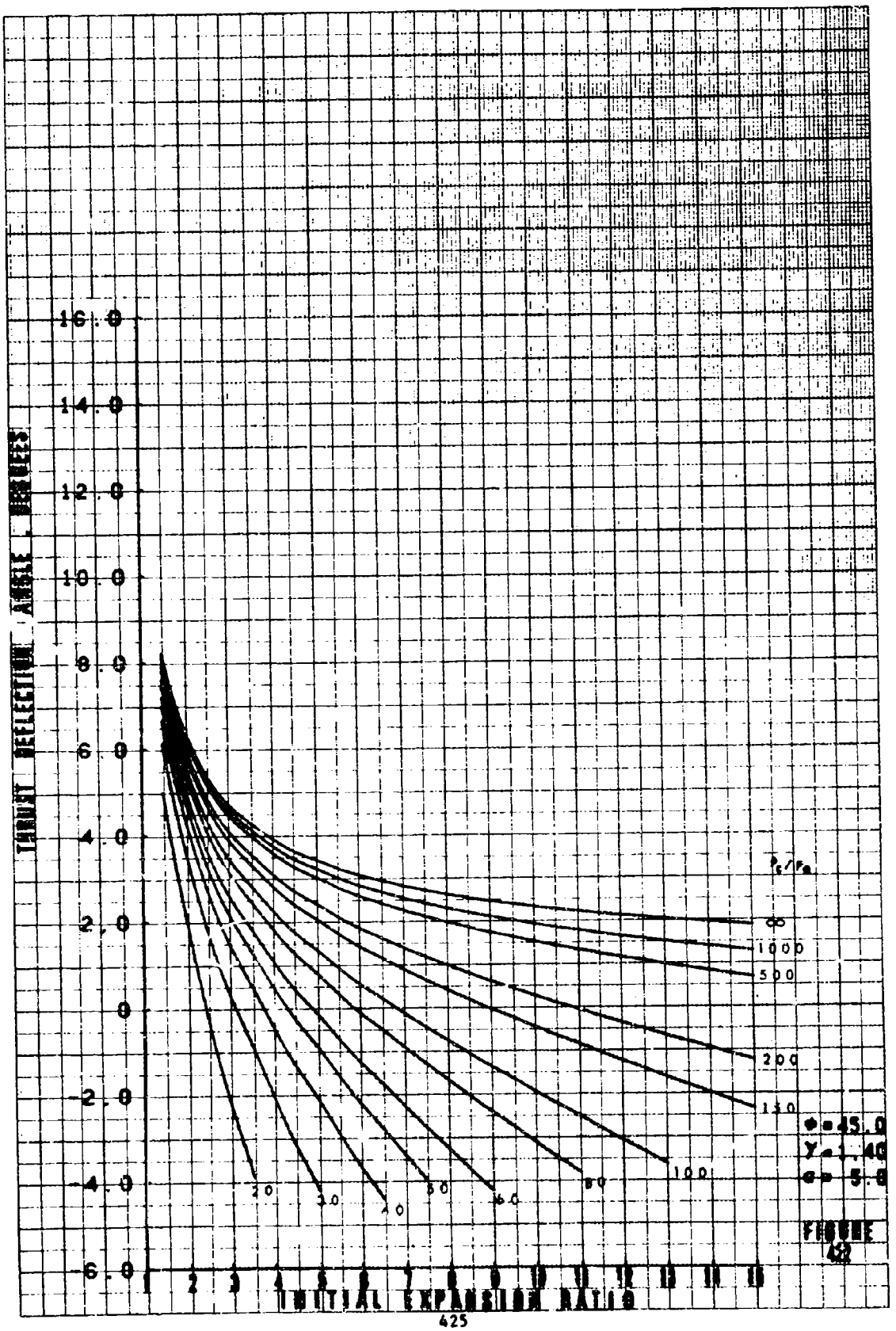

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
40
30
20
φ = 45.0
γ = 1.40
σ = 5.0

FIGURE 42

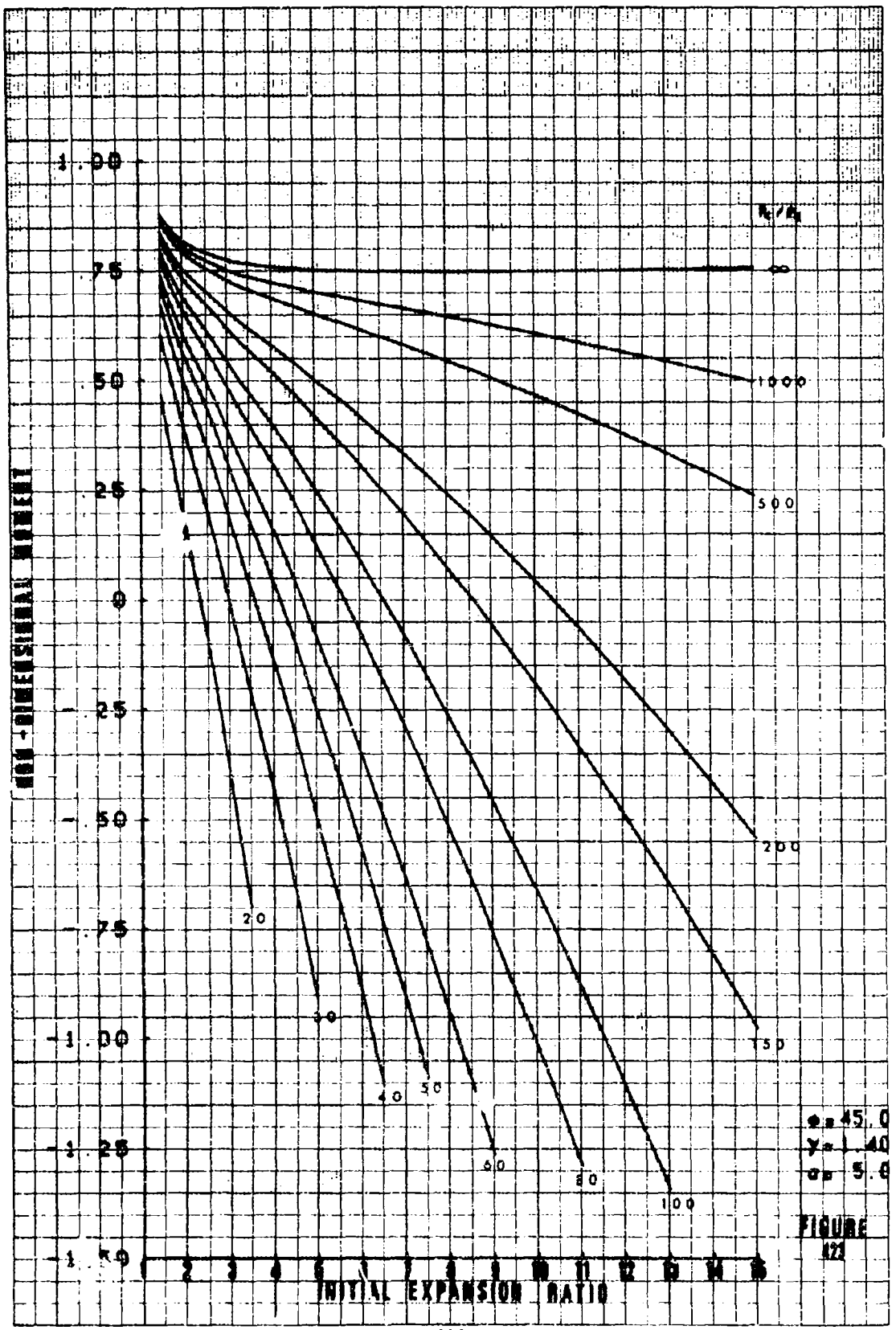
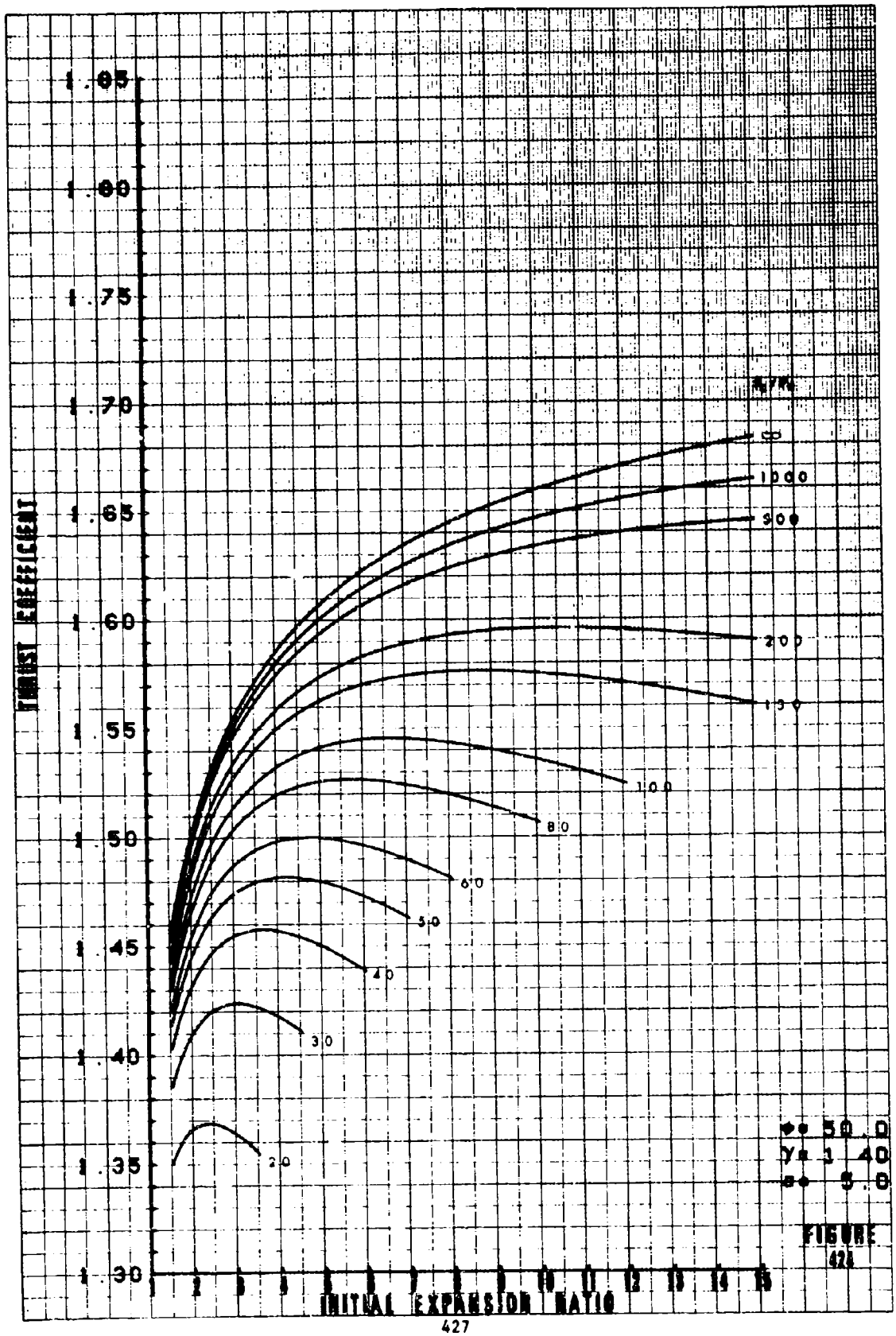

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
R_1/R_2
∞
1000
500
200
150
100
80
60
50
40
30
20
1
φ = 45.0
γ = 1.40
σ = 5.0

FIGURE 422



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.40
α= 5.0

FIGURE 424

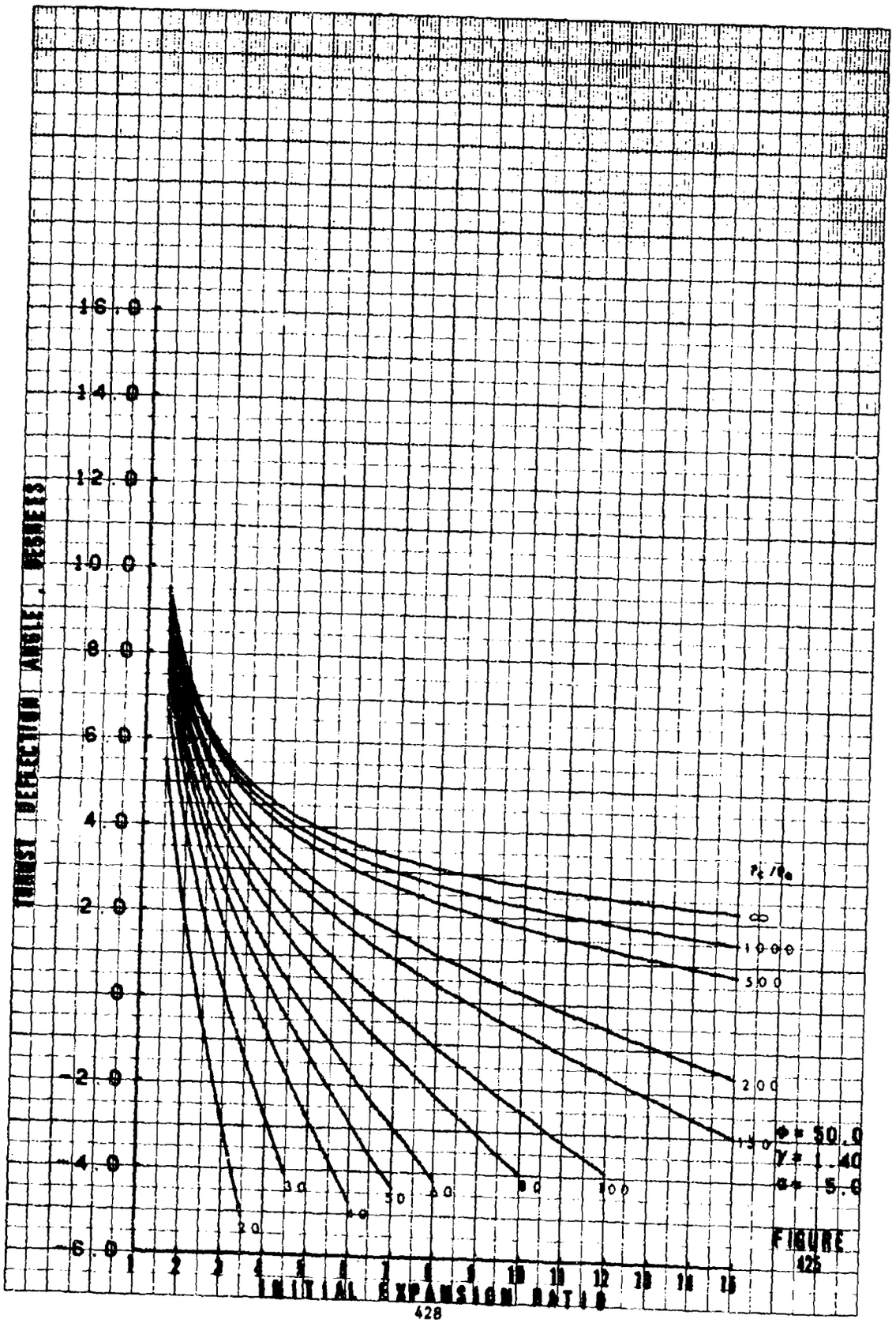
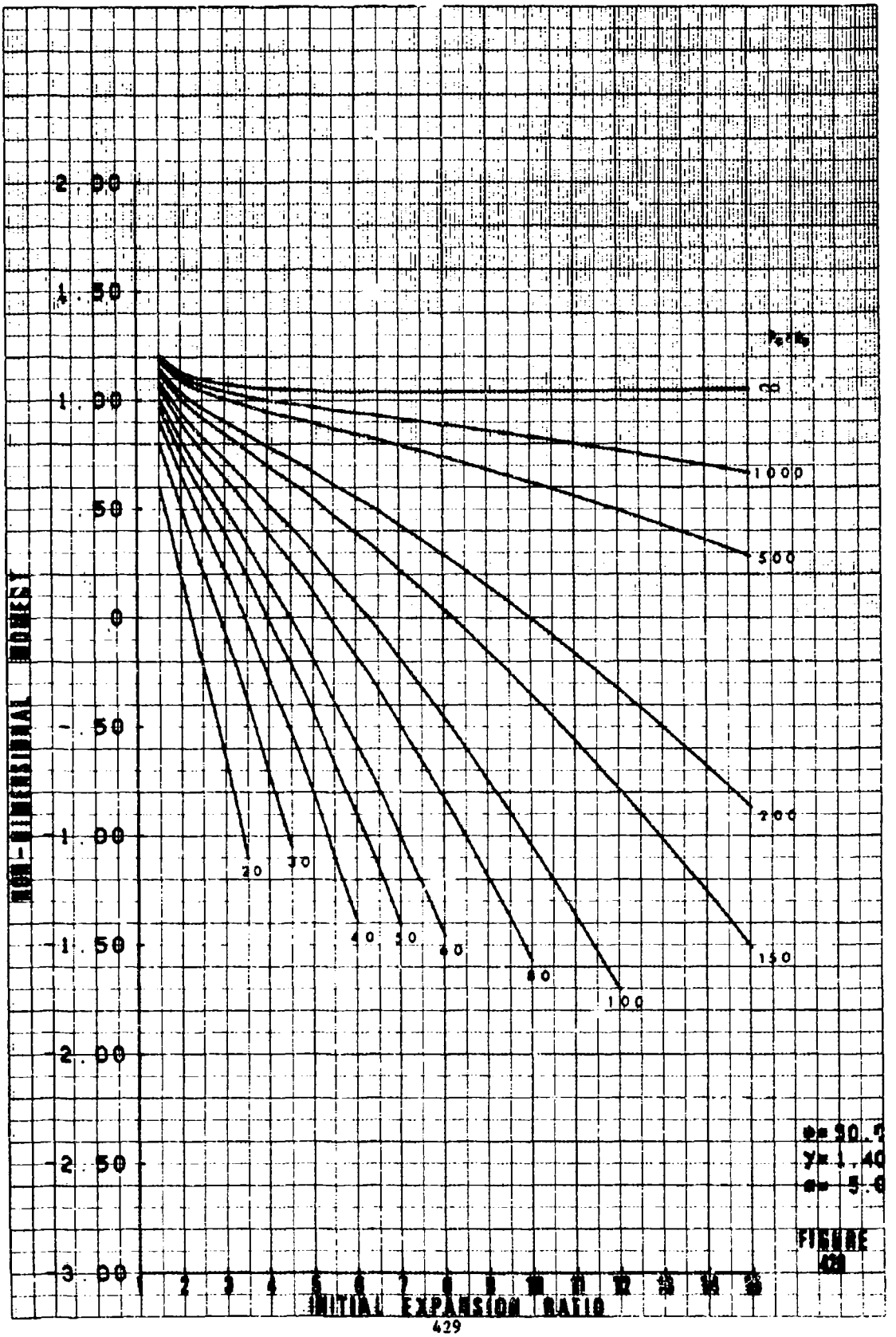

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
Φ = 50.0
γ = 1.40
α = 5.0

FIGURE 425



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
20
FIGURE

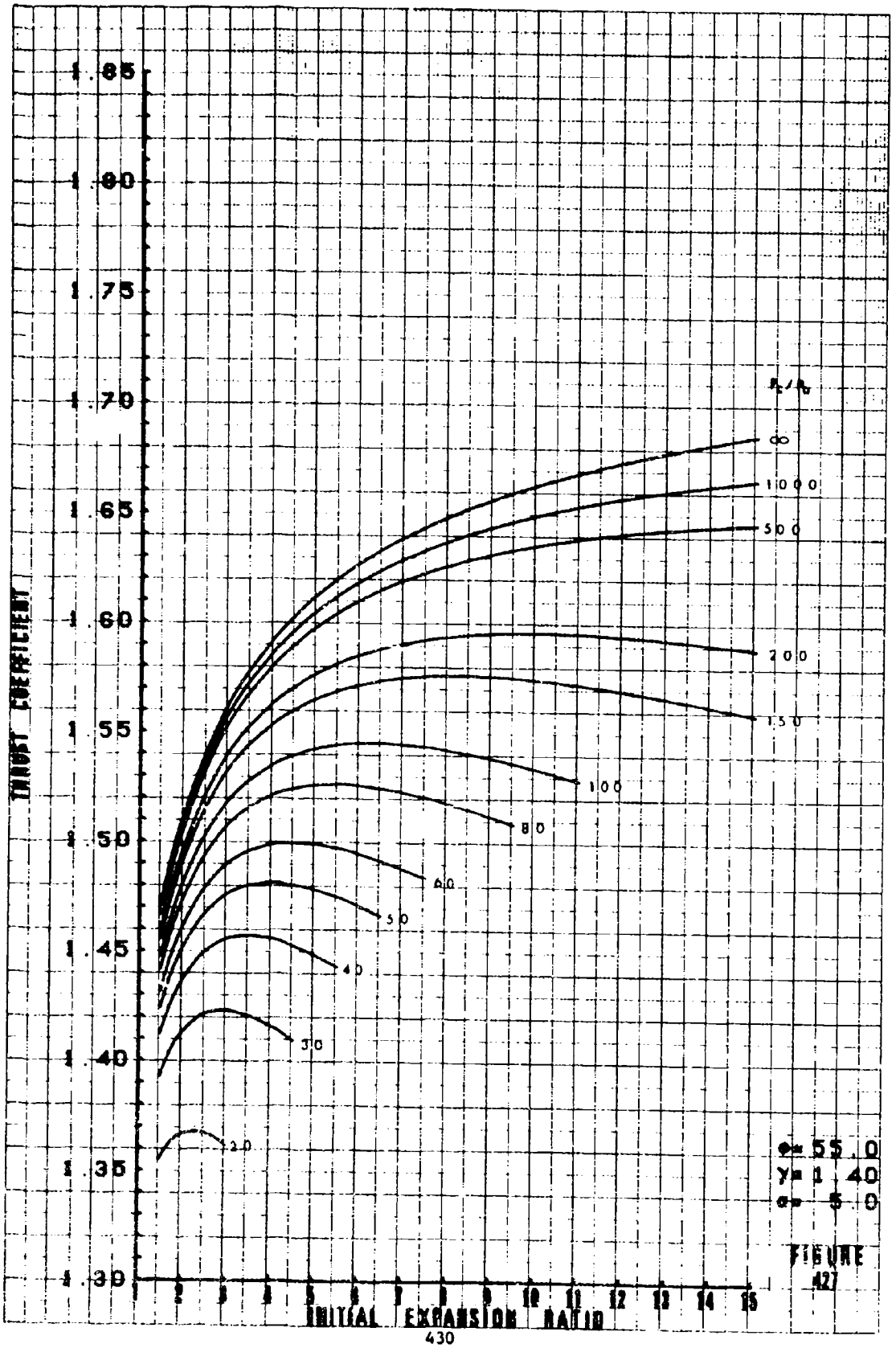

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
R_t/R_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 55.0
γ= 1.40
α= 5.0

FIGURE 427

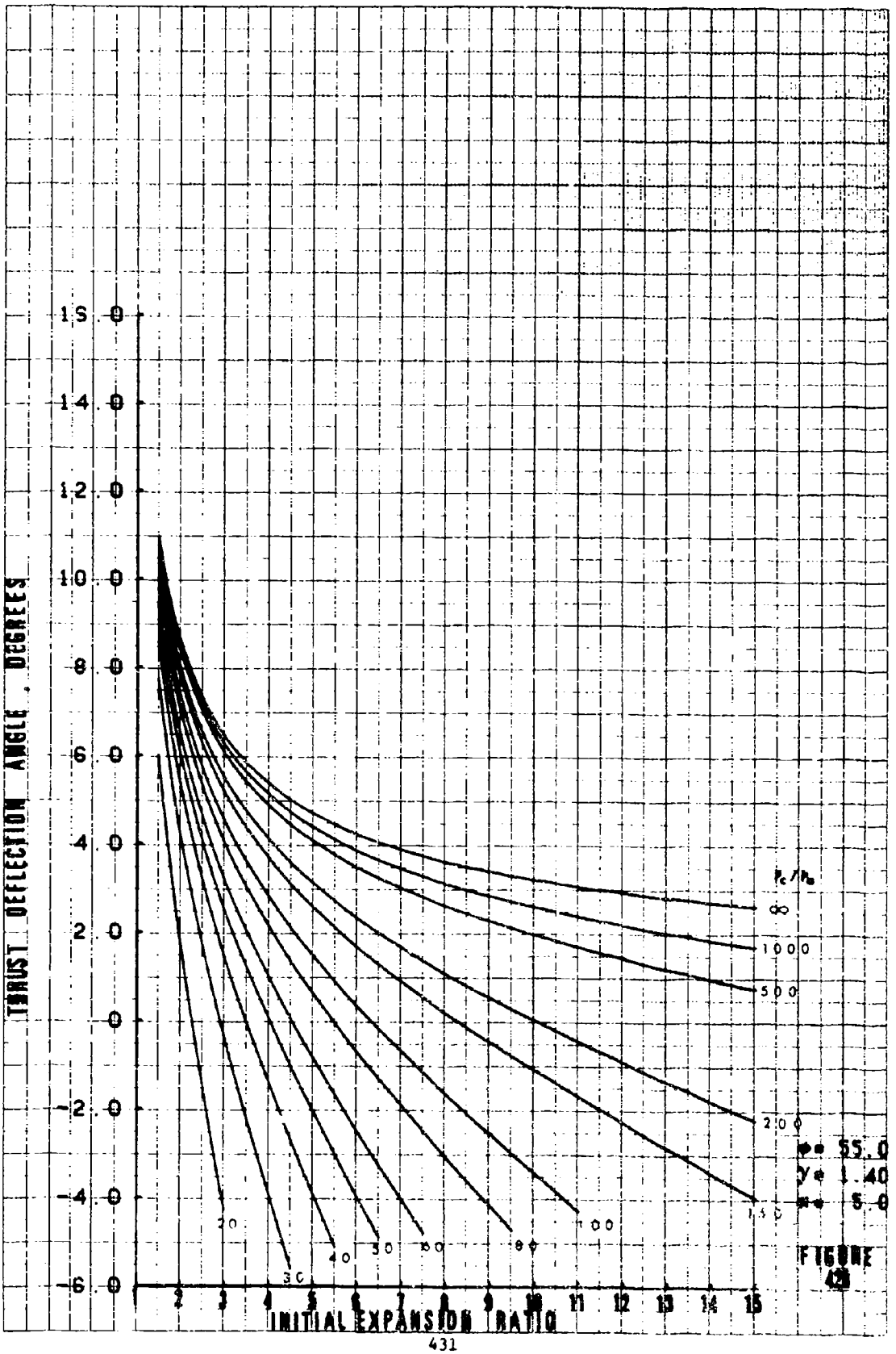
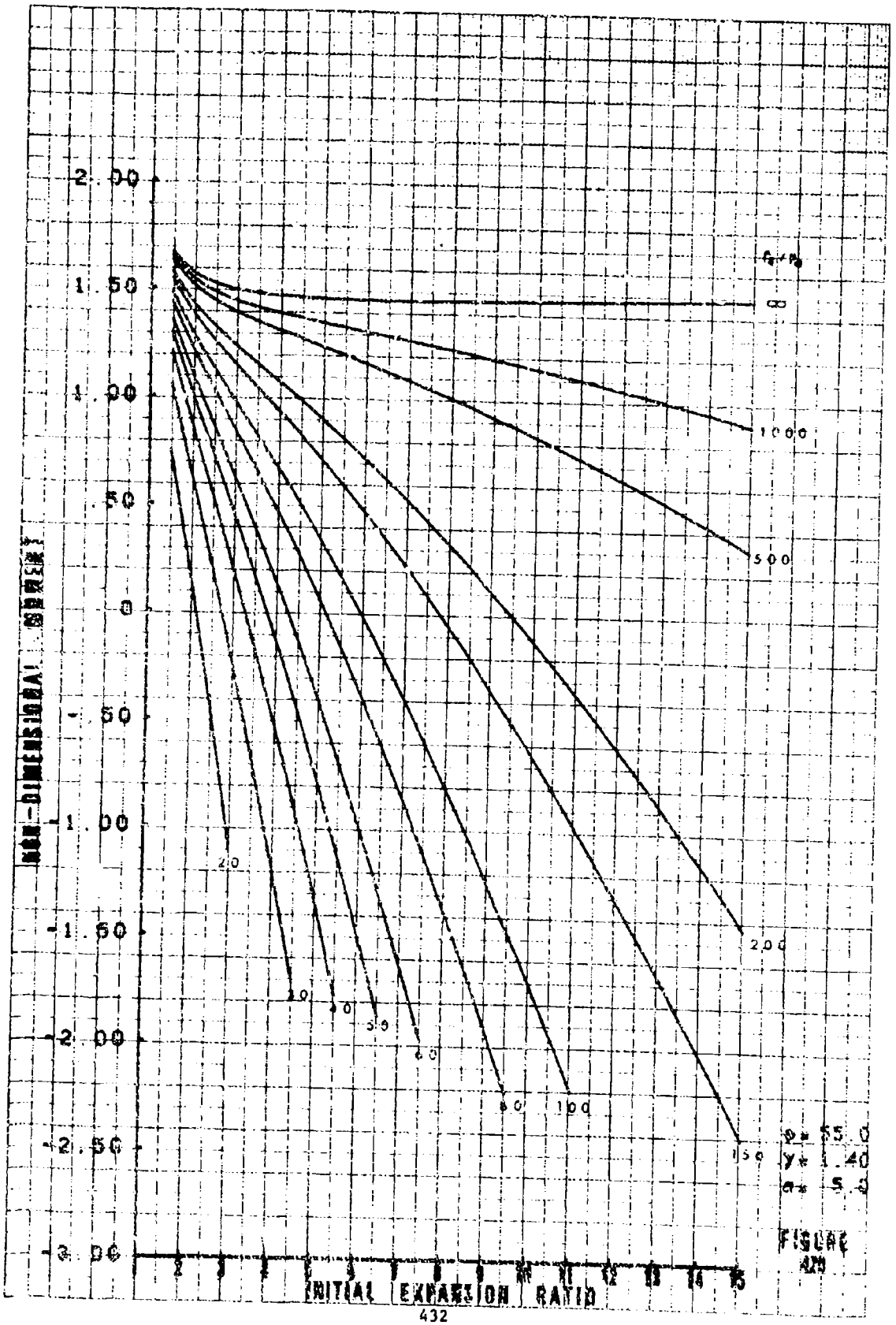
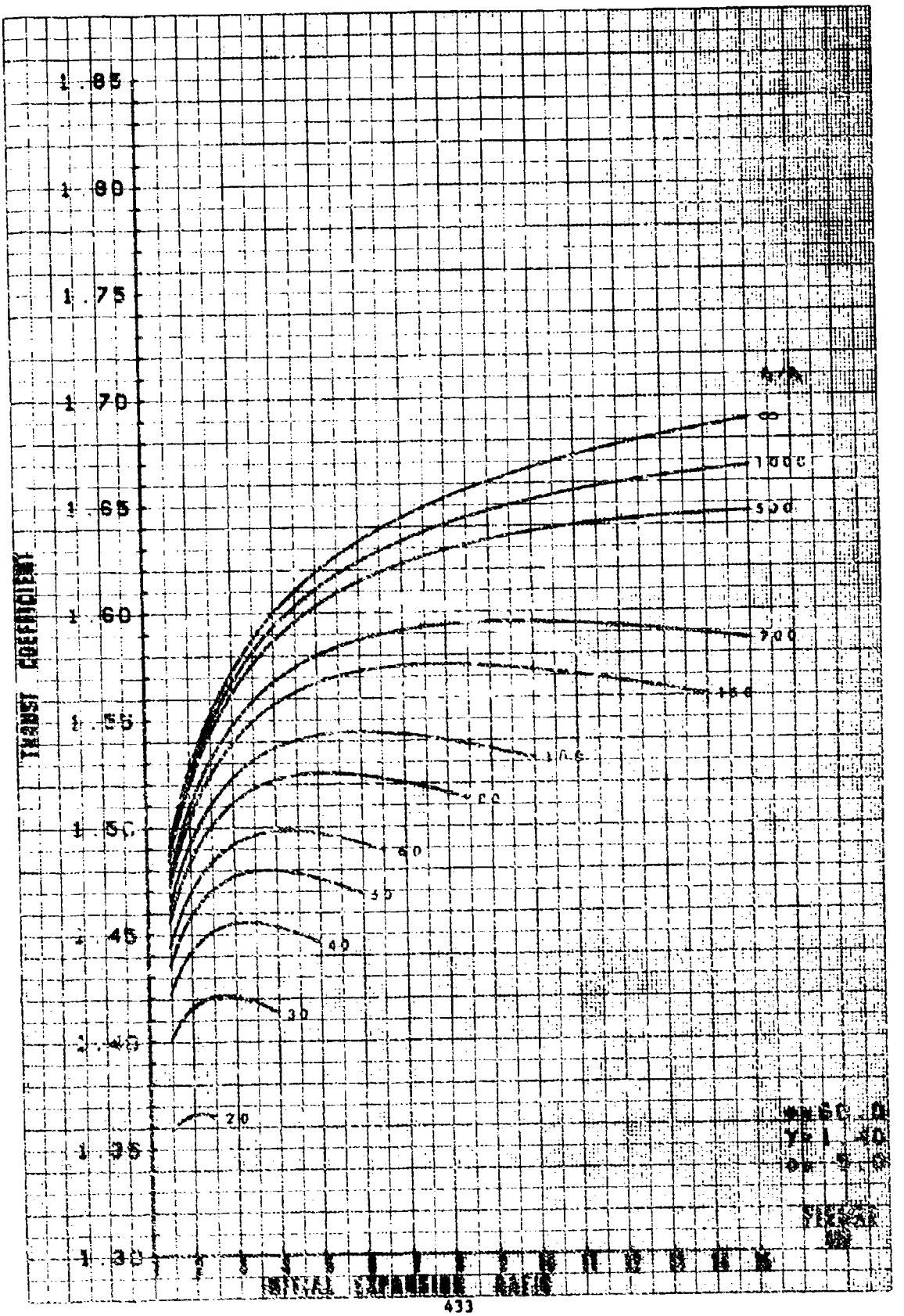

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 55.0
γ= 1.40
α= 5.0

FIGURE 428



2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
ρ = 55.0
γ = 1.40
a = 5.0

FIGURE 420


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20

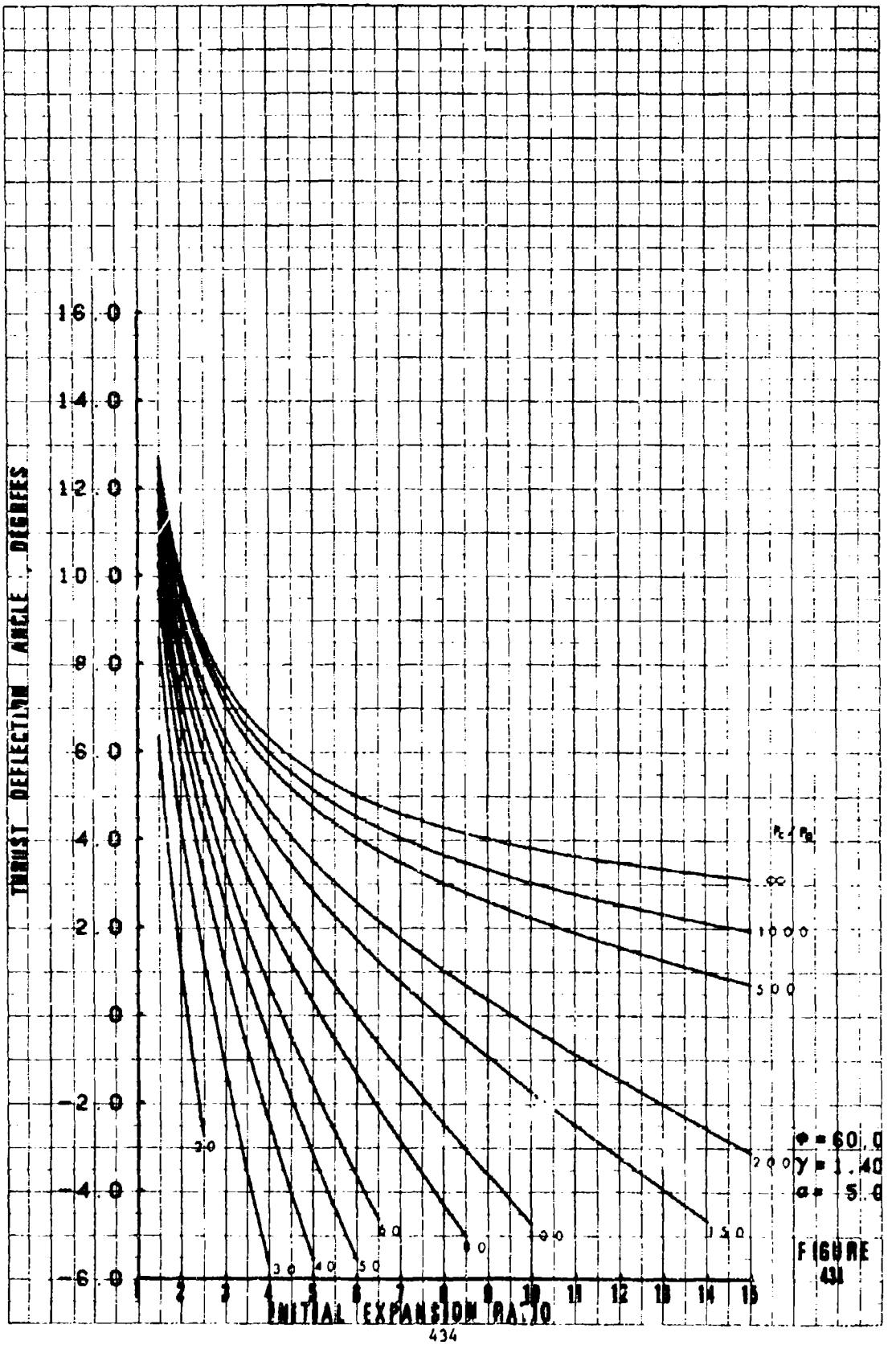

THRUST DEFLECTION ANGLE, DEGREES
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.40
α = 5.0

FIGURE 431

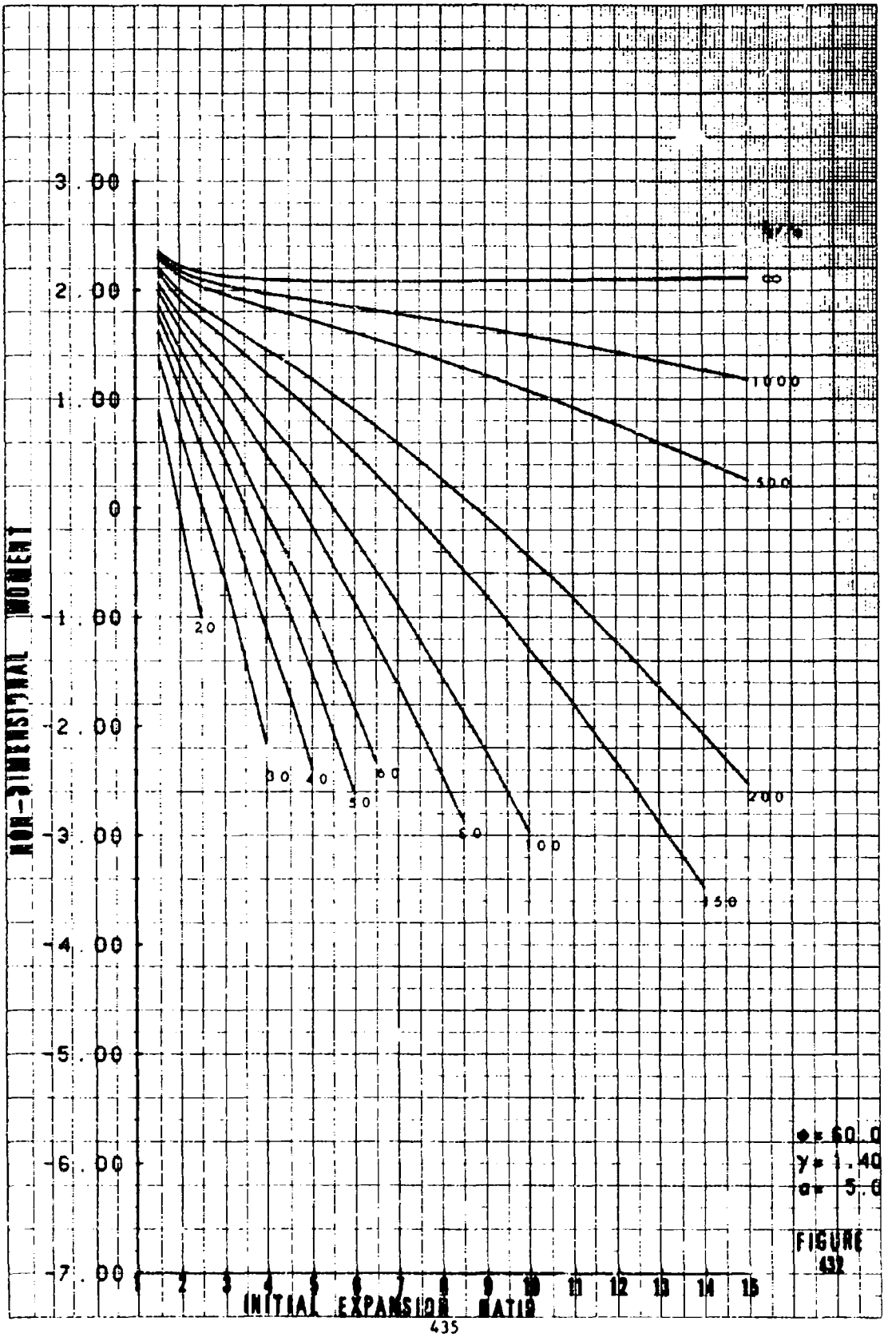

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.00
1.00
0
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 60.0
γ = 1.40
α = 5.6

FIGURE 432

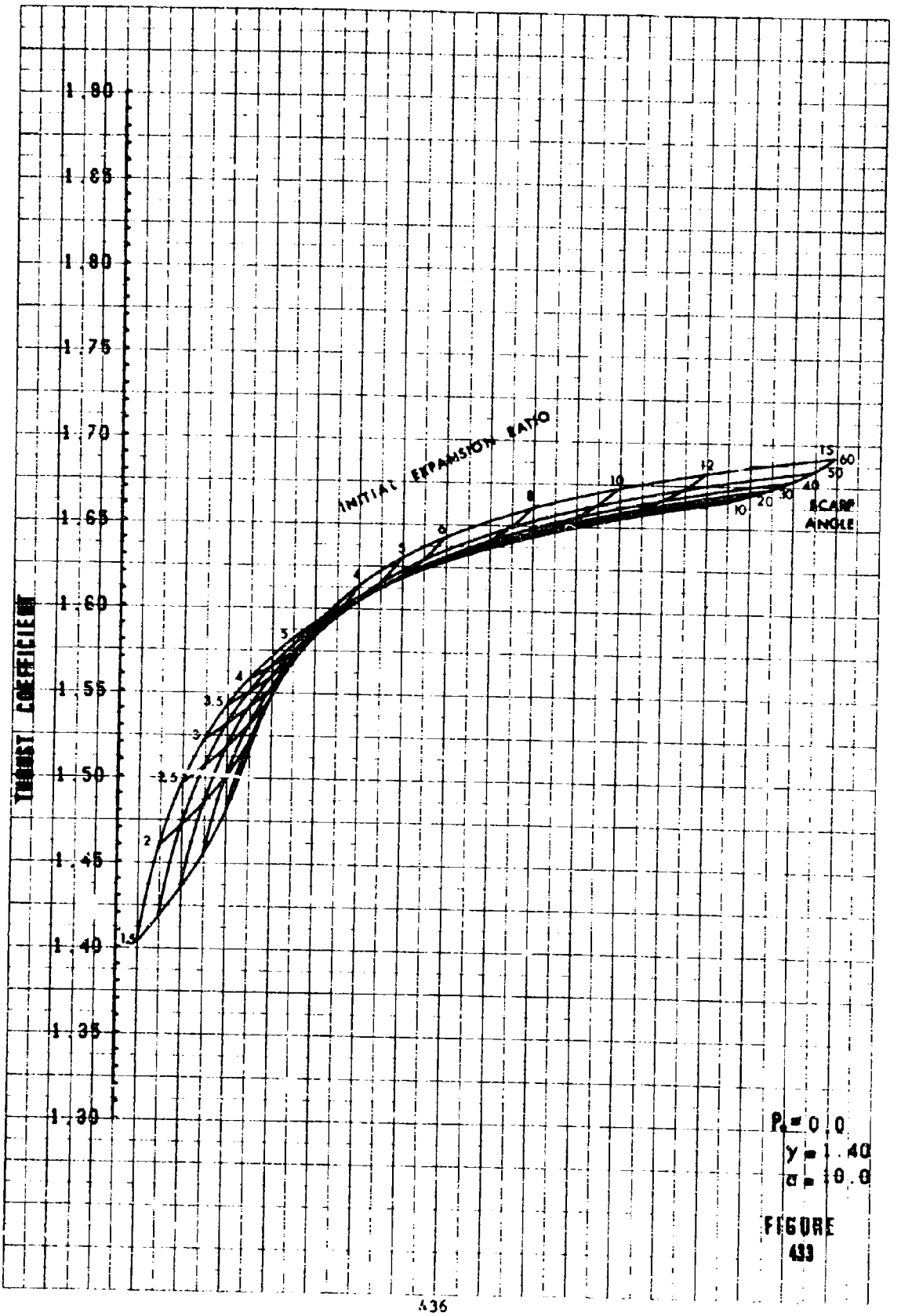

1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.5
2
2.5
3
3.5
4
5
6
8
10
12
15
60
50
40
30
20
10
SCARP ANGLE
$P_a = 0.0$
$\gamma = 1.40$
$\alpha = 0.0$

FIGURE 433

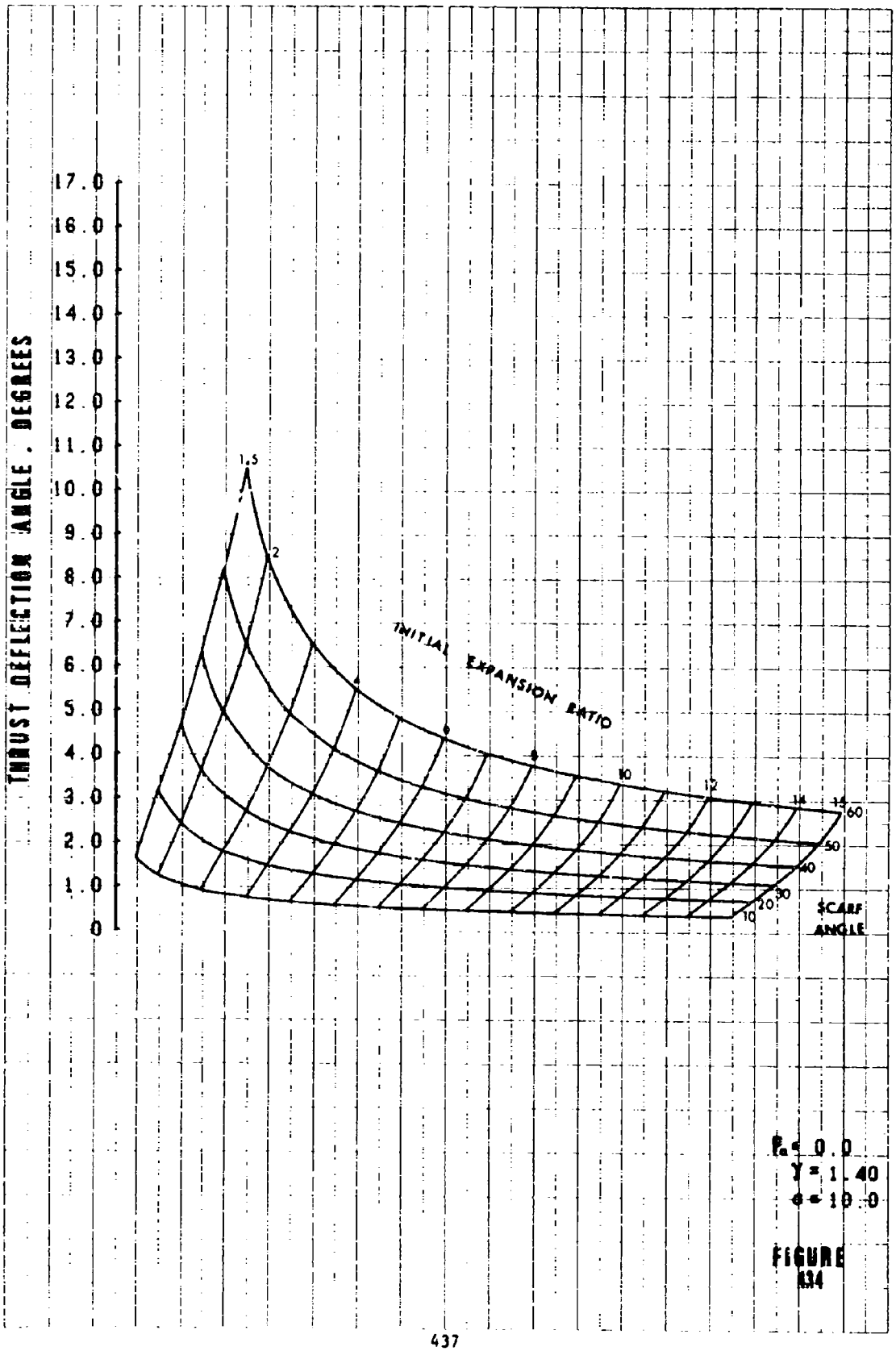

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
INITIAL EXPANSION RATIO
10
12
14
16
60
50
40
30
20
10
SCARF ANGLE
P_a = 0.0
γ = 1.40
ϕ = 10.0

FIGURE
A34

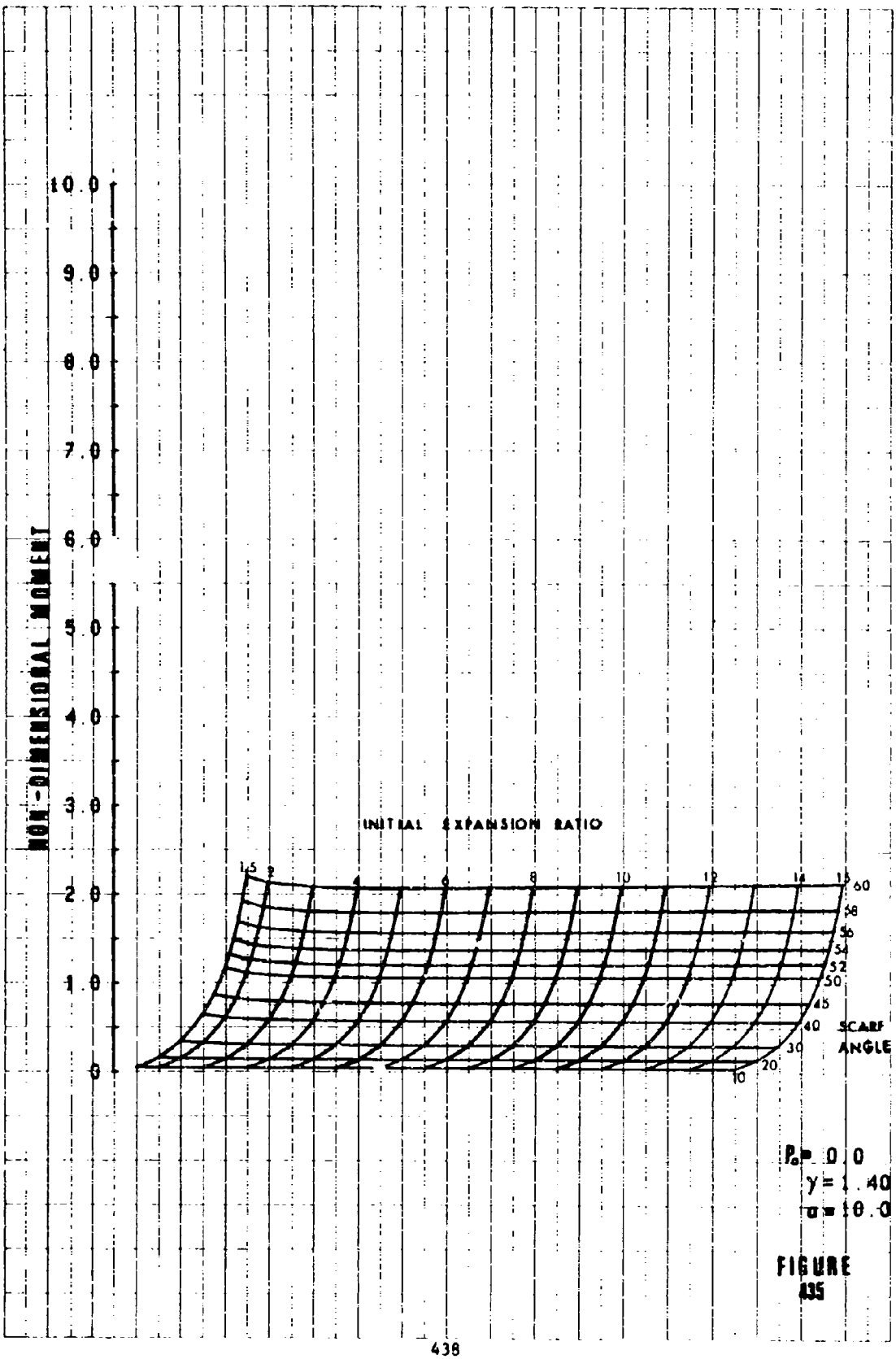

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
4
6
8
10
12
14
16
60
58
56
54
52
50
45
40
30
20
10
SCARF ANGLE
P_o= 0.0
γ = 1.40
α = 10.0

FIGURE 435

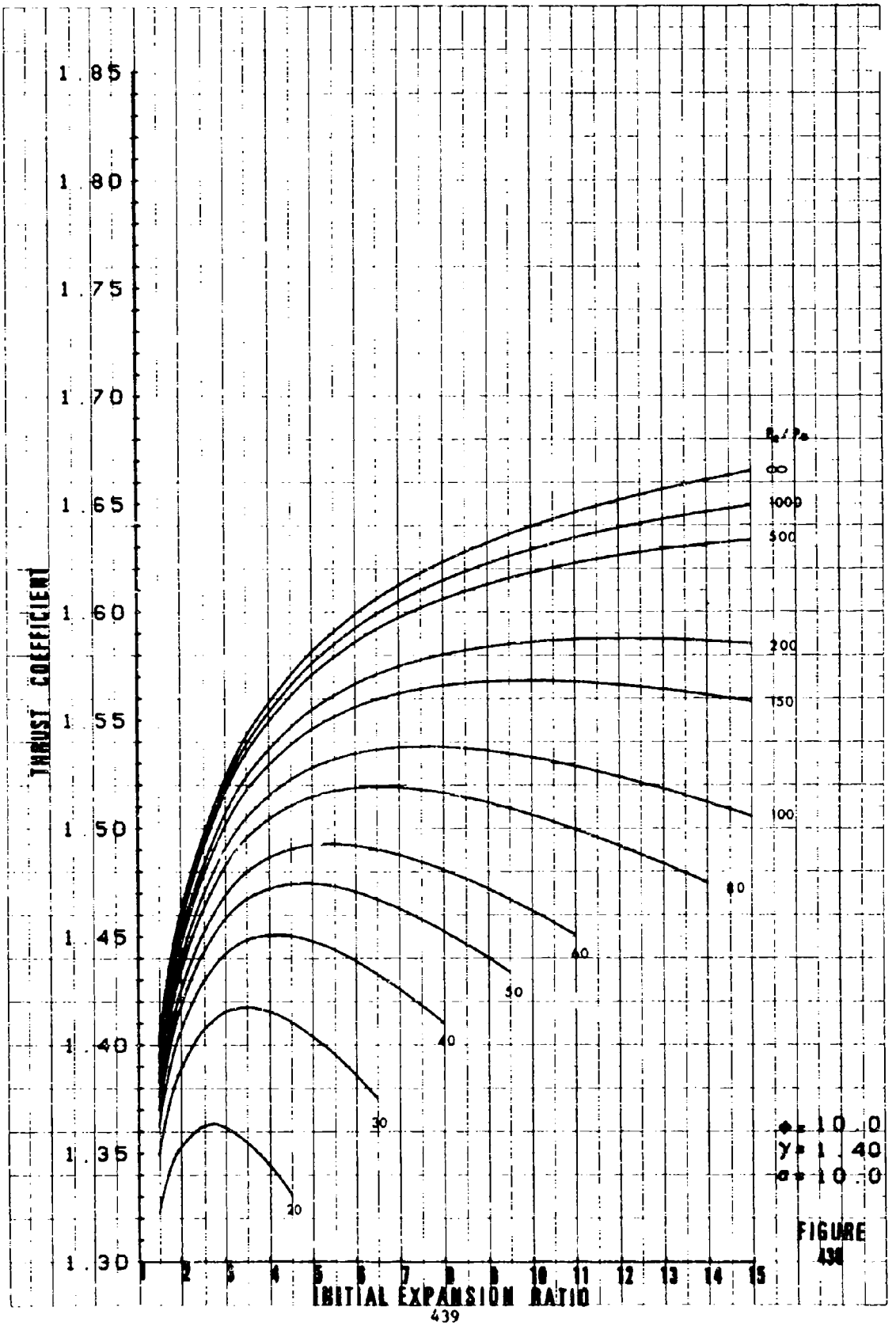

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40
α = 10.0

FIGURE 436

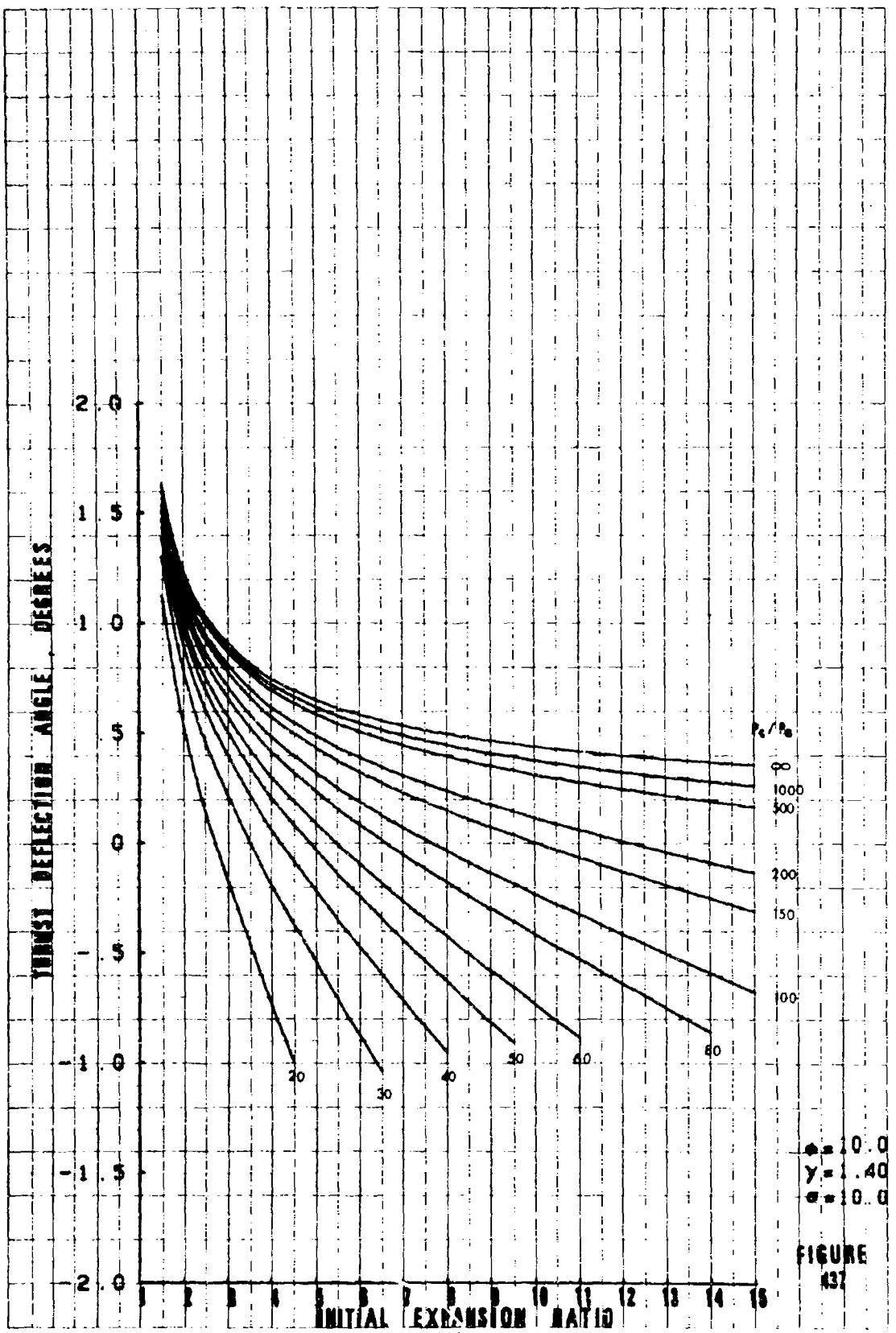

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ = 10.0
γ = 1.40
σ = 10.0

FIGURE 137

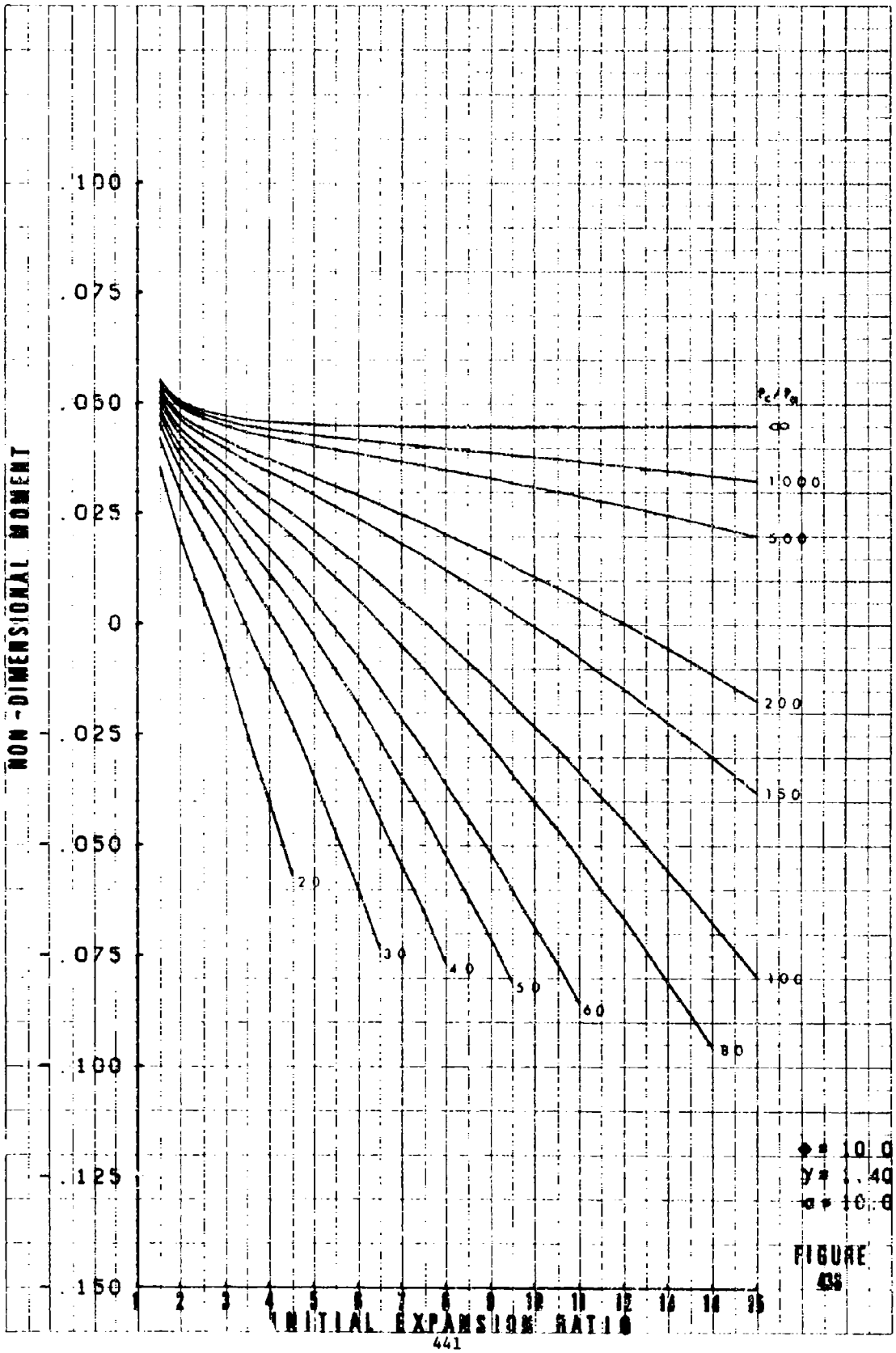

NON-DIMENSIONAL MOMENT
.100
.075
.050
.025
0
.025
.050
.075
.100
.125
.150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40

FIGURE 43

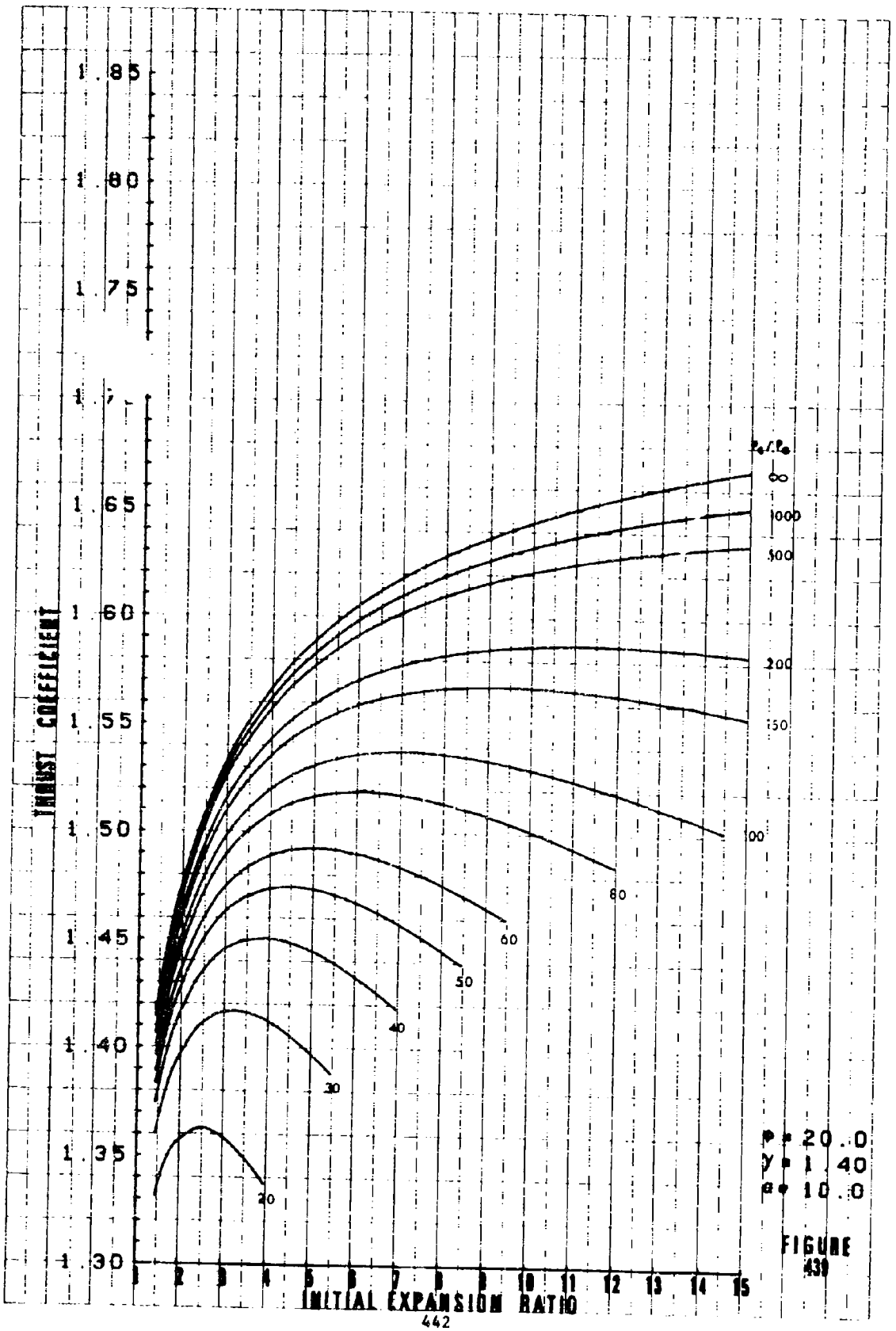

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
P = 20.0
γ = 1.40
ε = 10.0

FIGURE 439

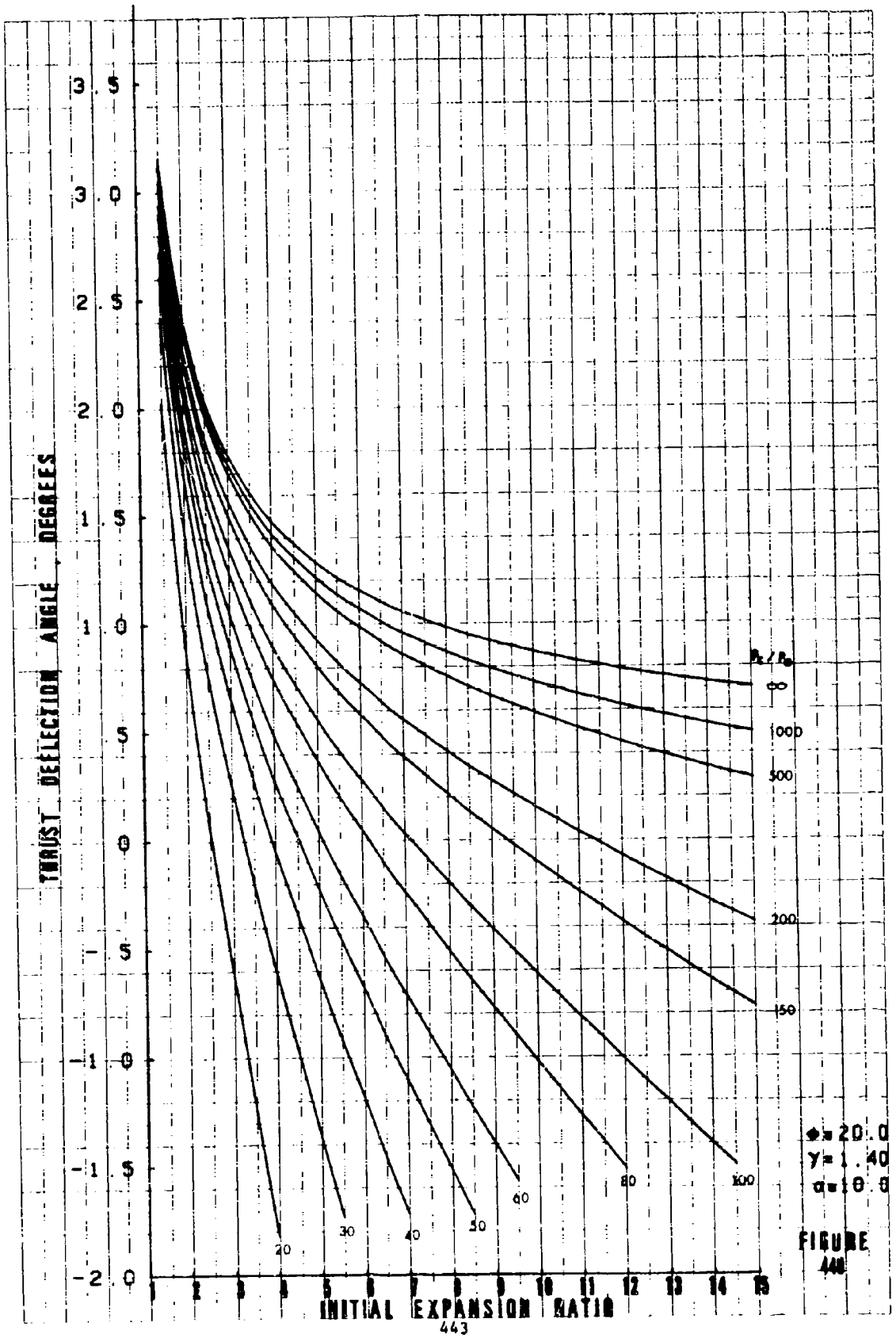

THRUST DEFLECTION ANGLE, DEGREES
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_t/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.40
α = 10.0

FIGURE 448

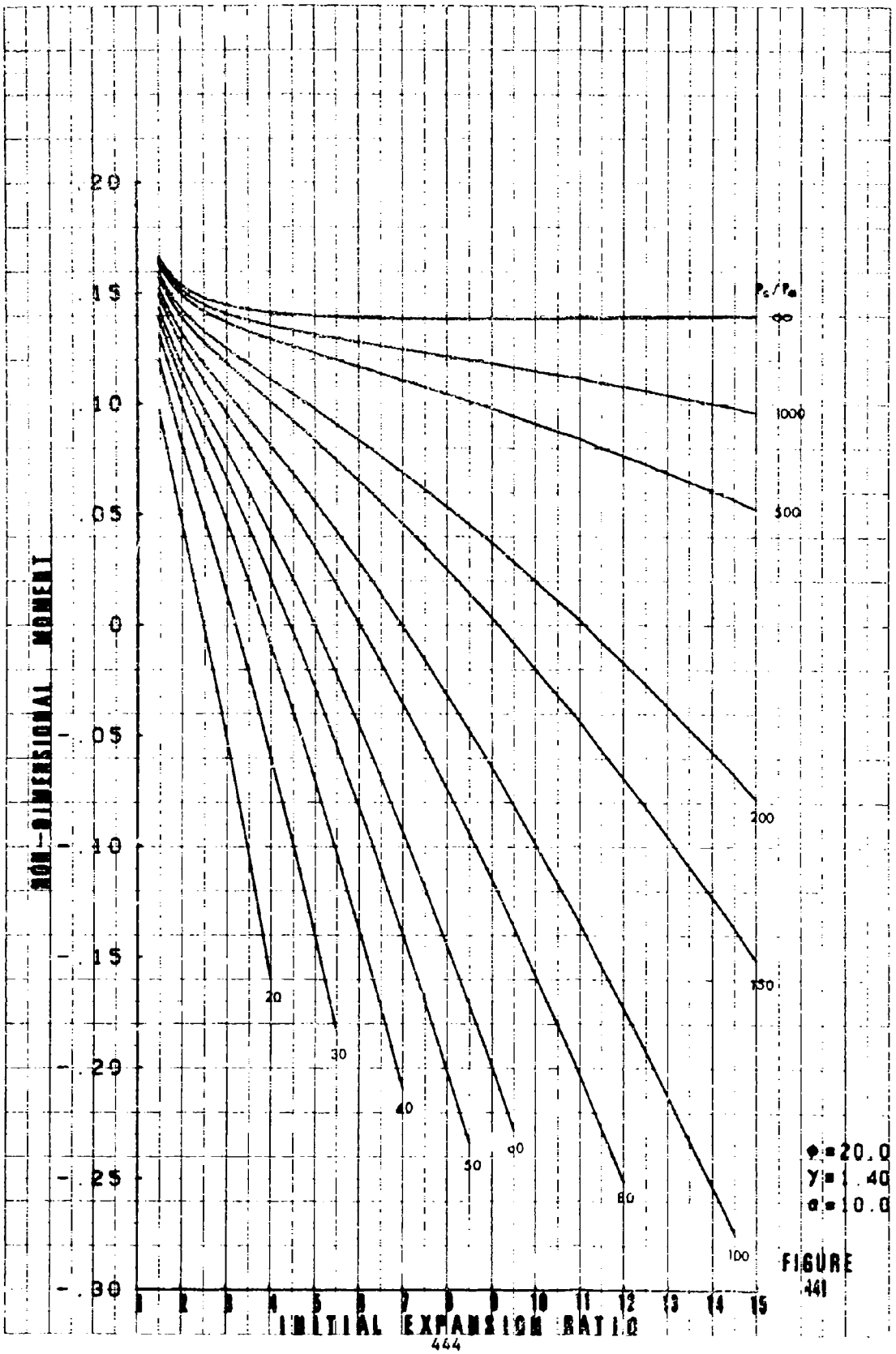

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.40
α = 10.0

FIGURE 441

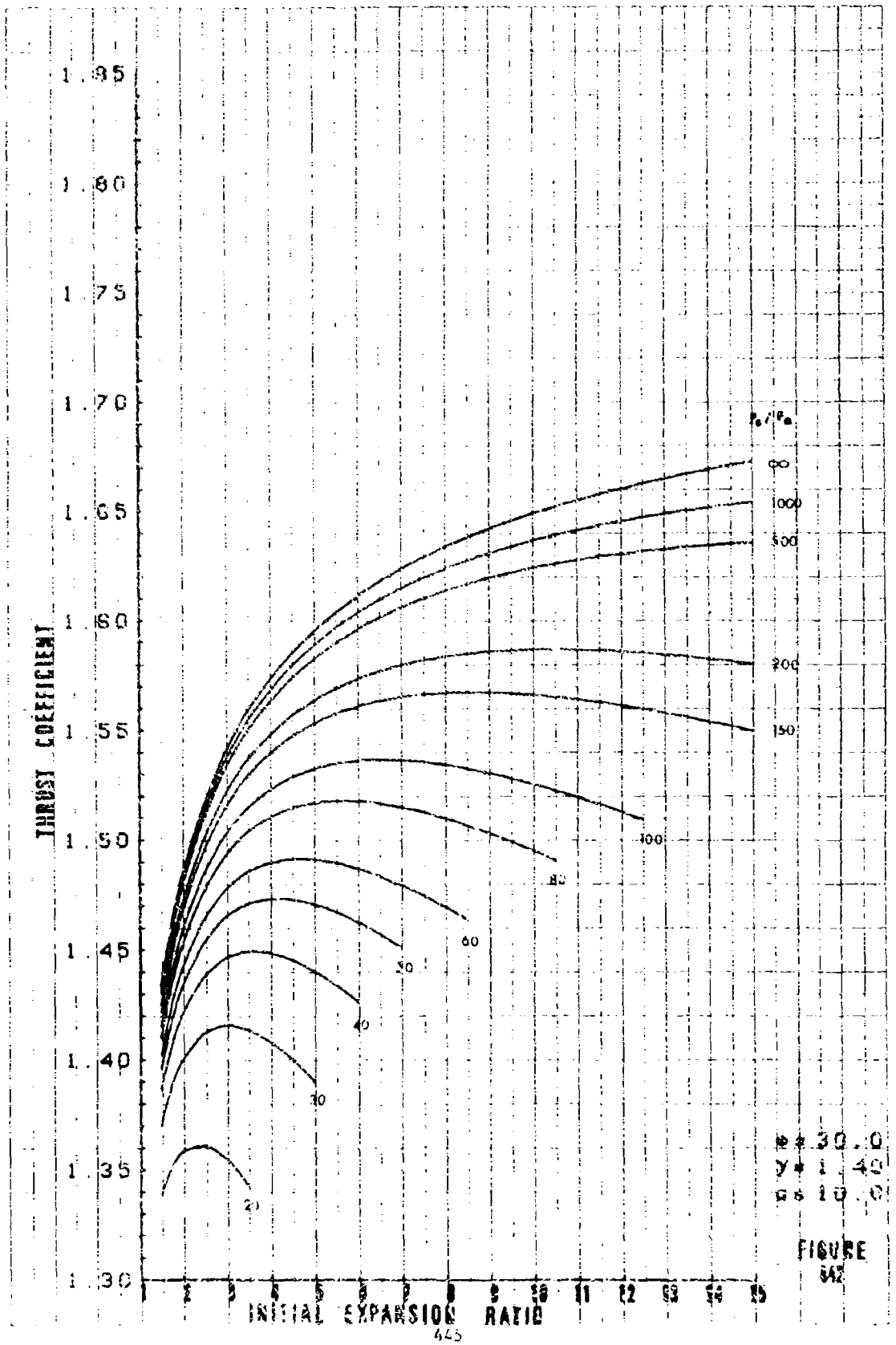

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
e = 30.0
γ = 1.40
α = 10.0

FIGURE 642

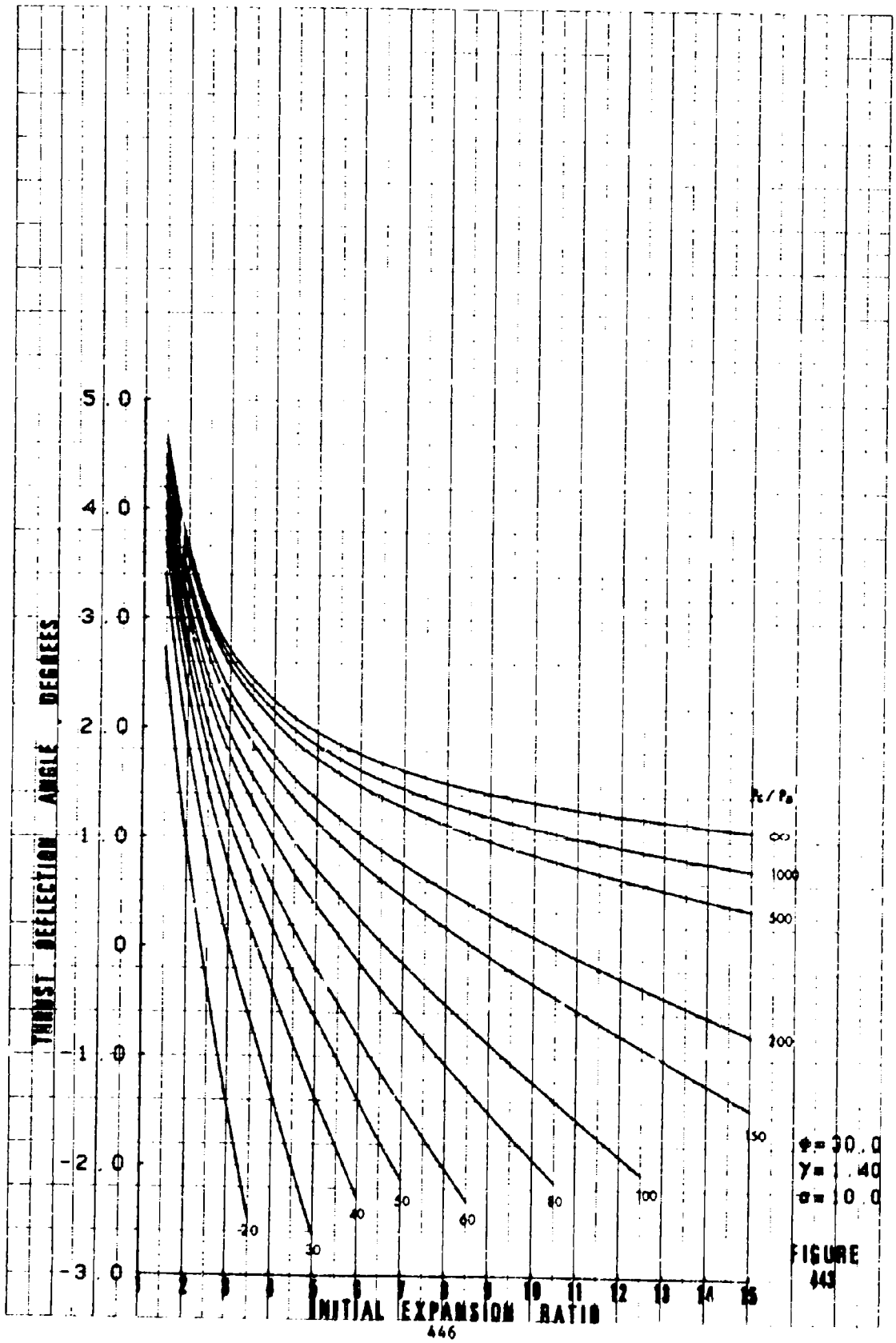

THRUST DEFLECTION ANGLE, DEGREES
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.40
α= 10.0

FIGURE 443

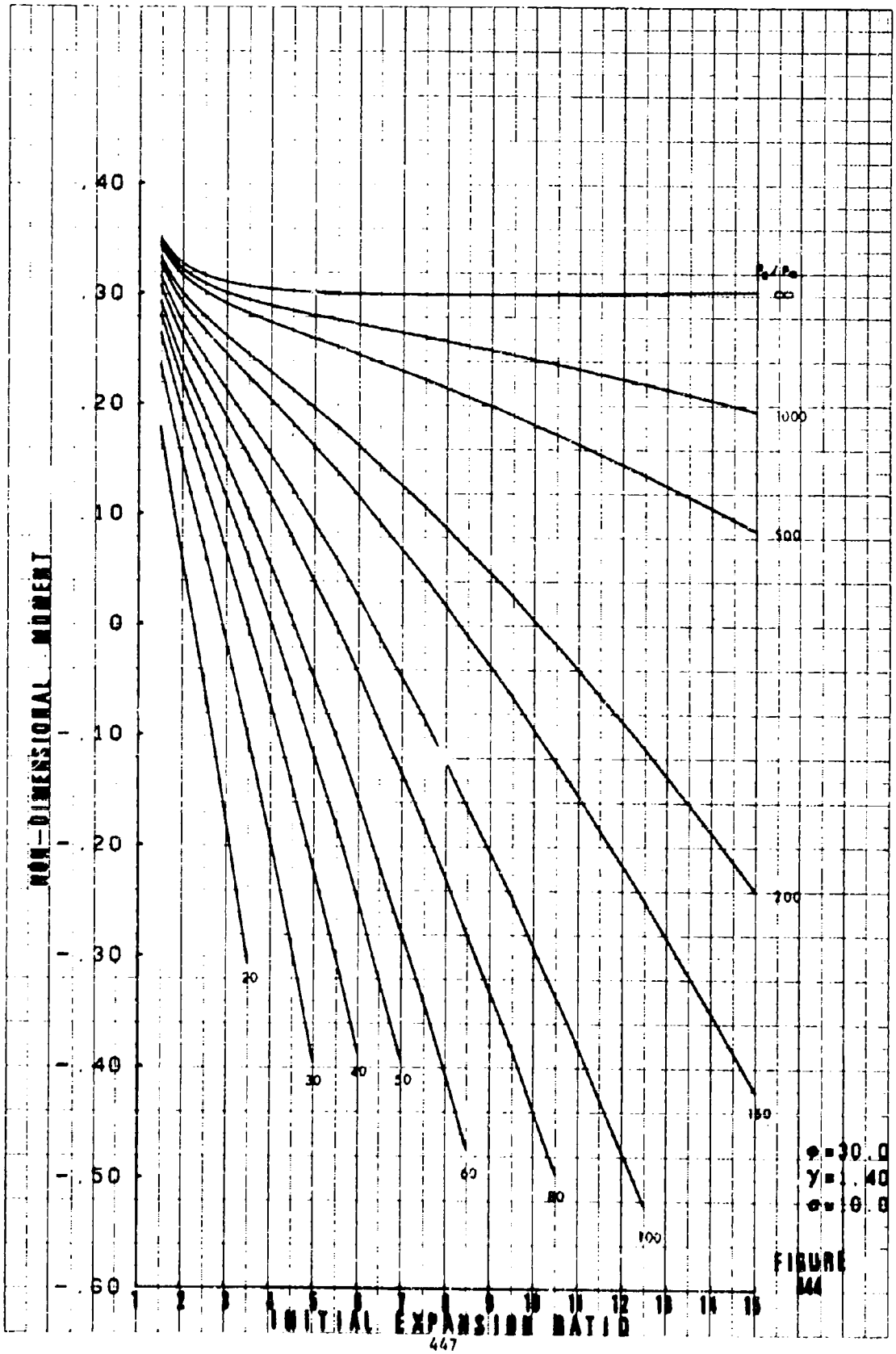

NON-DIMENSIONAL MOMENT
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_a/P_o
∞
1000
500
200
150
100
80
60
50
40
30
20
φ=30.0
γ=1.40
σ=0.0

FIGURE 44

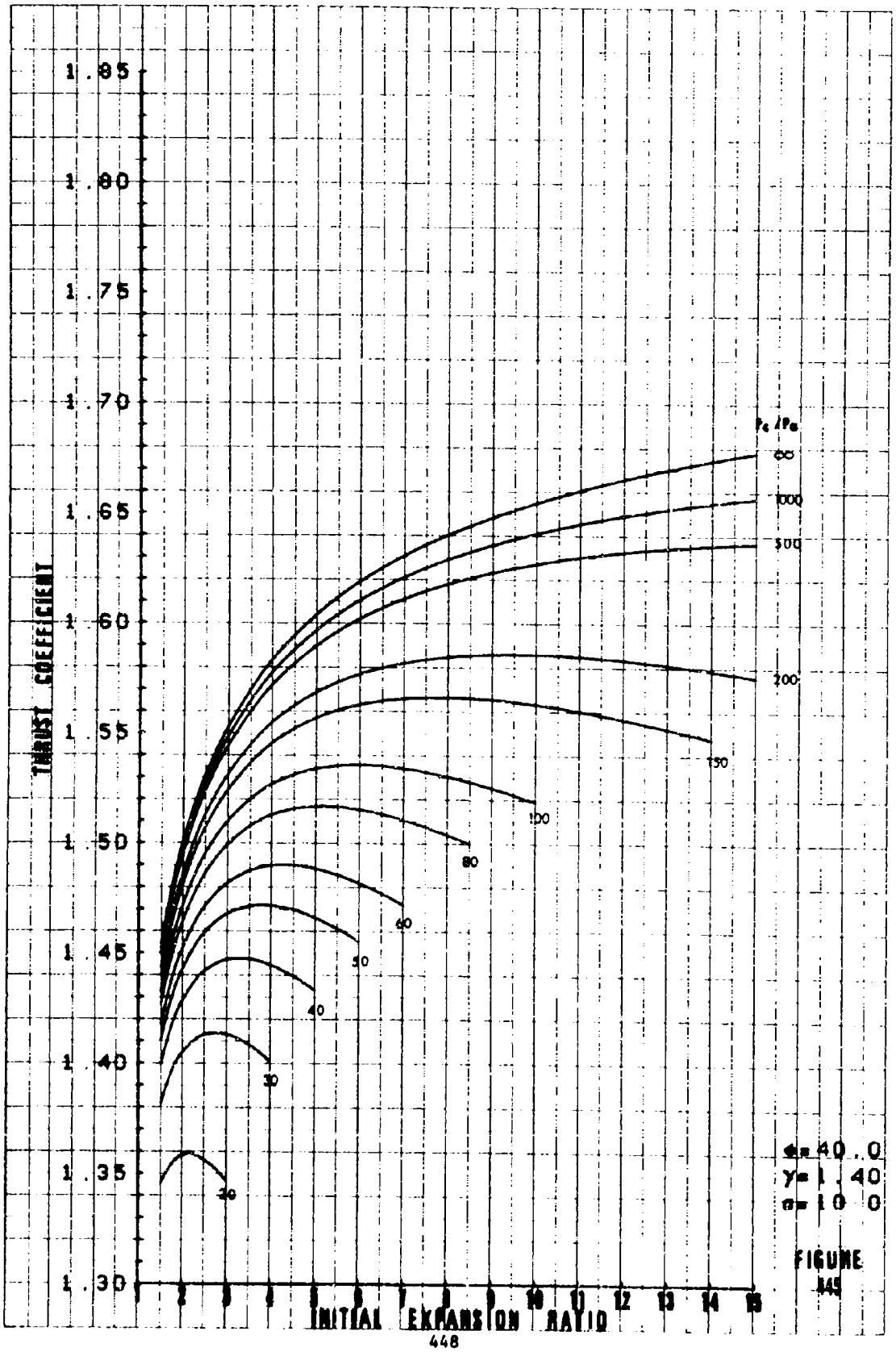

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
ϕ= 40.0
γ= 1.40
σ= 10.0

FIGURE 445

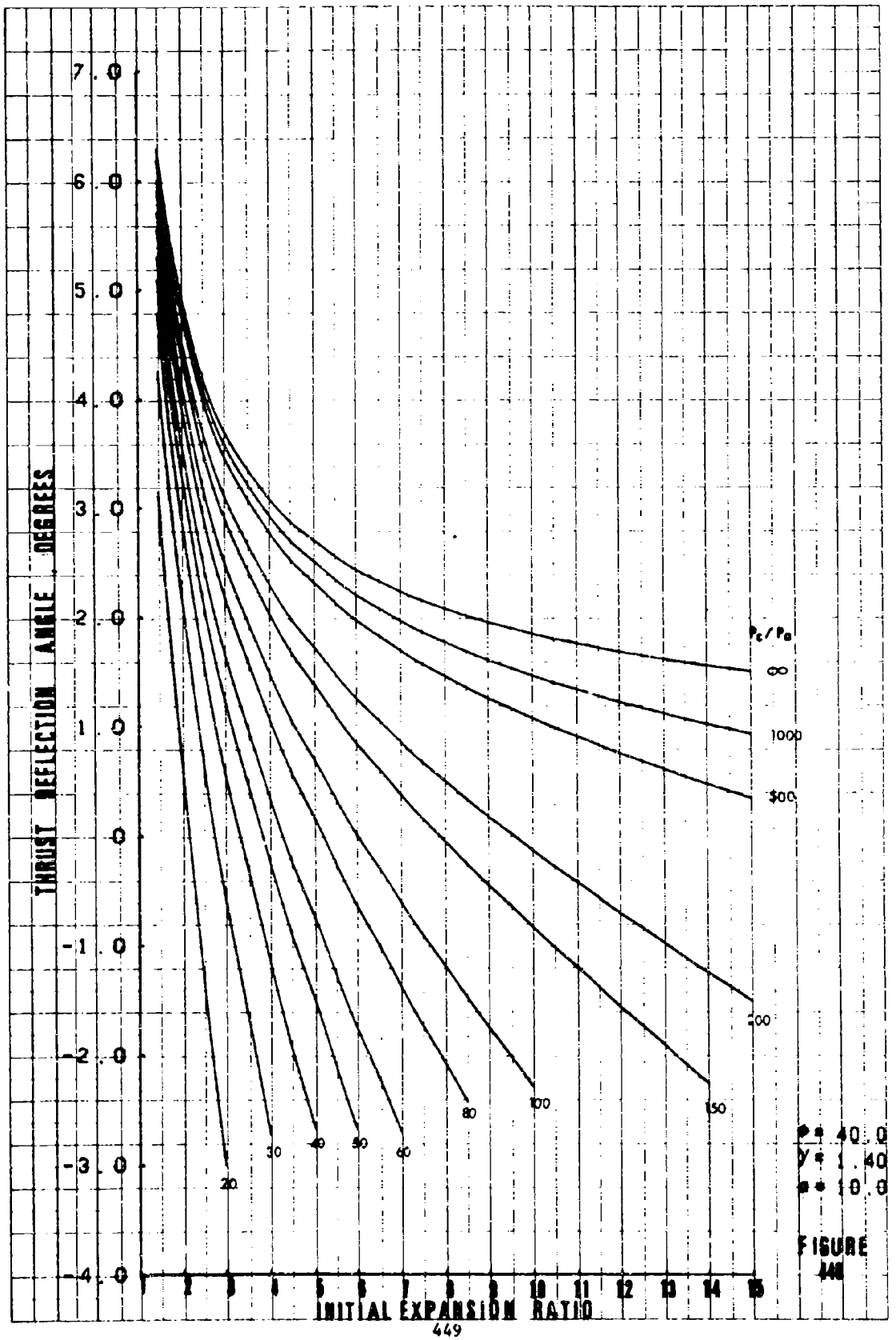

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40

FIGURE 448

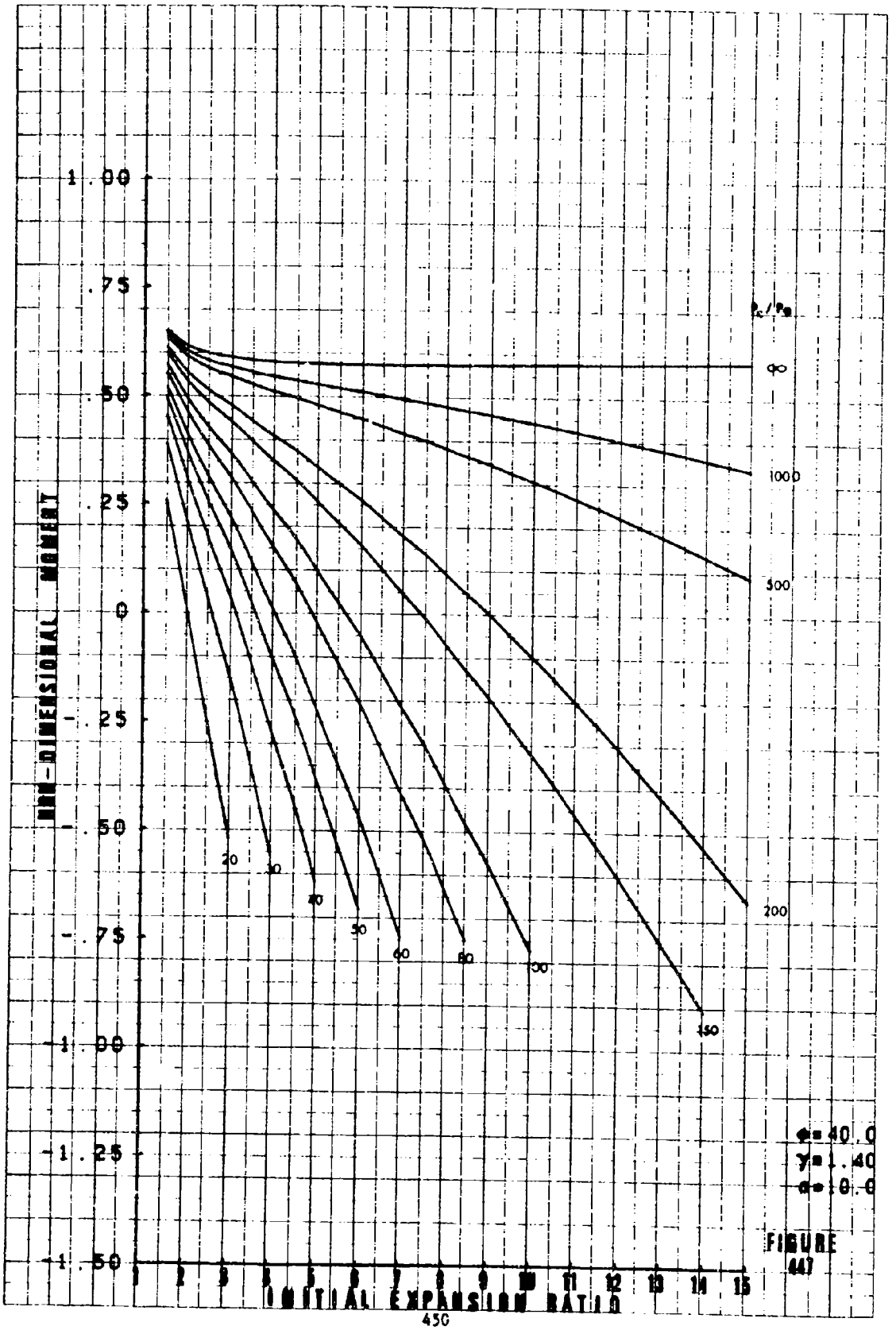

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
p_c/p_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 40.0
γ= 1.40
α= 0.0

FIGURE 447

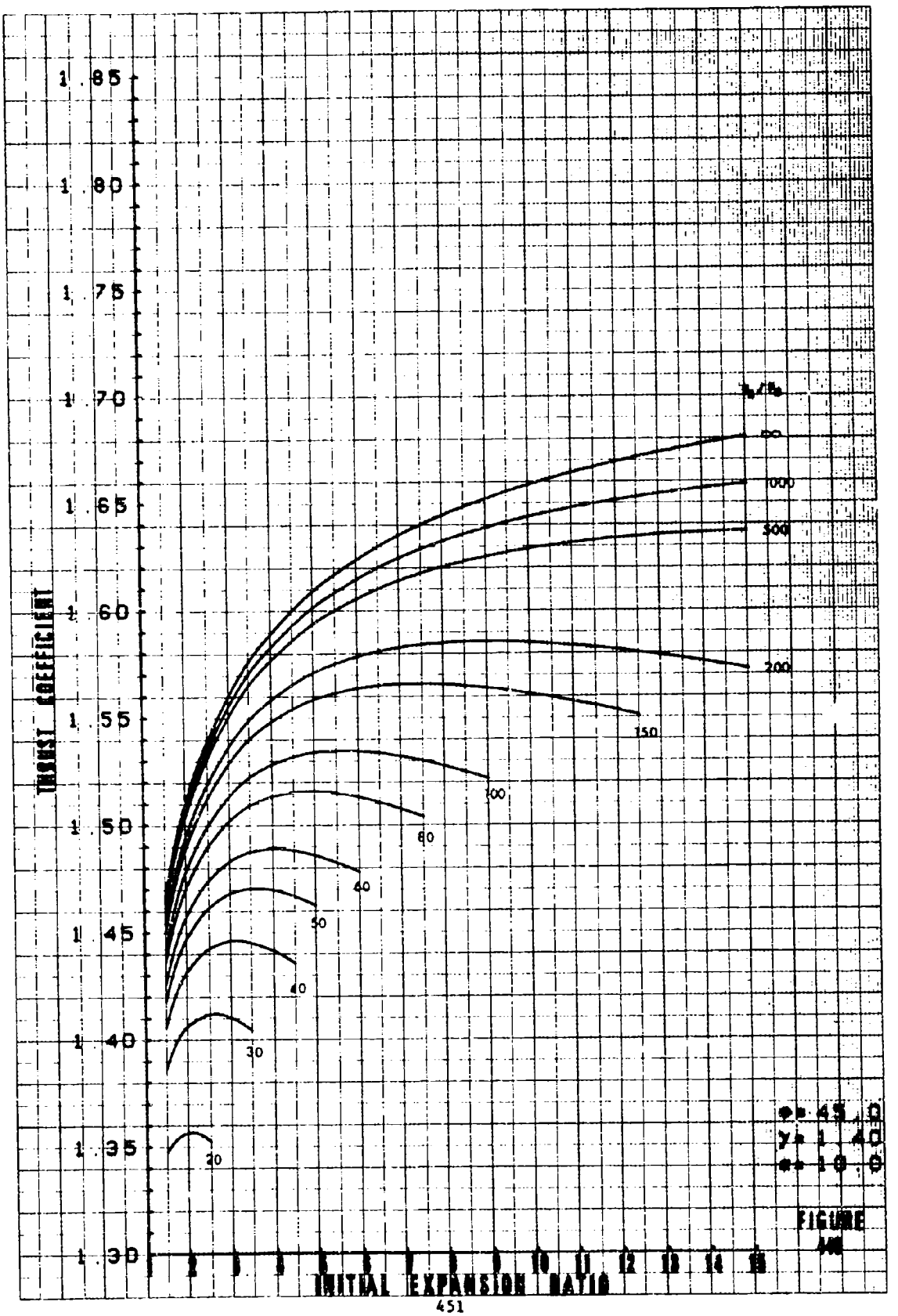

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 45.0
γ= 1.40
α= 10.0

FIGURE 4A

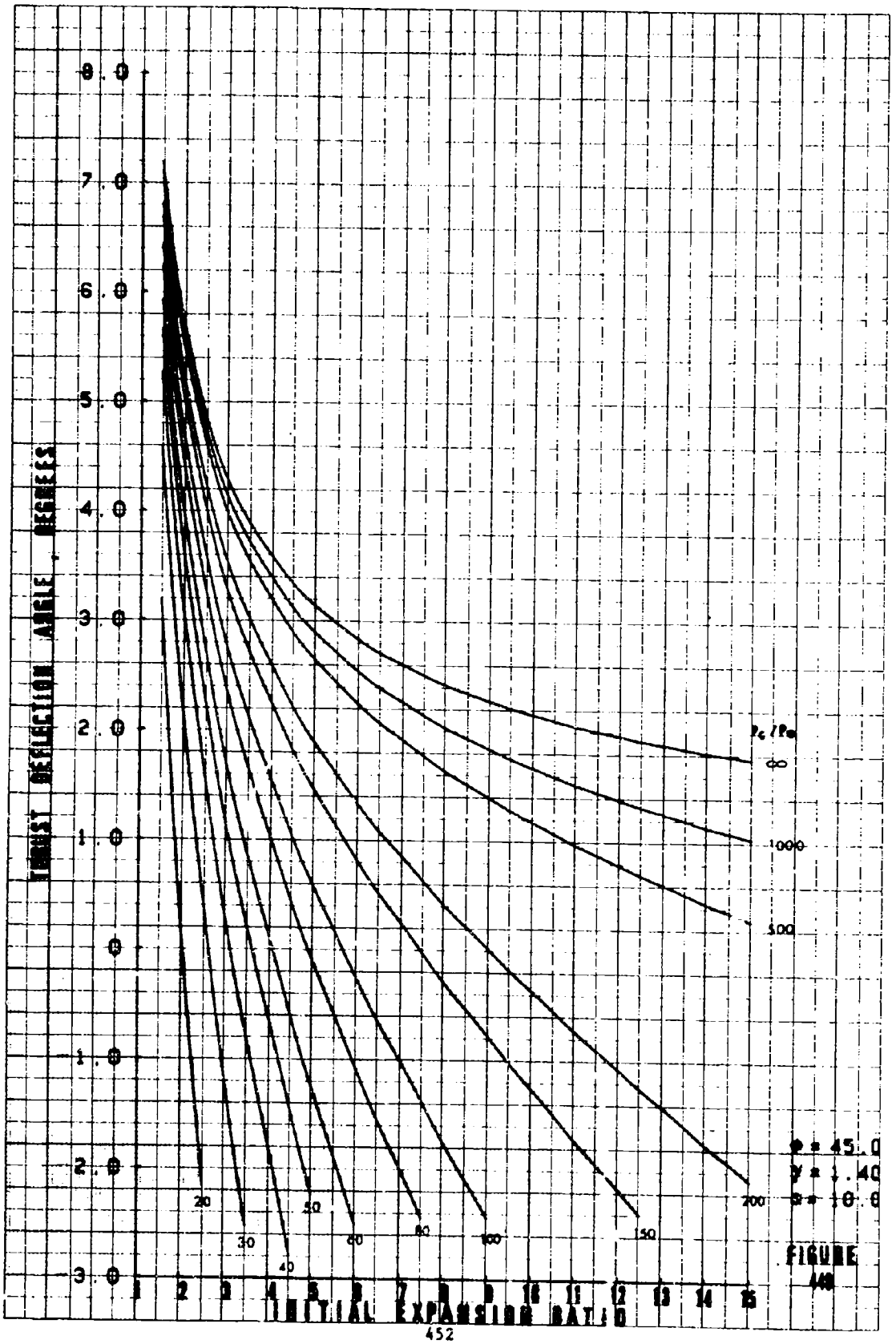

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 45.0
γ = 1.40
θ = 10.0

FIGURE 440

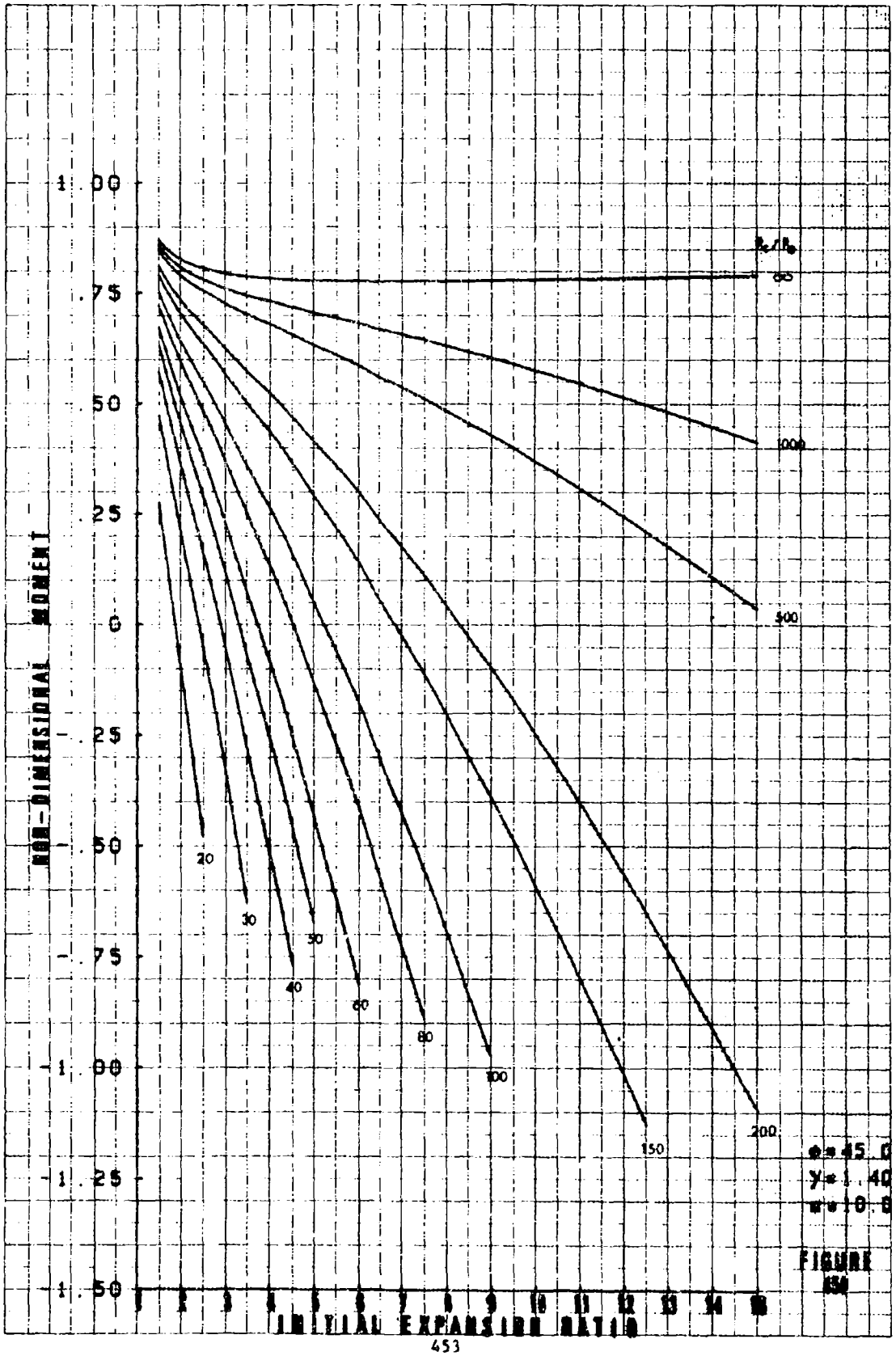

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
500
1000
∞
φ=45.0
γ=1.40
w=10.0

FIGURE 150

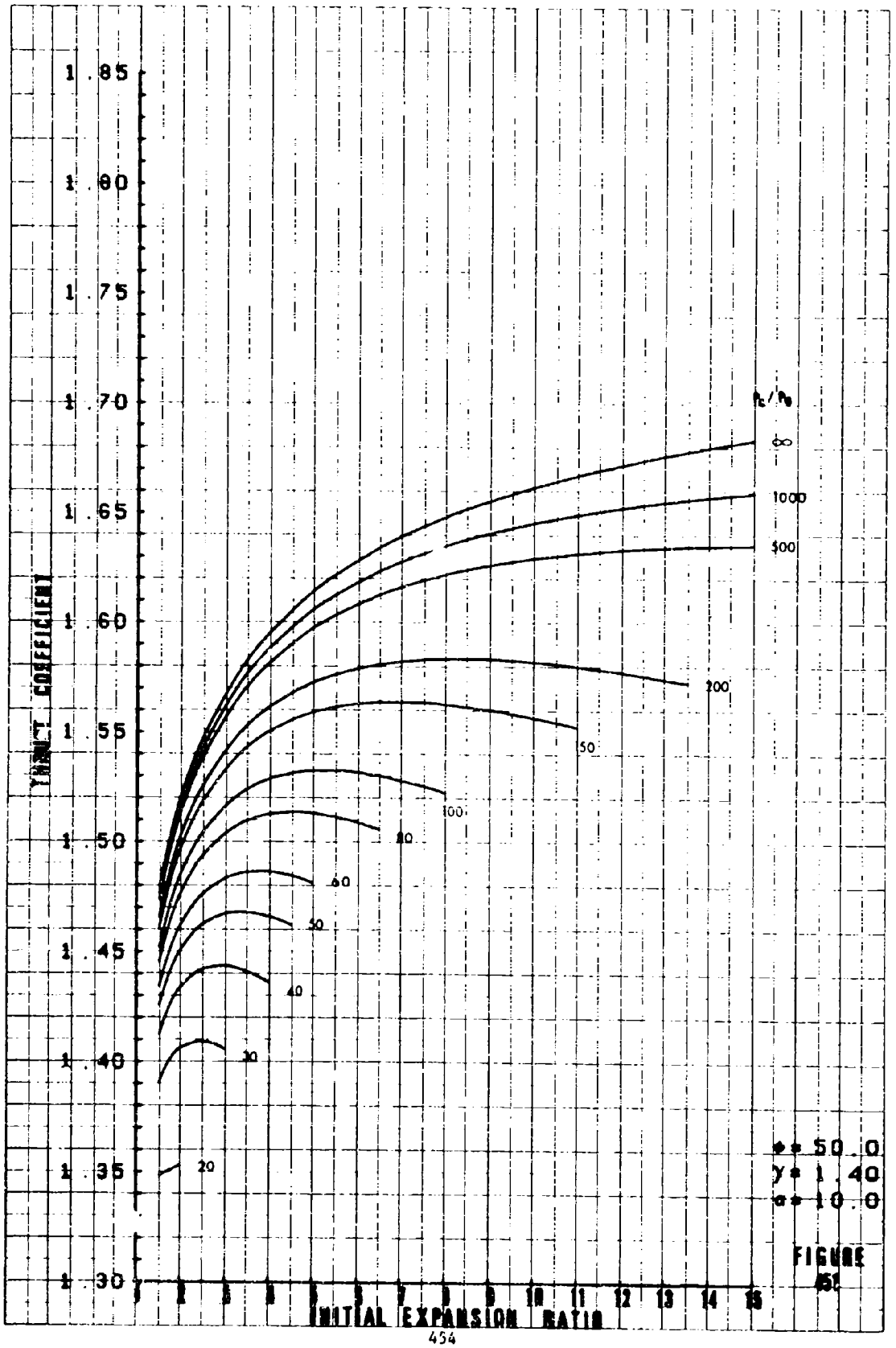

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_L/P_0
∞
1000
500
200
50
100
80
60
50
40
30
20
φ = 50.0
γ = 1.40
σ = 10.0

FIGURE 45

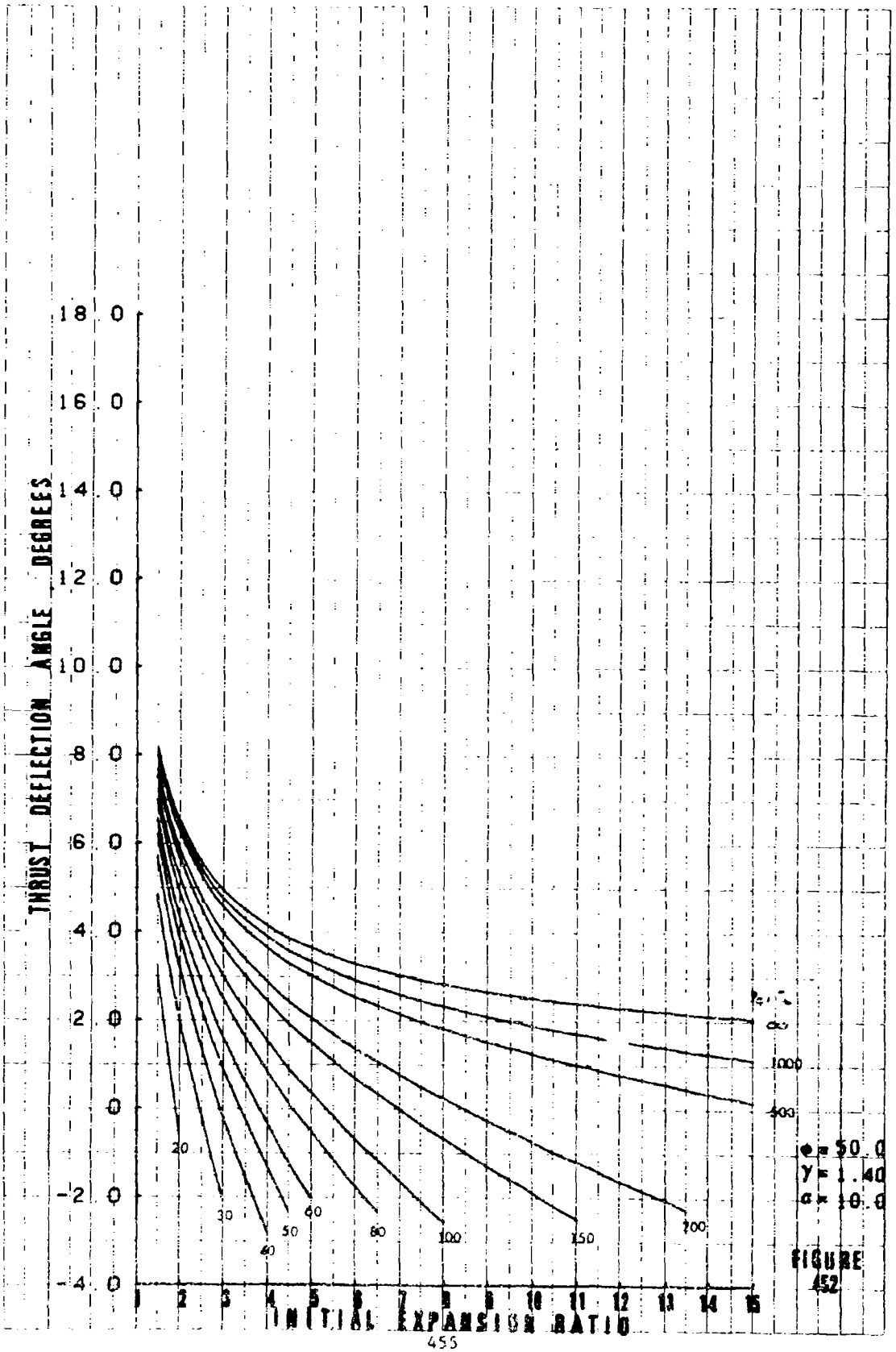

THRUST DEFLECTION ANGLE DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞
φ = 50.0
γ = 1.40
α = 10.0

FIGURE 452

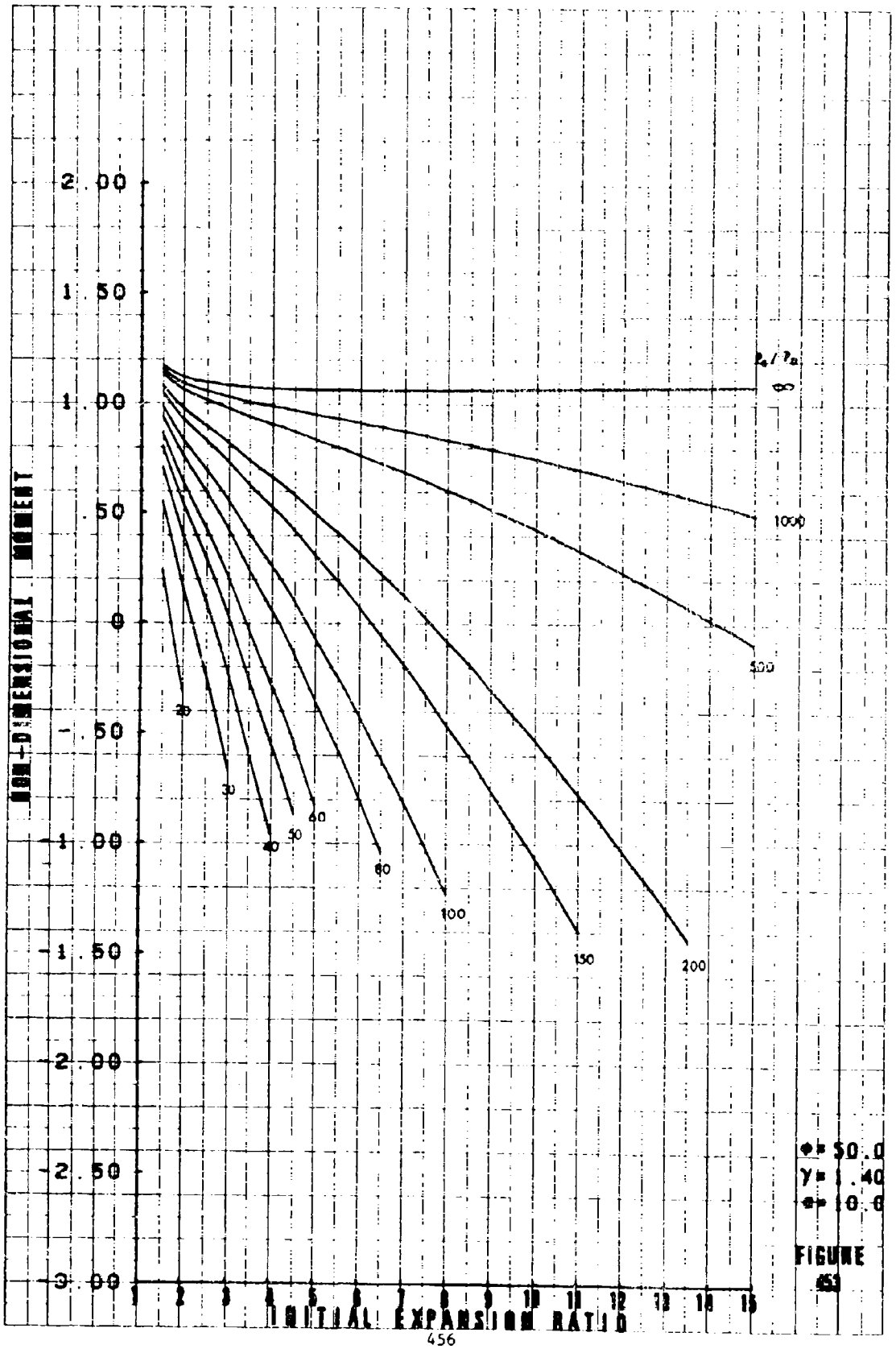

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_4/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
φ= 50.0
γ= 1.40
ε= 0.6

FIGURE 453

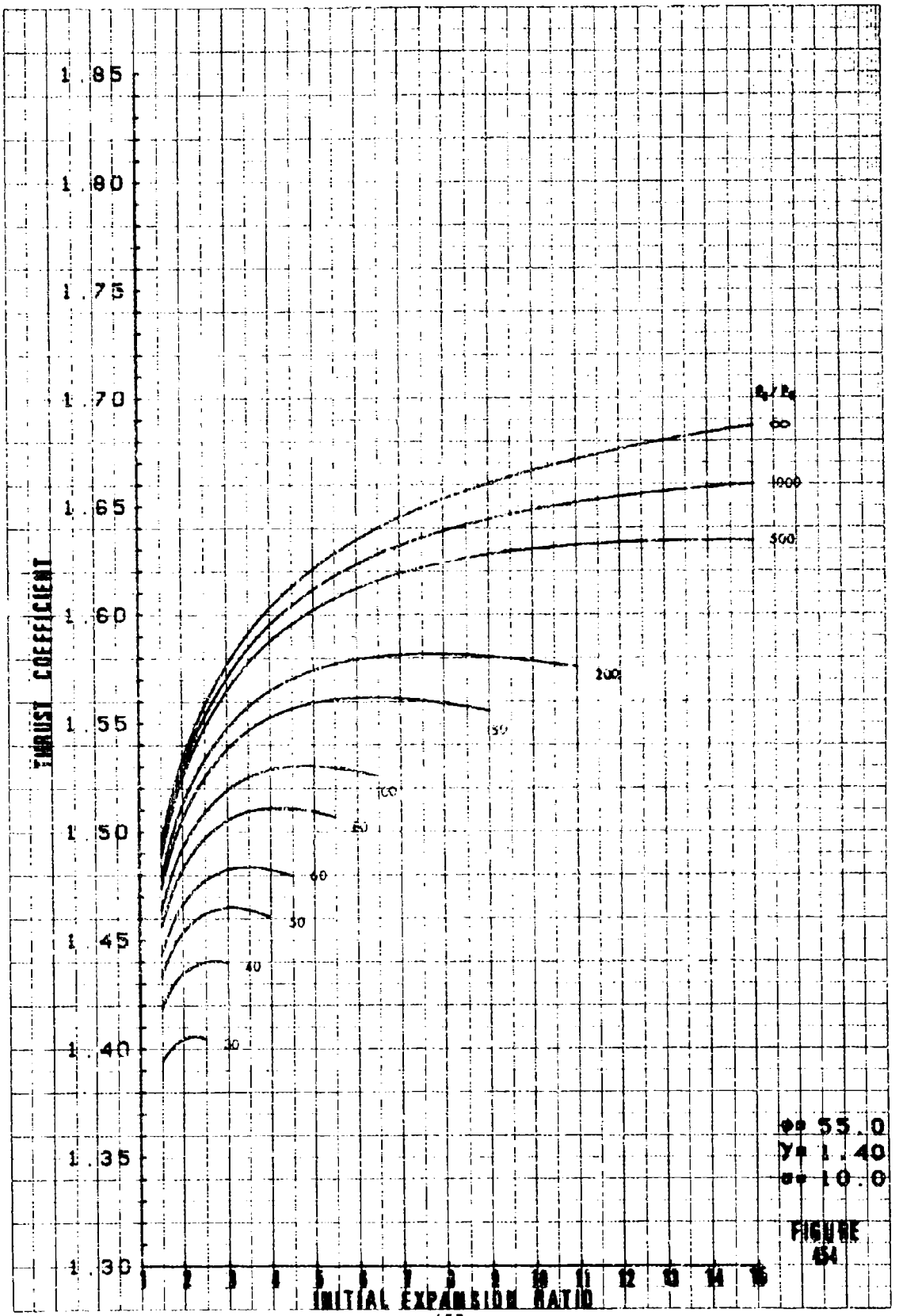

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
∞
1000
500
200
150
100
80
60
50
40
30
φ= 55.0
γ= 1.40
σ= 10.0

FIGURE 454

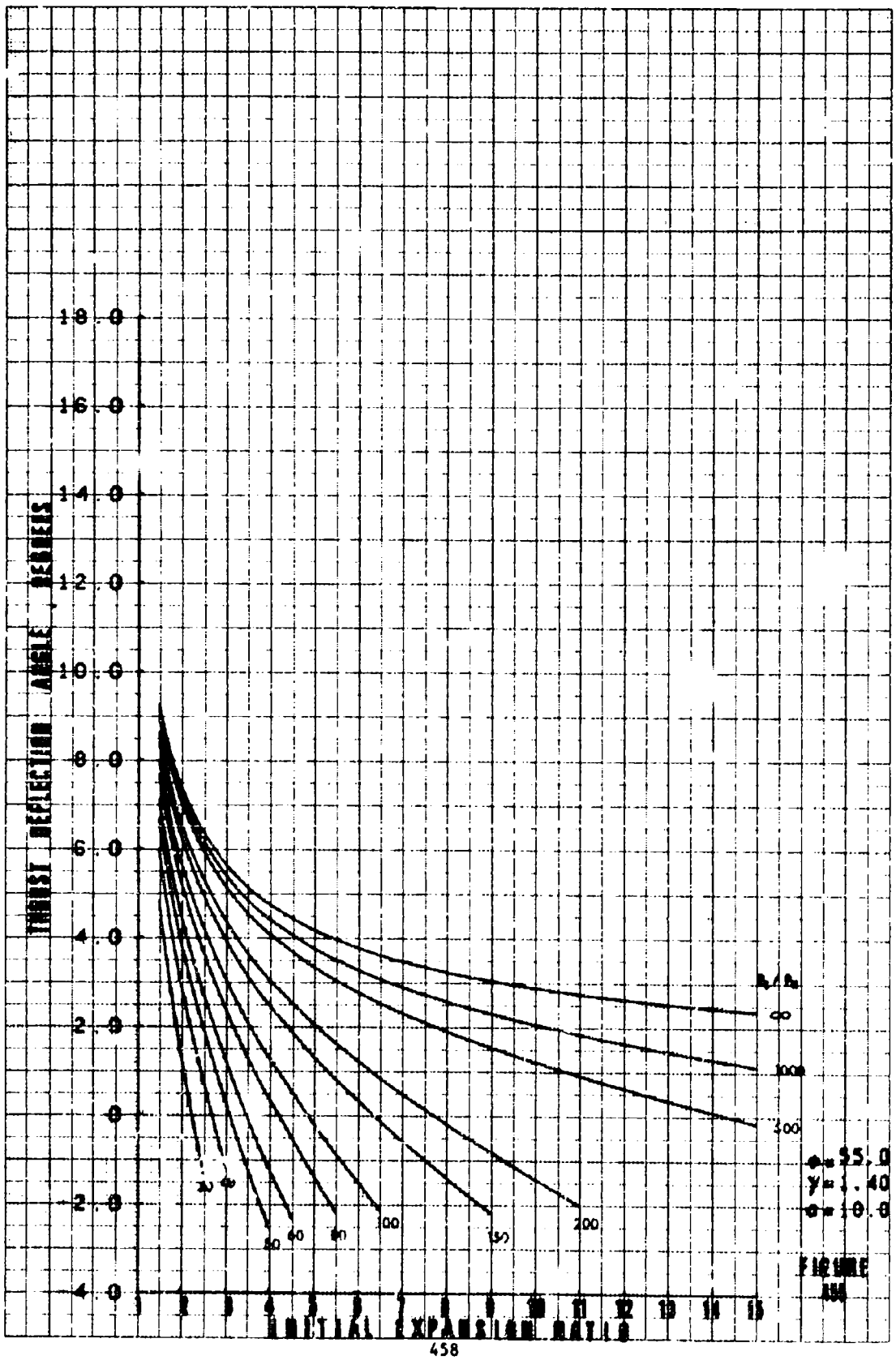
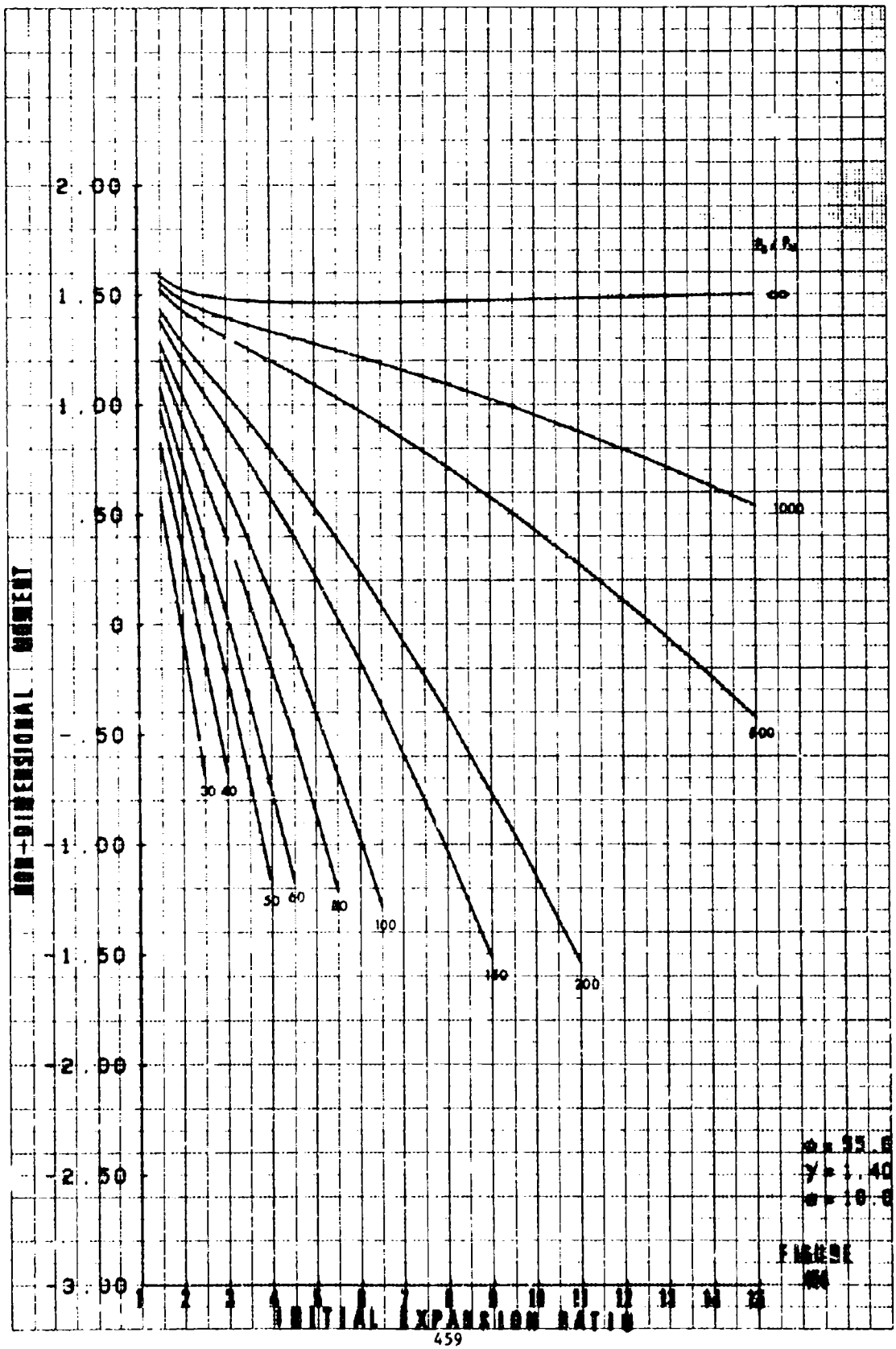
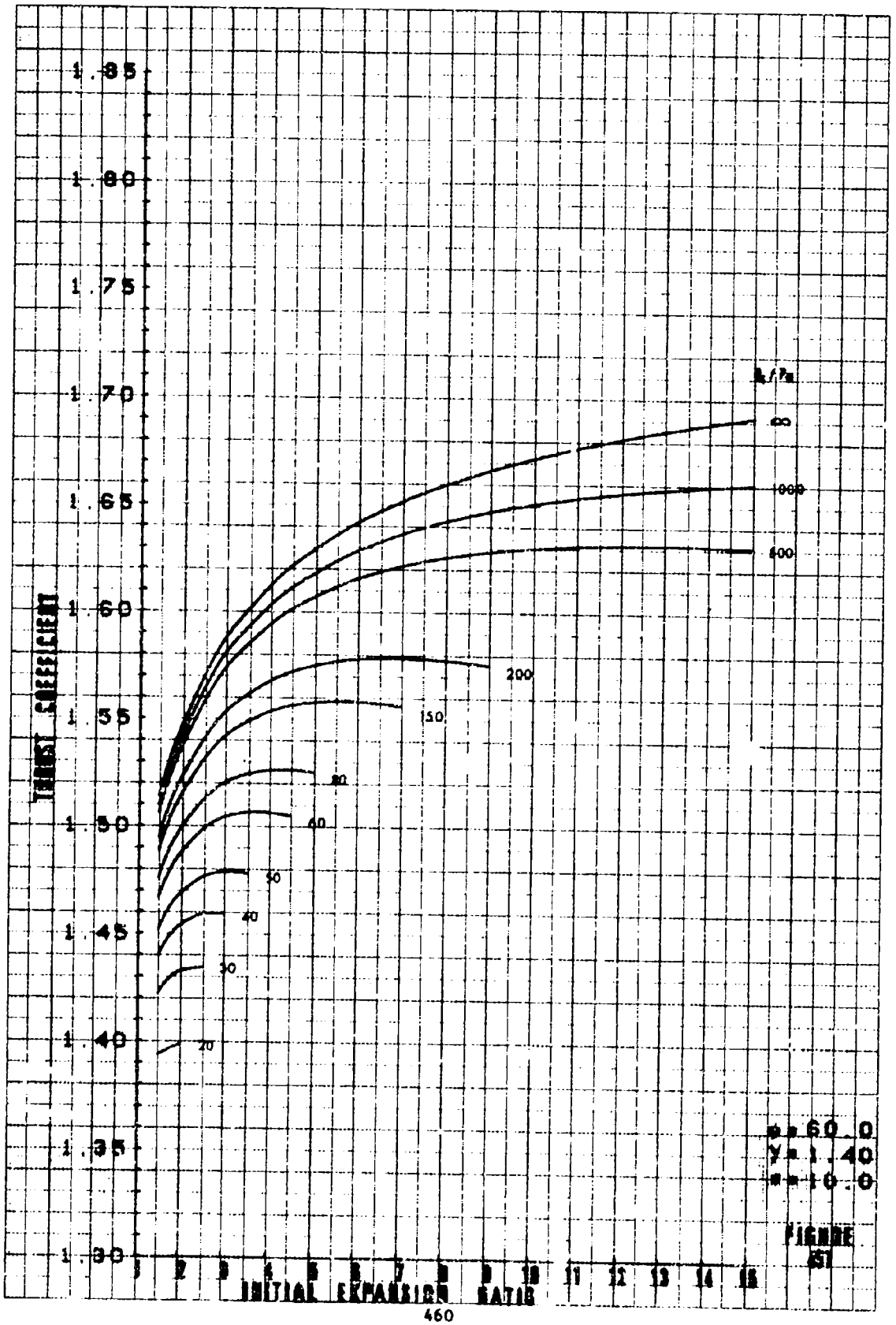
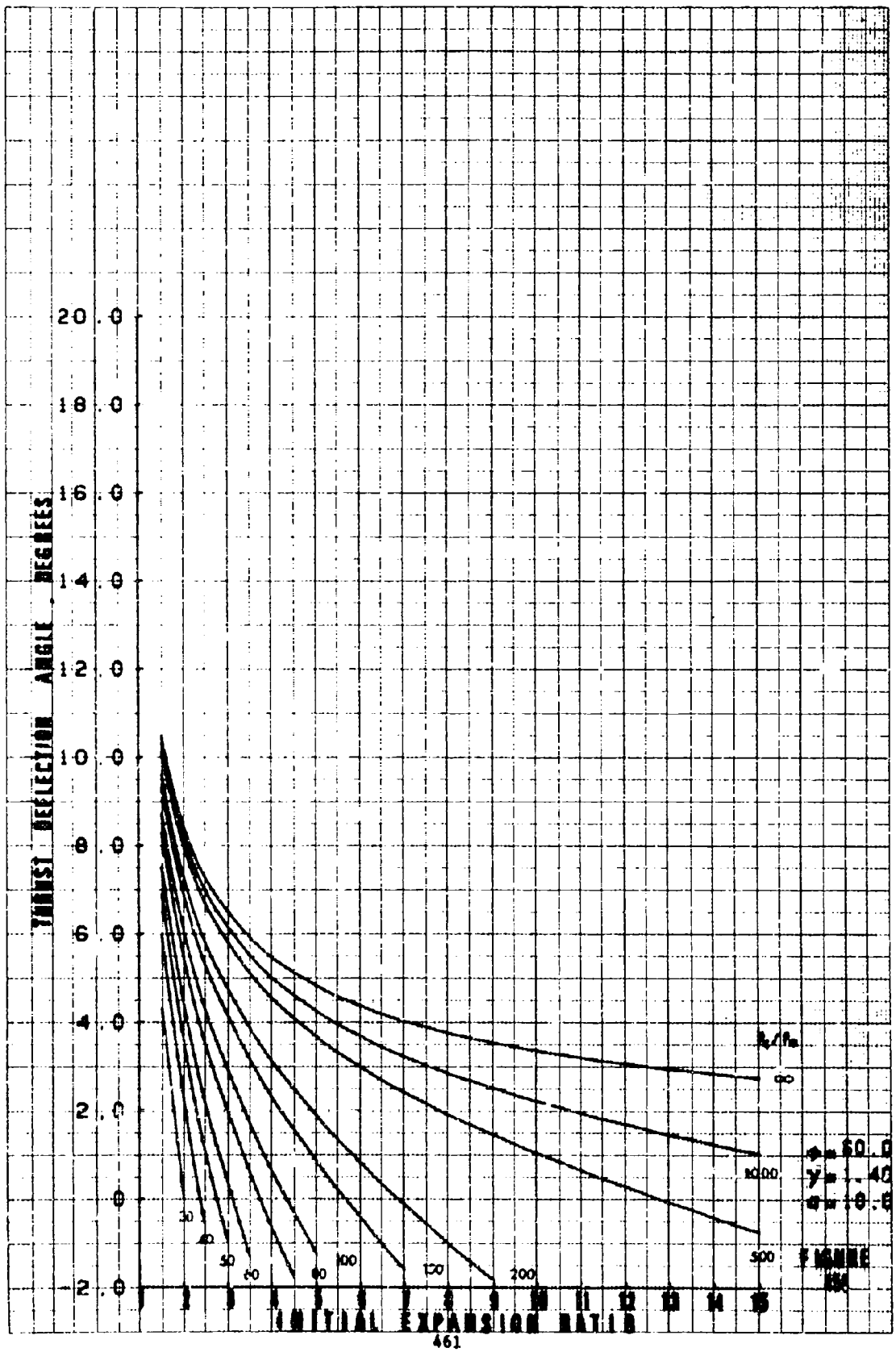

THRUST DEFLECTION ANGLE, DEGREES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
100
60
50
φ = 55.0
γ = 1.40
σ = 10.0

FIGURE 458

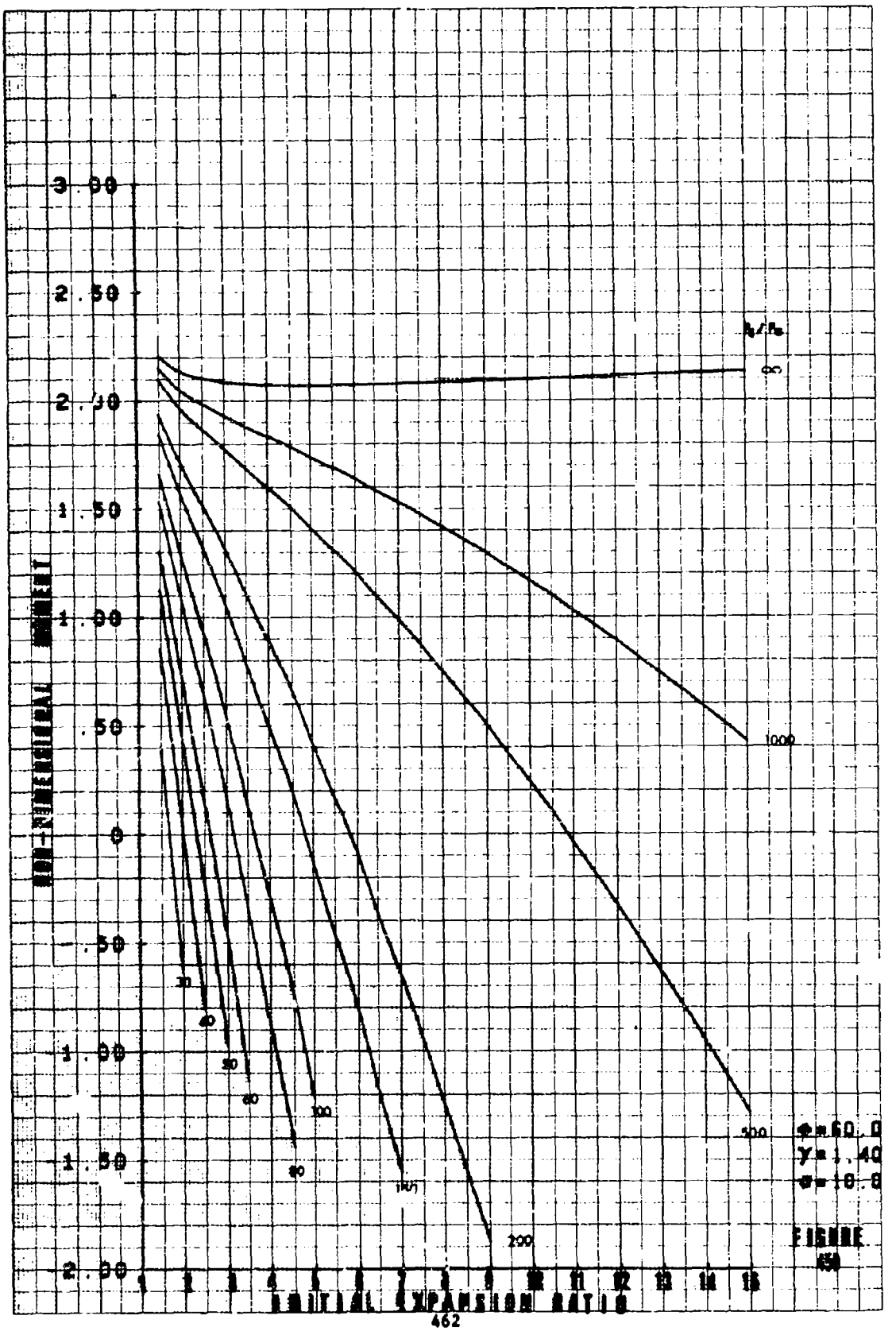

NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
600
200
100
80
60
50
40
30

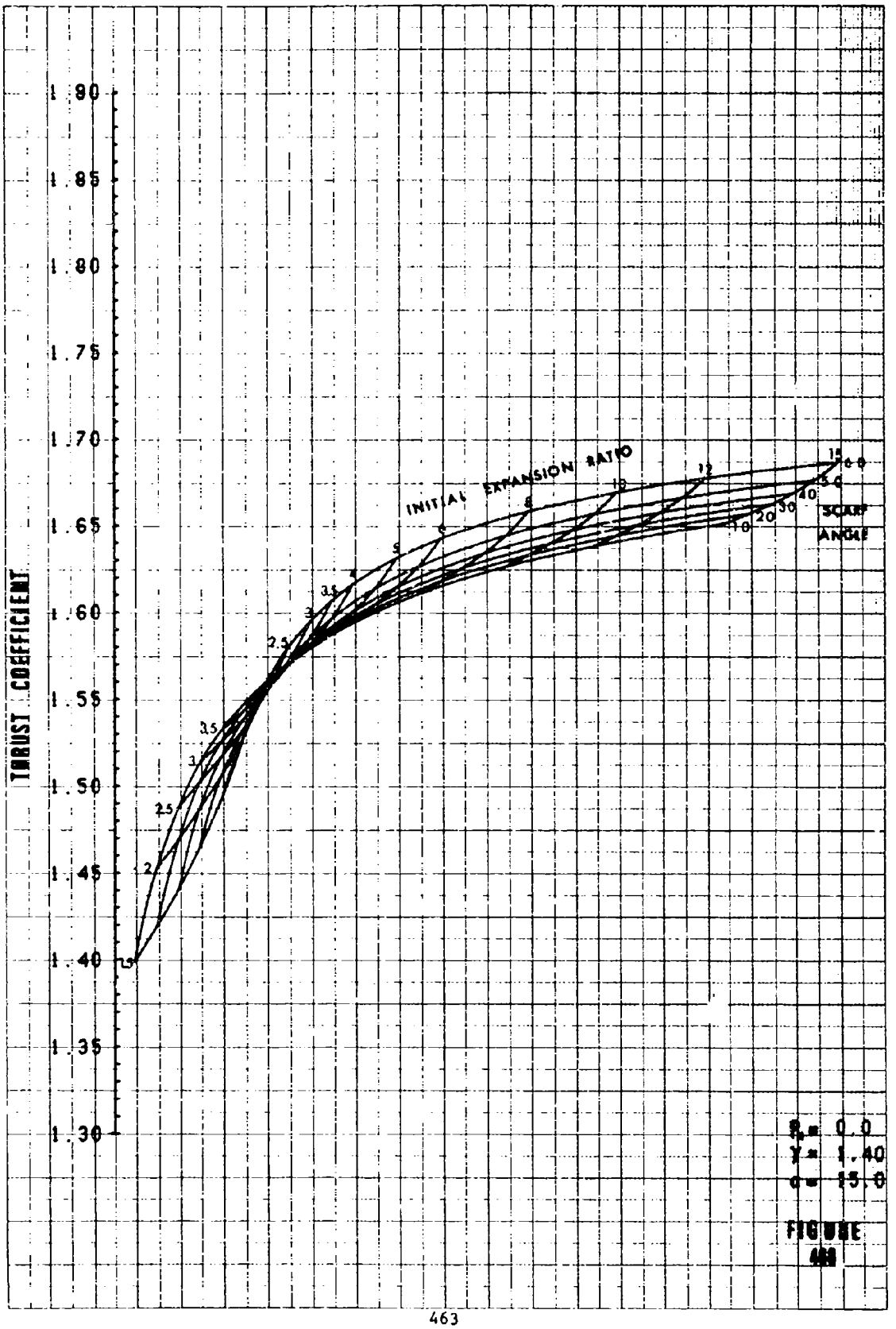


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
600
200
150
80
60
50
40
30
20
φ = 60.0
γ = 1.40
n = 10.0
FIGURE
457


THRUST DEFLECTION ANGLE, DEGREES
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
500
1000
∞
φ = 60.0
γ = 1.40
α = 10.0

FIGURE


3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
NON-DIMENSIONAL MOMENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
100
80
60
50
40
30
φ=60.0
γ=1.40
σ=10.0
FIGURE
450



THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
P_1 = 0.0
γ = 1.40
α = 15.0

FIGURE 4[illegible]

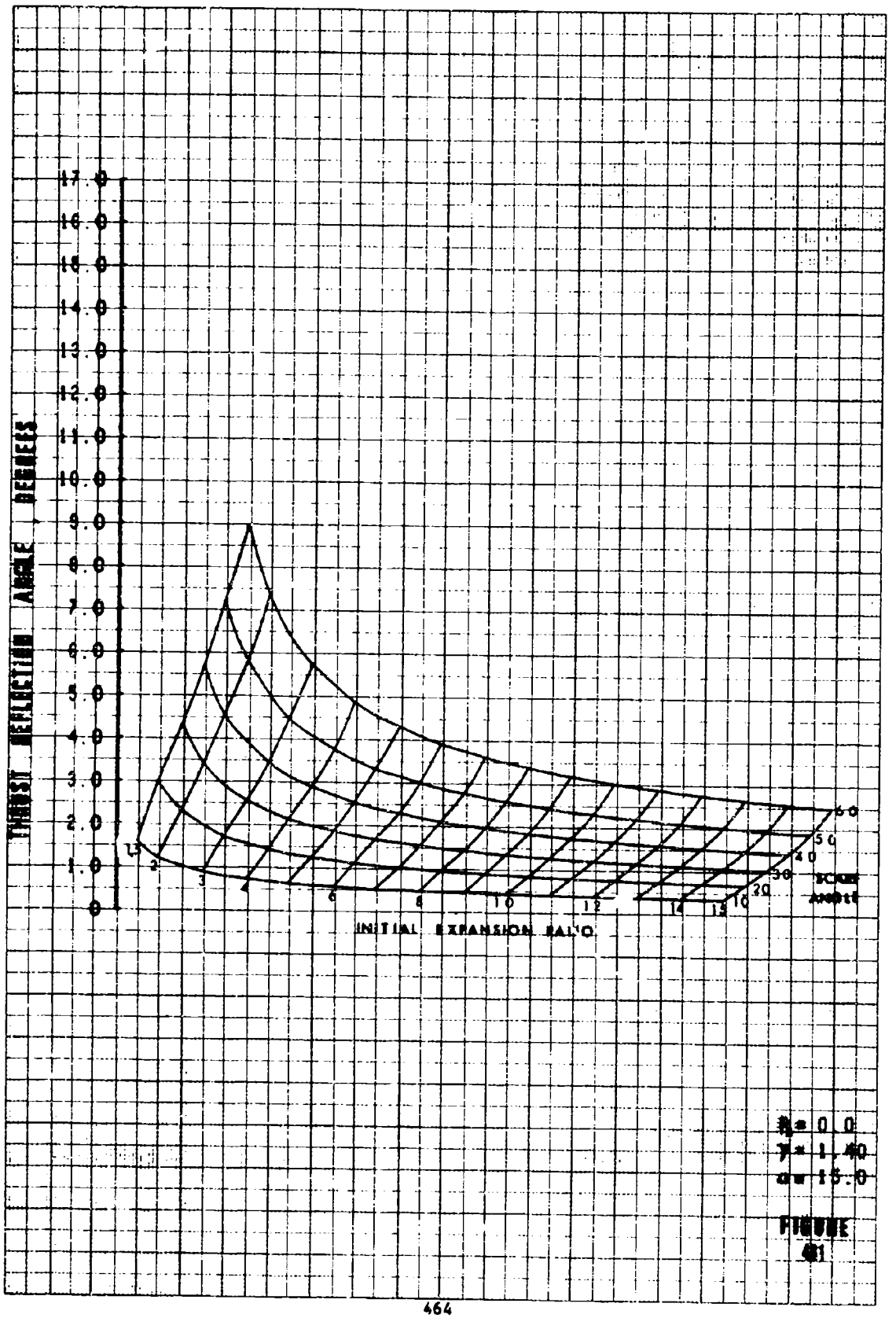

THRUST DEFLECTION ANGLE DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
1.5
2
3
4
6
8
10
12
14
15
10
20
30
40
50
60
INITIAL EXPANSION RATIO
γ = 1.40
α = 15.0

FIGURE 41

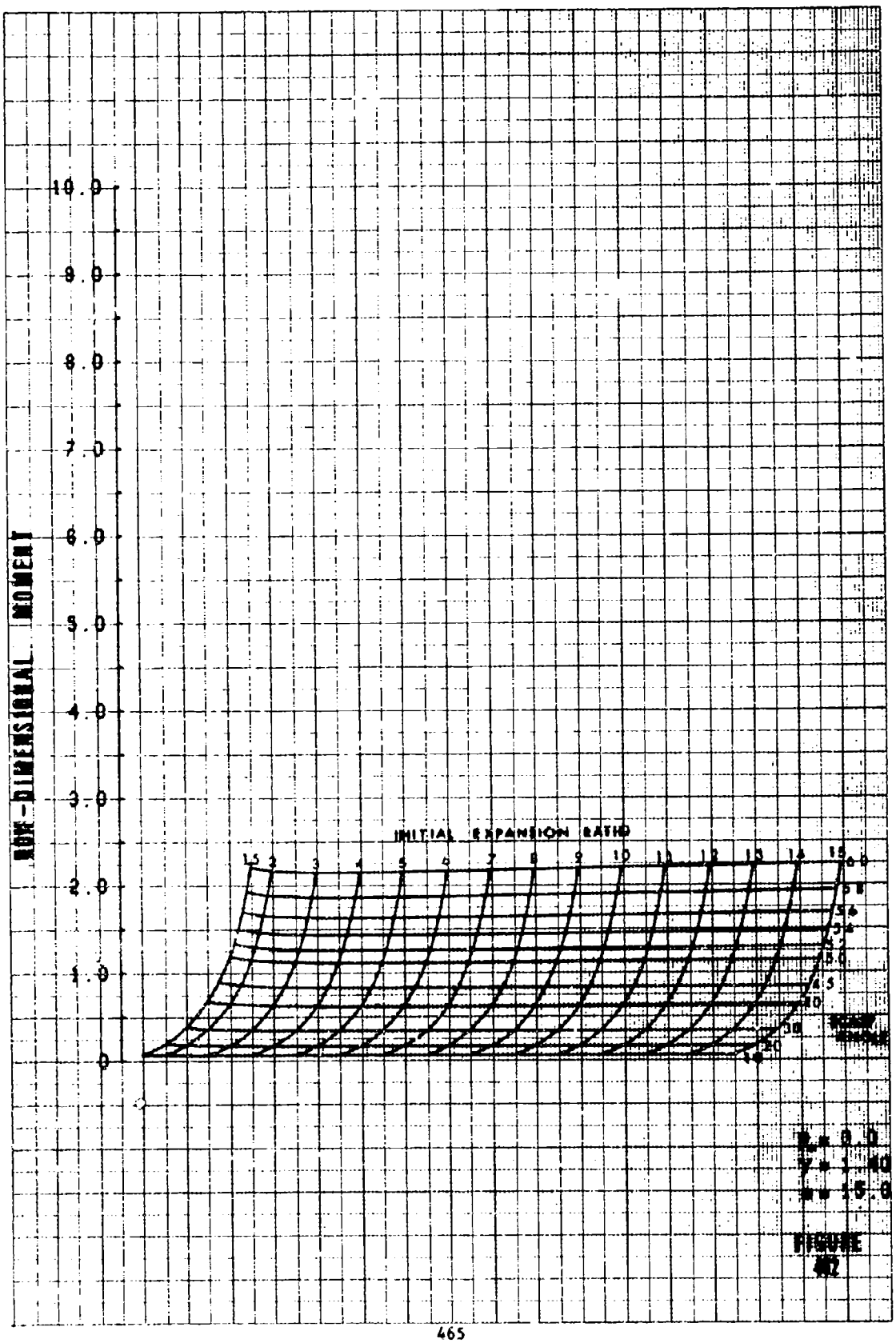
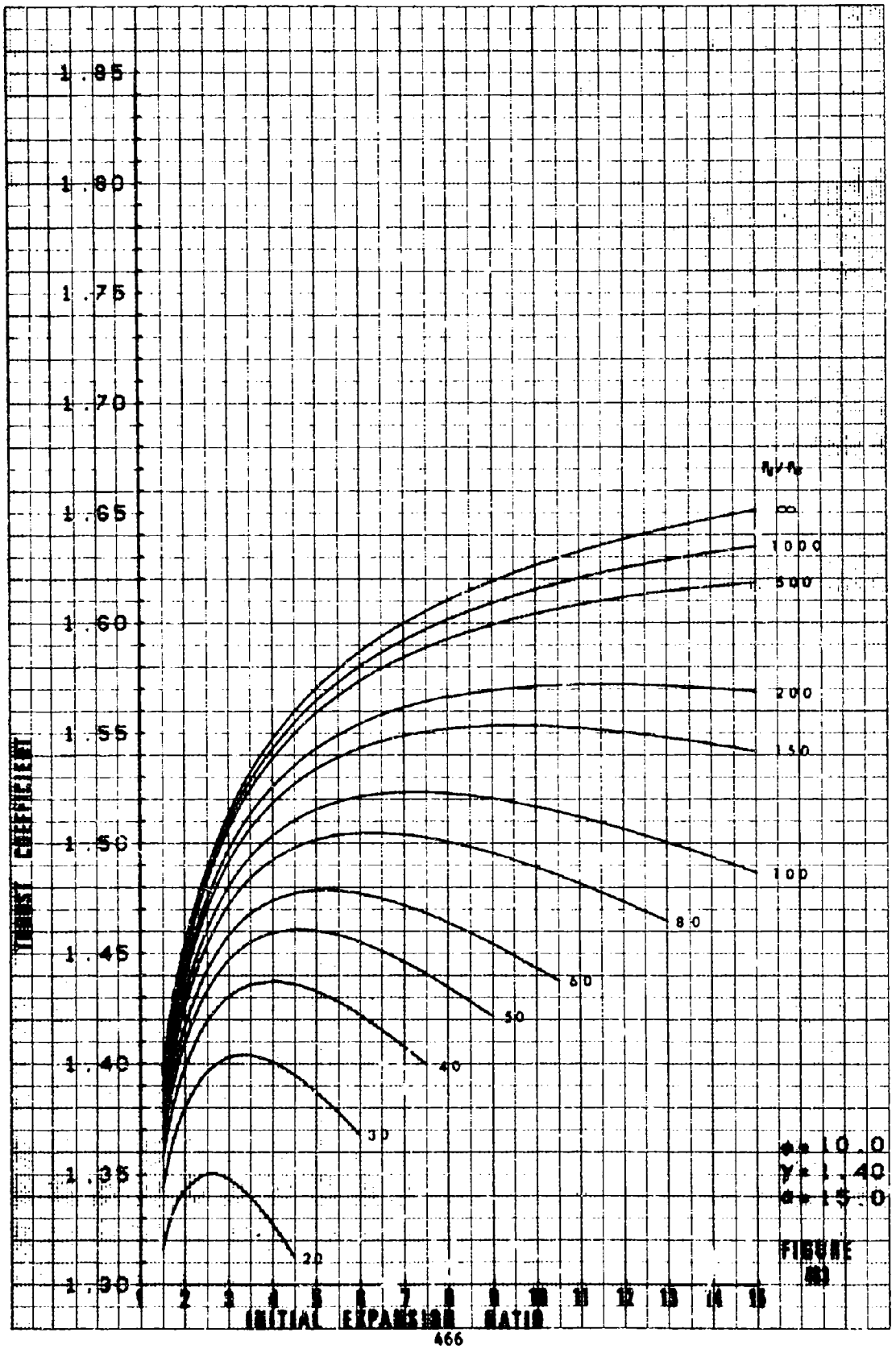

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
6.0
5.8
5.6
5.4
5.2
5.0
4.5
4.0
3.0
2.0
1.0
R_o = 0.0
γ = 1.40
n = 15.0

FIGURE 402



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
φ = 10.0
γ = 1.40
α = 15.0

FIGURE

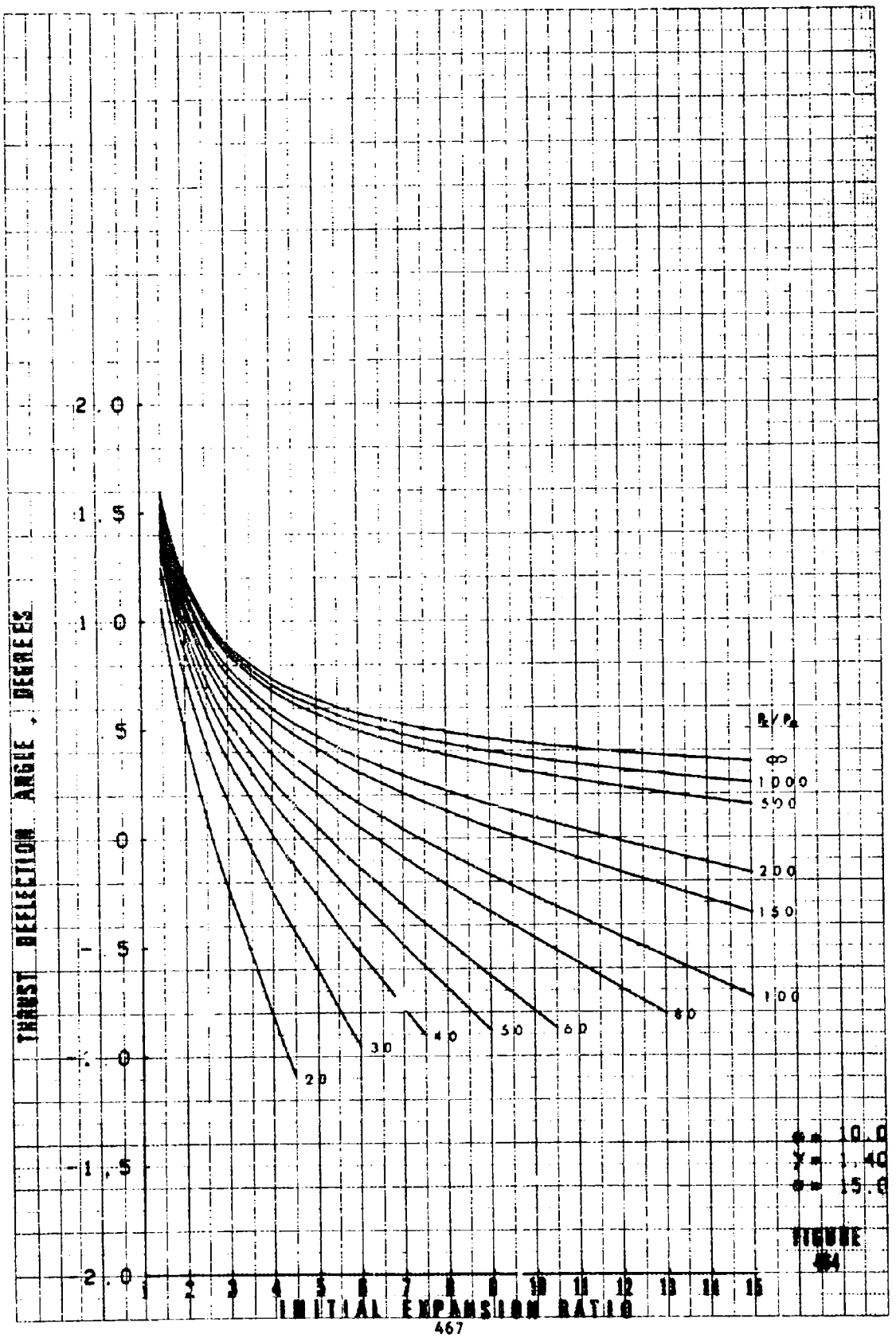

THRUST DEFLECTION ANGLE, DEGREES
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_E/P_a
∞
1000
500
200
150
100
80
60
50
40
30
20
θ_n = 10.0
γ = 1.40
θ_t = 15.0

FIGURE #4

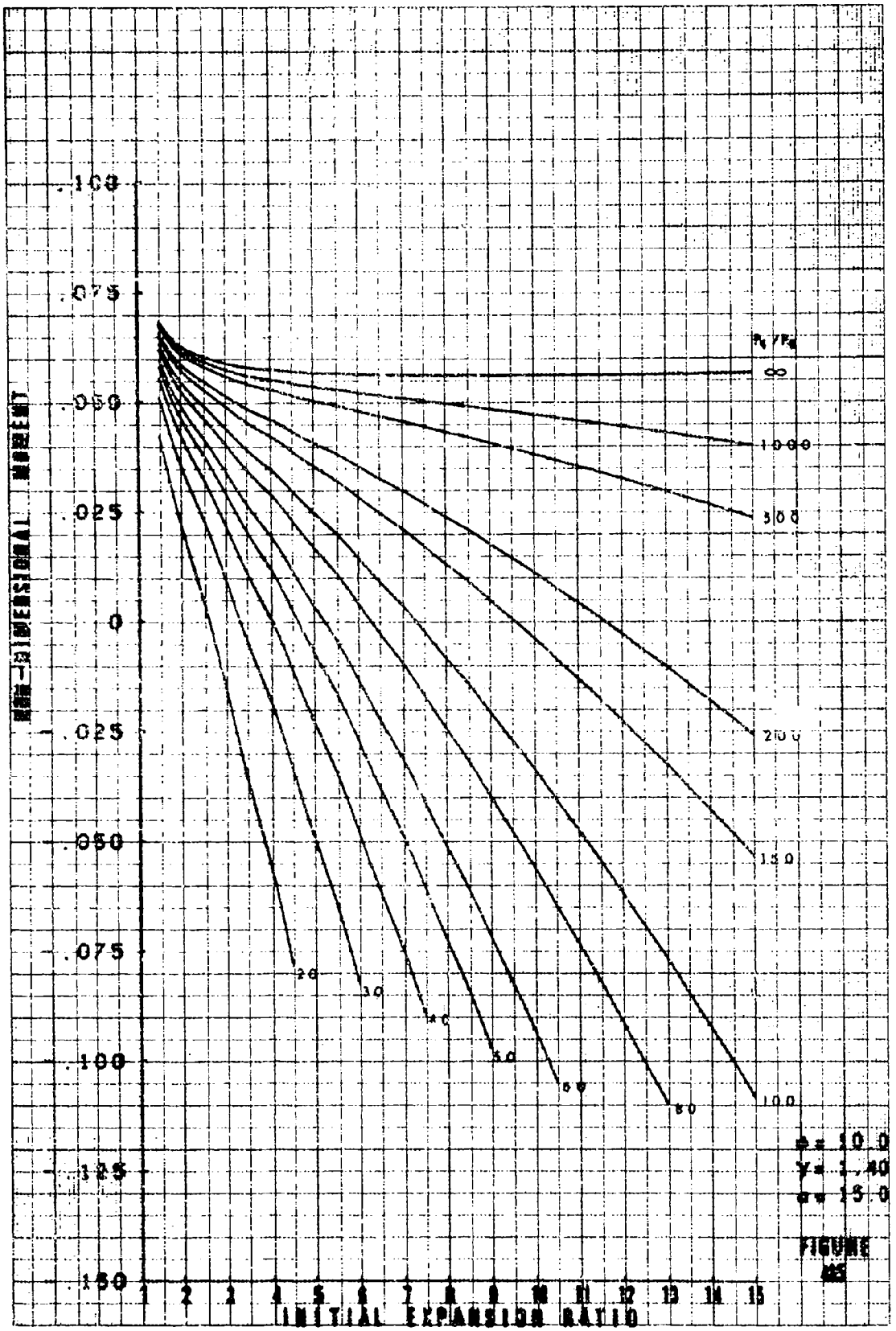

.100
.075
.050
.025
0
.025
.050
.075
.100
.125
.150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
20
e = 10.0
γ = 1.40
α = 15.0

FIGURE 465

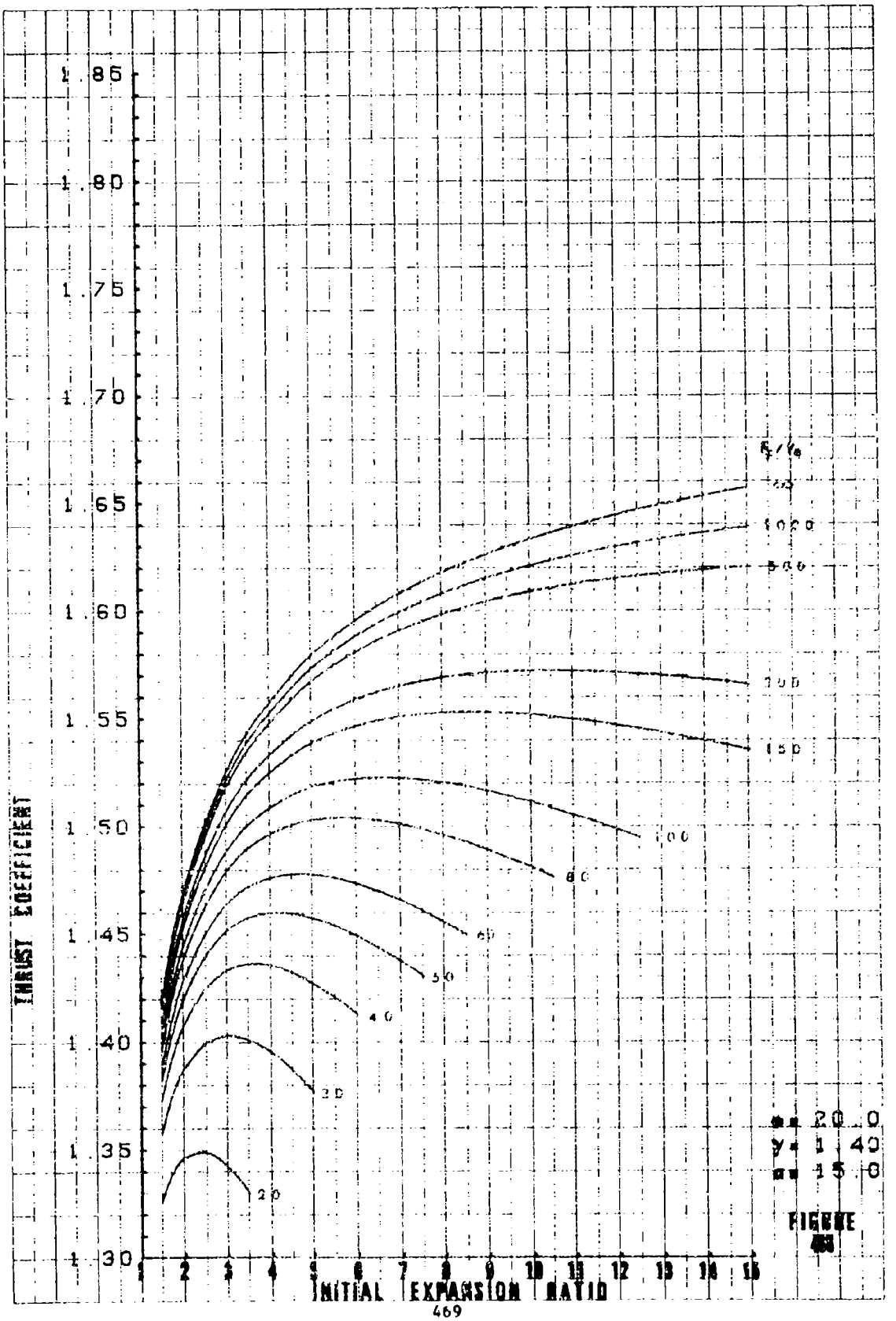

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
1000
500
200
150
100
80
60
50
40
30
20
γ = 1.40

FIGURE 45

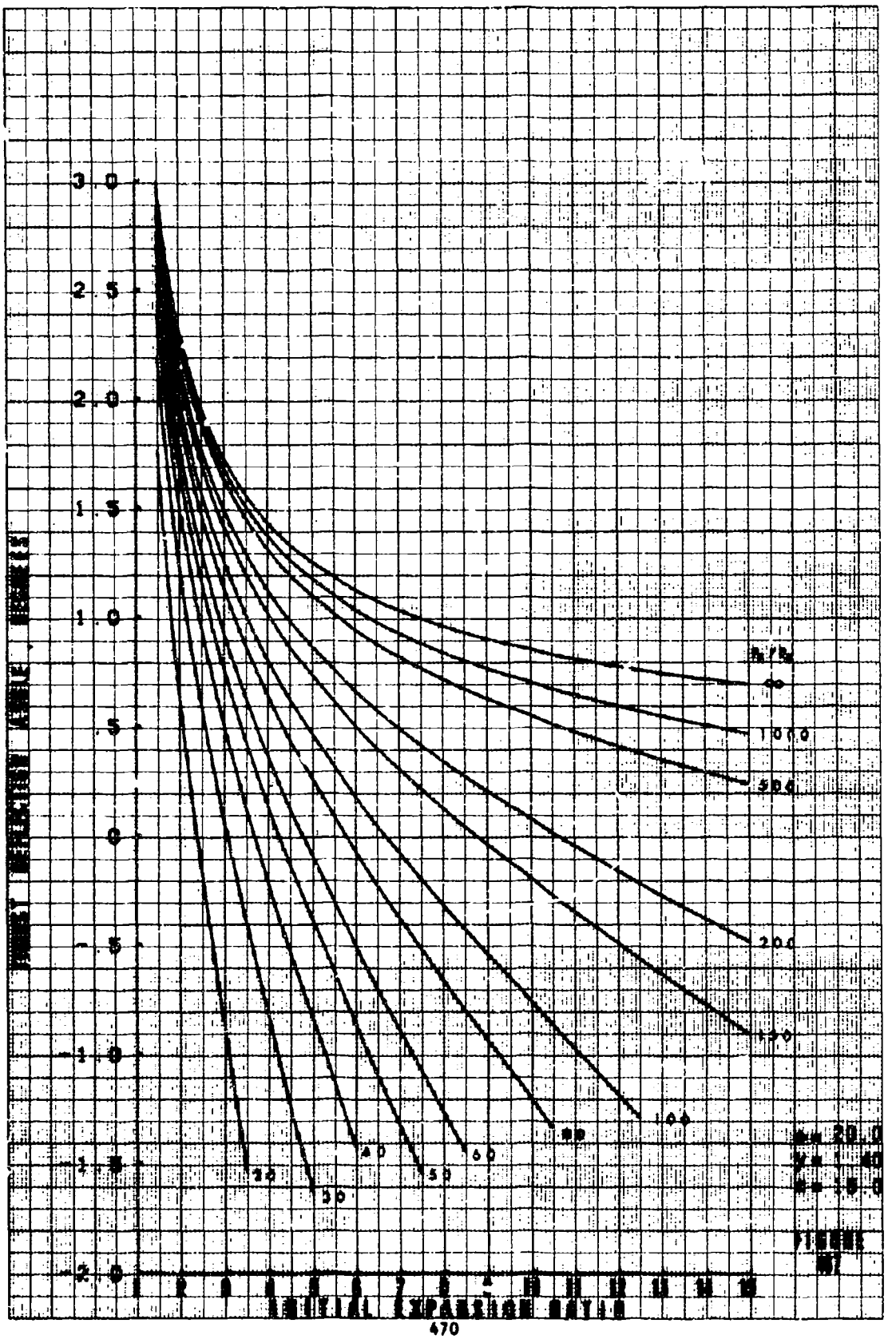
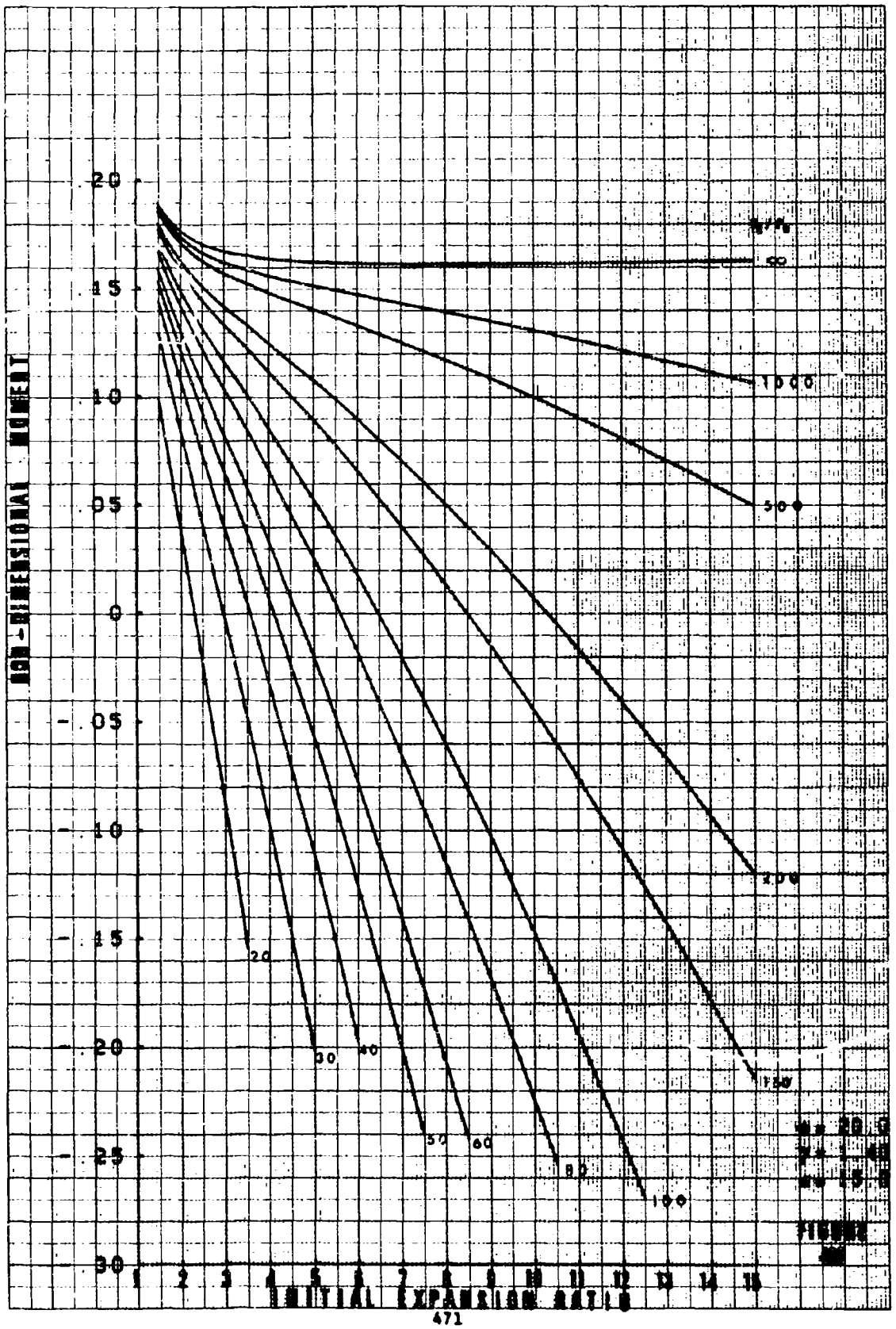
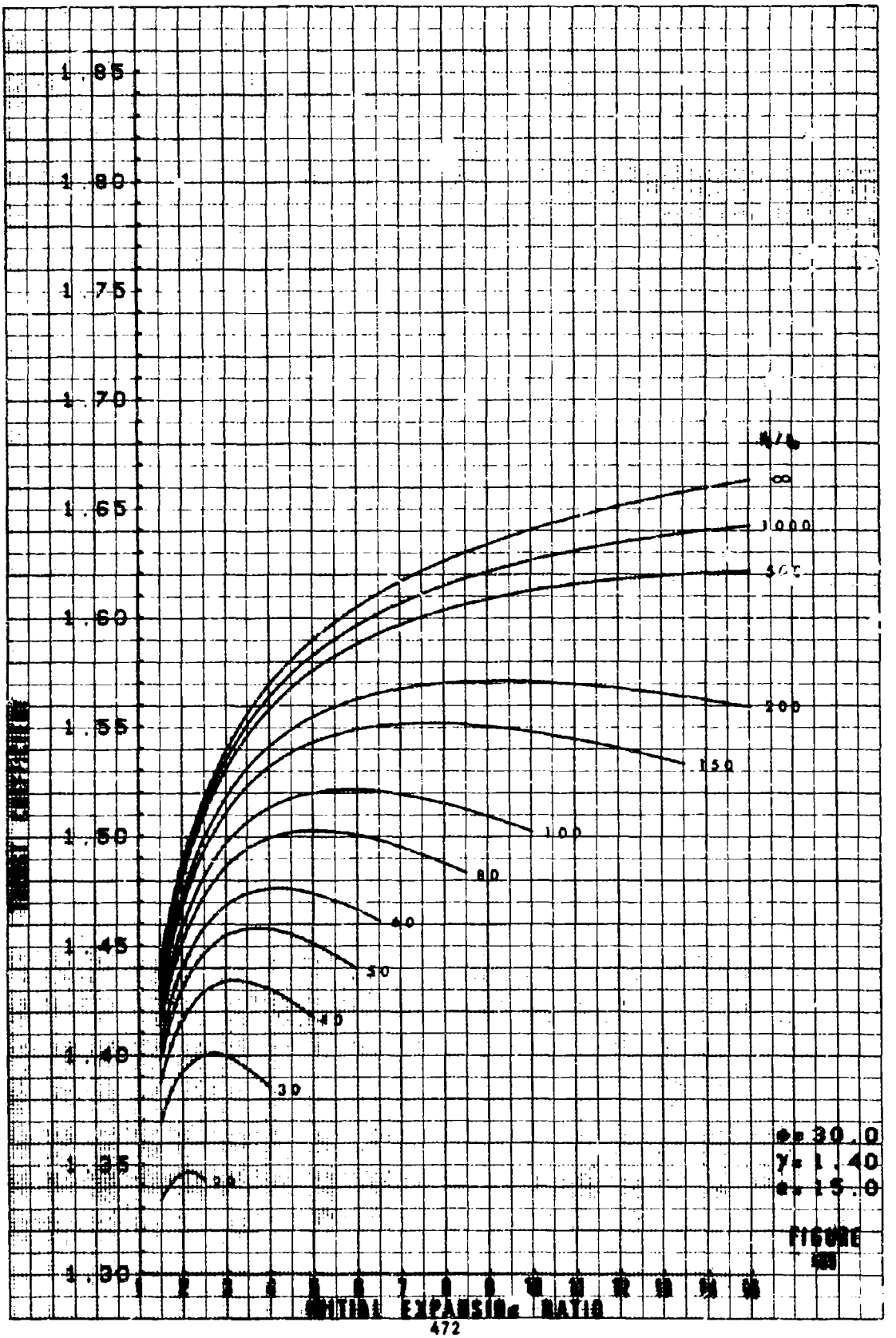
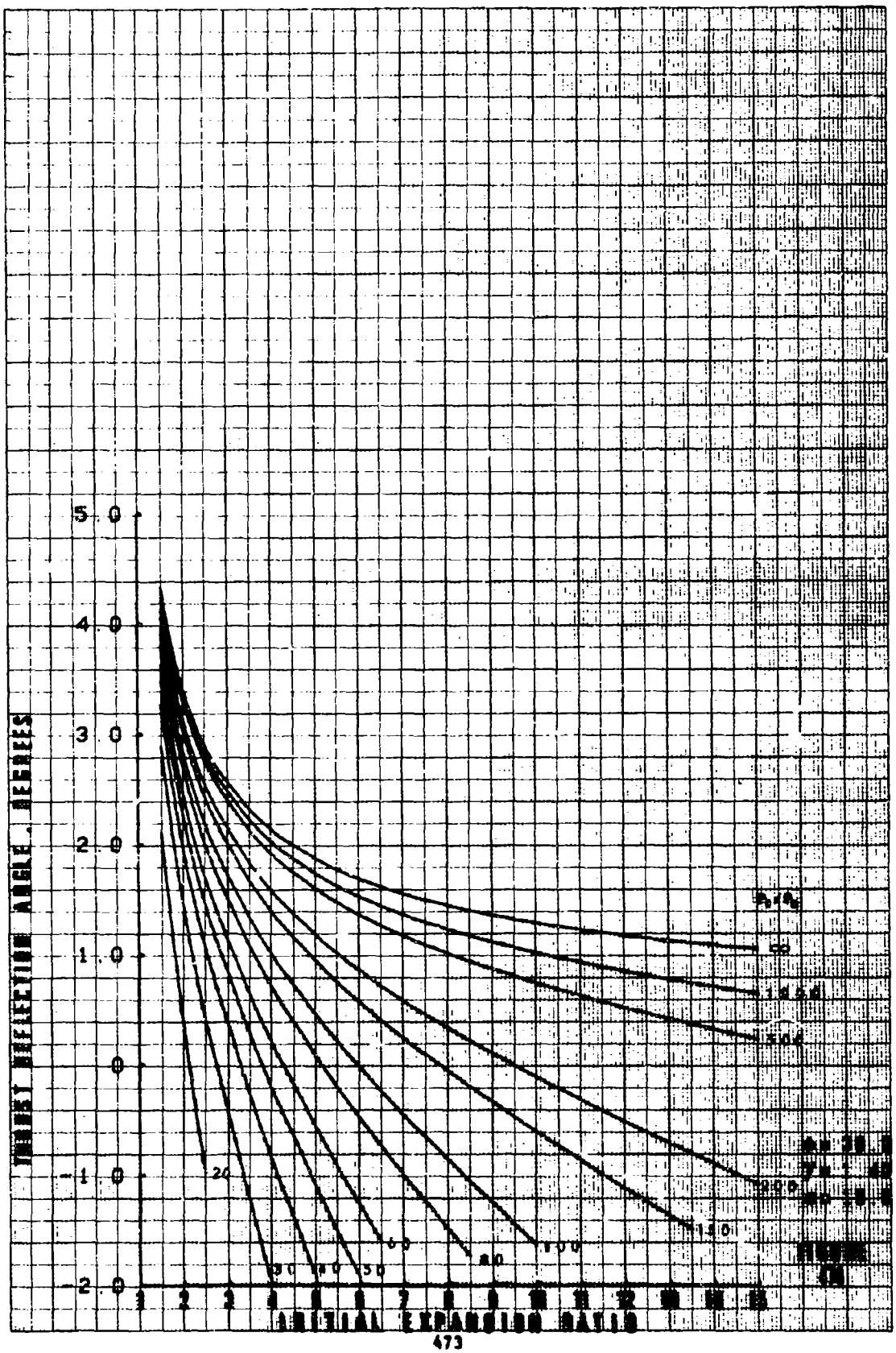

3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
h/h_0
∞
1000
500
200
150
100
80
60
50
40
30
20

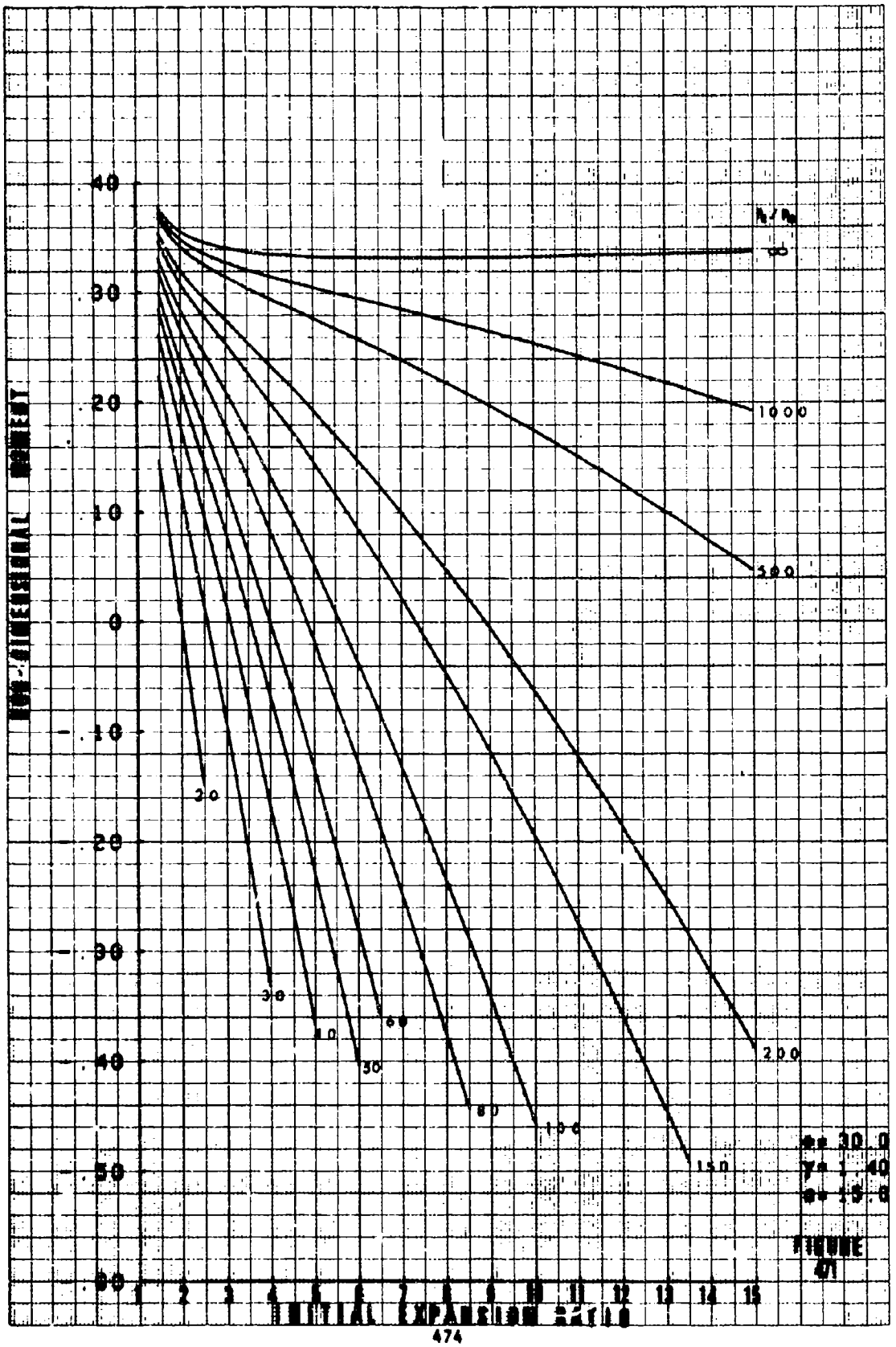
FIGURE 167


NON-DIMENSIONAL MOMENT
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
50
1000
500
200
150
100
80
60
50
40
30
20


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
∞
1000
200
150
100
80
60
50
40
30
20
φ= 30.0
γ= 1.40
e= 15.0
FIGURE
INITIAL EXPANSION RATIO

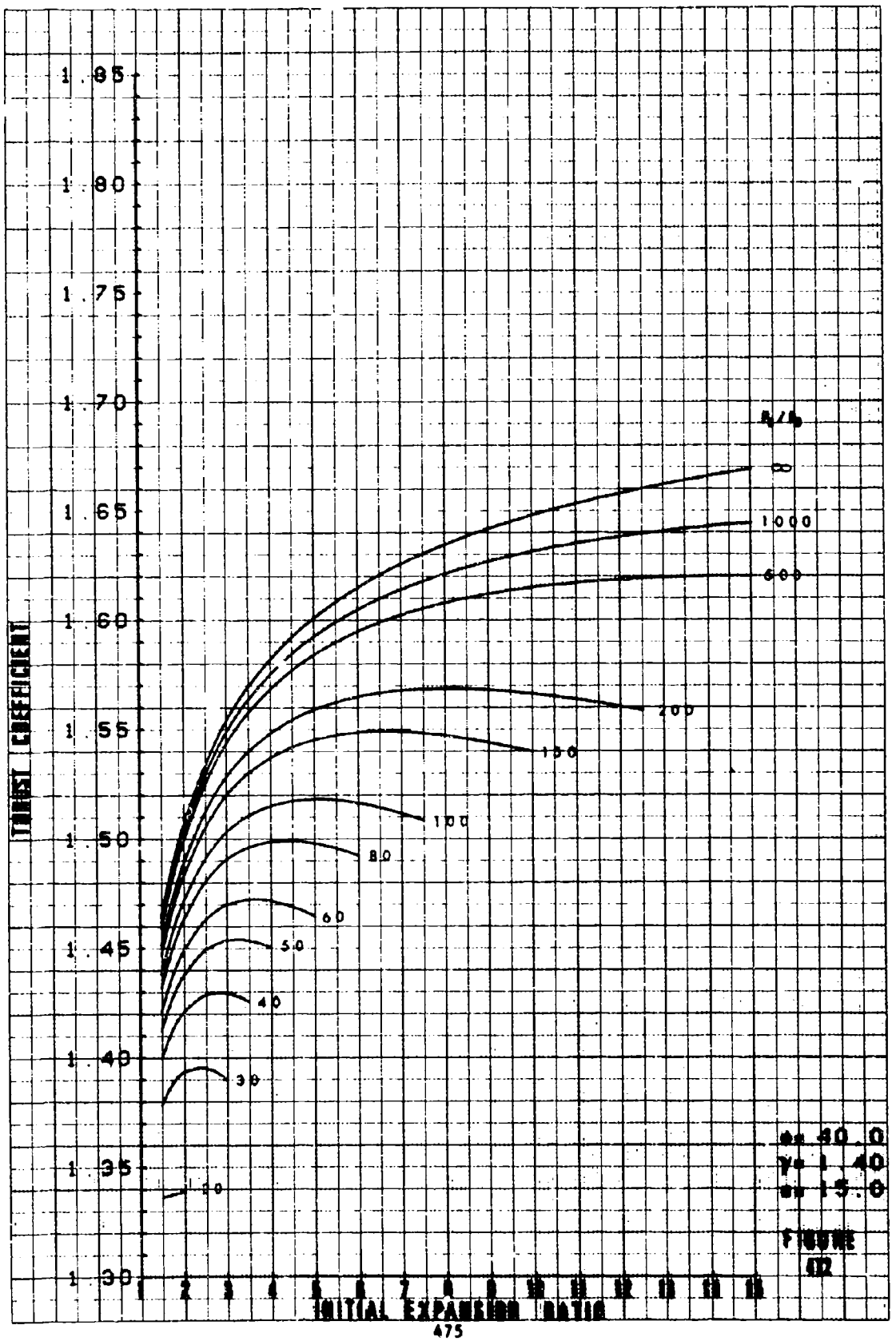


5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
20
30
40
50
60
80
100
150
200
500
1000
∞



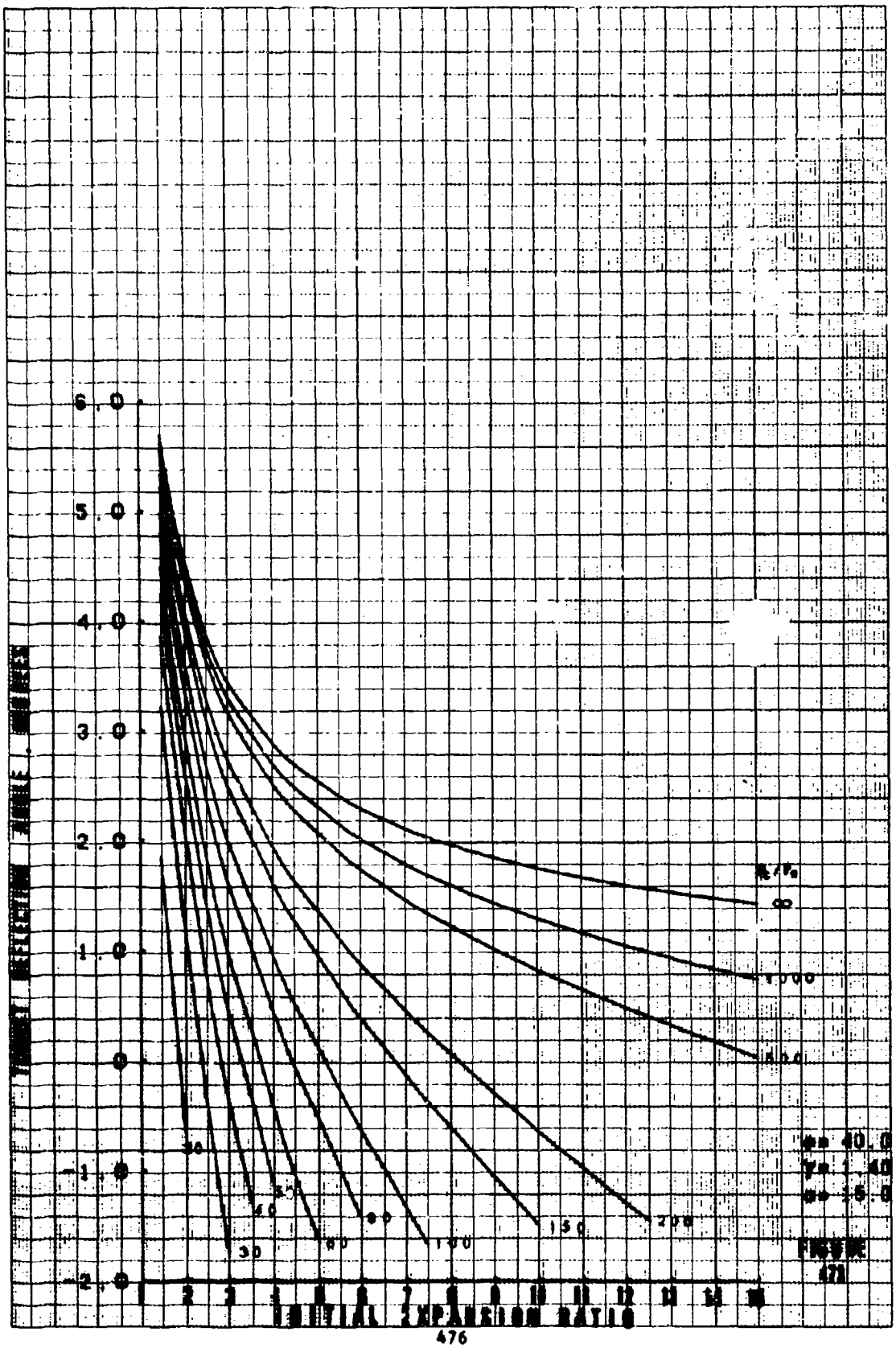
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_1/P_0
∞
1000
500
200
150
100
80
60
50
40
30
20
e= 30.0
γ= 1.40
e= 15.0

FIGURE 471



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
600
200
150
100
80
60
50
40
30
20
e= 40.0
γ= 1.40
α= 15.0

FIGURE 412


6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
φ= 40.0
γ= 1.40
α= 15.0
FIGURE
471

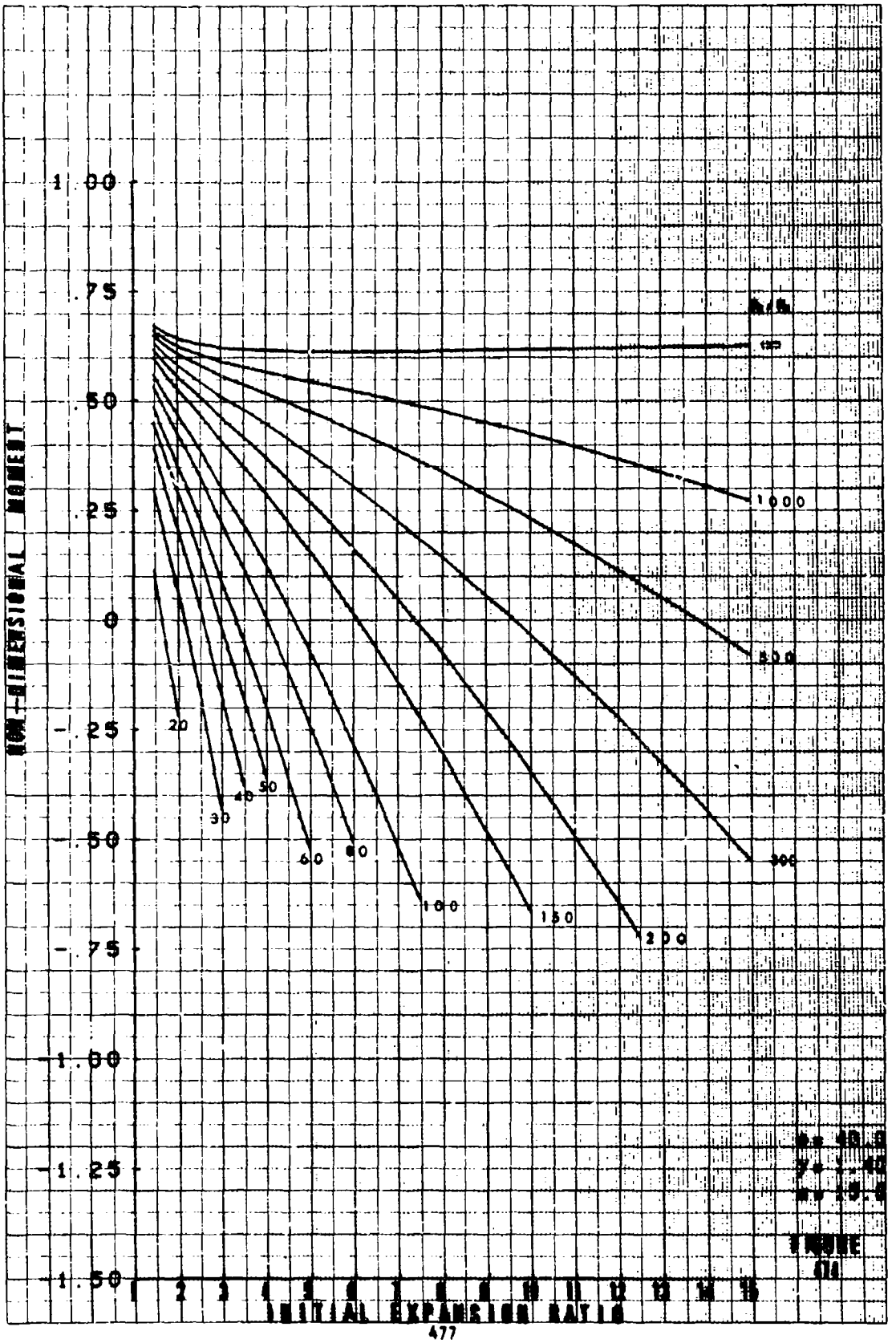

NON-DIMENSIONAL MOMENT
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1000
500
300
200
150
100
60
50
40
30
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 6A

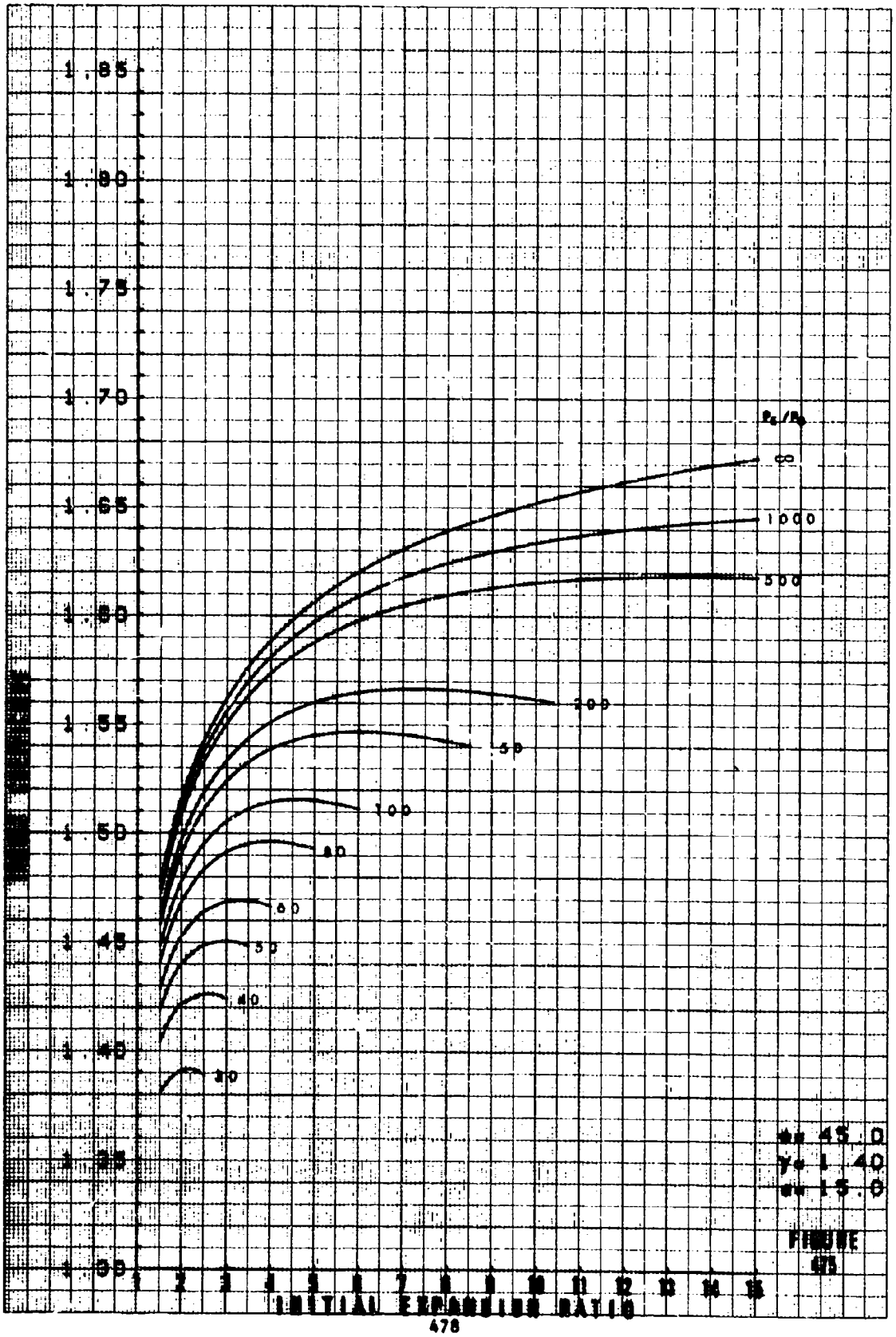
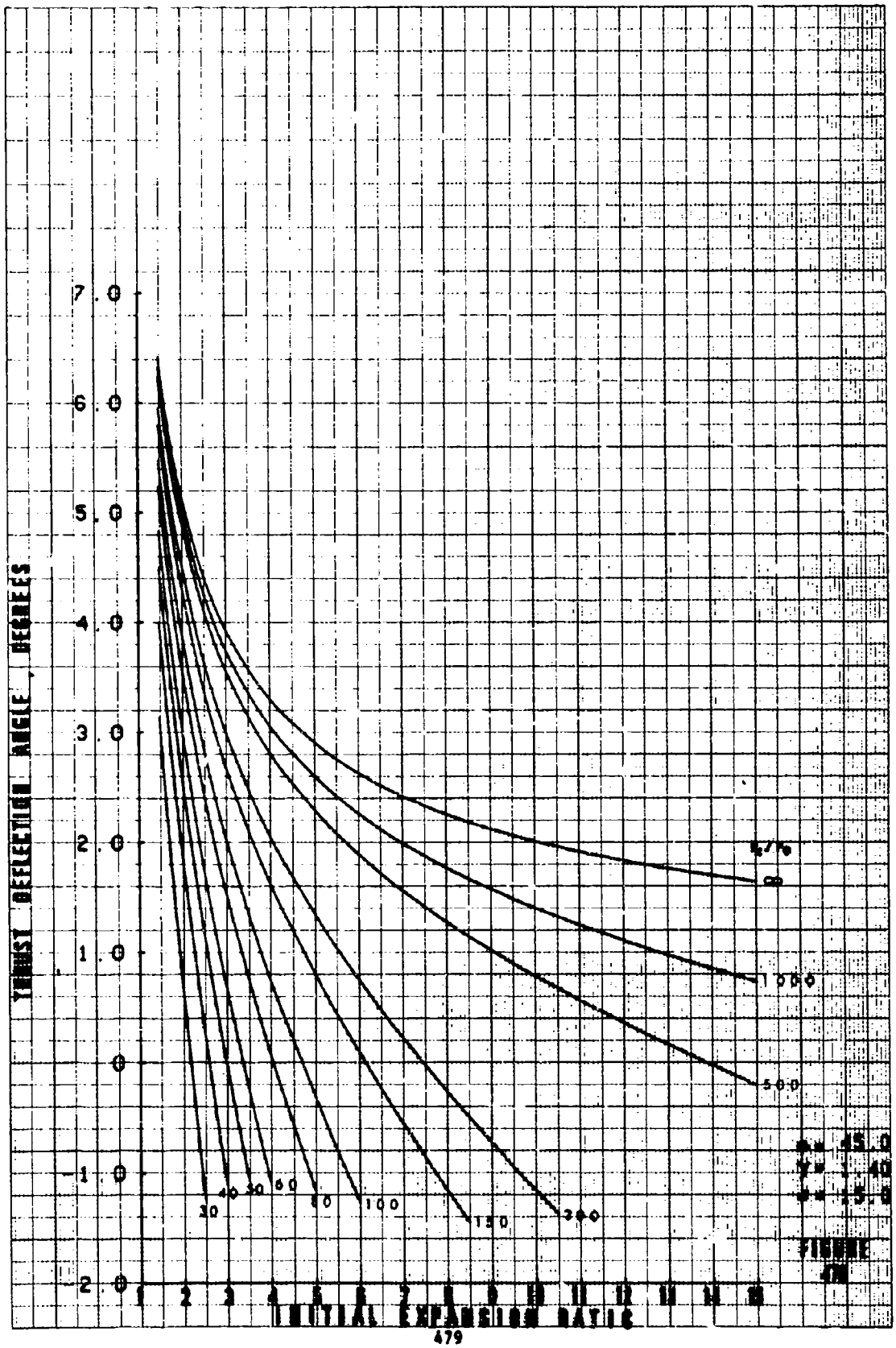

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_0
∞
1000
500
200
150
100
80
60
50
40
30
α= 45.0
γ= 1.40
ε= 15.0

FIGURE 475



THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
500
1000
∞

FIGURE 479

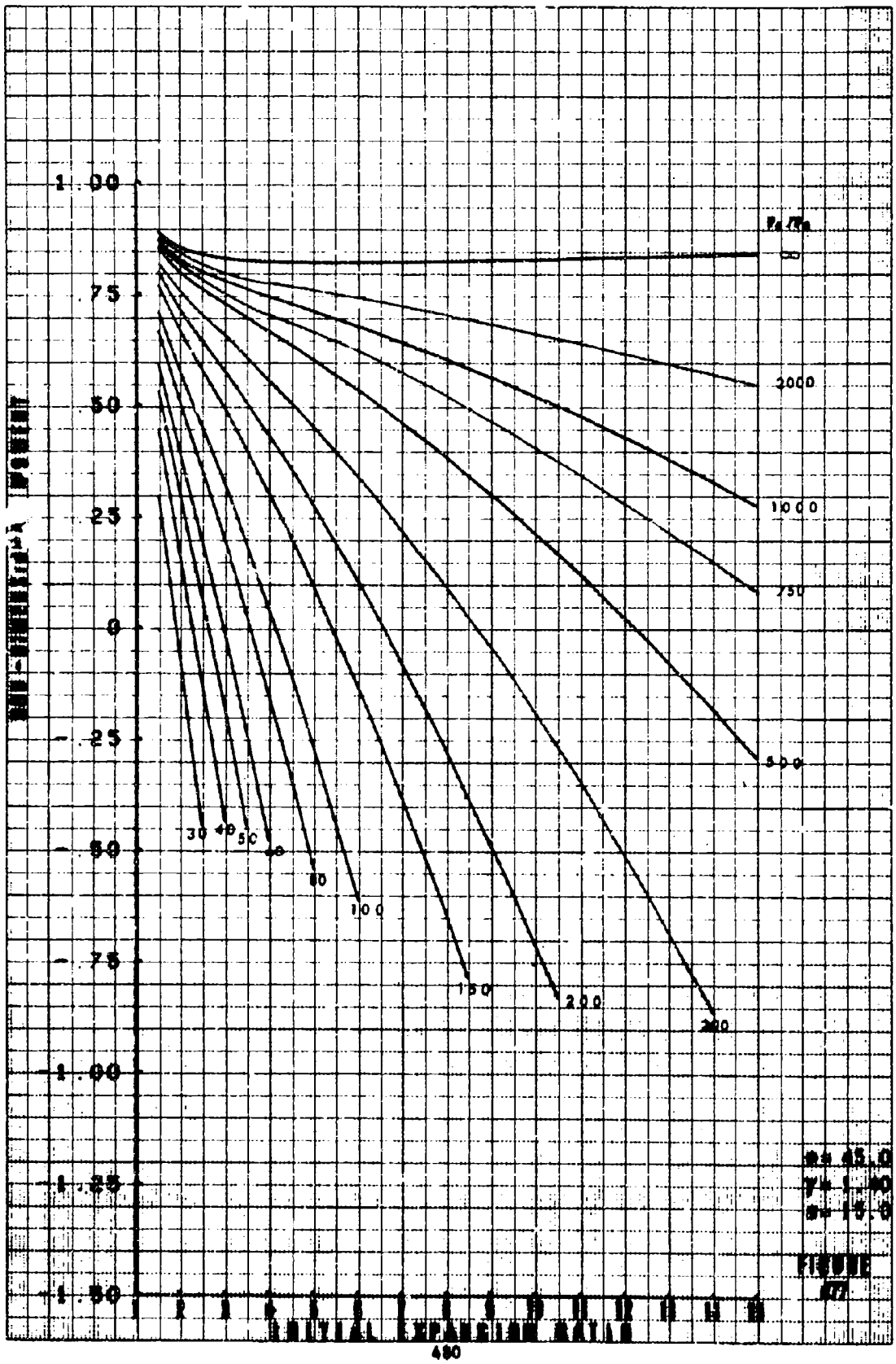
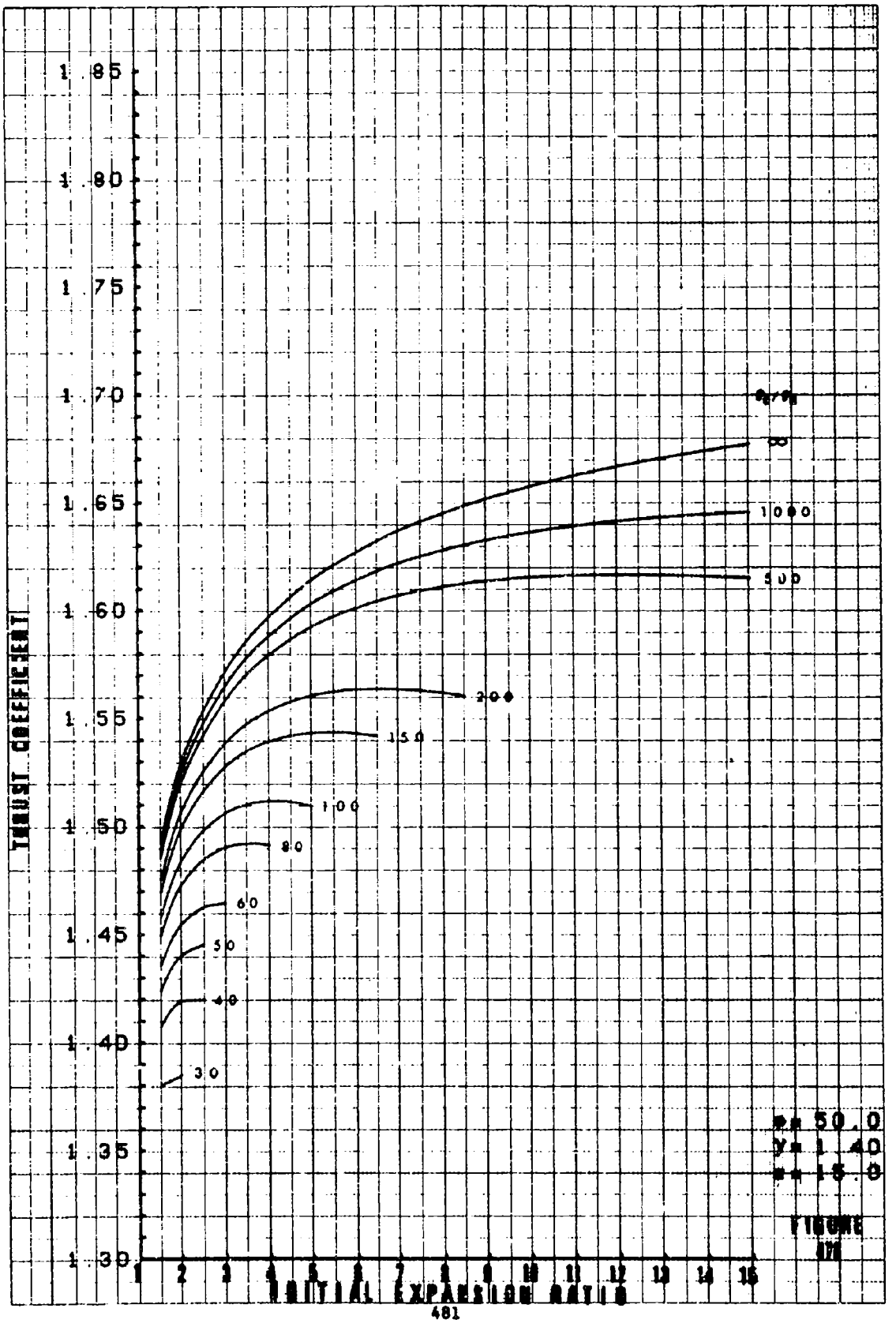
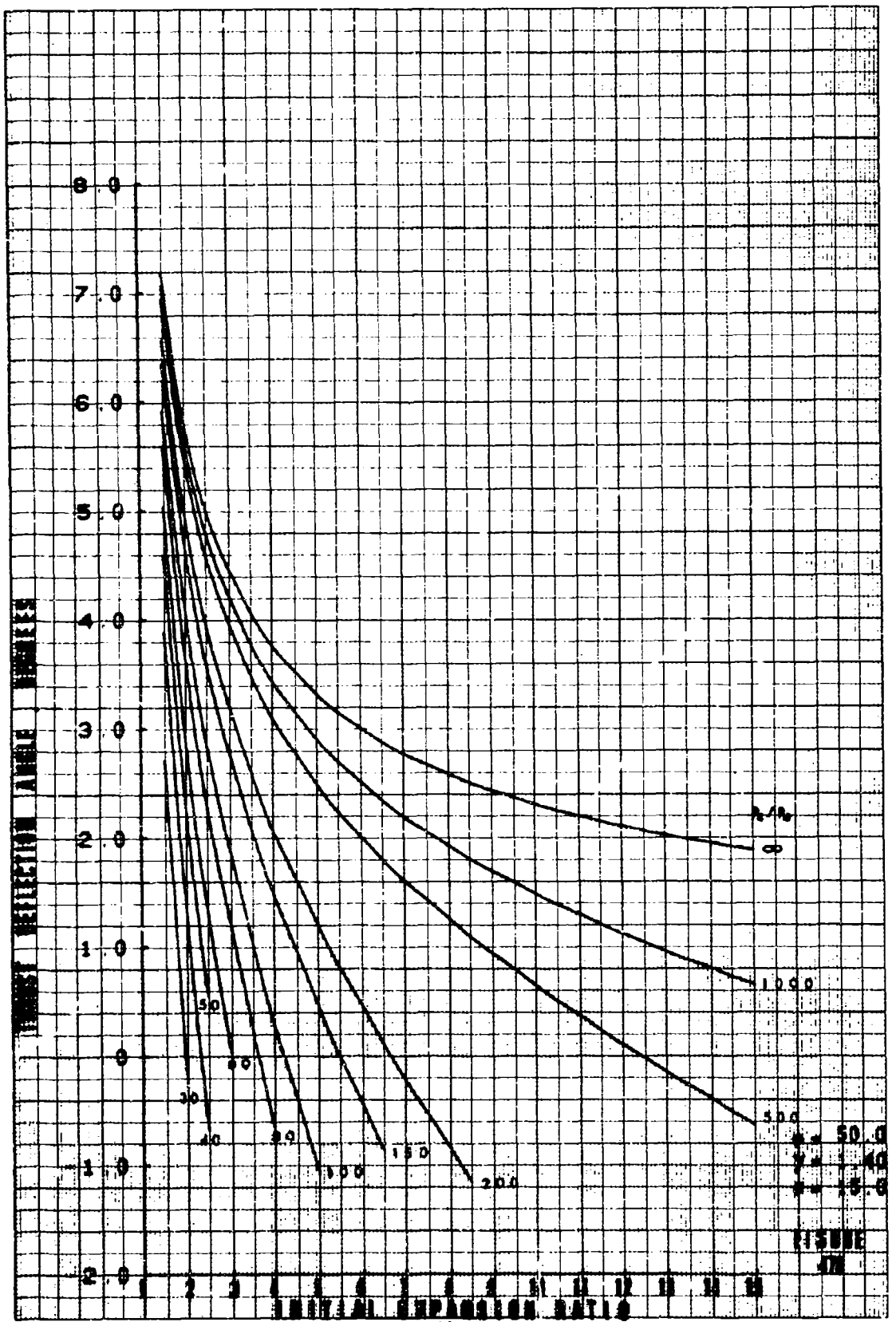
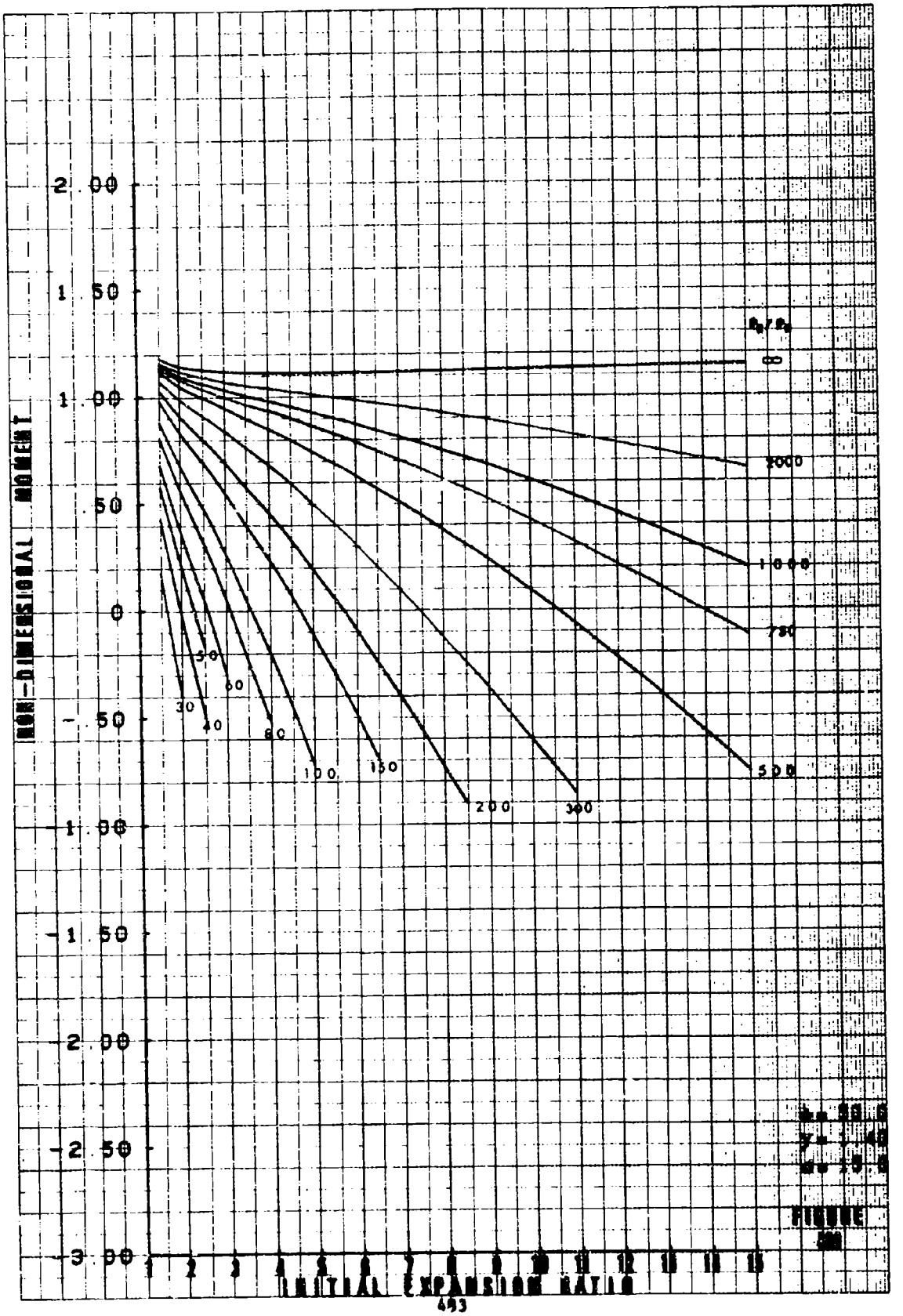

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
2000
1000
750
500
30
40
50
60
80
100
150
200
300
INITIAL EXPANSION RATIO

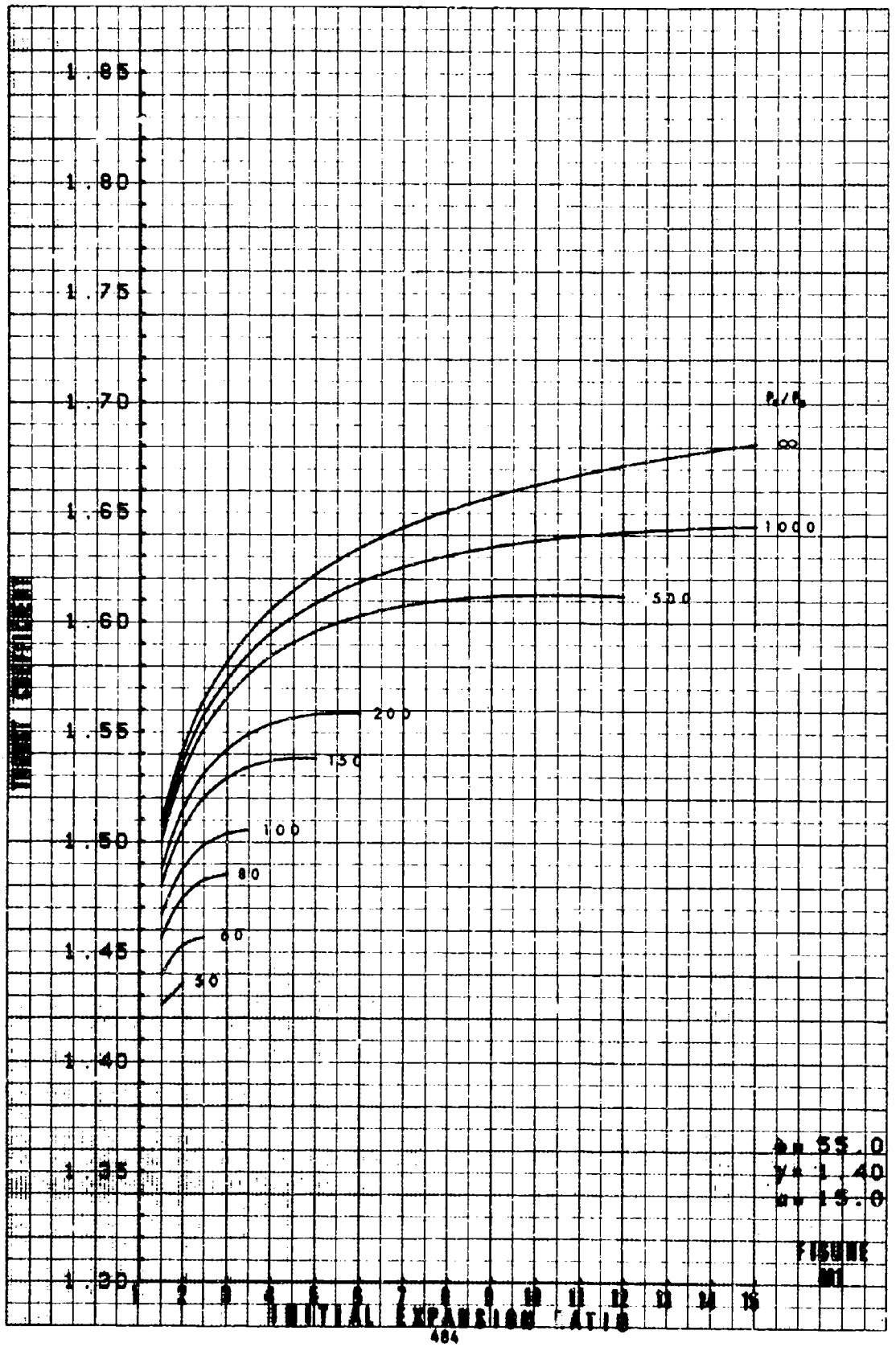
FIGURE 67

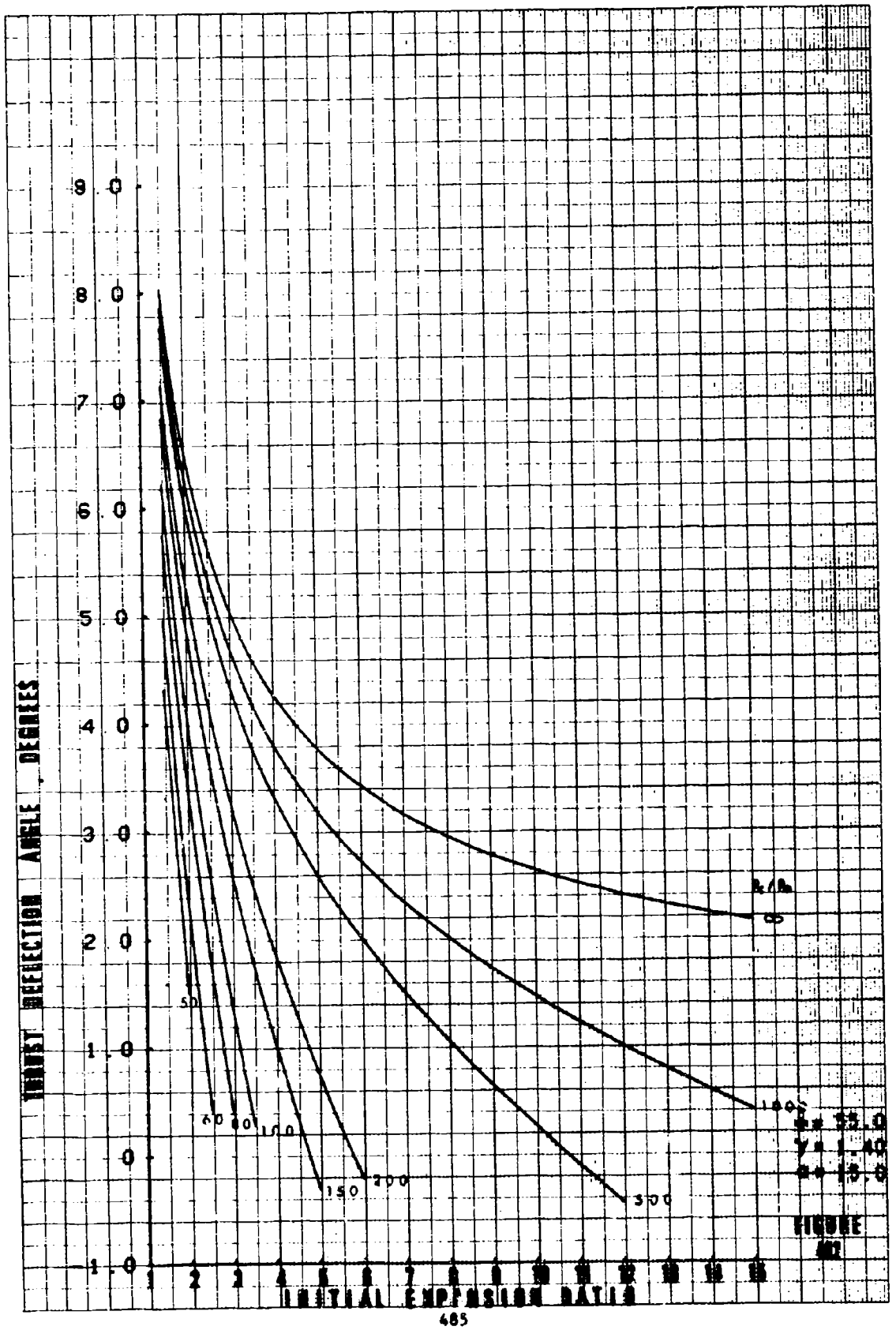

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
40
30
γ= 1.40
FIGURE


8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
200
150
100
90
80
60
50
40
30
φ = 50.0
γ = 1.40
θ = 15.0
FIGURE
478


NON-DIMENSIONAL MOMENT
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
2000
1000
750
500
300
200
150
100
80
60
50
40
30

FIGURE


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
60
50
a = 55.0
y = 1.40
α = 15.0
FIGURE



THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
50
60
80
100
150
200
300
1000
∞

FIGURE

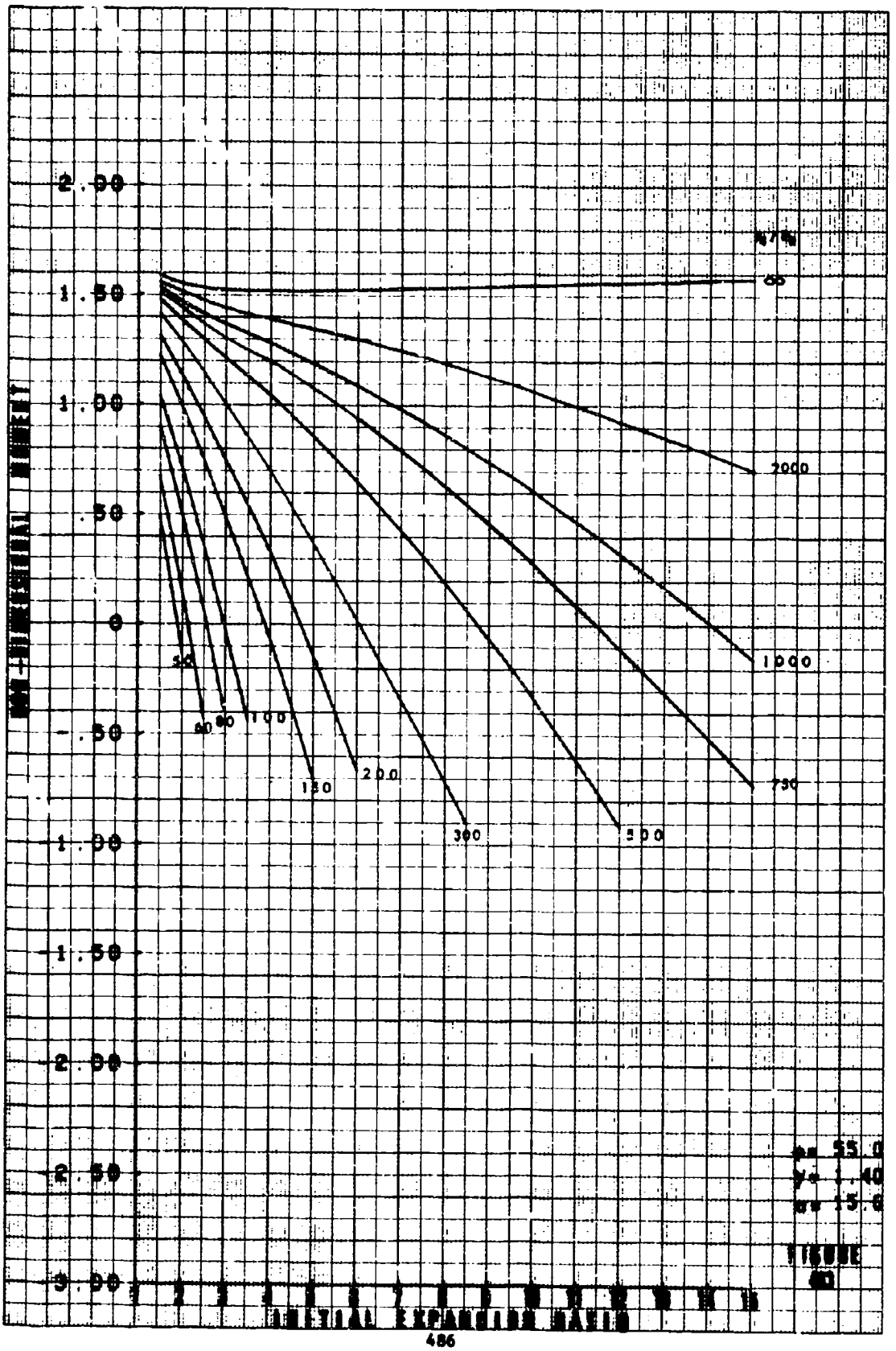
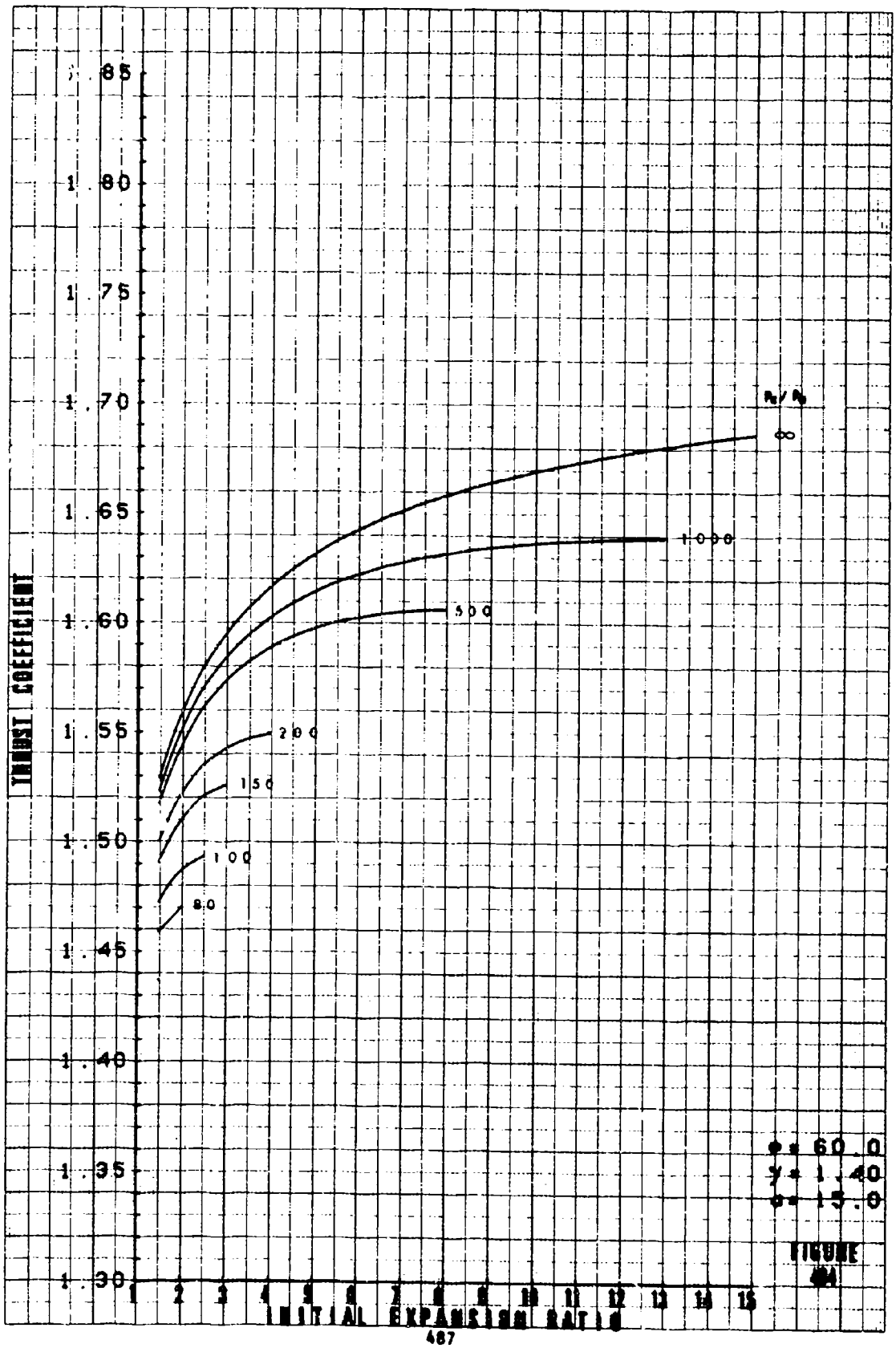
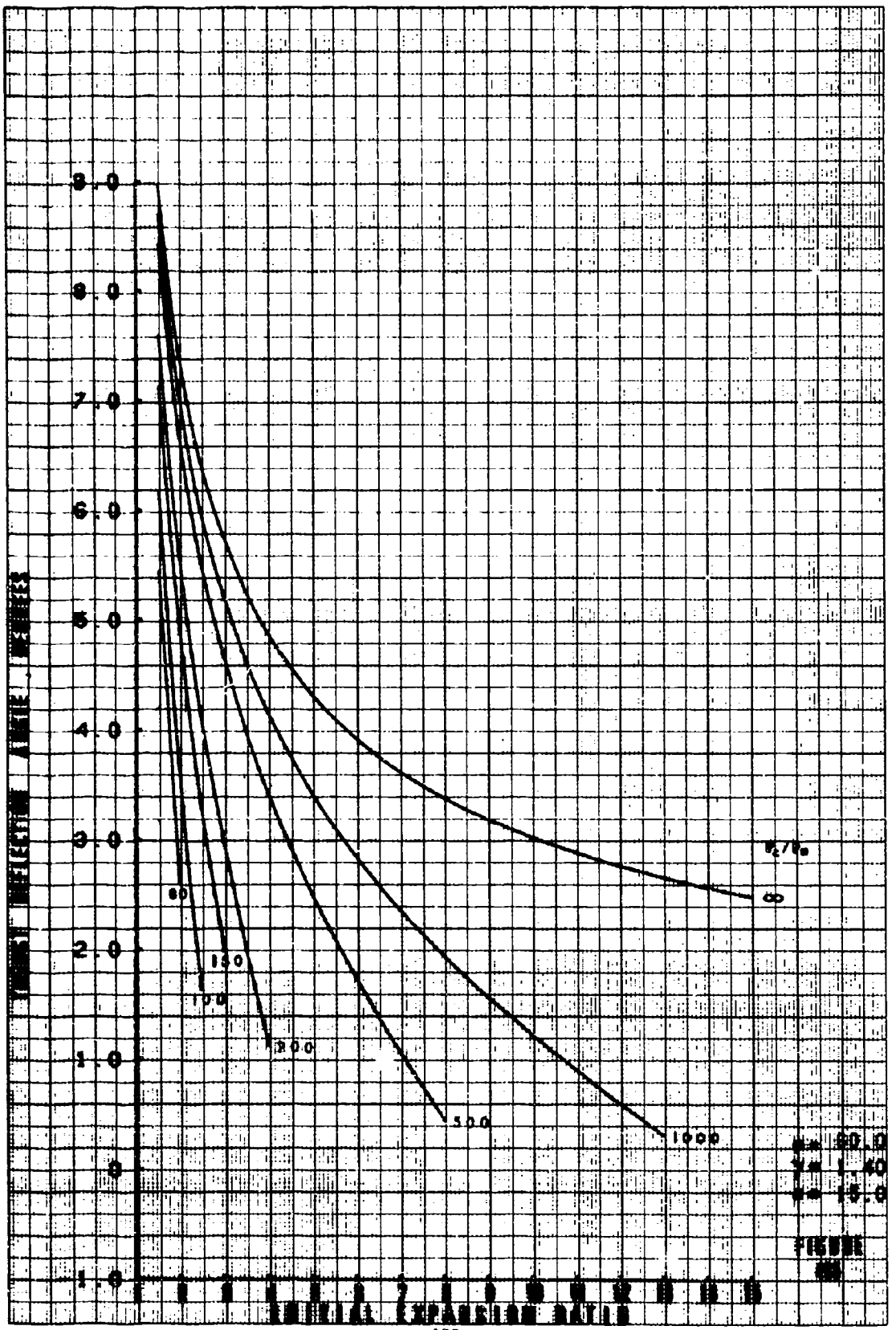

2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
-2.50
-3.00
2000
1000
750
500
300
200
150
100
80
60
50
INITIAL EXPANSION RATIO

FIGURE 40

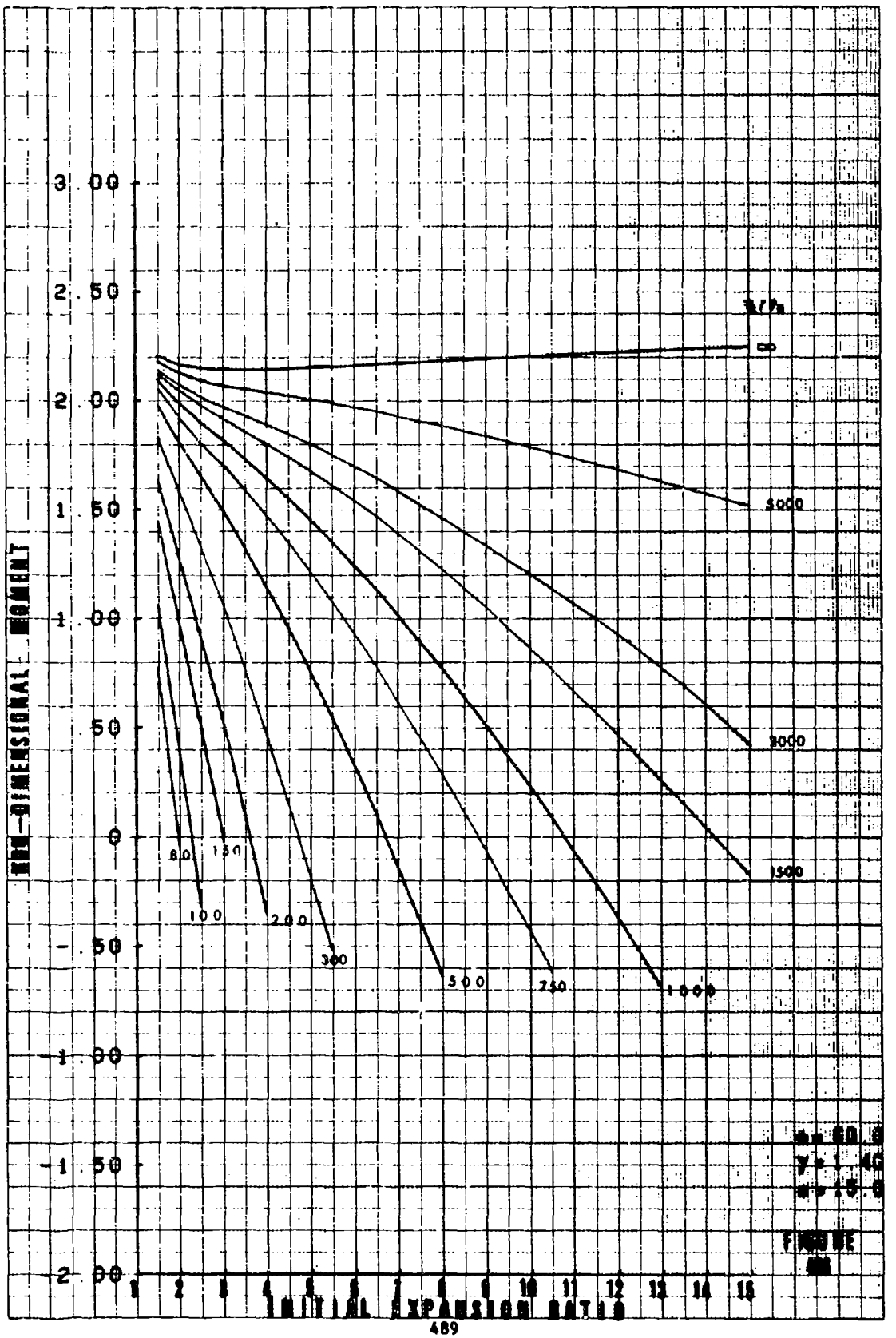


1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
1000
500
200
150
100
80
φ = 60.0
γ = 1.40
α = 15.0

FIGURE 484



8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
60
100
150
200
500
1000
∞


NON-DIMENSIONAL MOMENT
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
∞
5000
3000
1500
1000
500
250
300
200
100
150
80

FIGURE

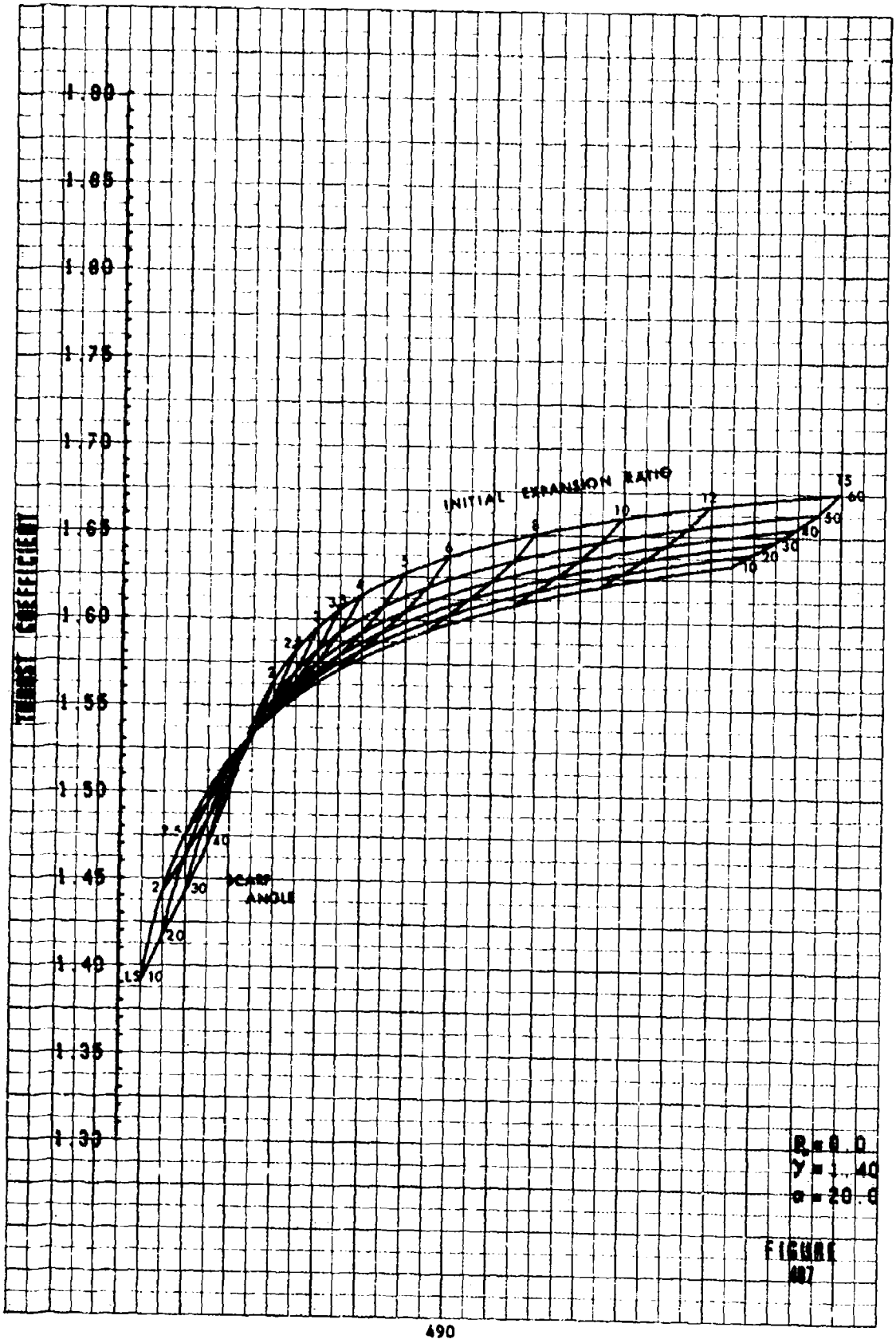

1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
SCARF ANGLE
R = 0.0
γ = 1.40
θ = 20.0

FIGURE 487

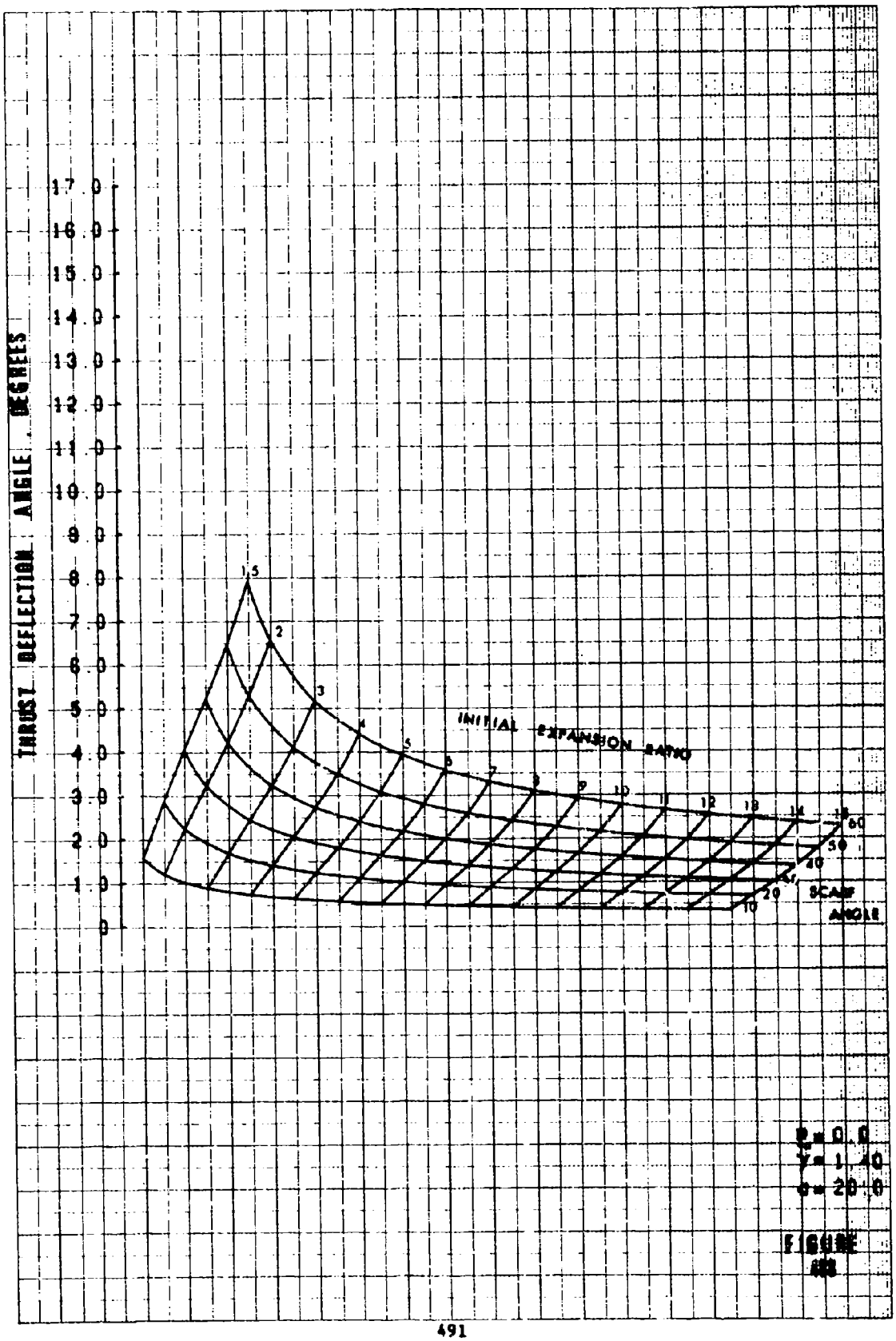
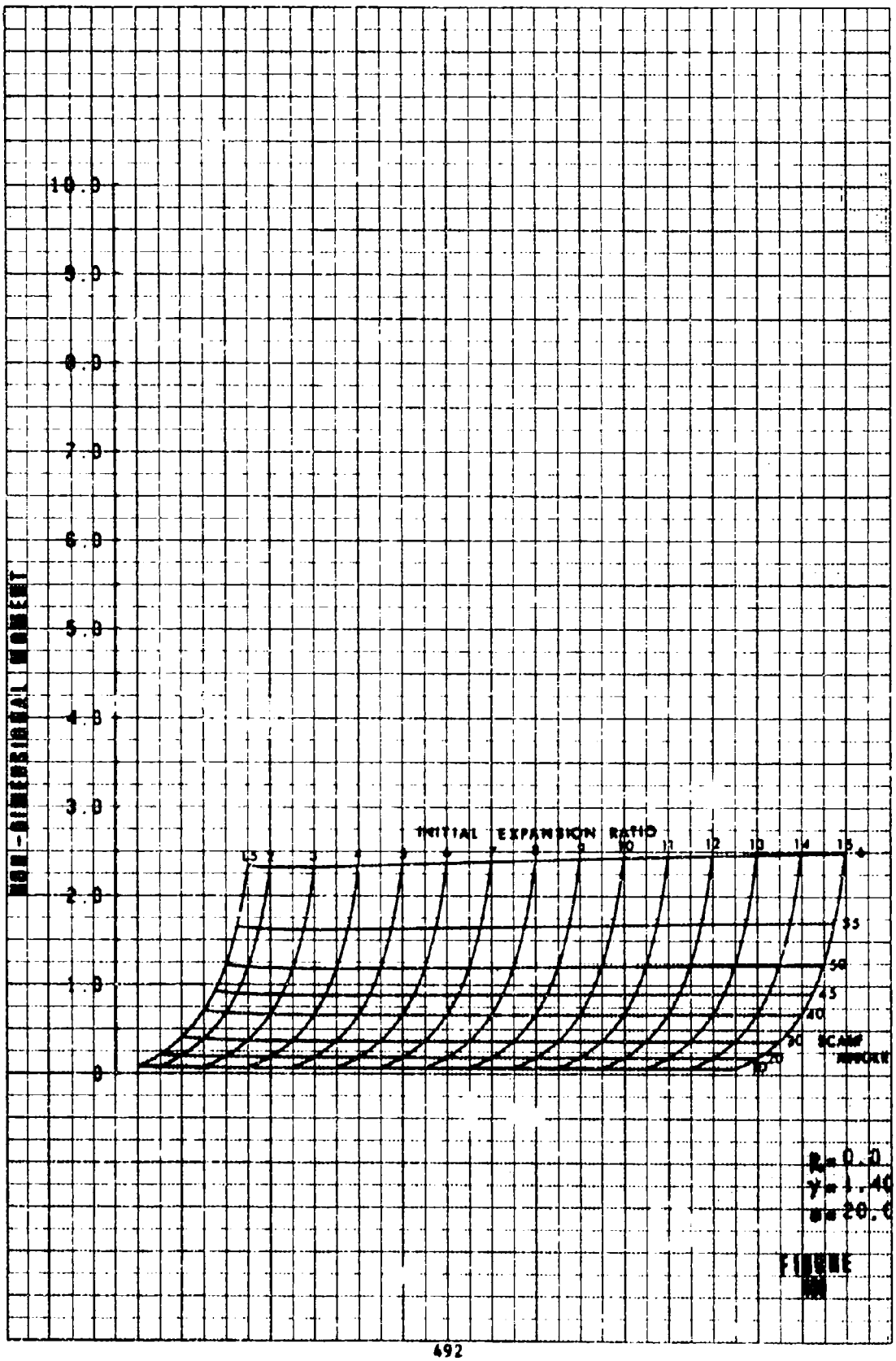
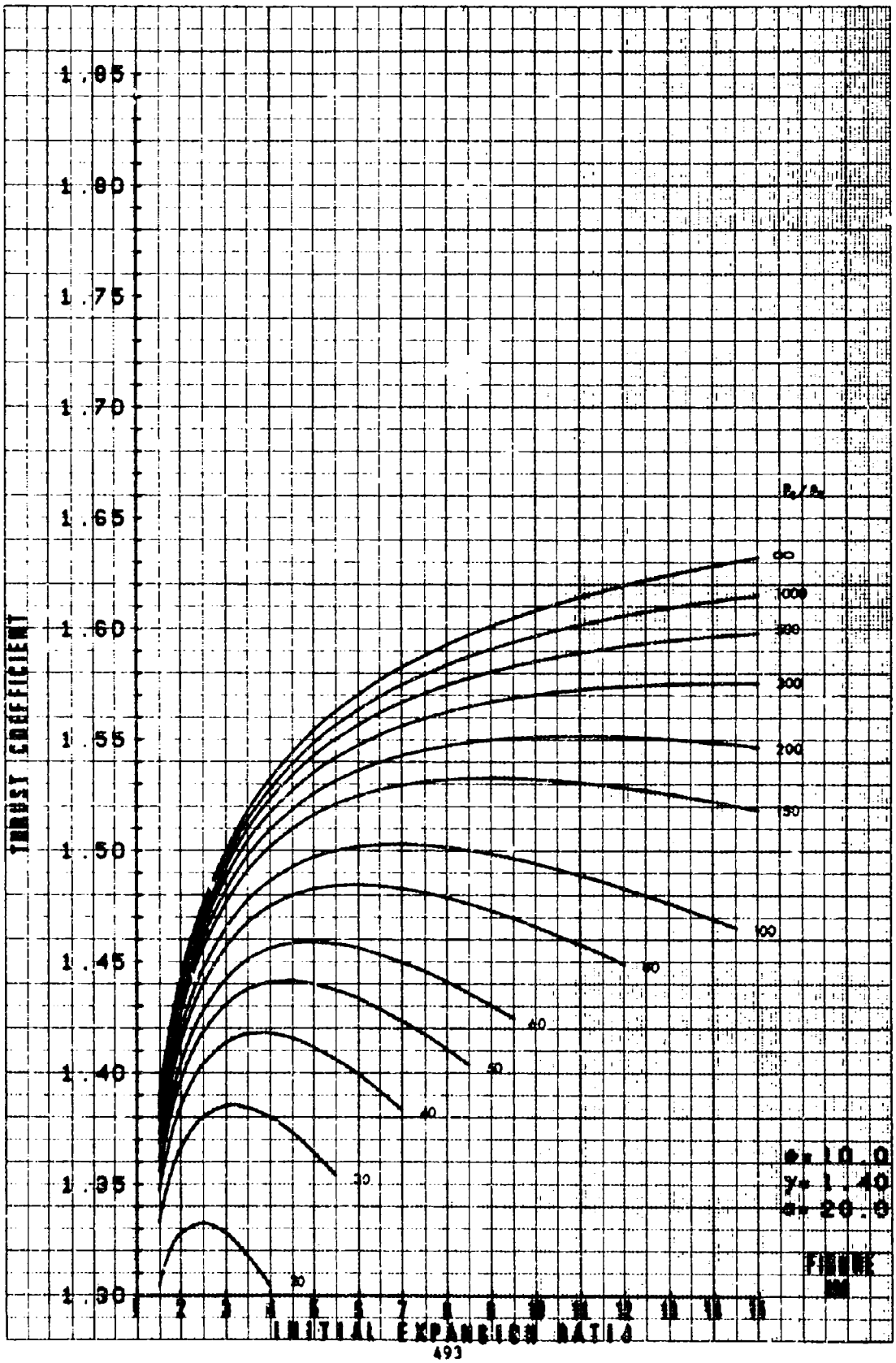

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
50
40
30
20
10
SCARF ANGLE
β = 0.0
γ = 1.40
σ = 20.0

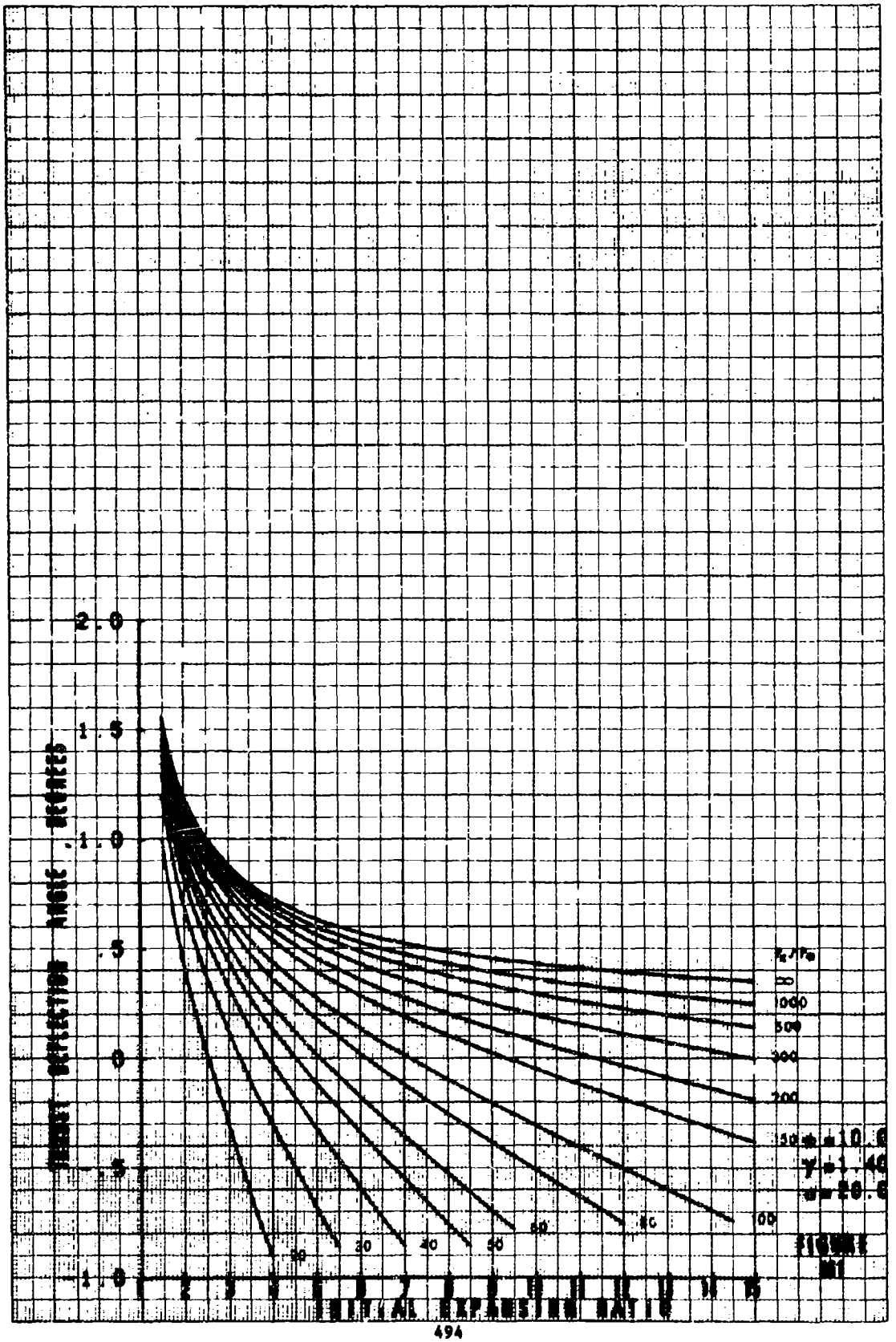
FIGURE [illegible]



NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
55
50
45
40
30
20
10
SCARF ANGLE
R = 0.0
γ = 1.40
a = 20.0
FIGURE



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
30
20
γ= 1.40


2.0
1.5
1.0
.5
0
-.5
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

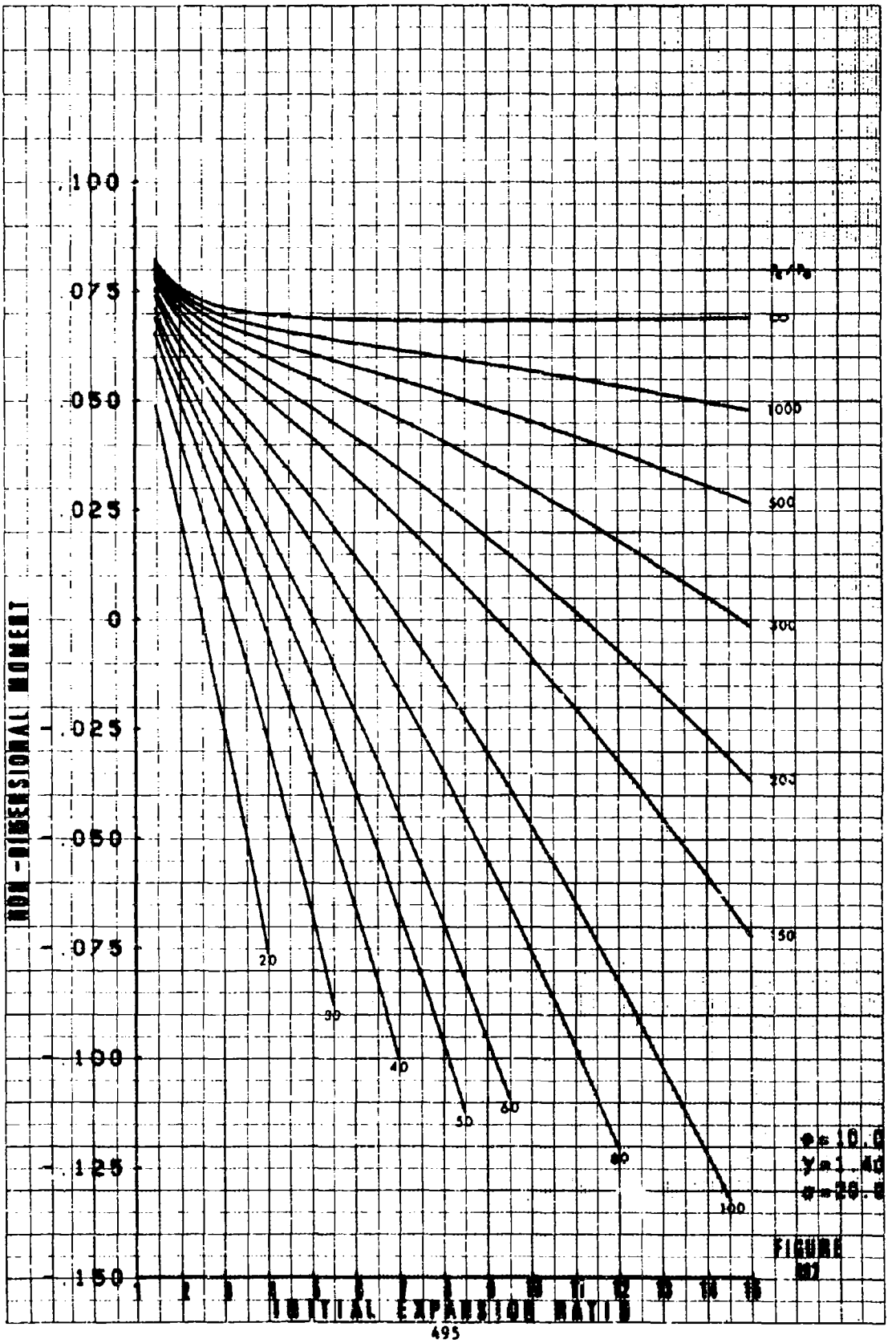
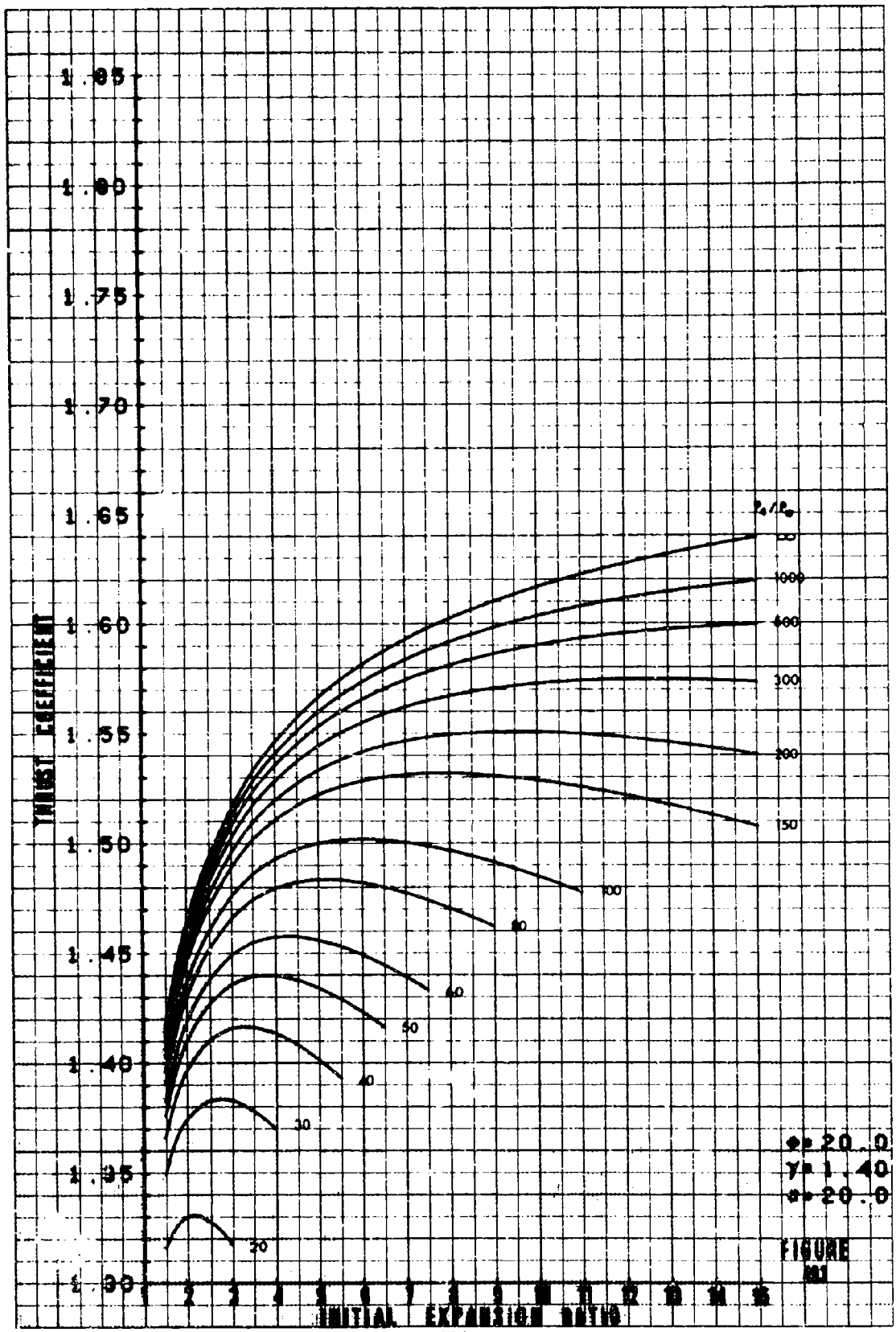
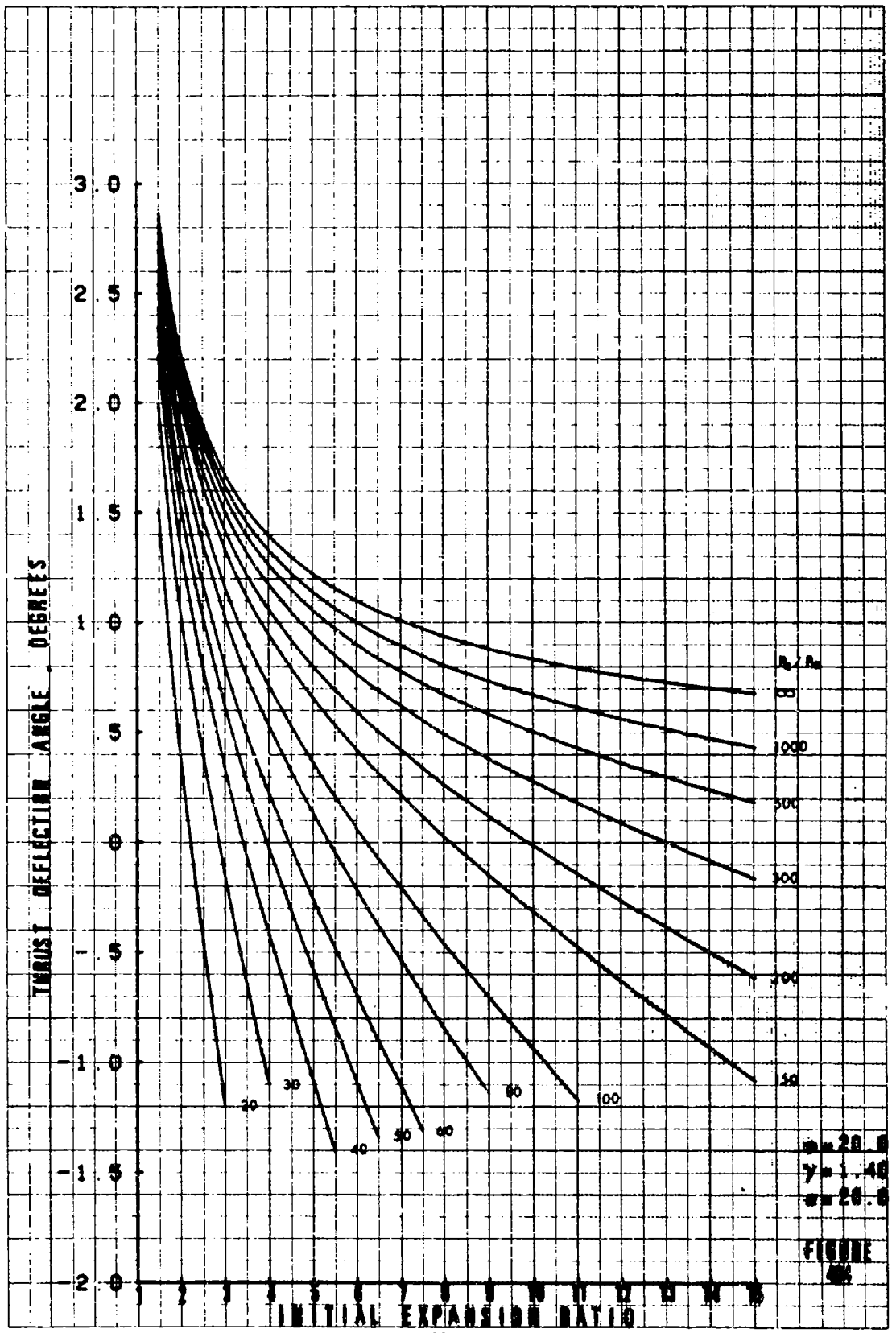

.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1000
500
300
200
150
100
80
60
50
40
30
20

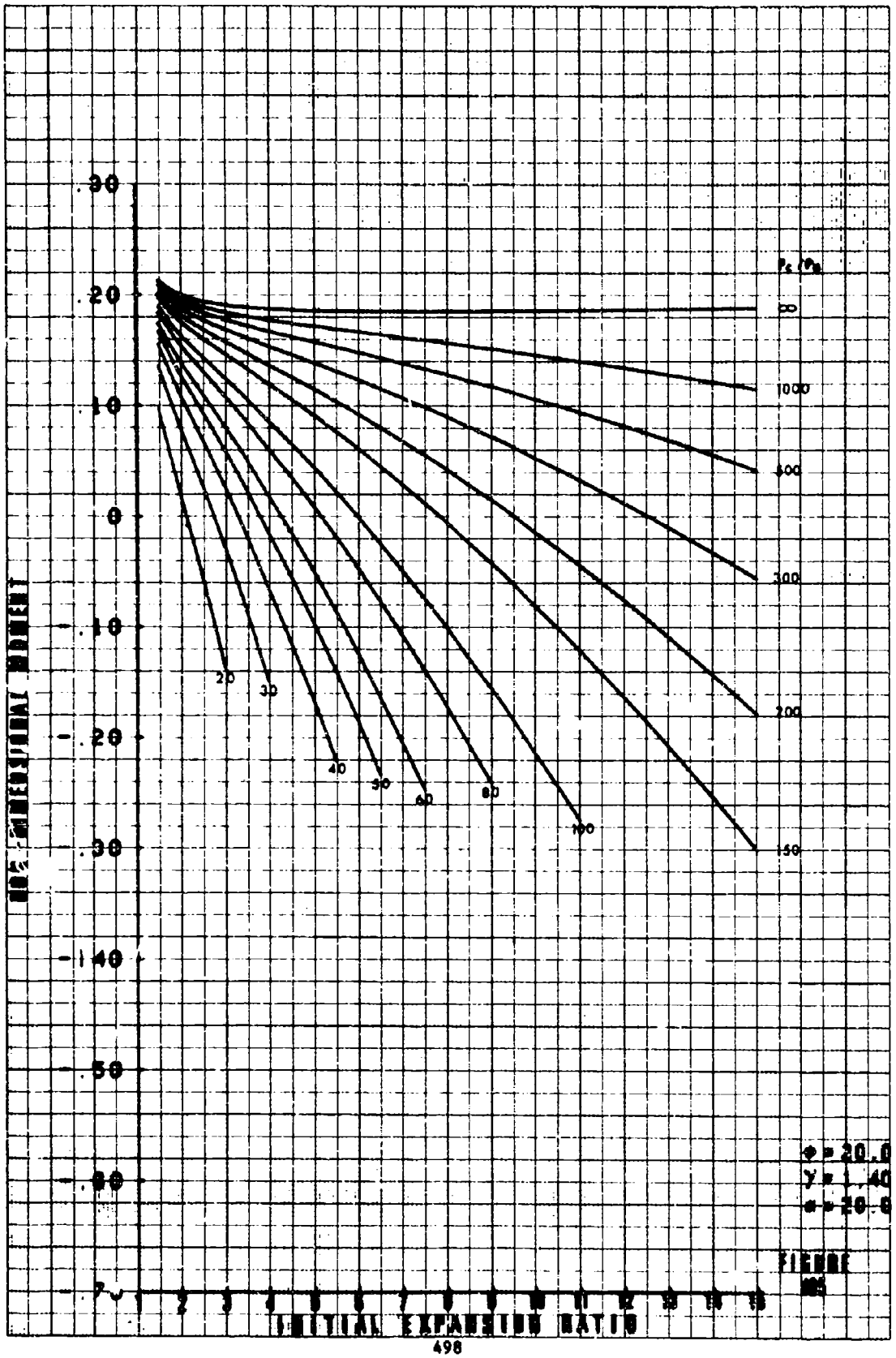
FIGURE 107

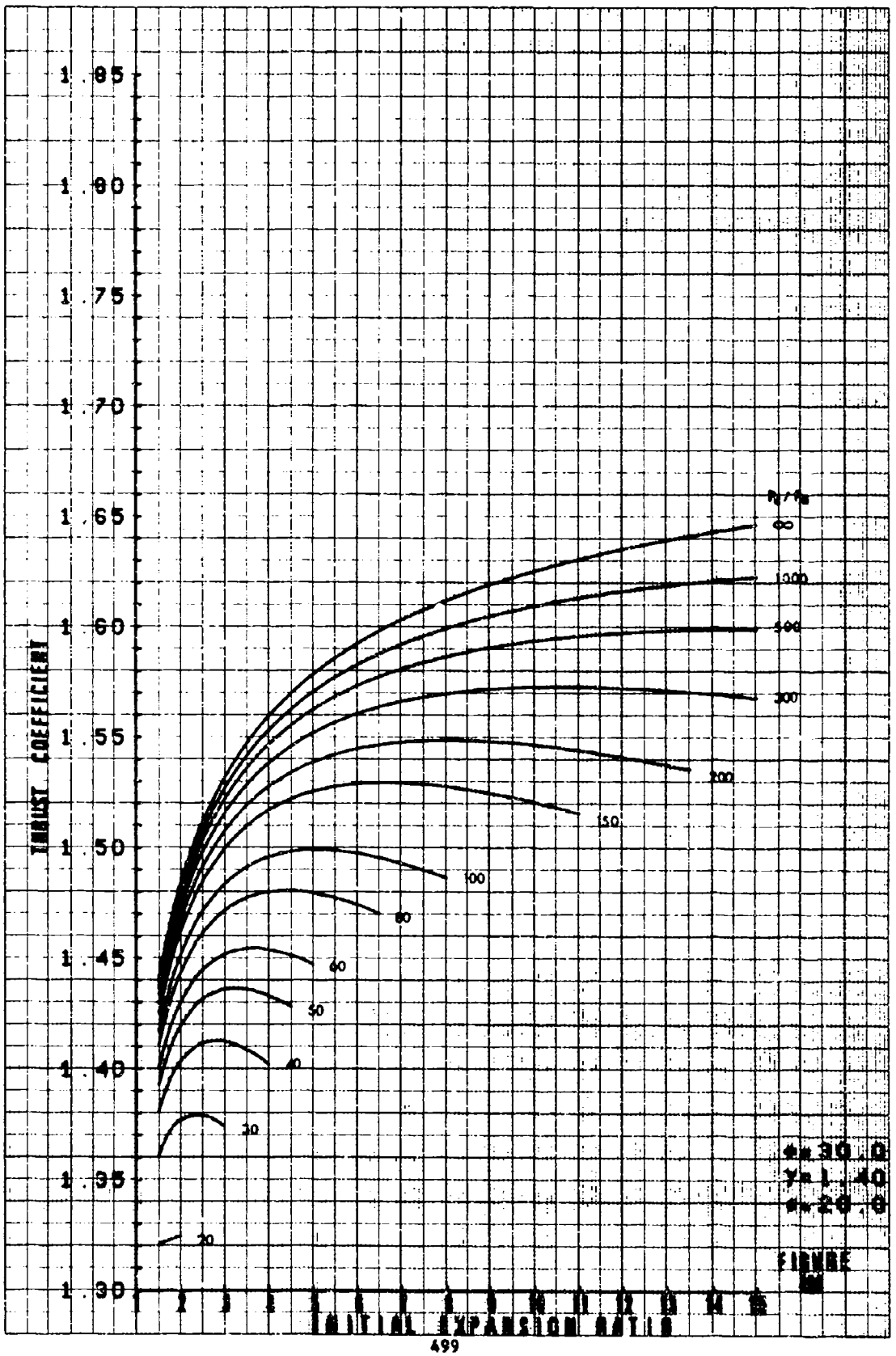


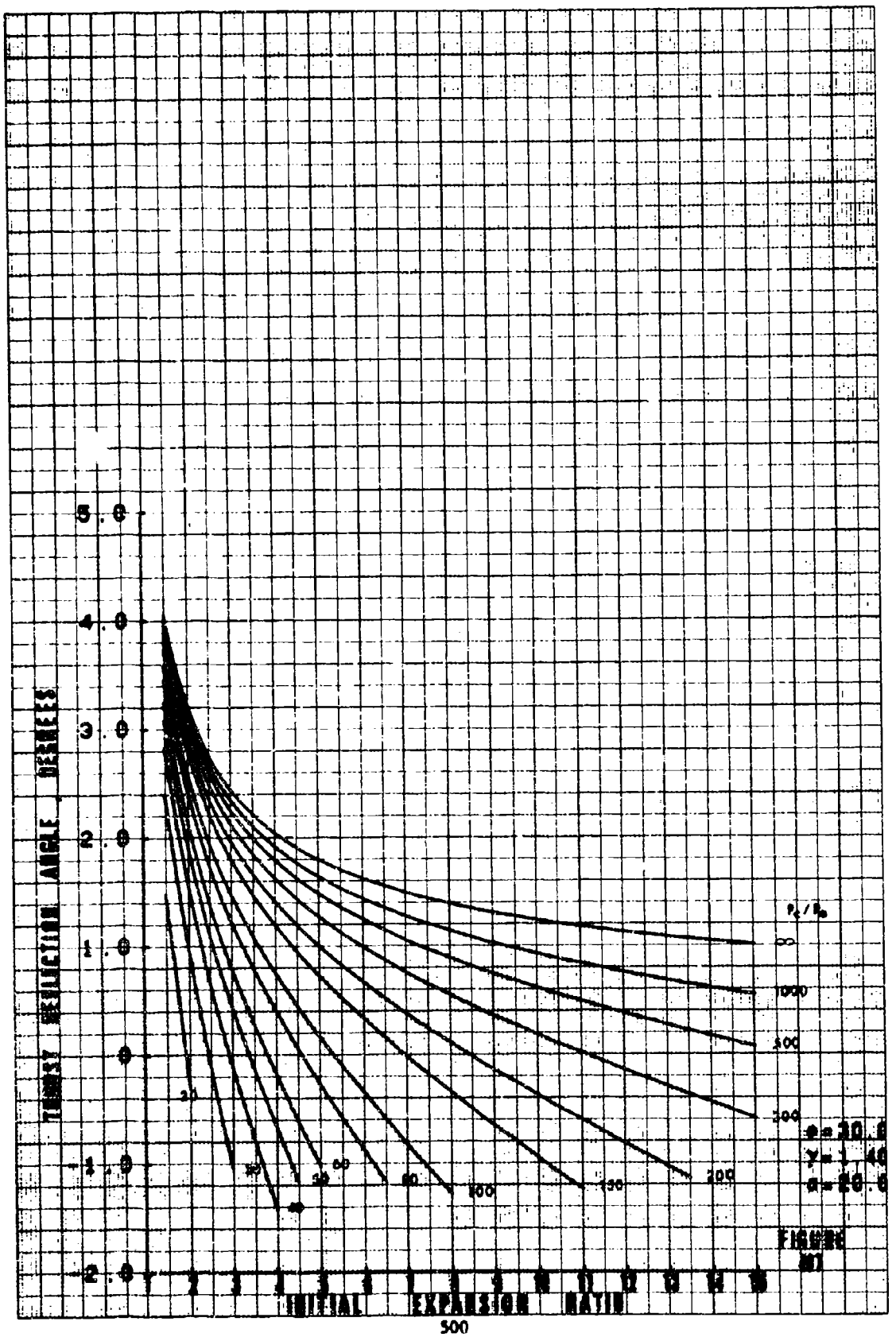
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_4/P_∞
∞
1000
600
300
200
150
100
80
60
50
40
30
20
φ = 20.0
γ = 1.40
α = 20.0

FIGURE


THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_0/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
FIGURE

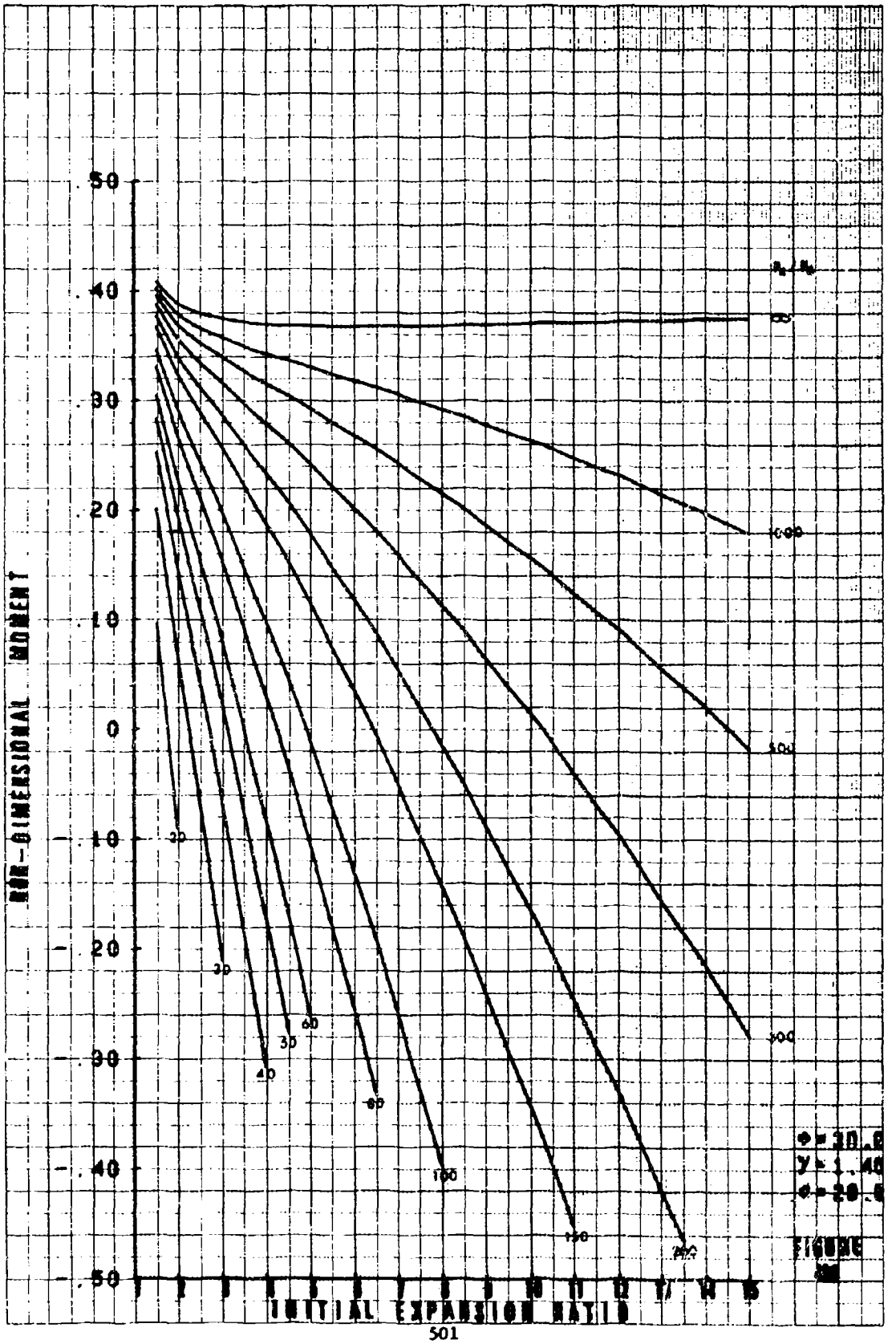

.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
20
30
40
50
60
80
100
φ = 20.0
γ = 1.40
α = 20.0
FIGURE


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50
40
30
20
γ=1.40
FIGURE



5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_o
∞
1000
500
300
200
150
100
80
60
50
40
30
20

FIGURE 87



.50
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1000
500
300
20
30
40
50
60
80
100
150
200

FIGURE

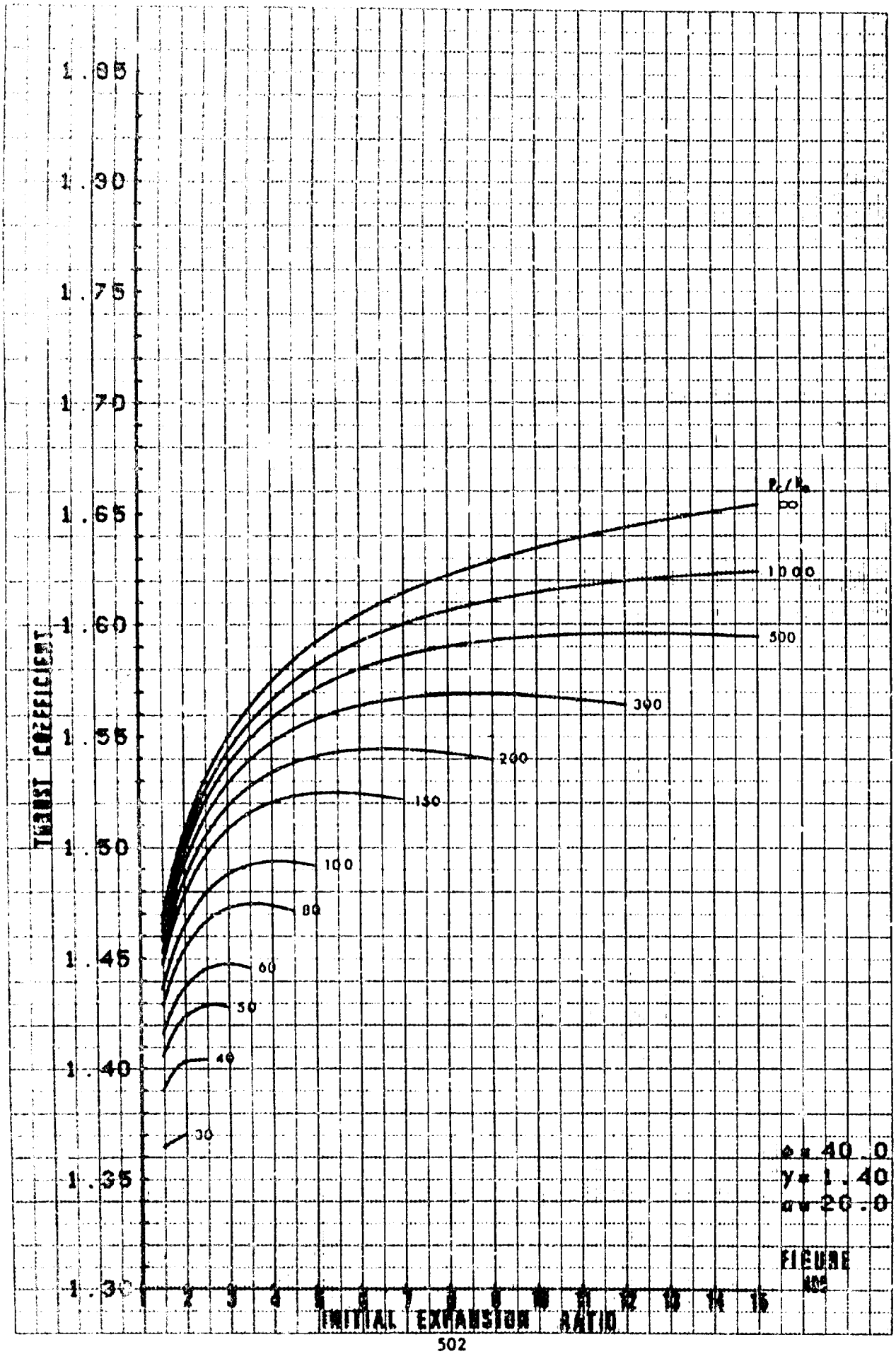

THRUST COEFFICIENT
1.95
1.90
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
ϕ = 40.0
γ = 1.40
α = 20.0

FIGURE NO.

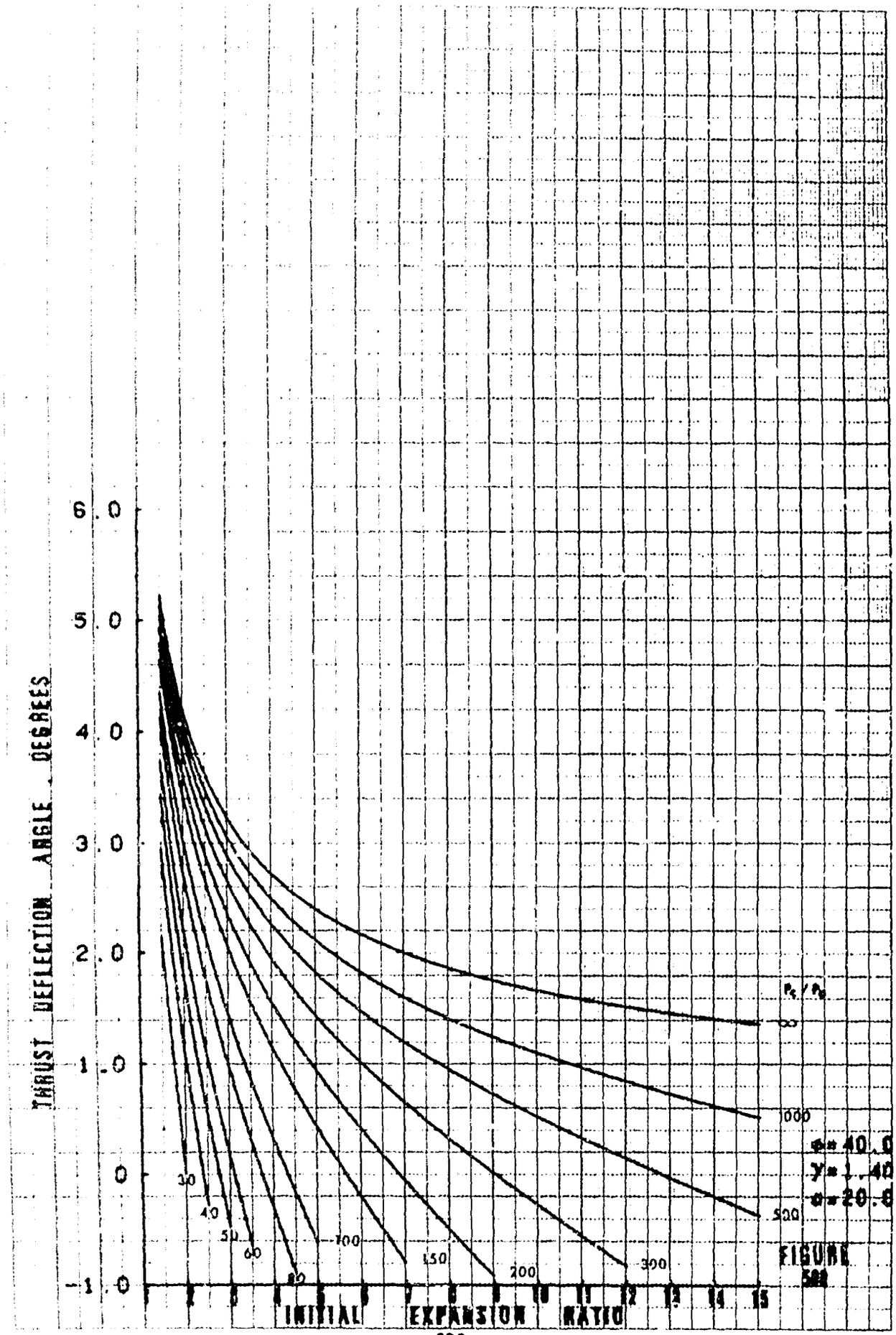

THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
300
500
1000
∞
φ = 40.0
γ = 1.40
α = 20.0

FIGURE 500

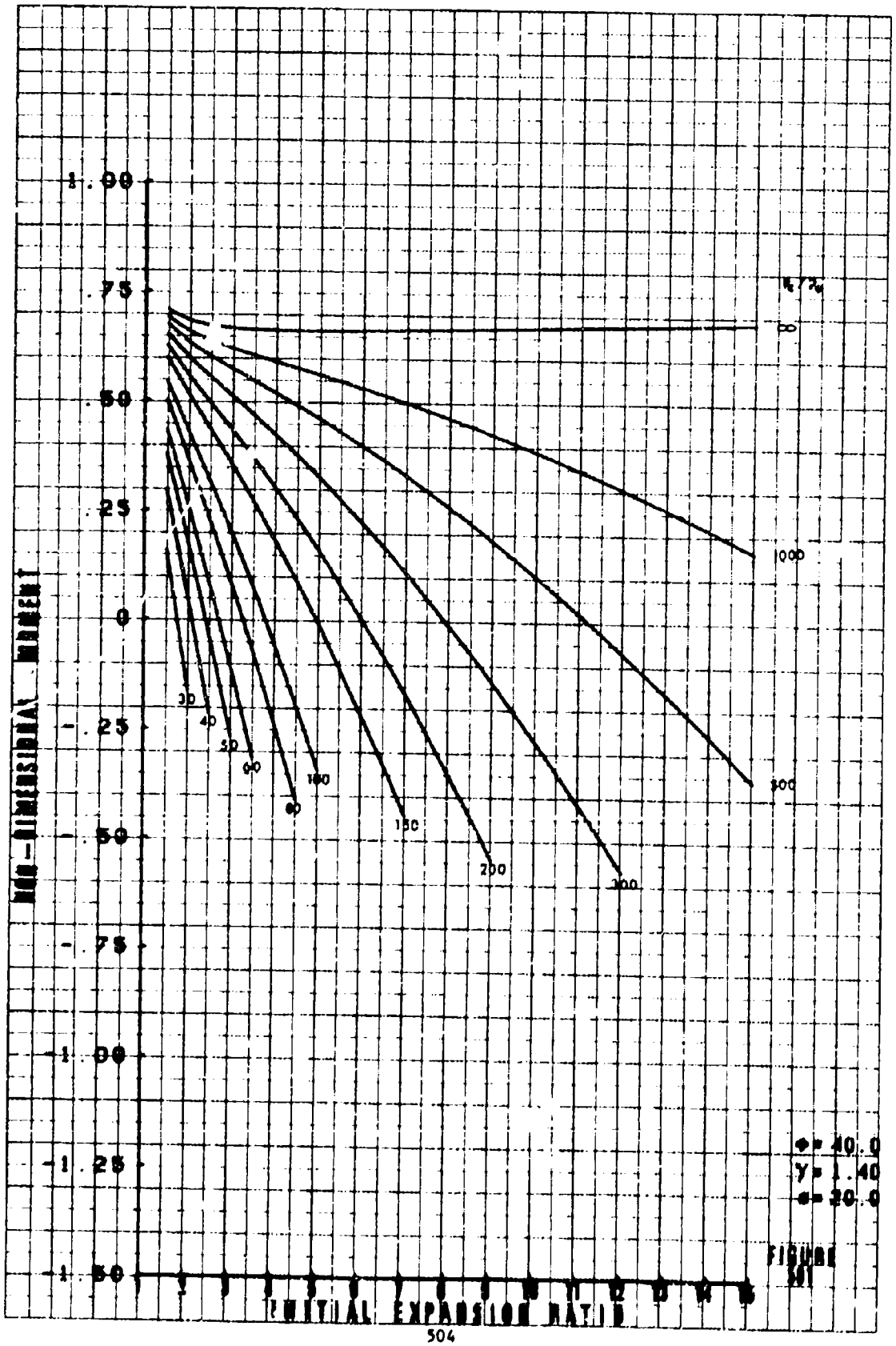

1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
30
40
50
60
80
100
150
200
300
1000
∞
φ= 40.0
γ= 1.40
α= 20.0

FIGURE 501

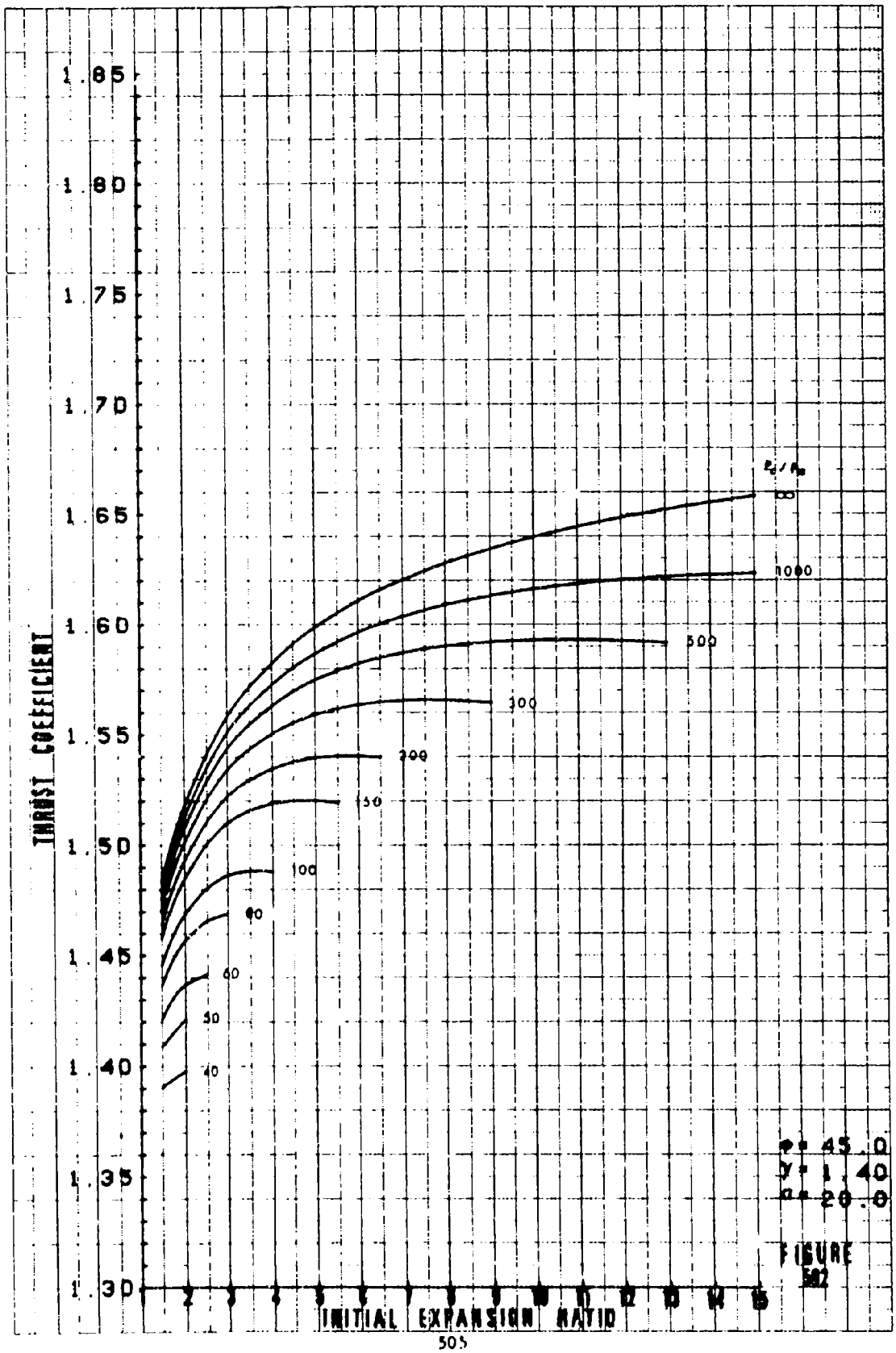
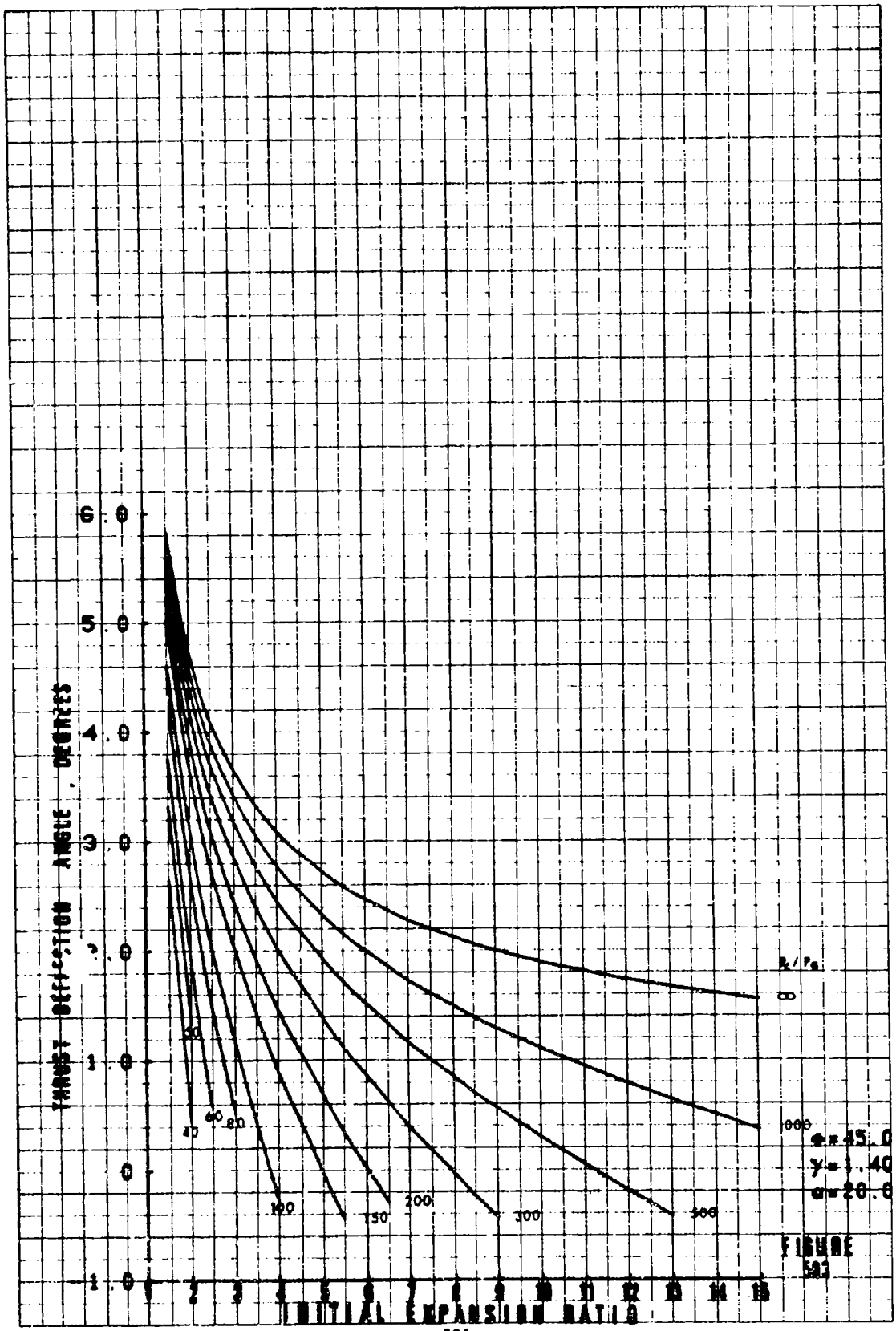

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
1000
500
300
200
150
100
80
60
50
40
φ = 45.0
γ = 1.40
α = 20.0

FIGURE 502



THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
INITIAL EXPANSION RATIO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
40
30
φ=45.0
γ=1.40
α=20.0

FIGURE 583

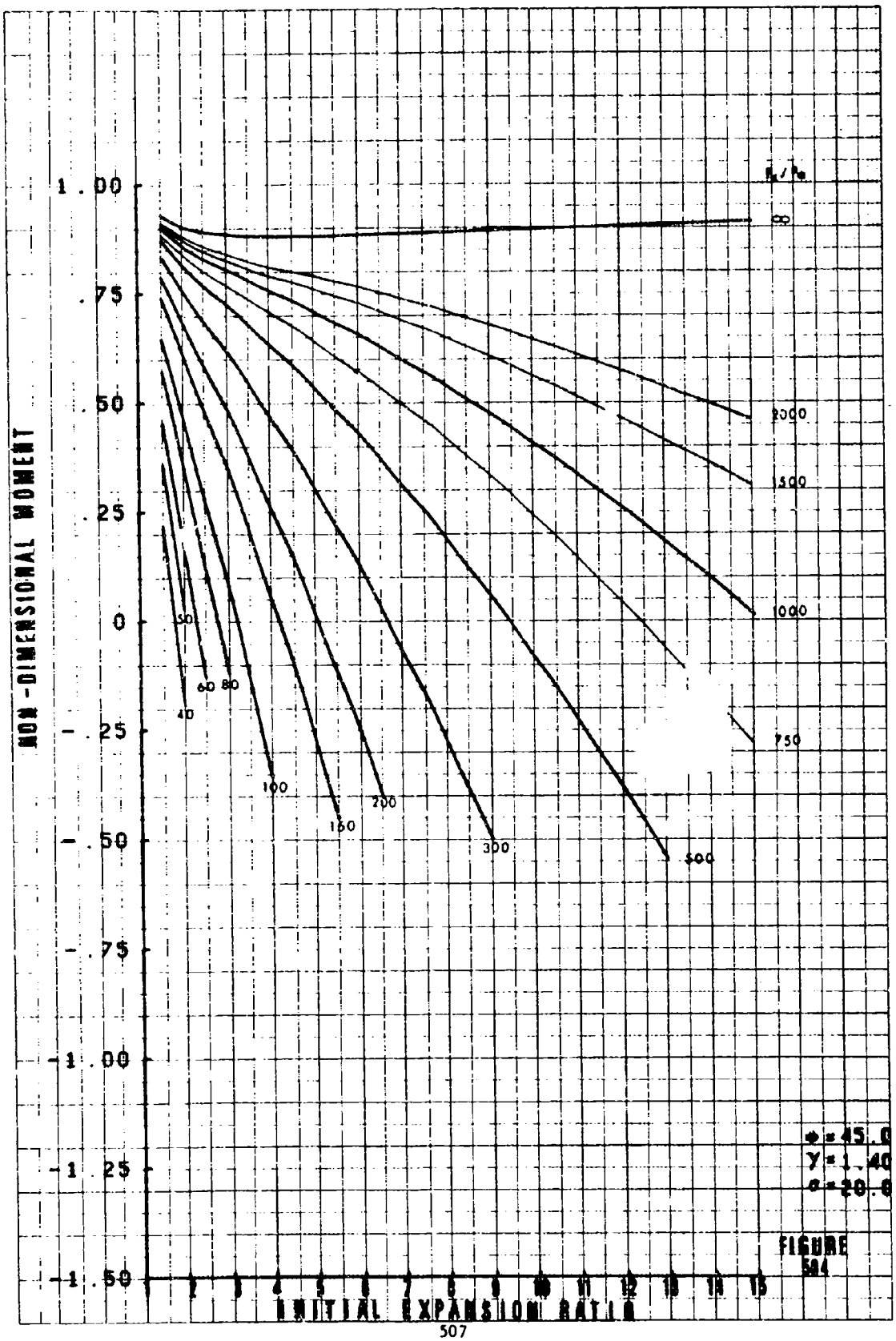

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
p_1/p_0
∞
2000
1500
1000
750
500
300
200
160
100
80
60
50
40
φ = 45.0
γ = 1.40
σ = 20.0

FIGURE 504

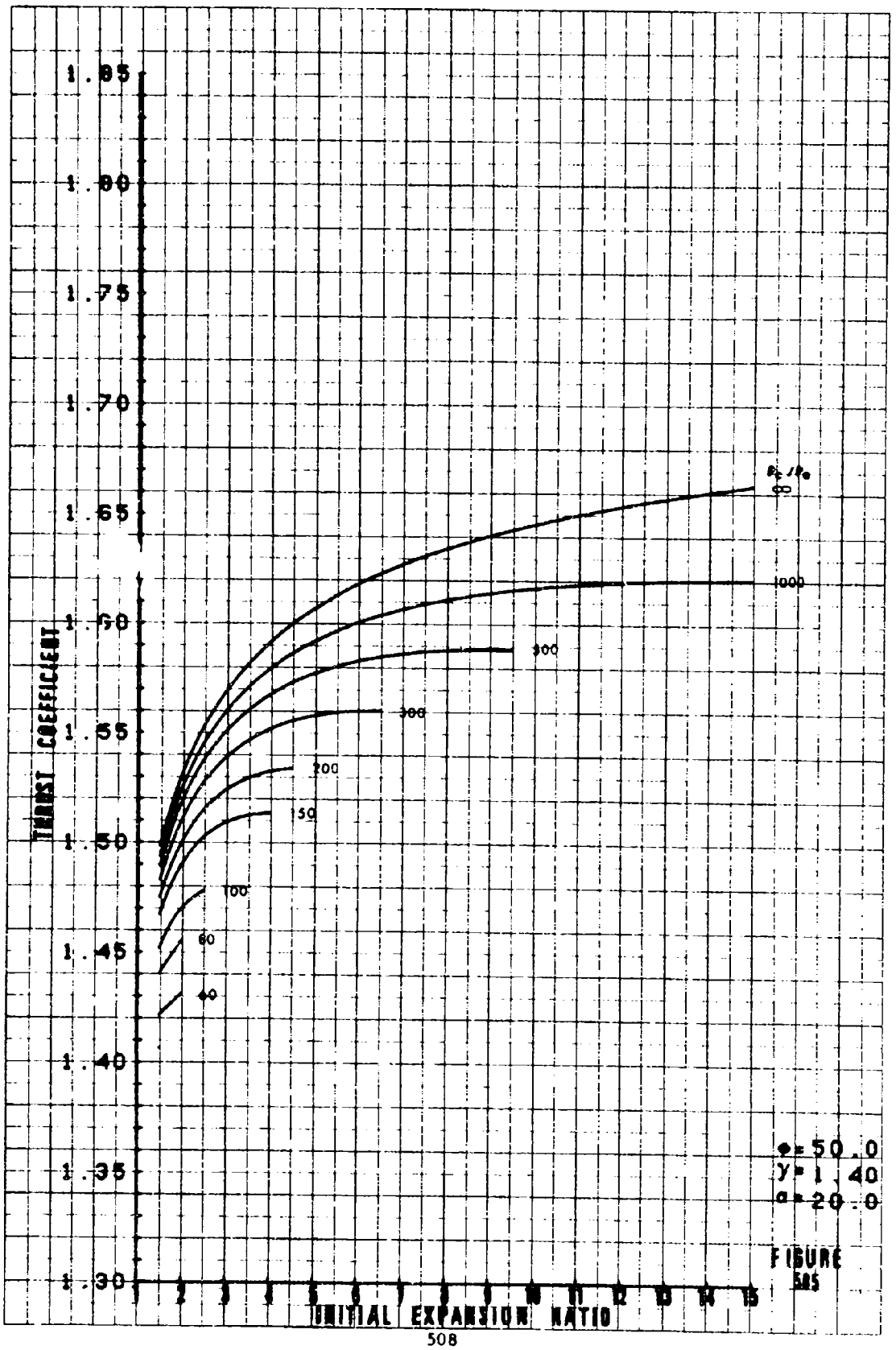

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
300
200
150
100
60
40
Φ = 50.0
γ = 1.40
α = 20.0

FIGURE 505

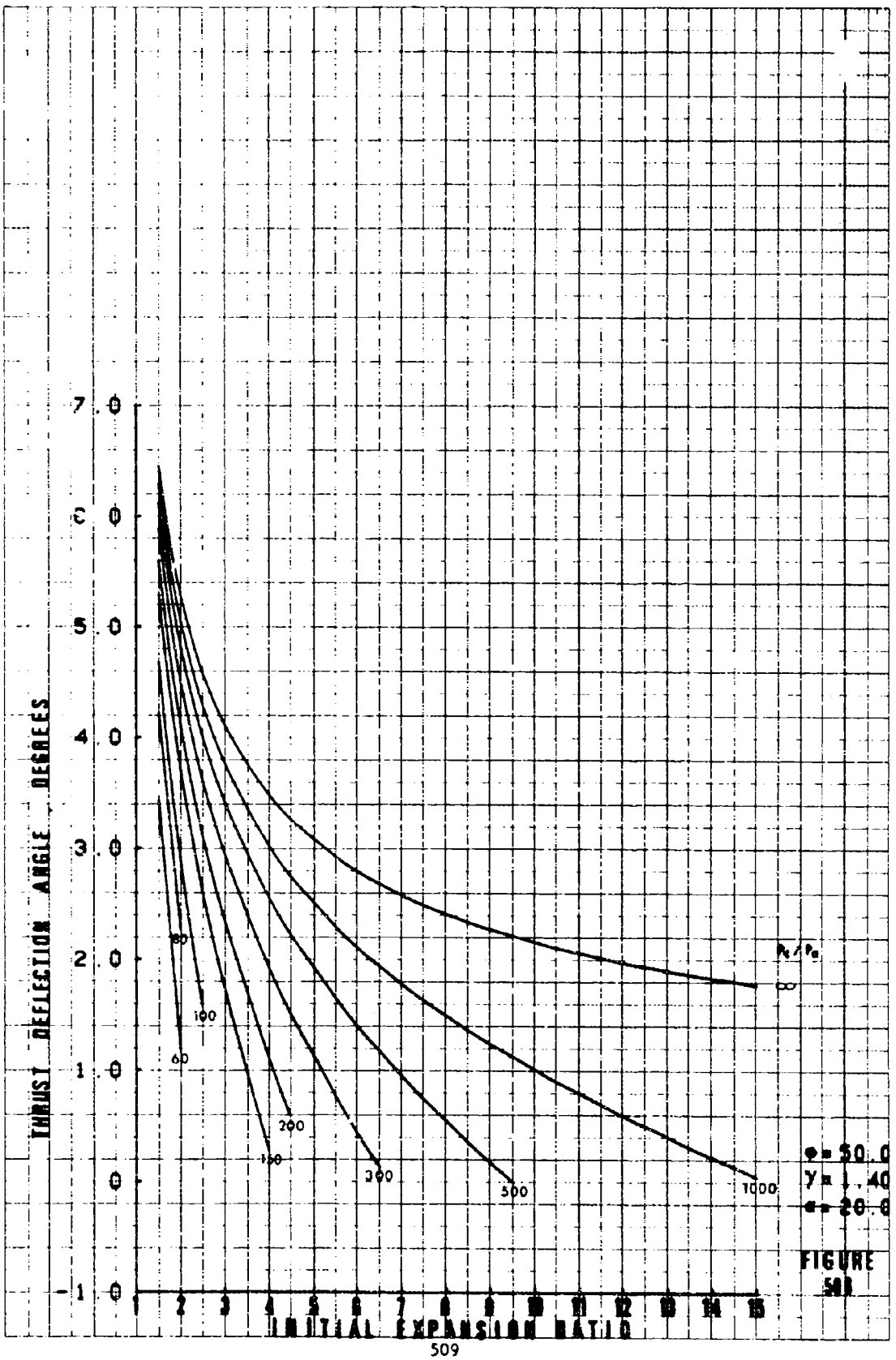
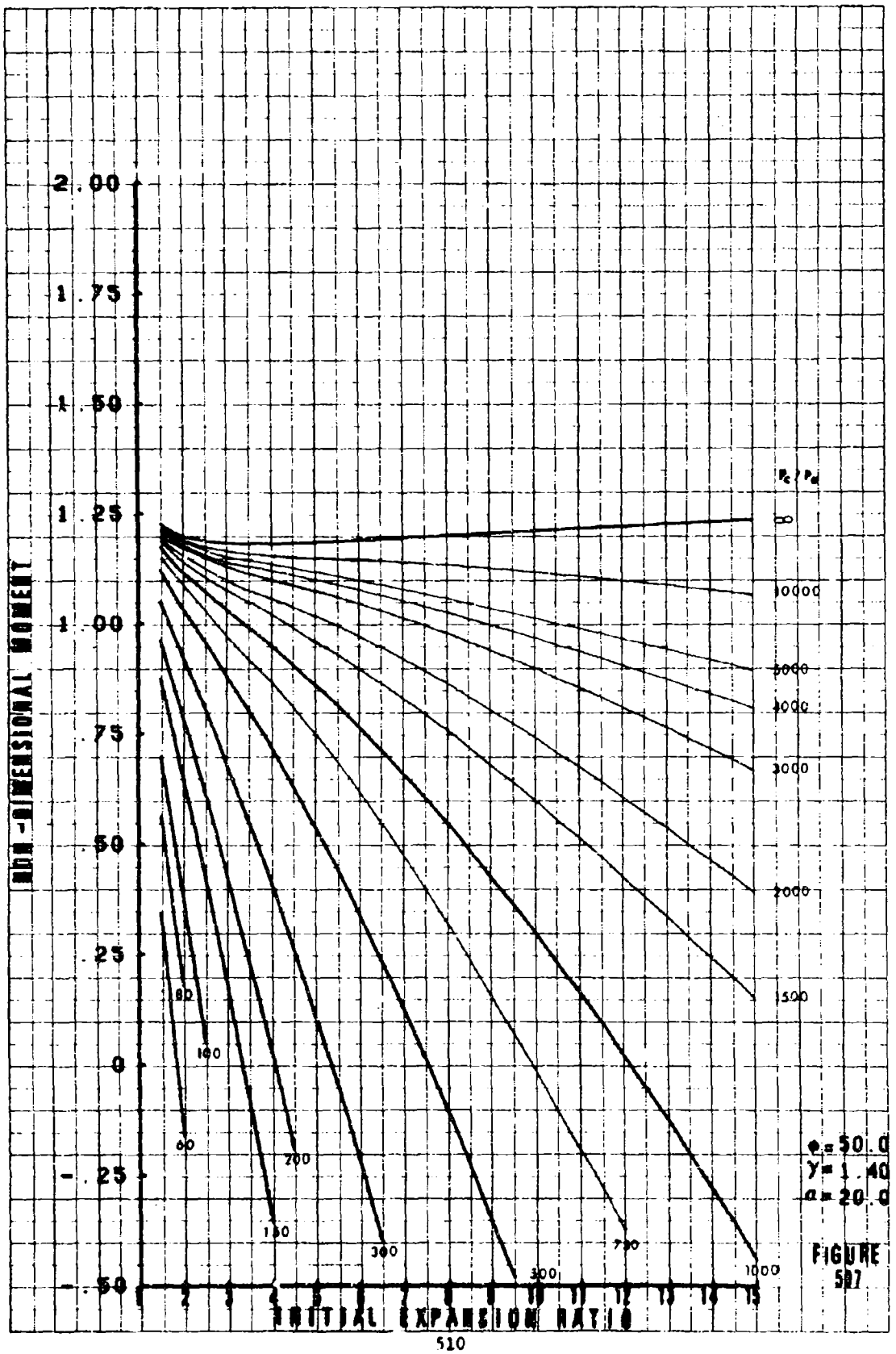
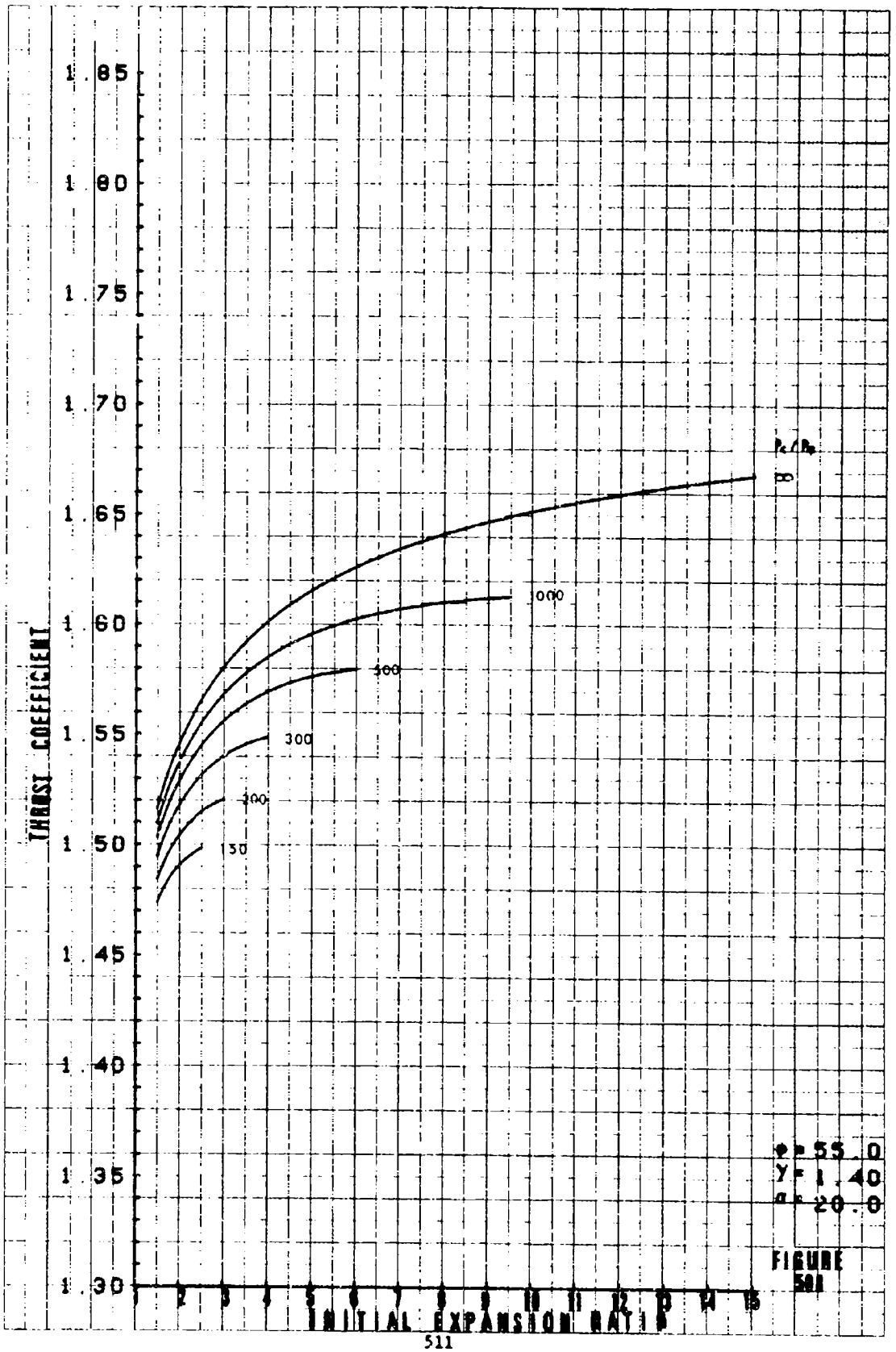

THRUST DEFLECTION ANGLE, DEGREES
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
60
80
100
150
200
300
500
1000
∞
P_t/P_a
φ = 50.0
γ = 1.40
α = 20.0

FIGURE 501



2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
10000
5000
4000
3000
2000
1500
1000
750
500
300
200
150
100
80
60
φ = 50.0
γ = 1.40
α = 20.0

FIGURE 507



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
300
200
150
φ = 55.0
γ = 1.40
α = 20.0

FIGURE 50A

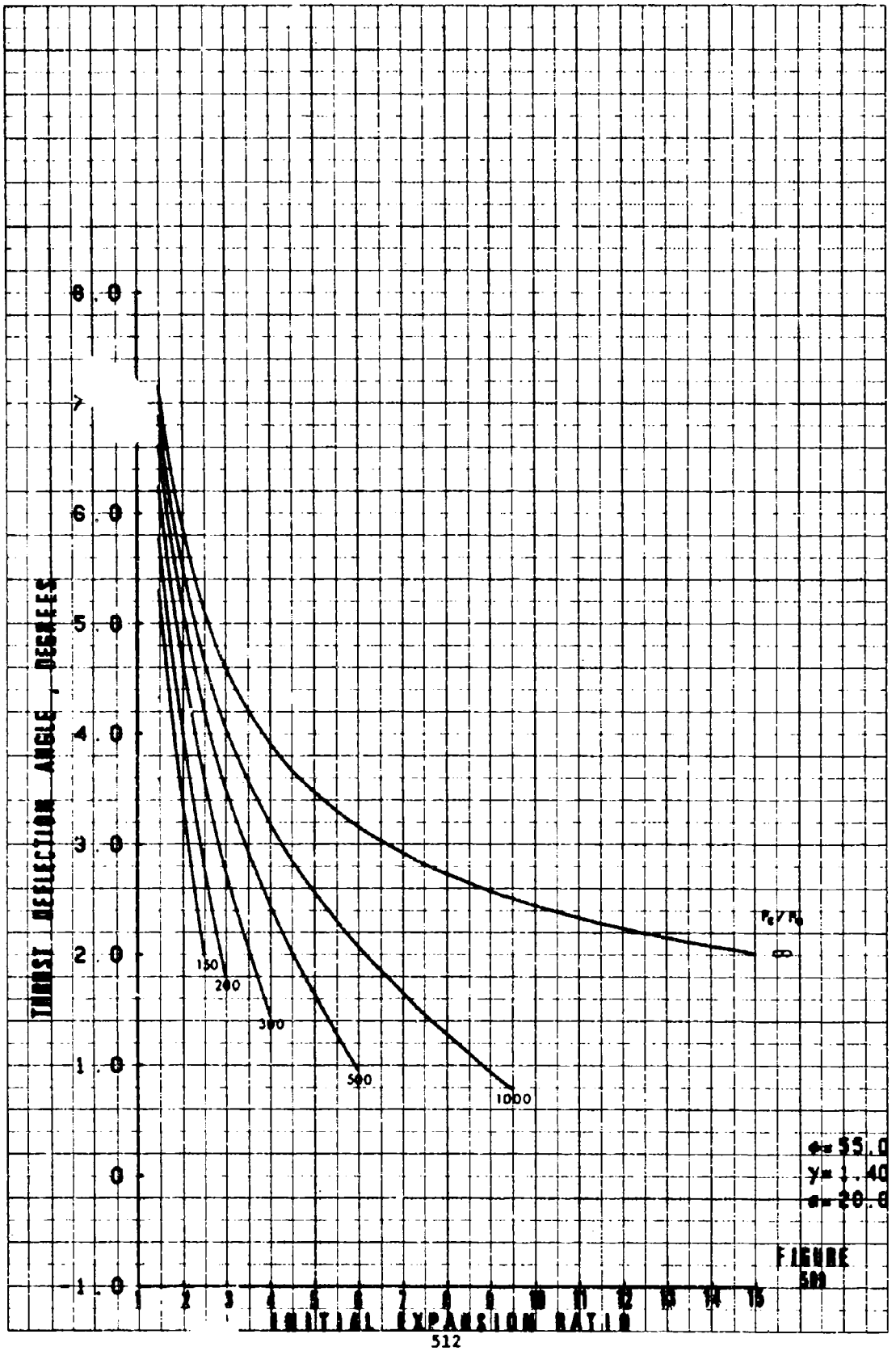

THRUST DEFLECTION ANGLE, DEGREES
8.0
7
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
150
200
300
500
1000
∞
φ=55.0
γ=1.40
α=20.0

FIGURE 509

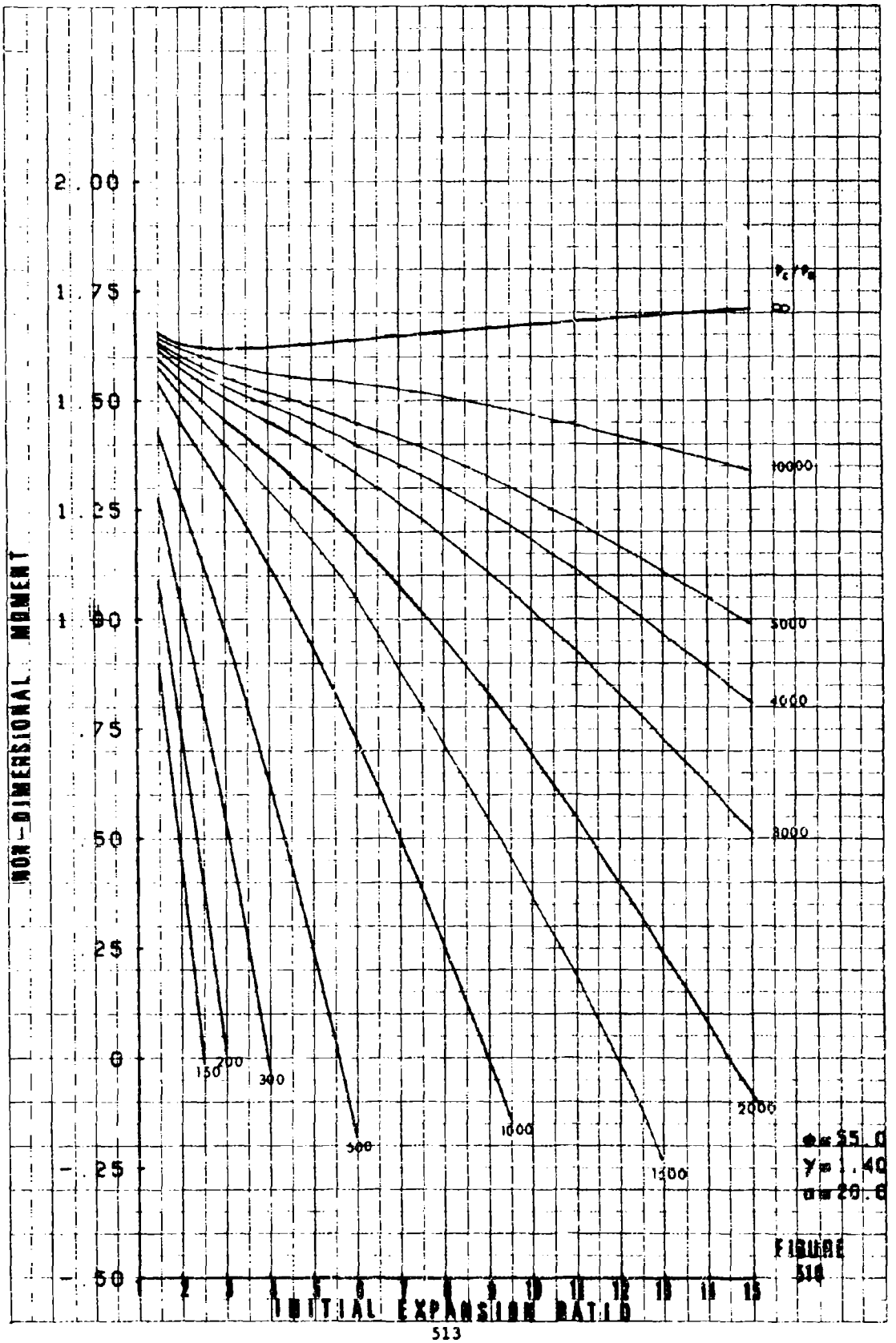

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
2
3
4
5
6
7
8
9
10
11
12
13
14
15
p_c/p_a
∞
10000
5000
4000
3000
2000
1500
1000
500
300
200
150
$\phi = 55.0$
$\gamma = 1.40$
$\alpha = 20.0$

FIGURE 51A

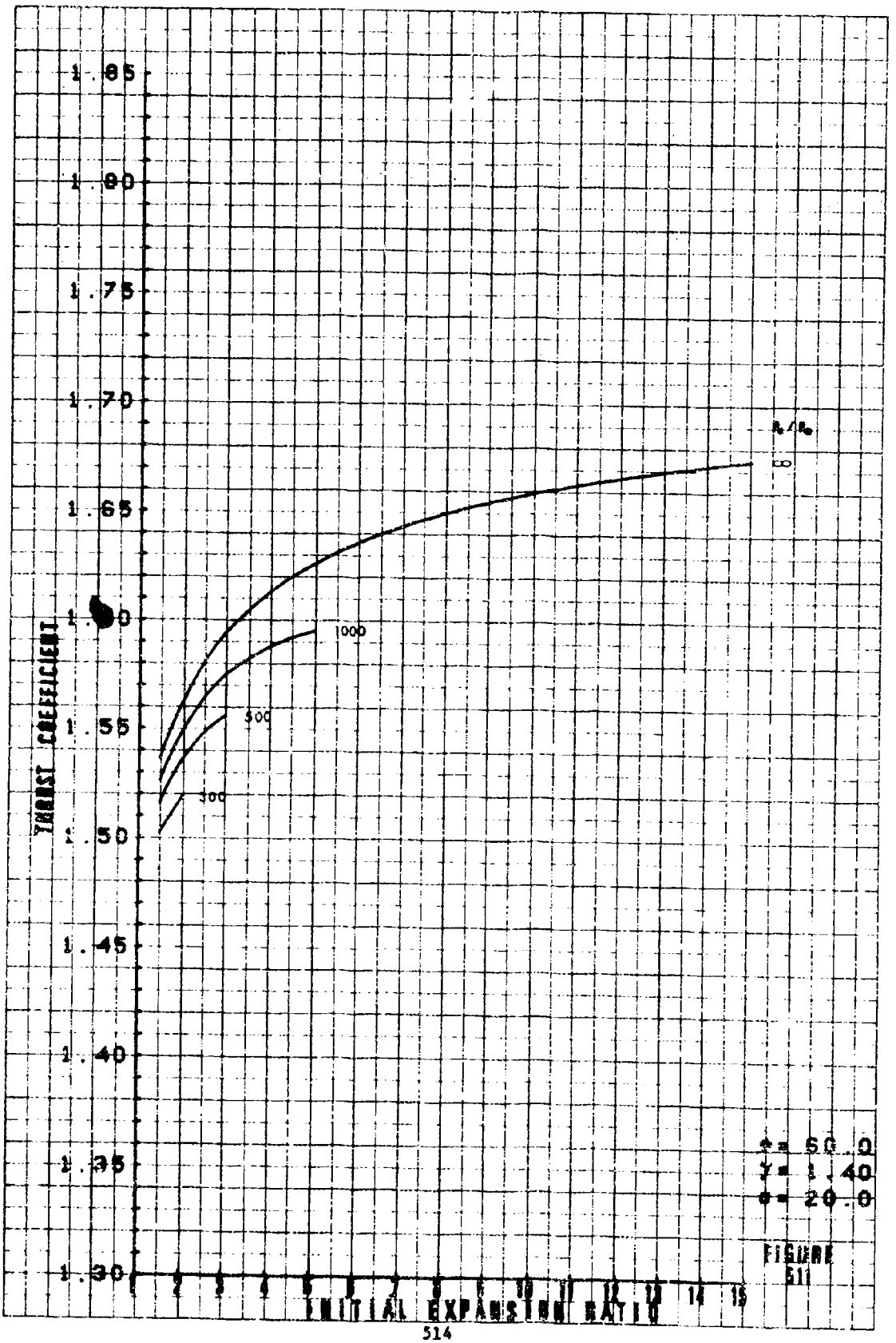

1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1000
500
300
∞
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
= 50.0
= 1.40
= 20.0

FIGURE 511

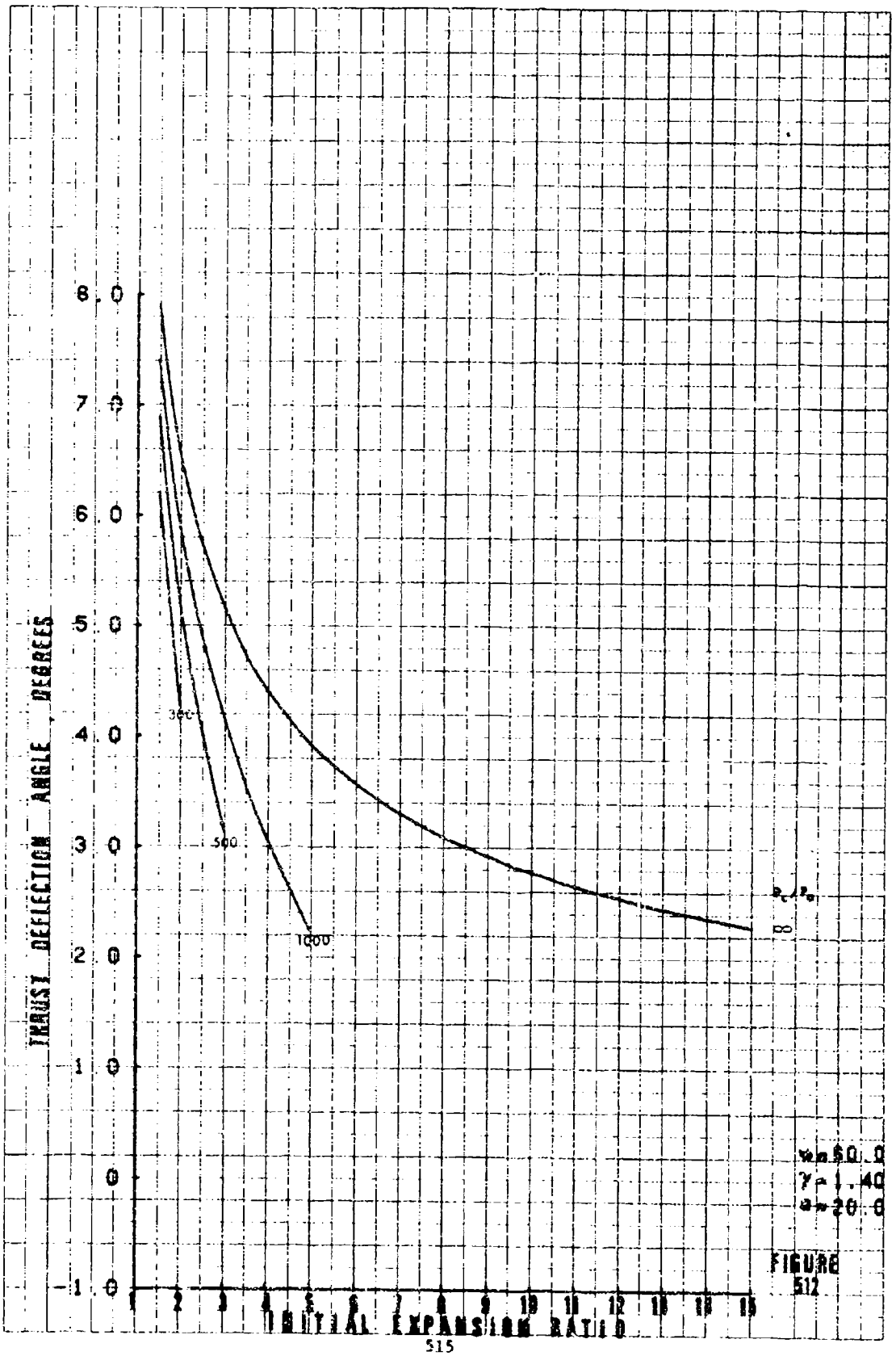
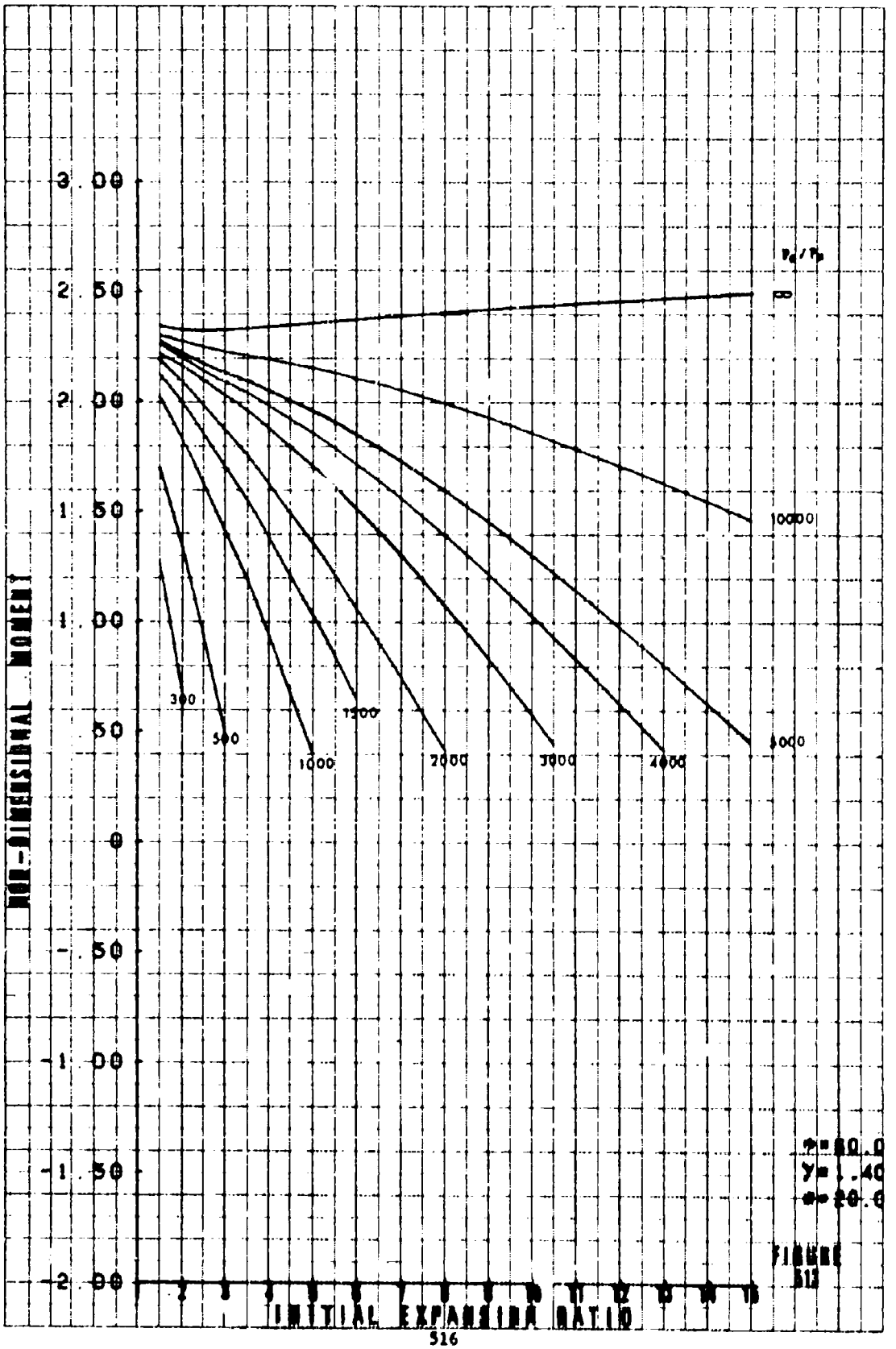

THRUST DEFLECTION ANGLE, DEGREES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
300
500
1000
P_c/P_o
∞
ω = 50.0
γ = 1.40
α = 20.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 512


NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
-1.50
-2.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_d/P_s
∞
10000
5000
4000
3000
2000
1500
1000
500
300
FIGURE
512

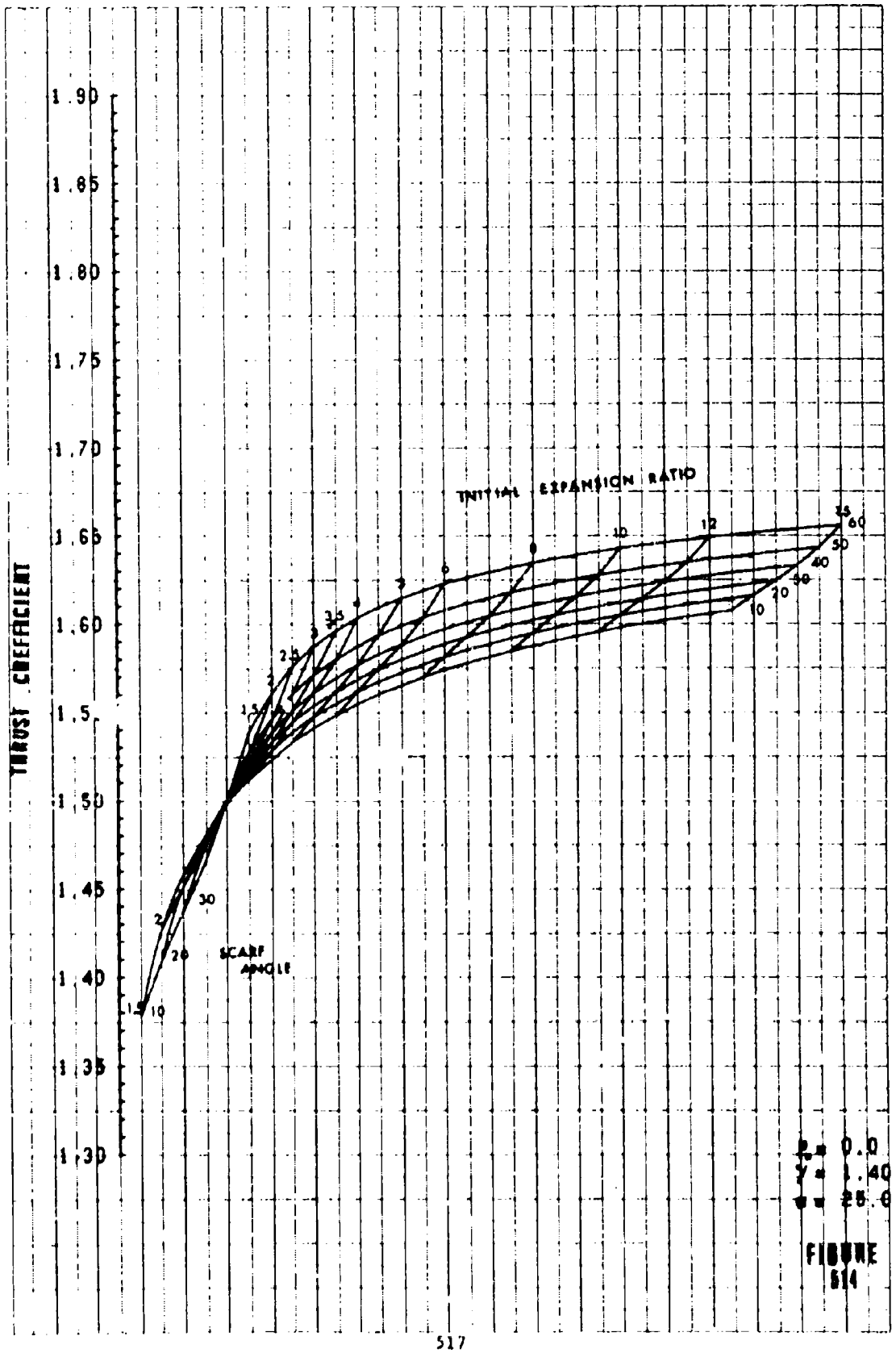

THRUST COEFFICIENT
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.5
1.50
1.45
1.40
1.35
1.30
INITIAL EXPANSION RATIO
SCARF ANGLE
γ = 1.40

FIGURE 514

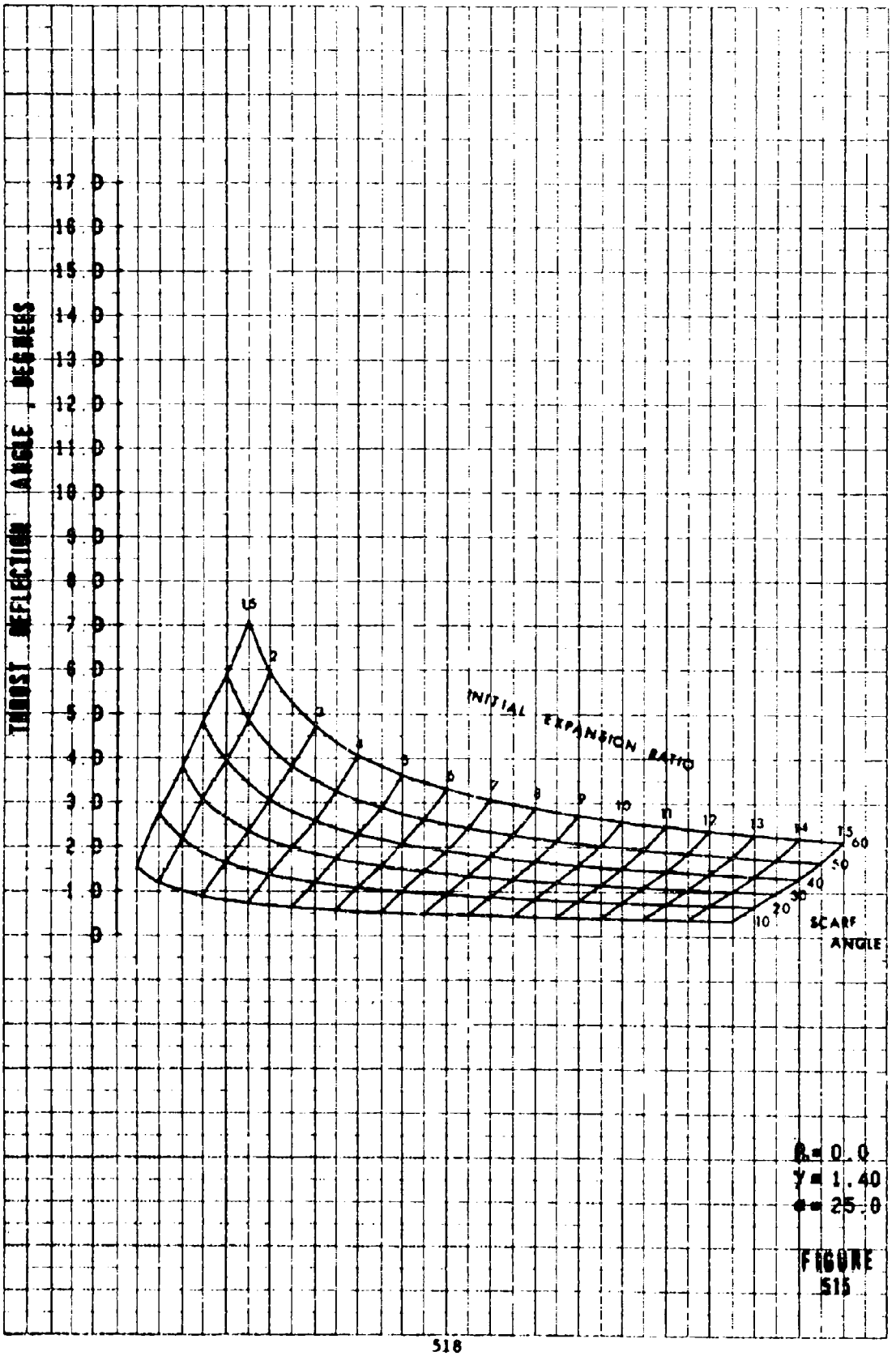

THRUST DEFLECTION ANGLE, DEGREES
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
SCARF ANGLE
10
20
30
40
50
60
R = 0.0
γ = 1.40
ε = 25.0

FIGURE 515

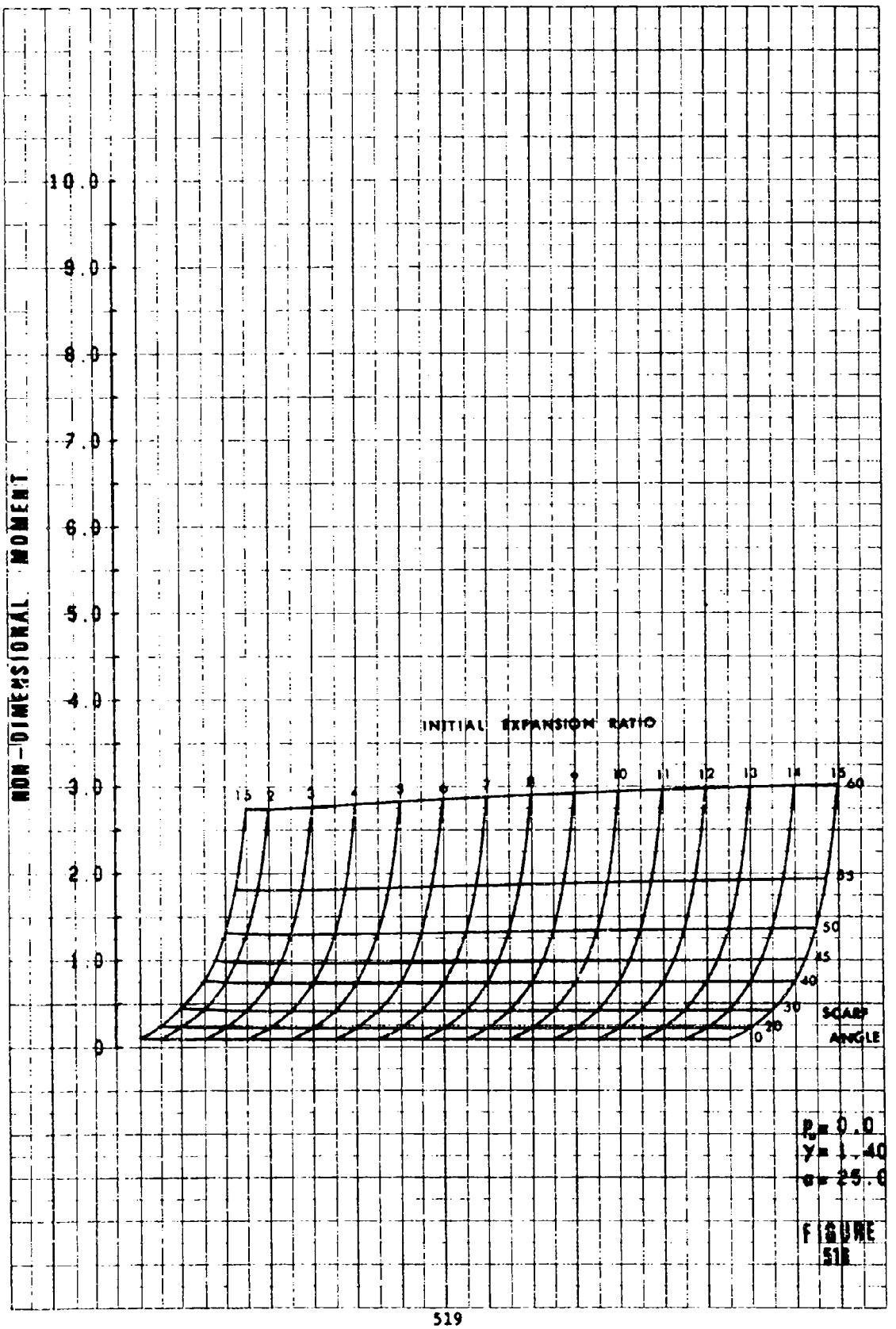

NON-DIMENSIONAL MOMENT
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
INITIAL EXPANSION RATIO
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60
55
50
45
40
35
30
20
0
SCARF ANGLE
P_o = 0.0
γ = 1.40
σ = 25.0

FIGURE 51E

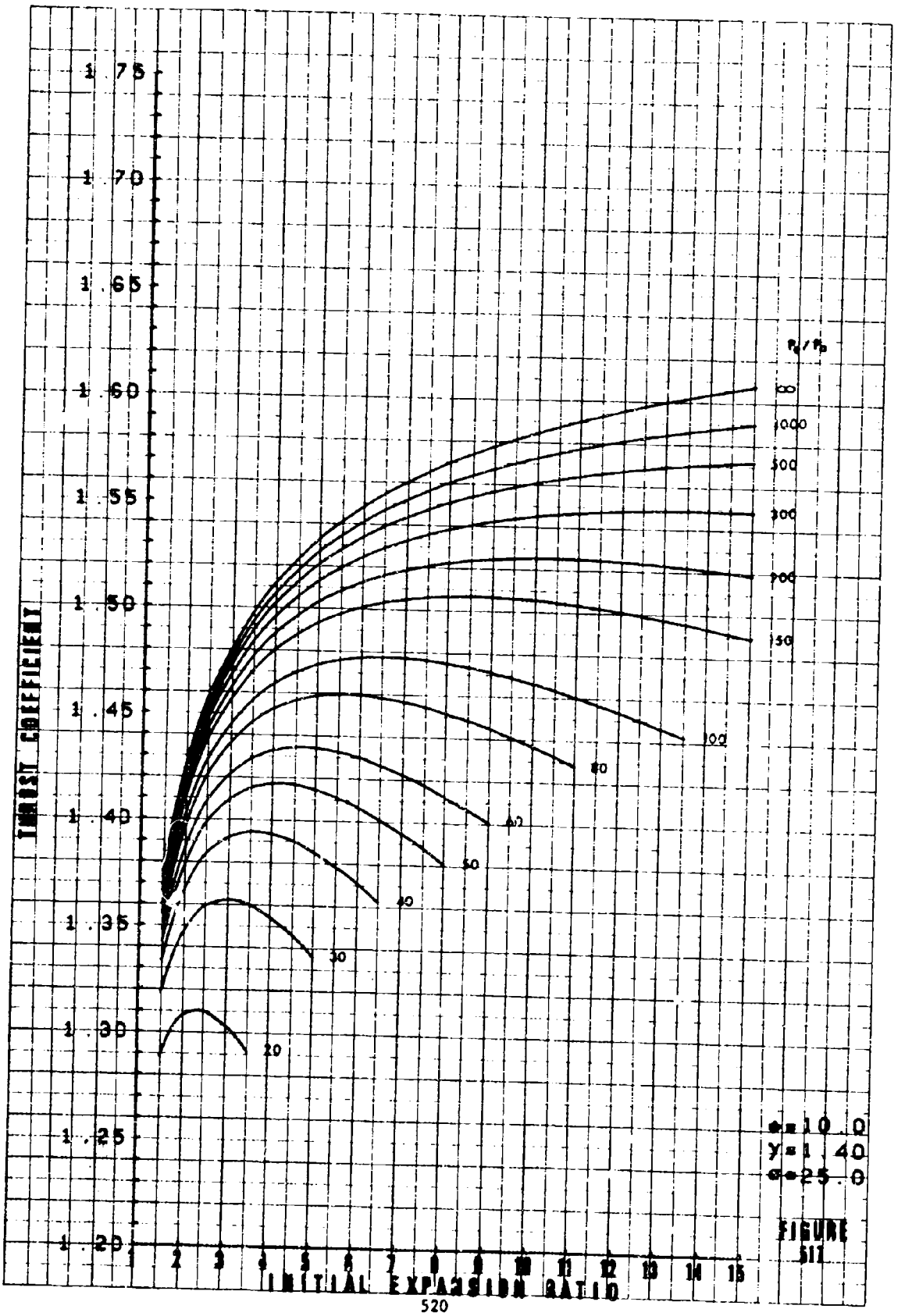

THRUST COEFFICIENT
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
ε=10.0
γ=1.40
α=25.0

FIGURE 511

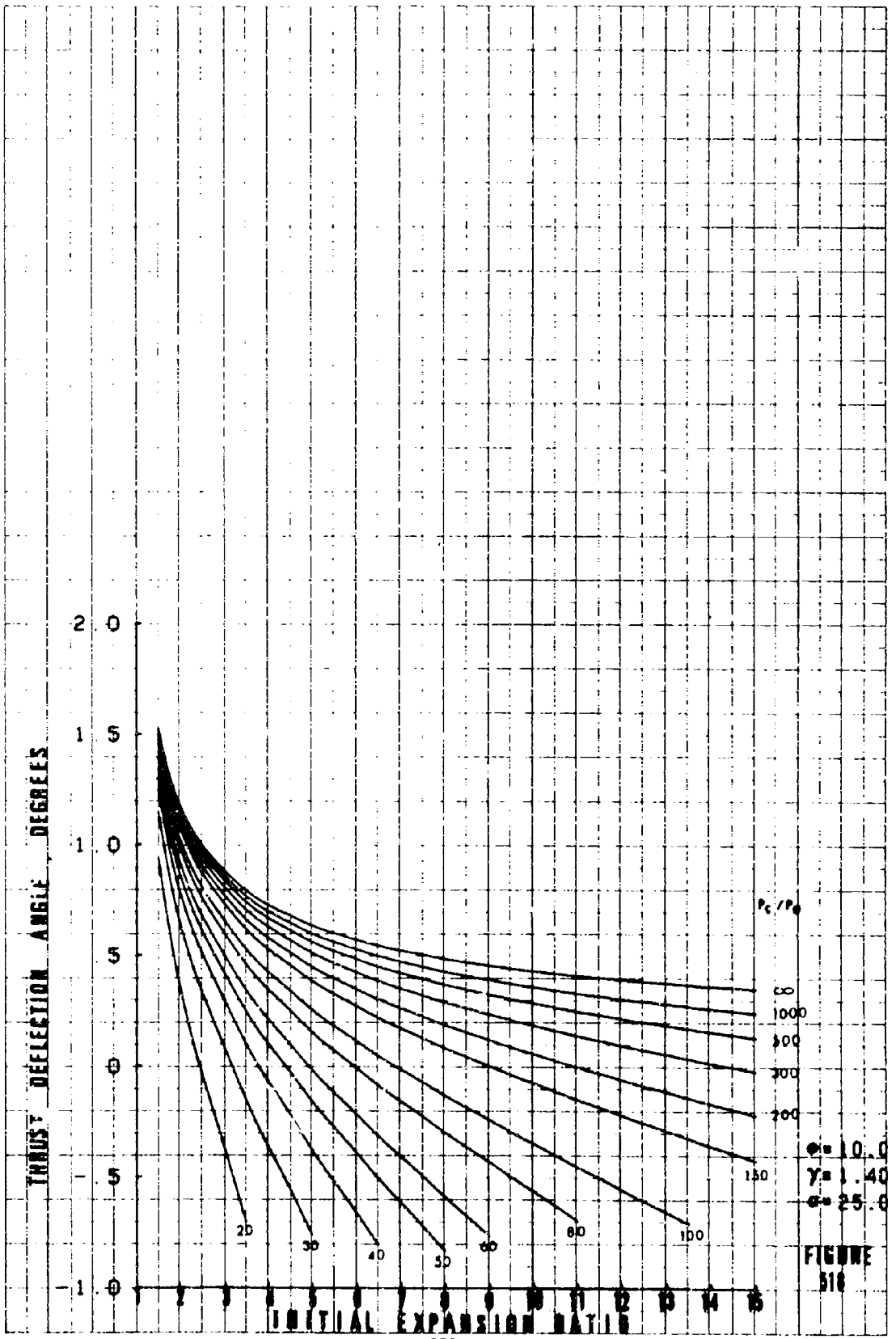
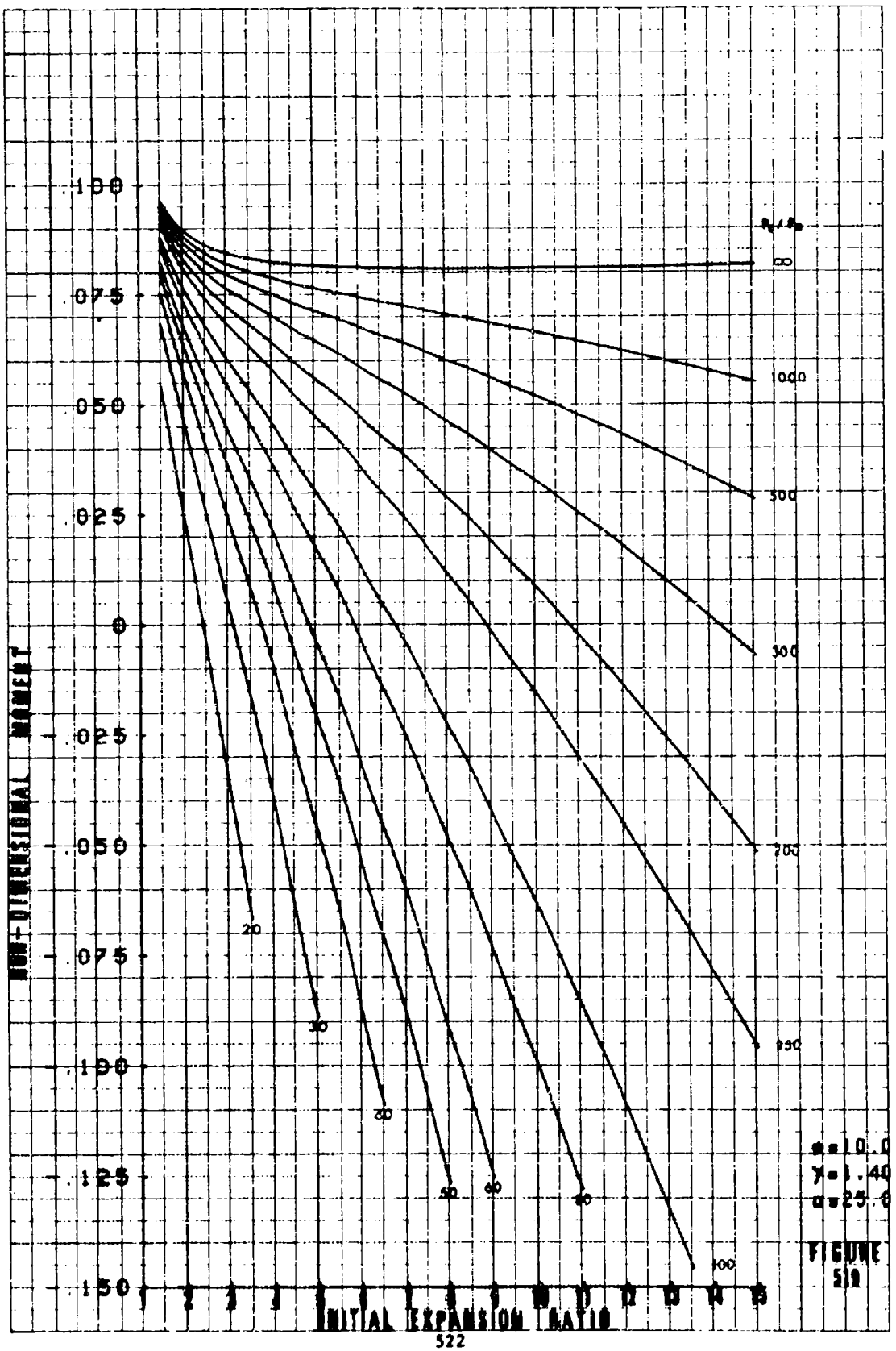
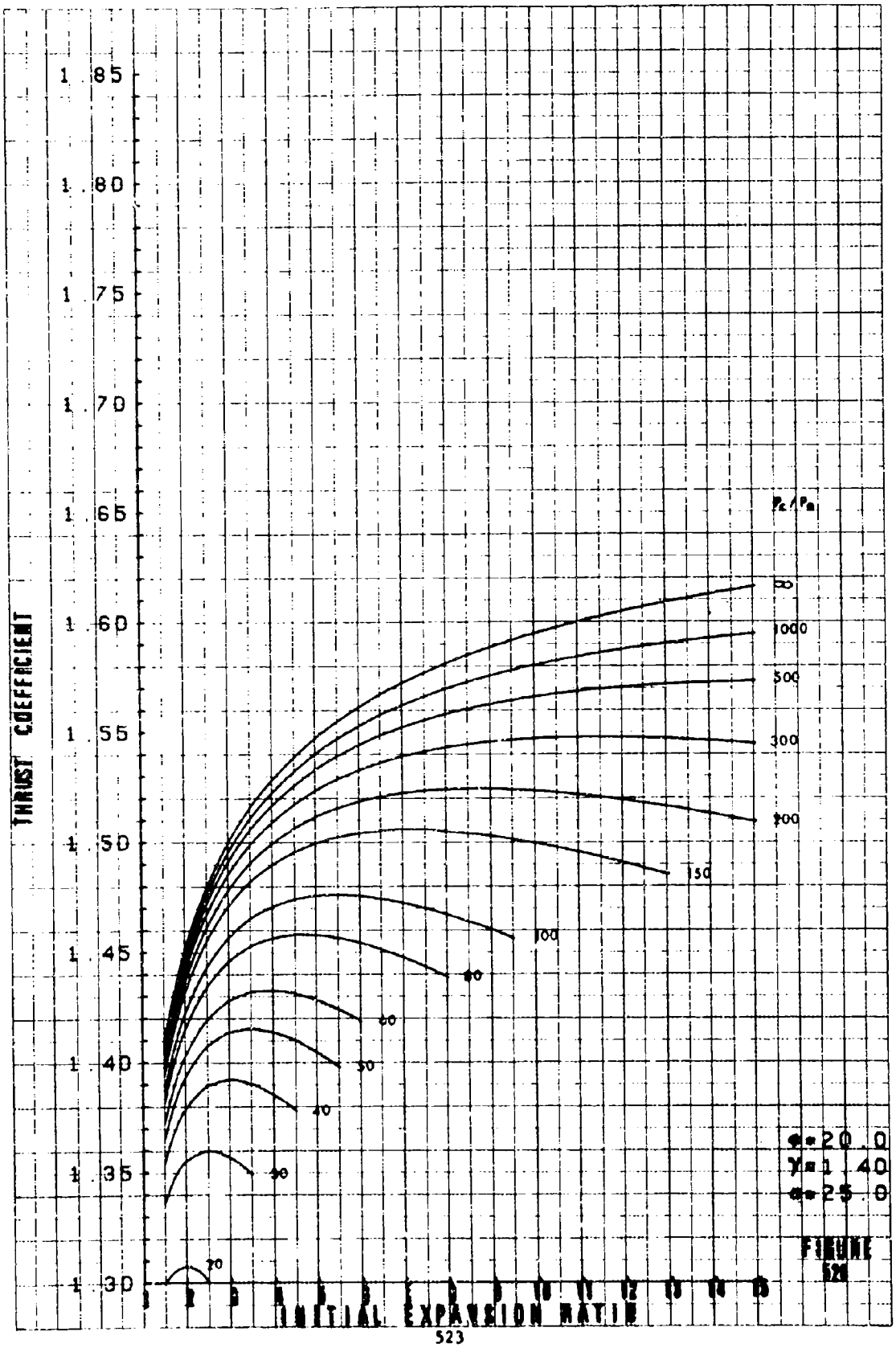

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ= 10.0
γ= 1.40
α= 25.0

FIGURE 518



.100
.075
.050
.025
0
-.025
-.050
-.075
-.100
-.125
-.150
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
20
30
40
50
60
80
α=10.0
γ=1.40
α=25.0

FIGURE 519



THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
P_c/P_a
∞
1000
500
300
200
150
100
80
60
50
40
30
20
φ=20.0
γ=1.40
α=25.0
INITIAL EXPANSION RATIO

FIGURE 526

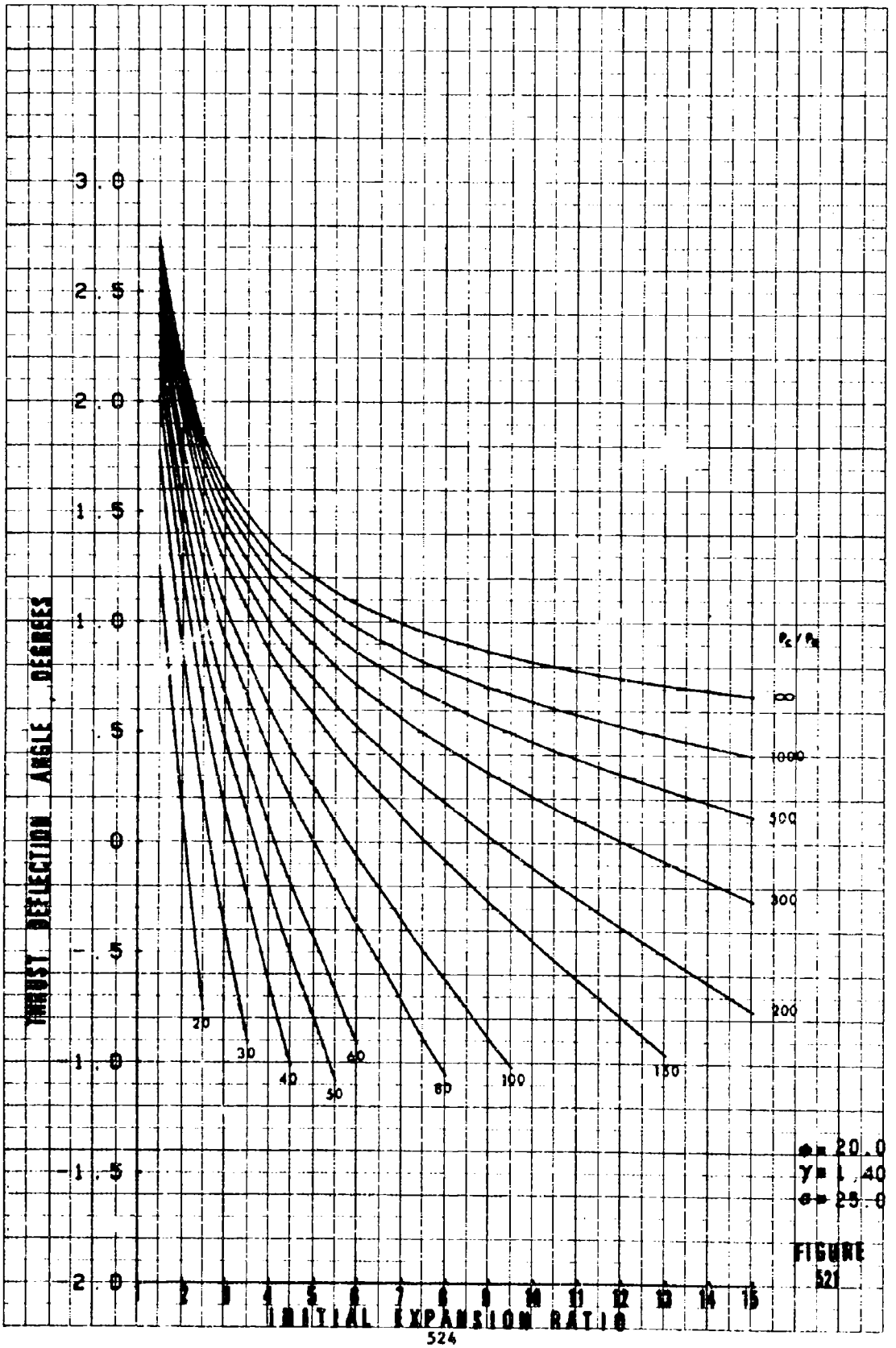
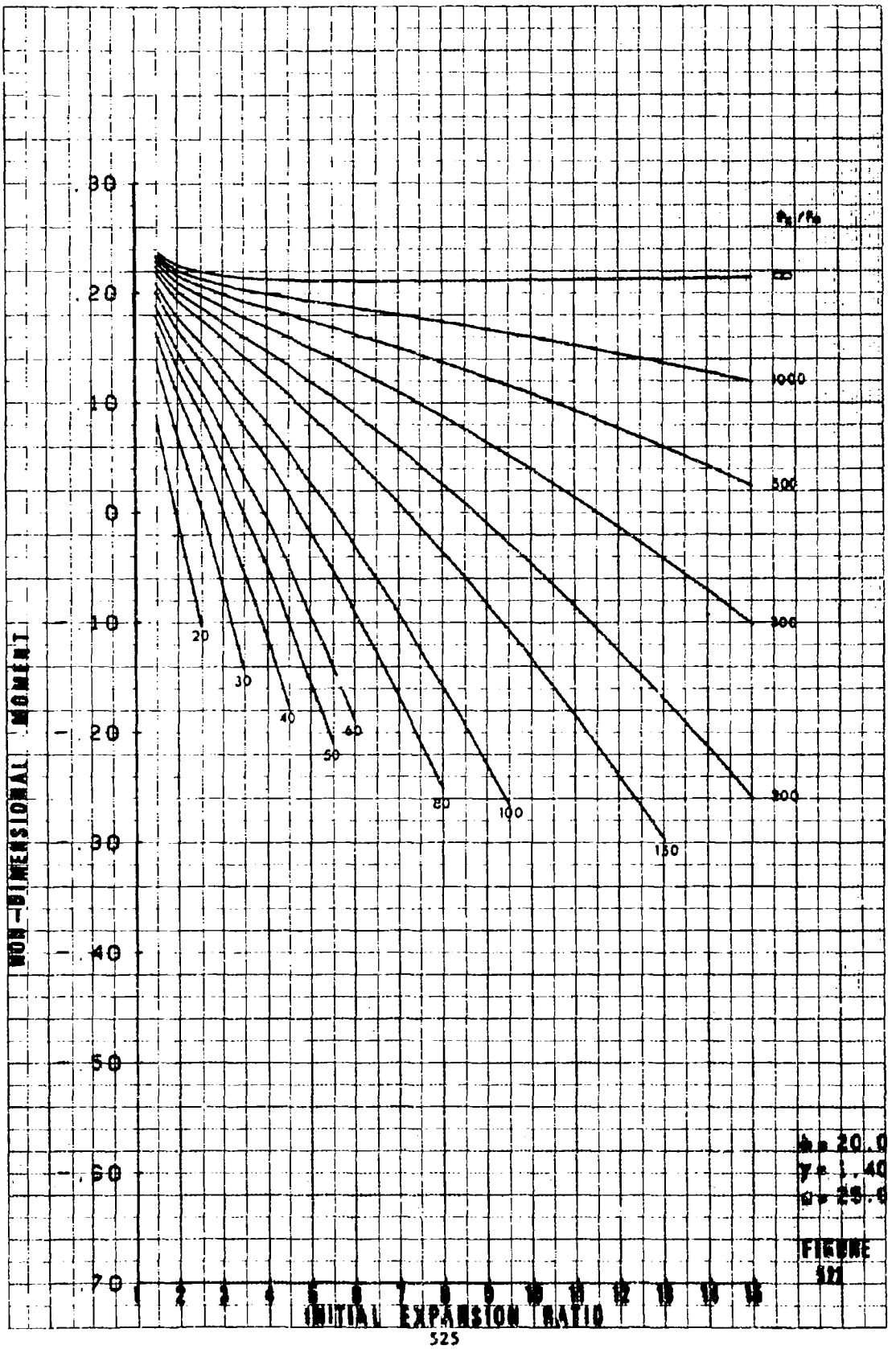

THRUST DEFLECTION ANGLE, DEGREES
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
20
30
40
50
60
80
100
150
ϕ = 20.0
γ = 1.40
θ = 25.0

FIGURE 521



NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
-.70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
80
100
150
200
300
500
1000
∞

FIGURE 521

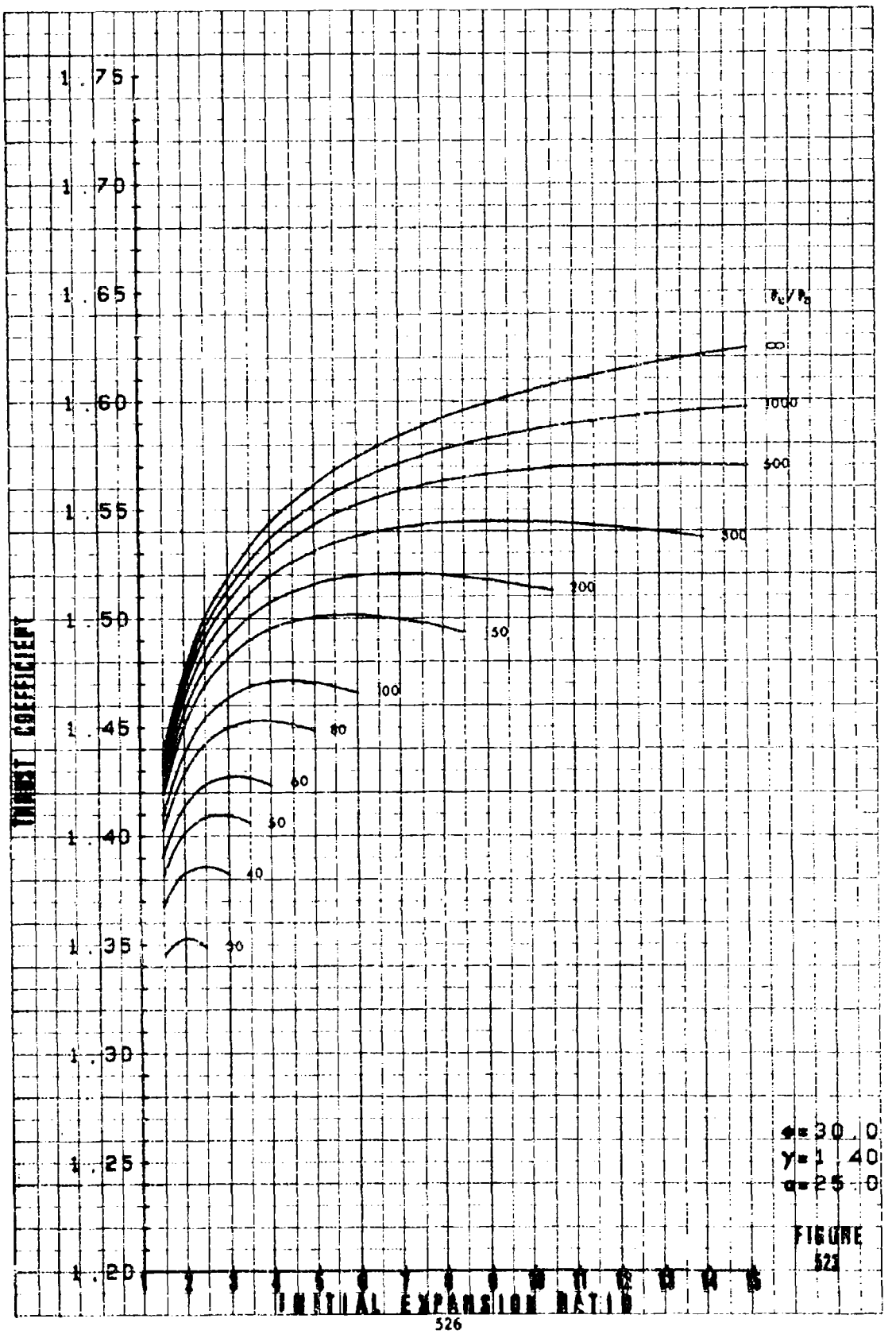

1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
P_c/P_a
∞
1000
500
300
200
50
100
80
60
50
40
30
φ=30.0
γ=1.40
α=25.0

FIGURE 523

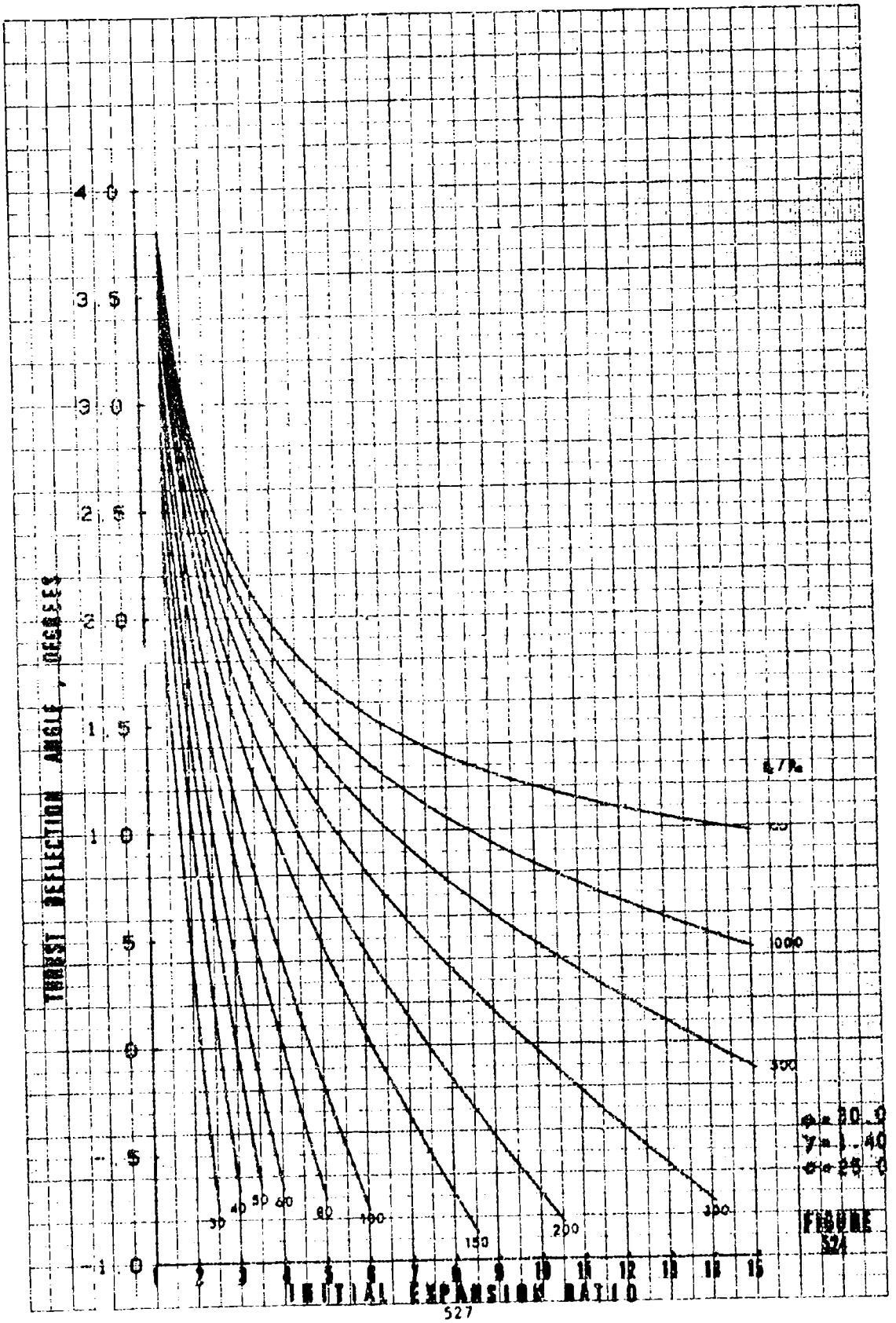
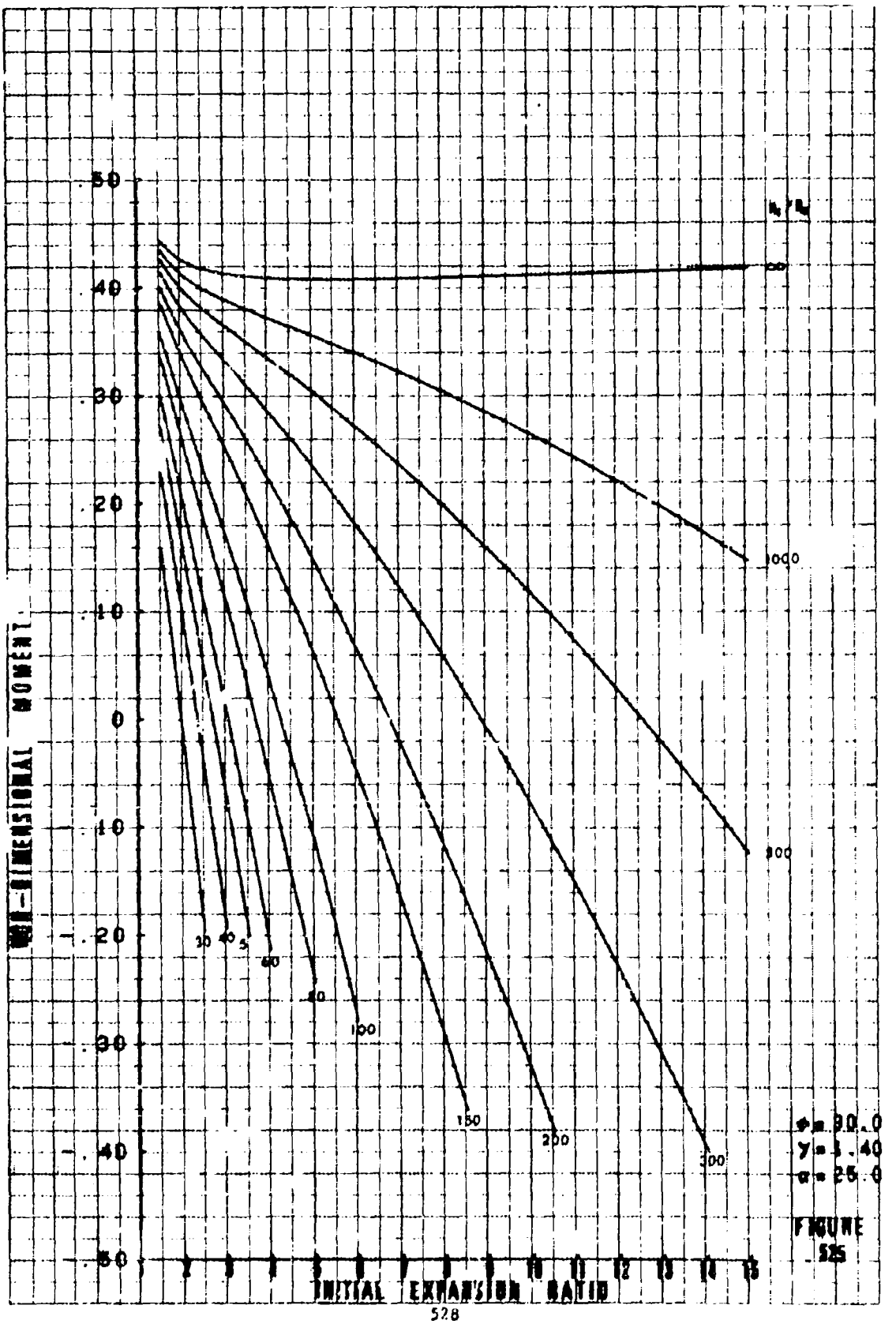
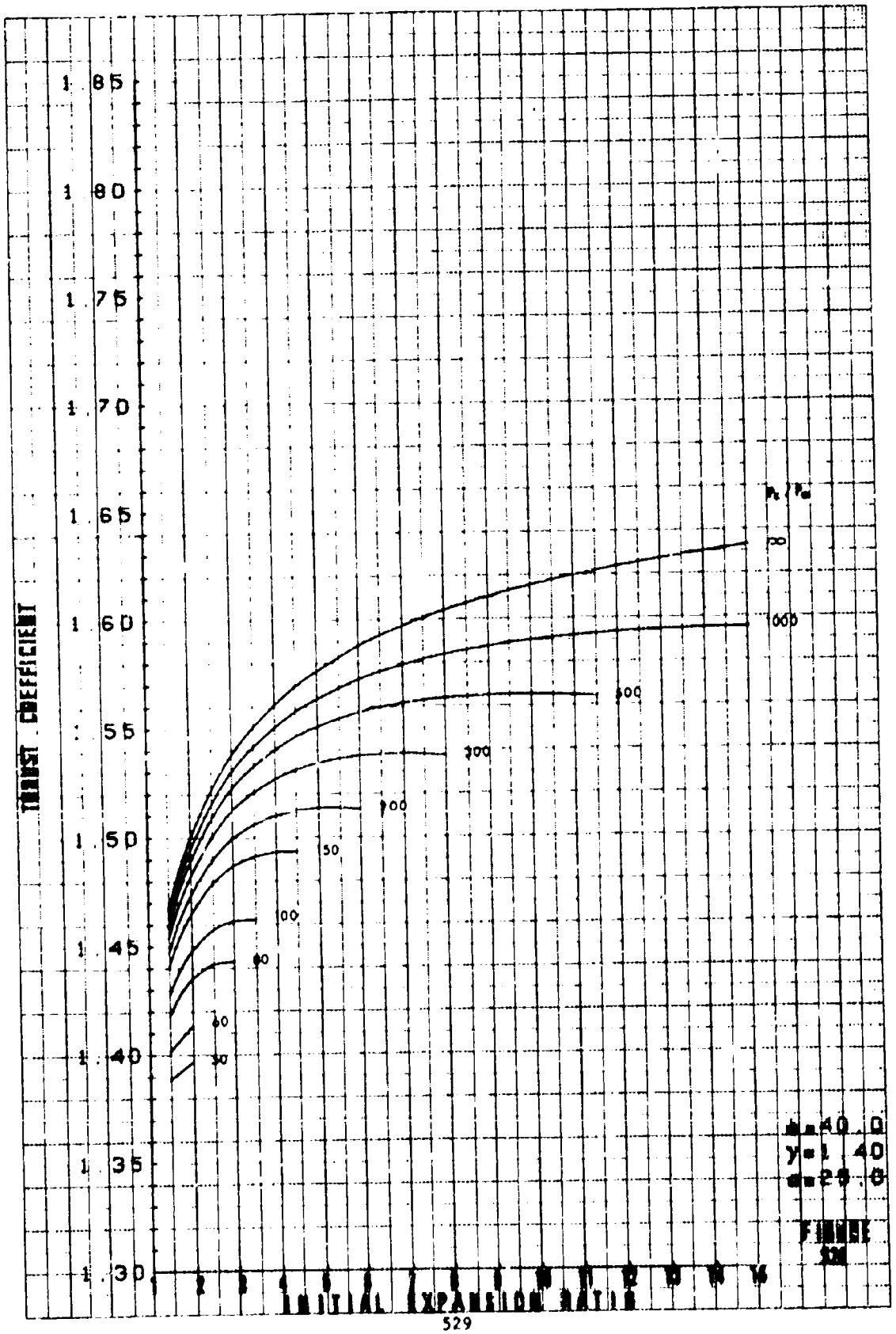

THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
30
40
50
60
80
100
150
200
300
1000
300
φ = 30.0
γ = 1.40
σ = 25.0

FIGURE 524



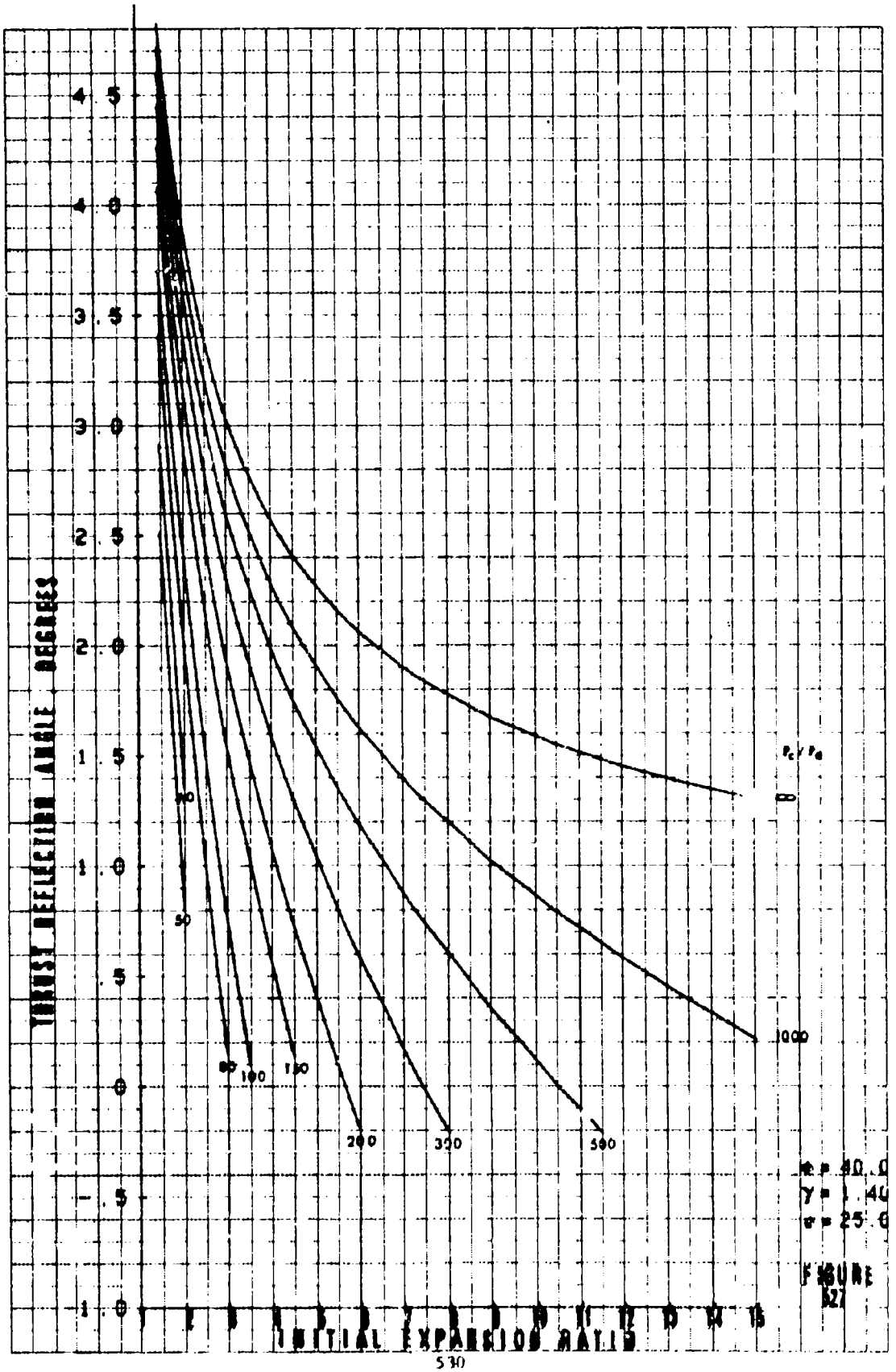
.50
.40
.30
.20
.10
0
-.10
-.20
-.30
-.40
-.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1000
300
200
150
100
60
30
40
5
φ = 30.0
γ = 1.40
α = 25.0

FIGURE 525



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
INITIAL EXPANSION RATIO
∞
1000
500
300
200
150
100
80
60
50

FIGURE


THRUST DEFLECTION ANGLE, DEGREES
INITIAL EXPANSION RATIO
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
P_c/P_a
∞
1000
500
300
200
150
100
80
50
40
α = 40.0
γ = 1.40
σ = 25.0
FIGURE
527

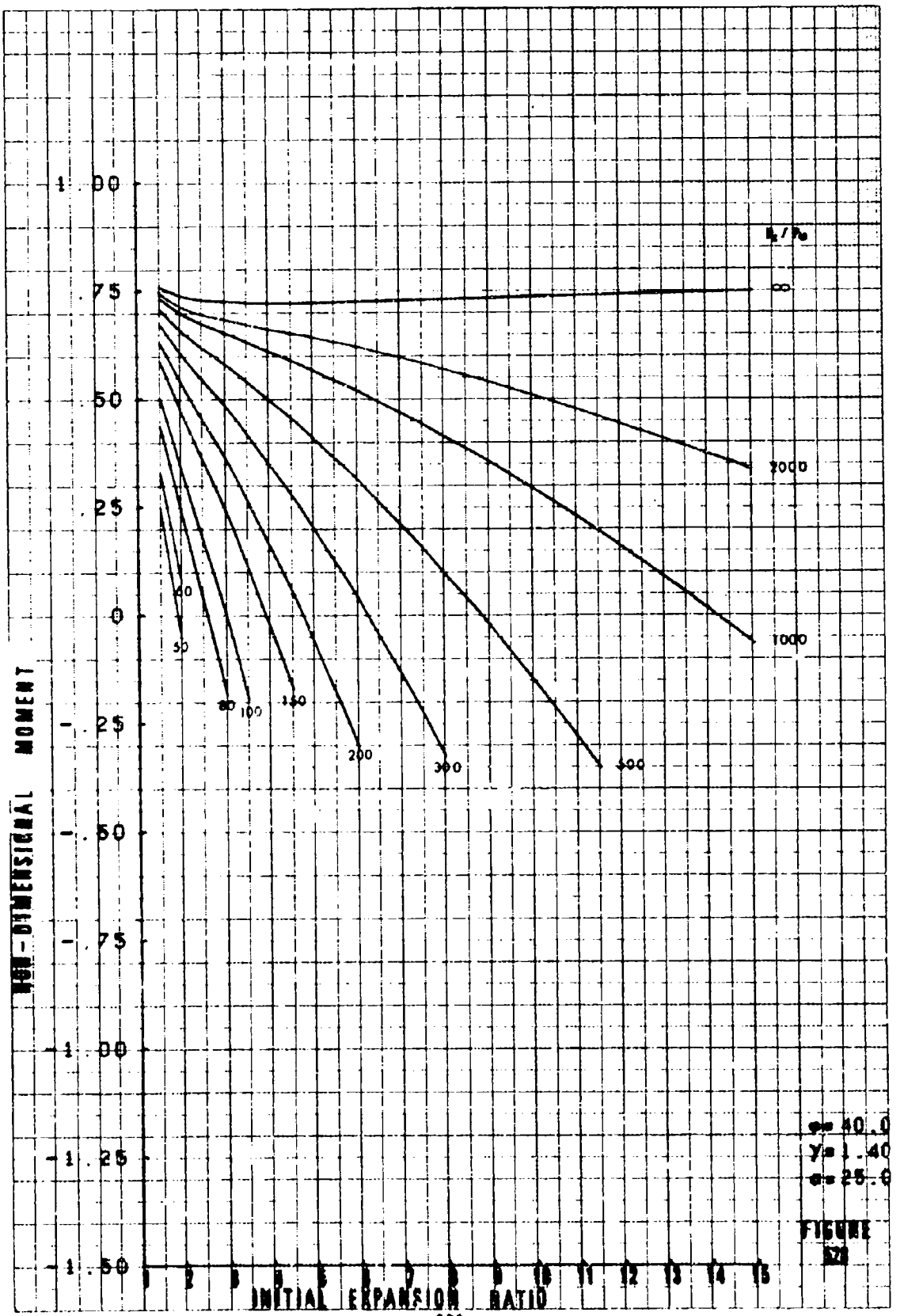
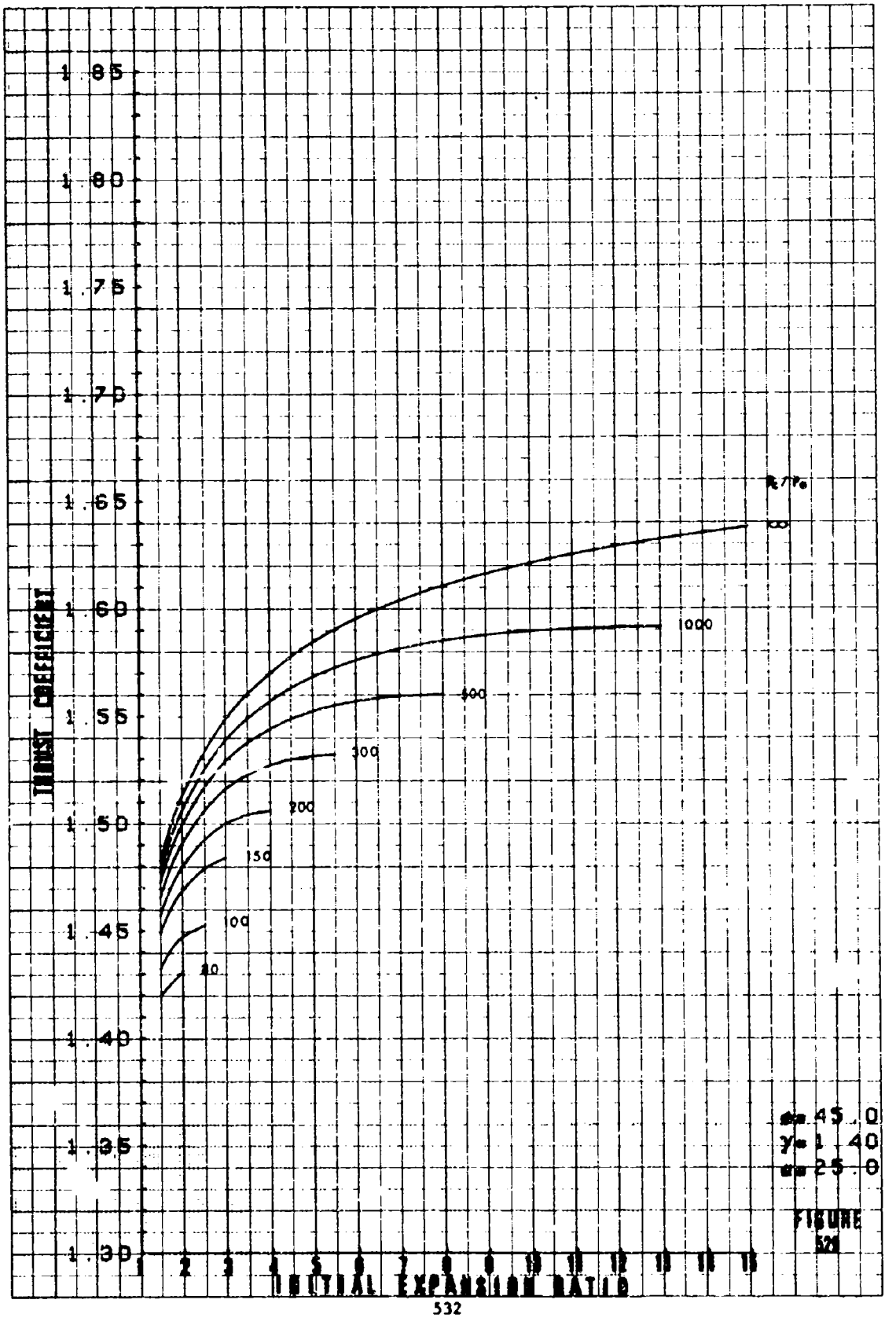
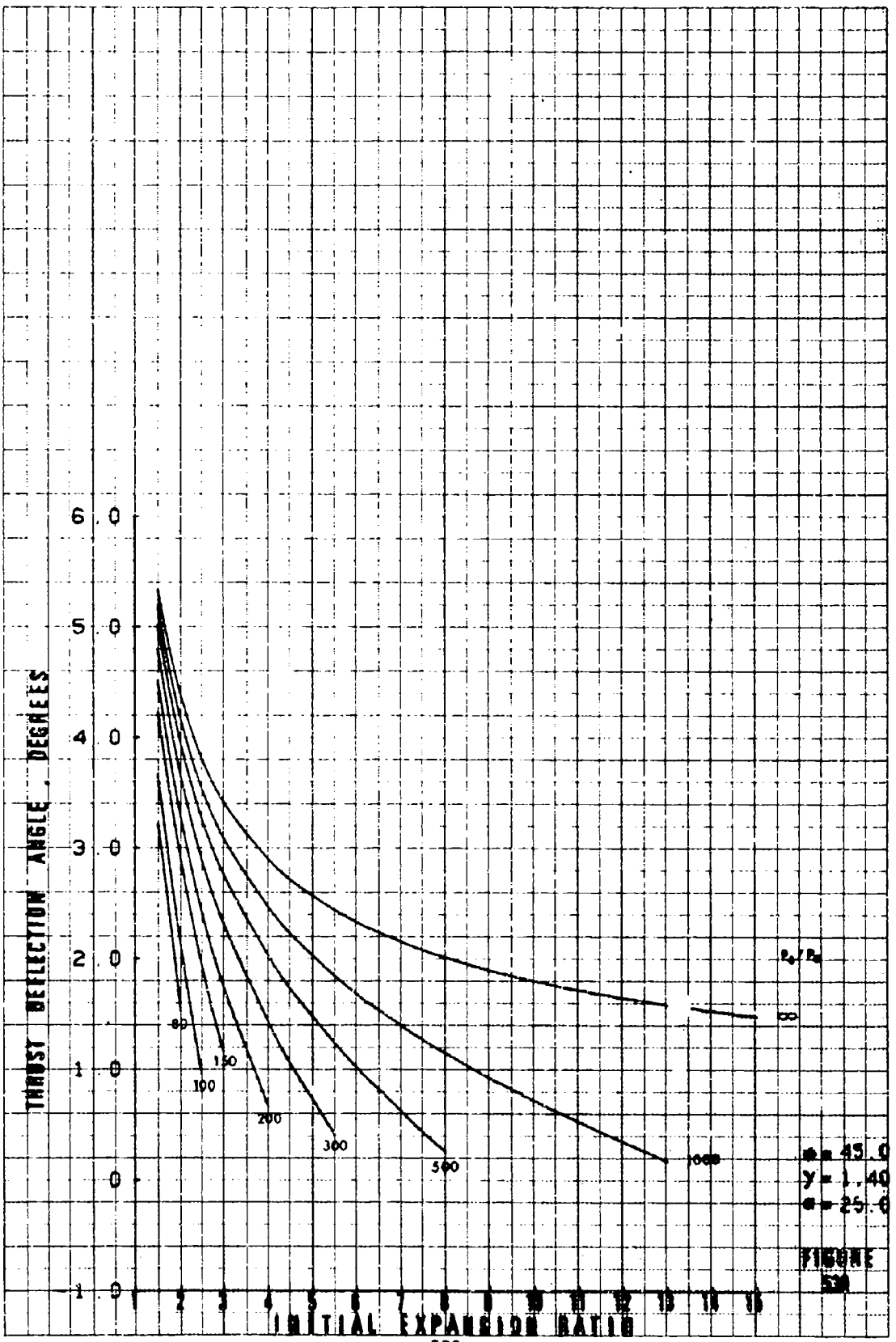

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
-1.25
-1.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
2000
1000
400
300
200
150
100
80
60
50
φ= 40.0
γ= 1.40
σ= 25.0

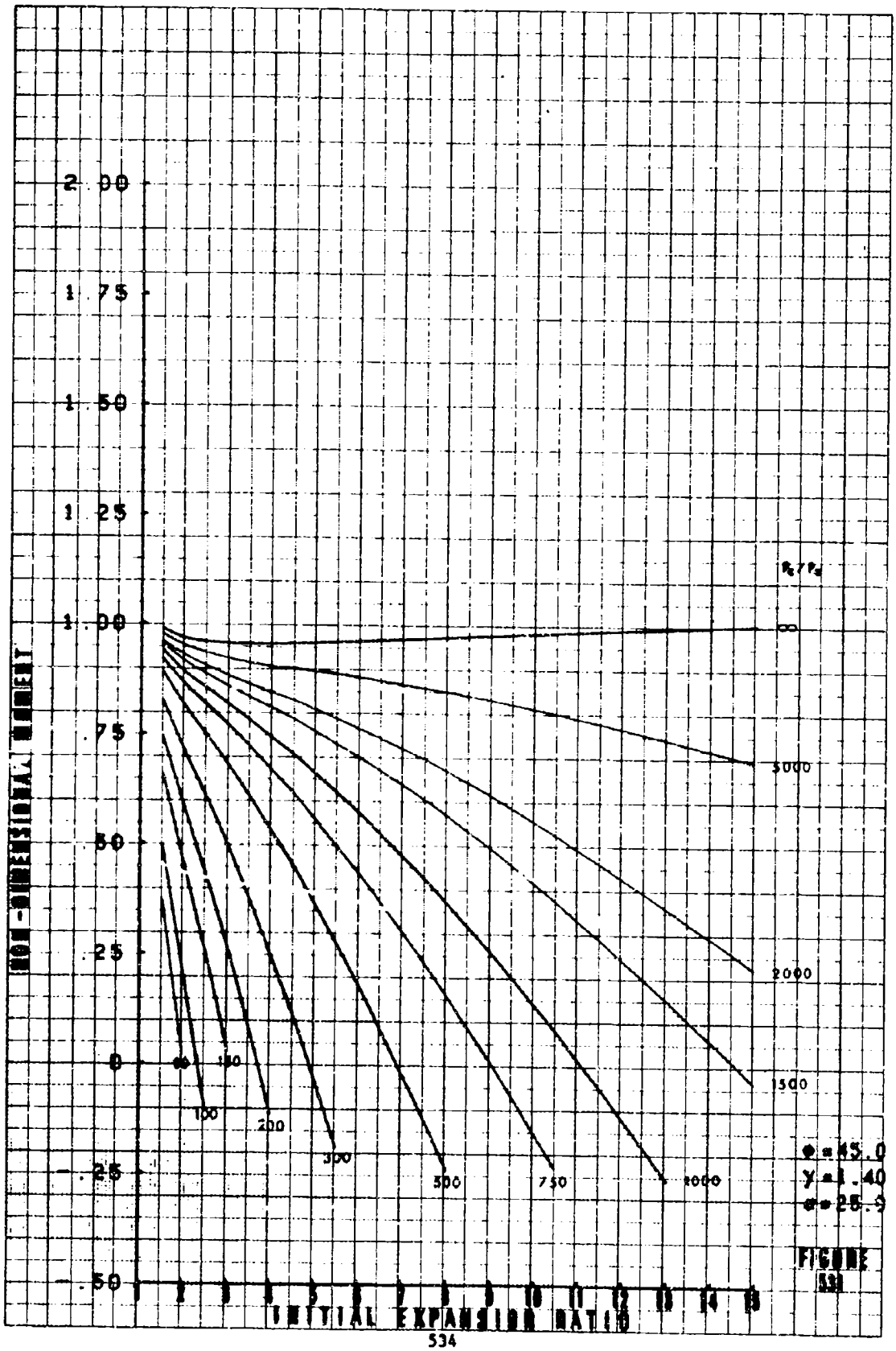
FIGURE 52



1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_c/P_e
∞
1000
500
300
200
150
100
80
α= 45.0
γ= 1.40
α= 25.0

FIGURE 529


THRUST DEFLECTION ANGLE, DEGREES
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
80
100
150
200
300
500
1000
∞
φ = 45.0
γ = 1.40
α = 25.0
FIGURE



2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
P_c/P_s
∞
5000
2000
1500
1000
750
500
300
200
150
100
φ = 45.0
γ = 1.40
α = 25.9

FIGURE 531

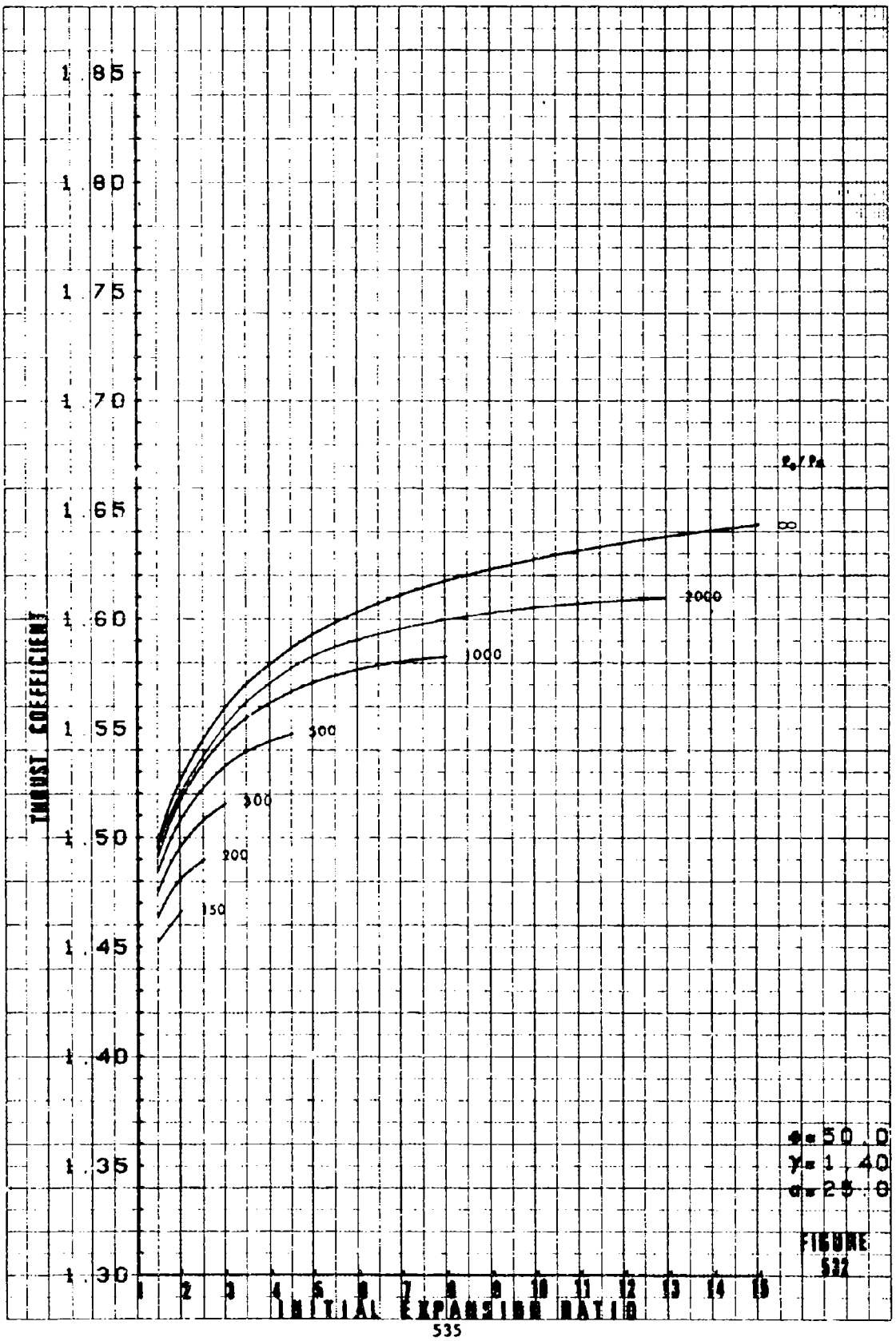
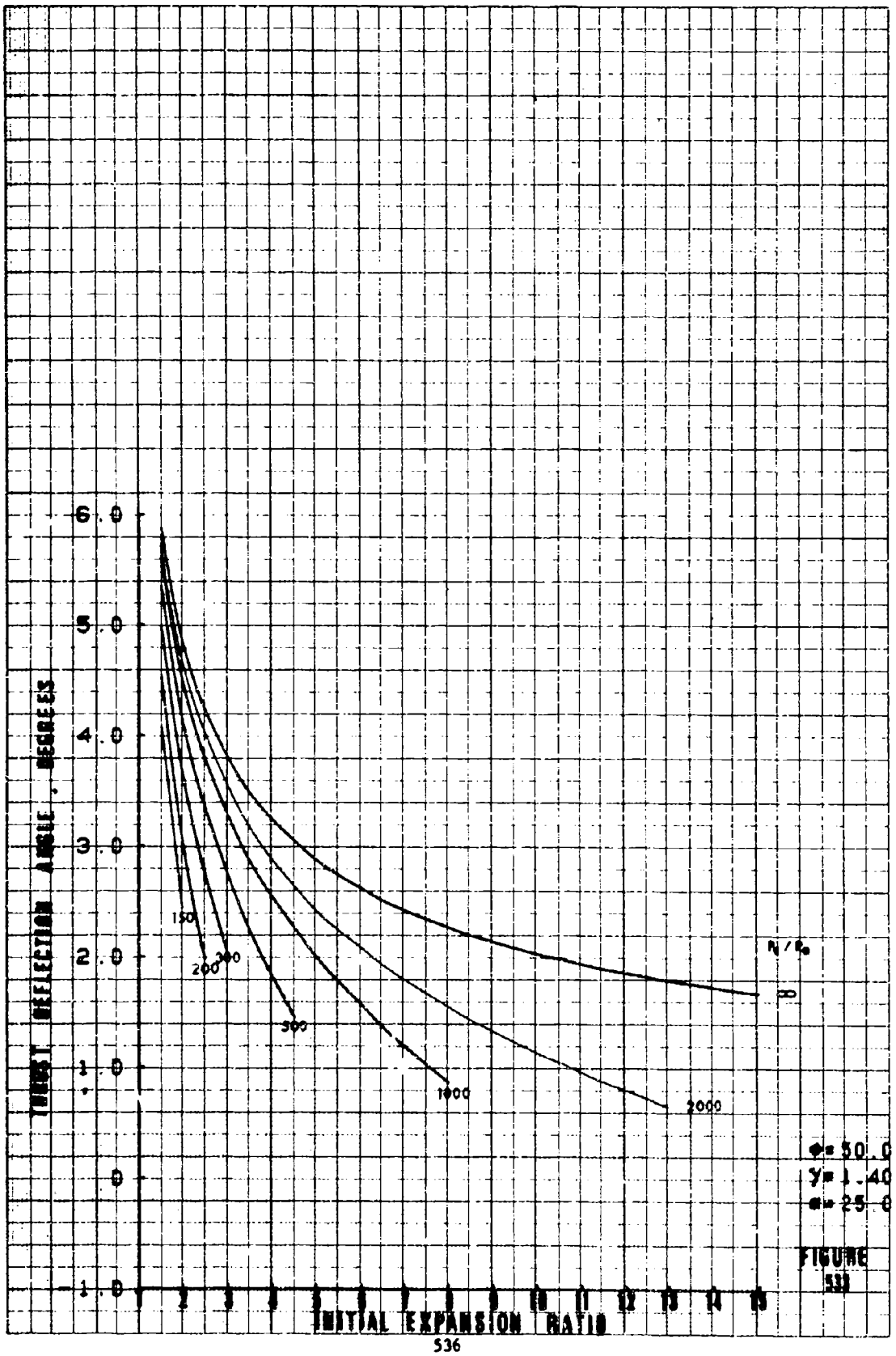

THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_0/P_A
∞
2000
1000
500
300
200
150
γ= 1.40

FIGURE 532



6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
THRUST DEFLECTION ANGLE, DEGREES
150
200
300
500
1000
2000
R_i/R_o
∞
φ= 50.0
γ= 1.40
α= 25.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INITIAL EXPANSION RATIO

FIGURE 533

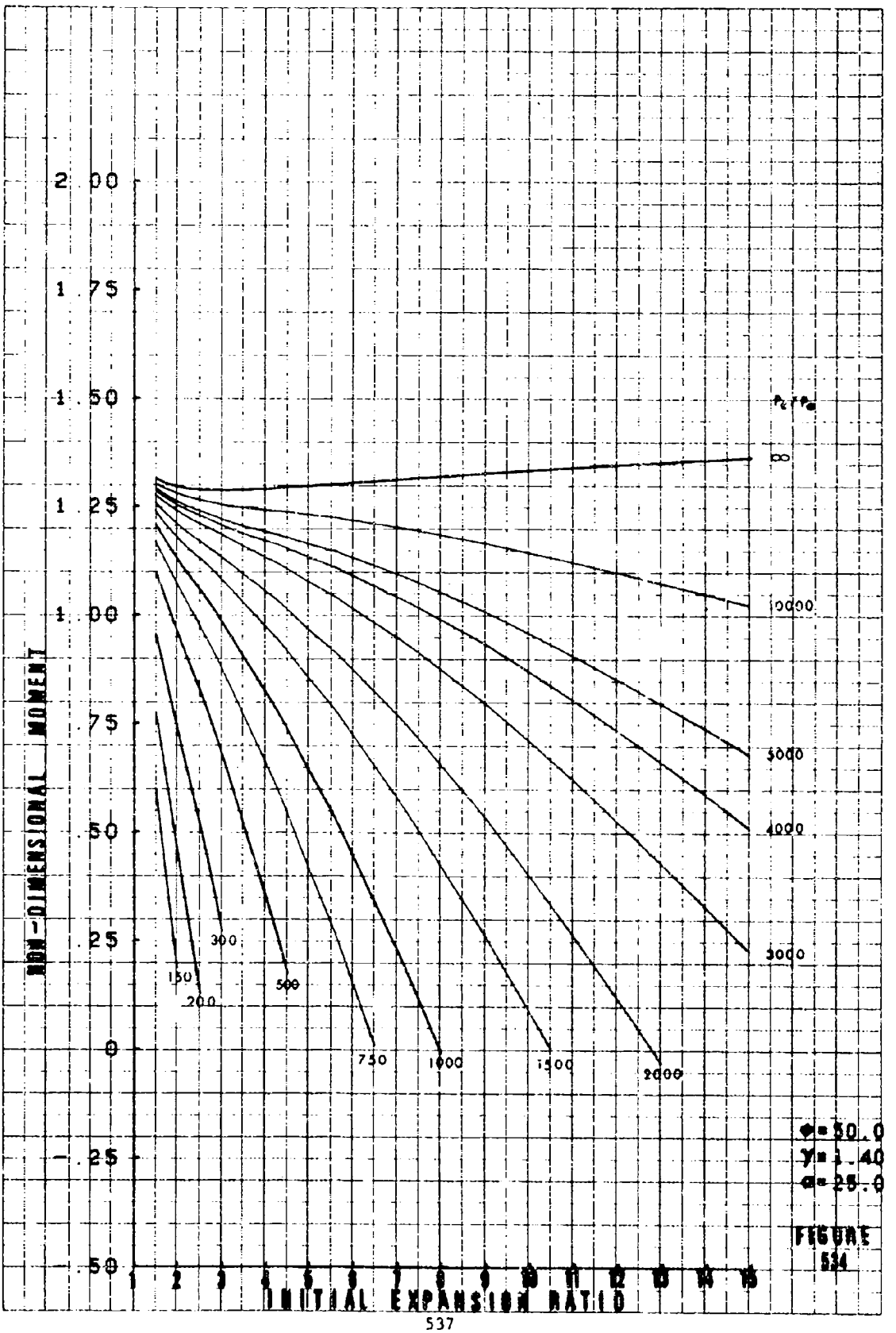
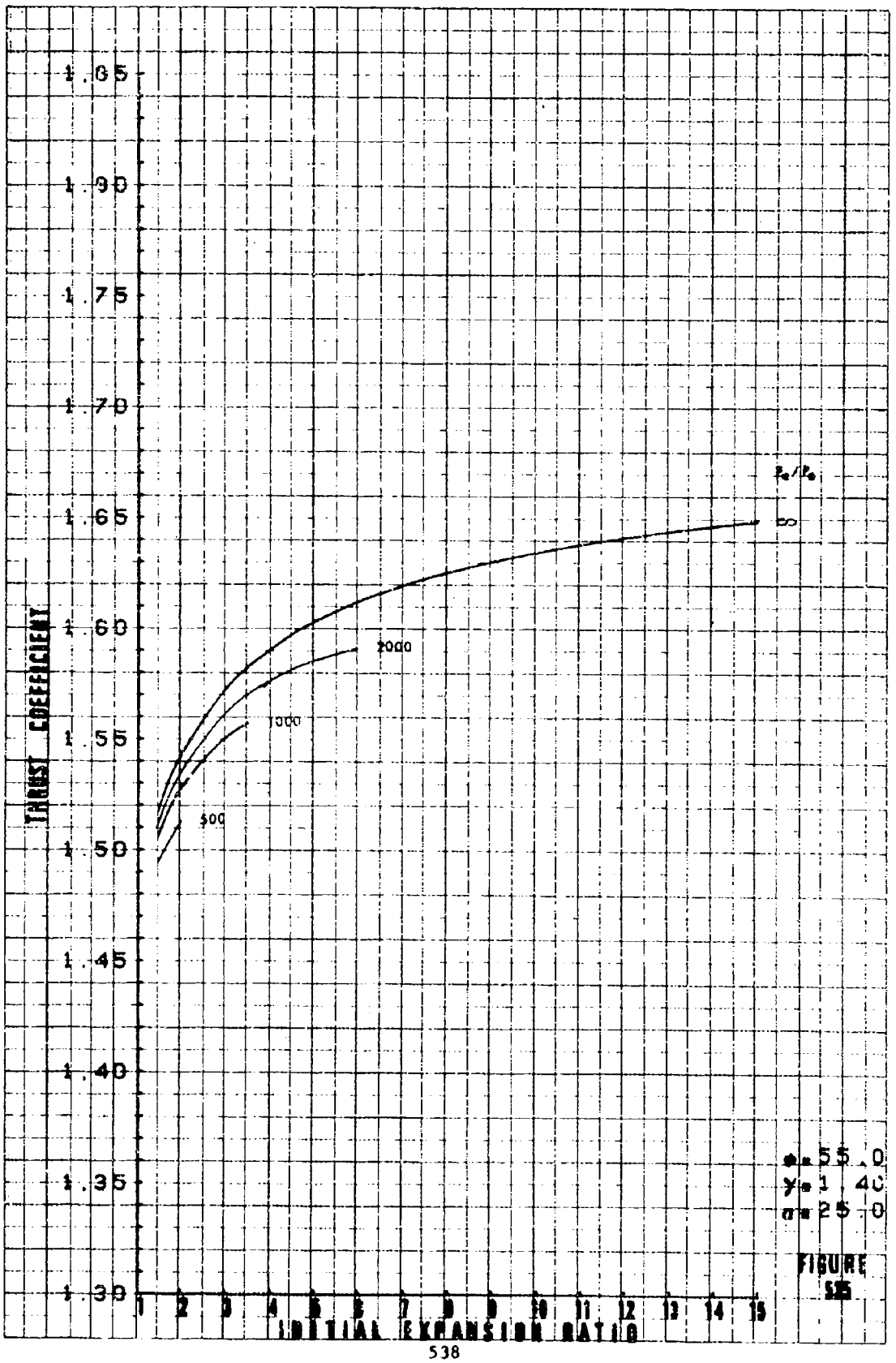
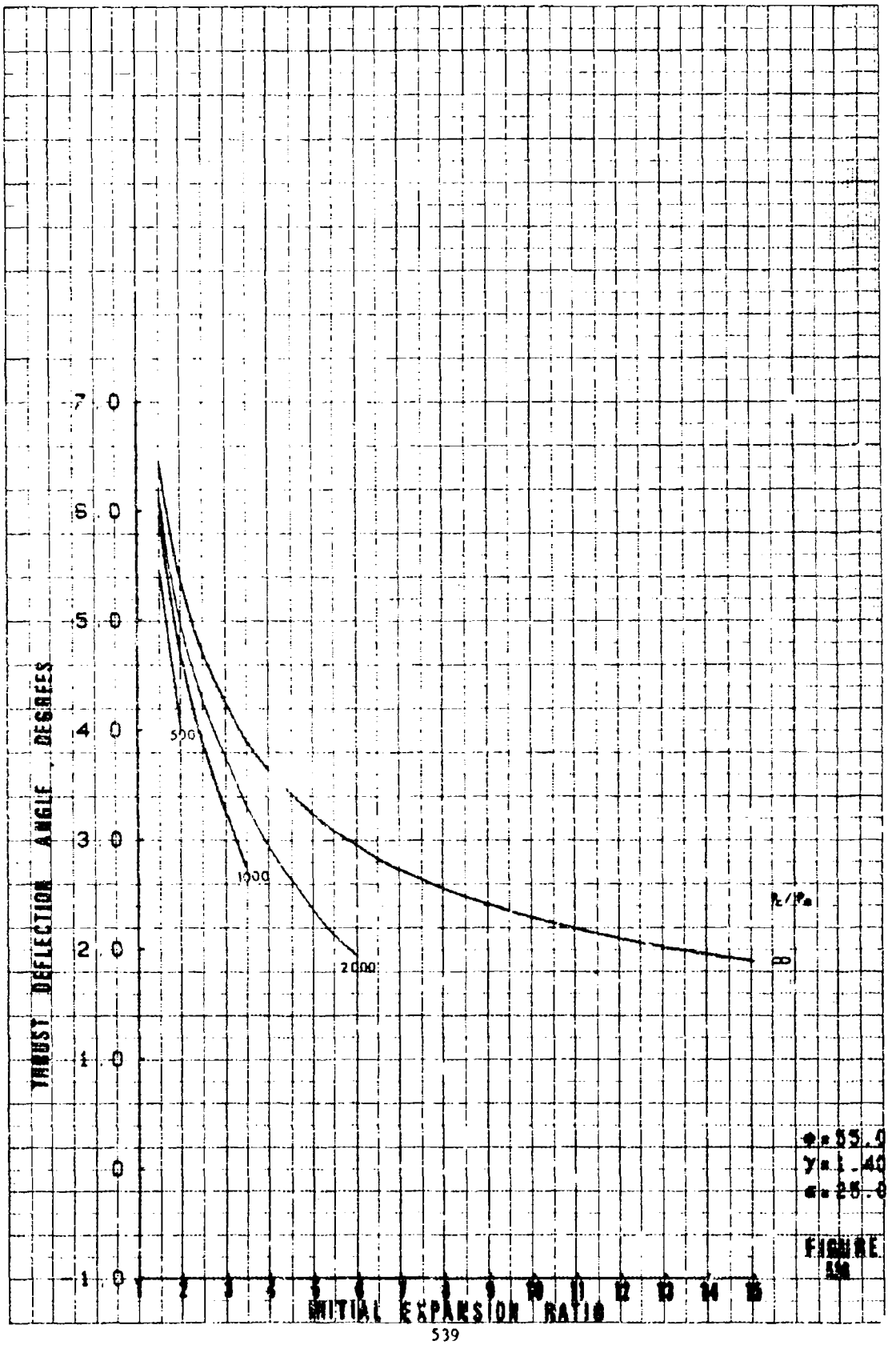

NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
∞
10000
5000
4000
3000
300
150
200
500
750
1000
1500
2000
φ= 50.0
γ= 1.40
α= 25.0

FIGURE 534

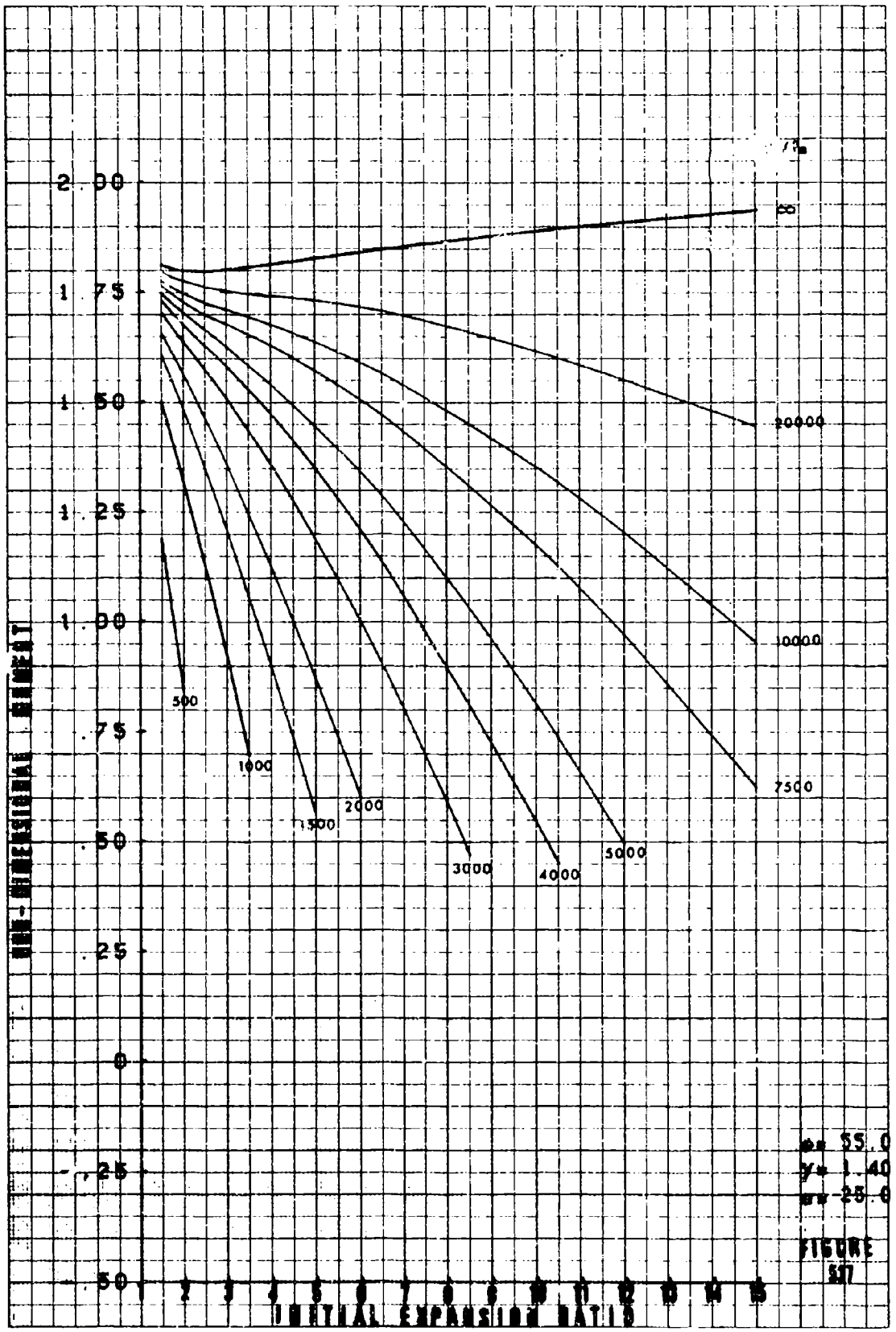


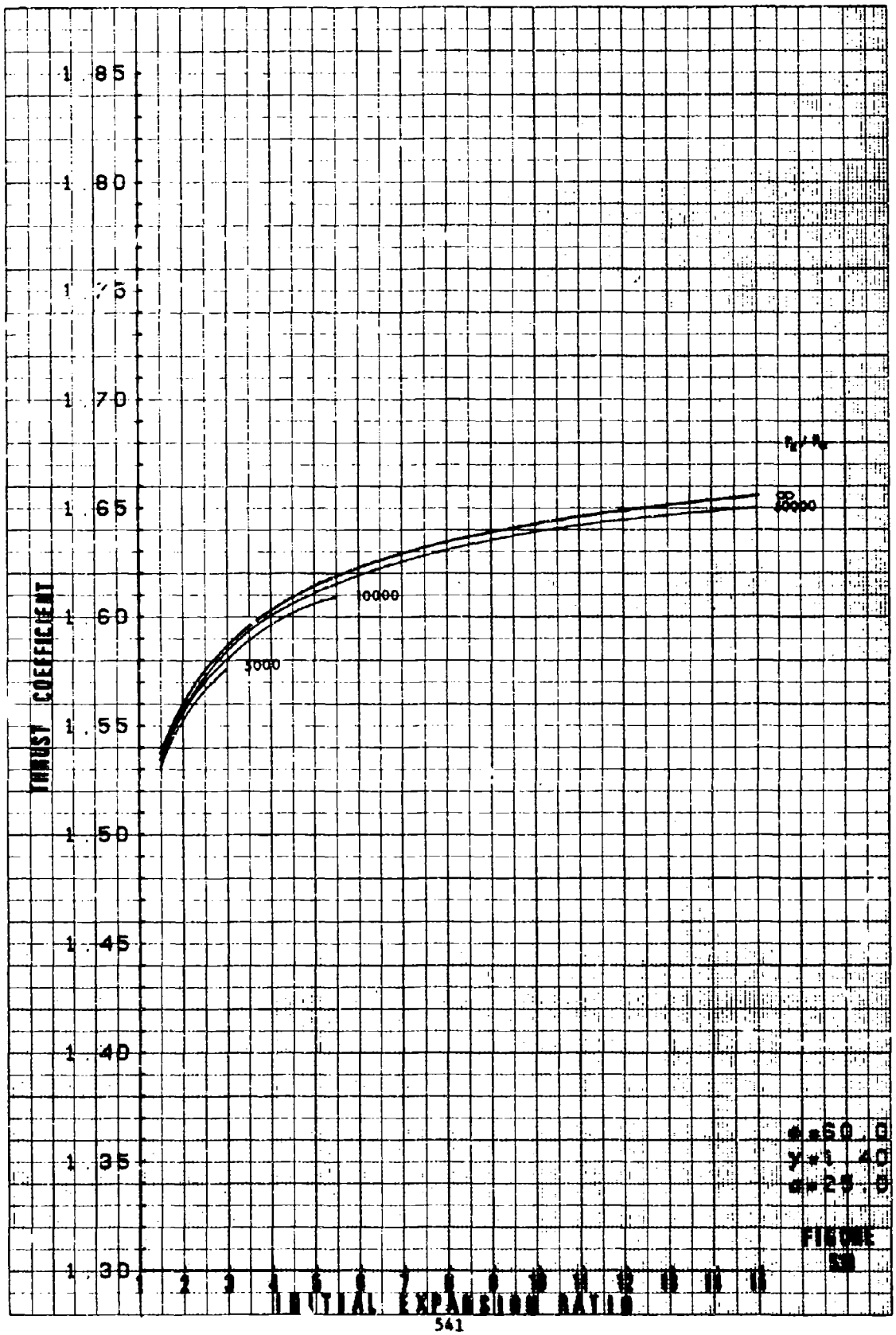
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
THRUST COEFFICIENT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
P_e/P_o
∞
2000
1000
500
φ = 55.0
γ = 1.40
α = 25.0

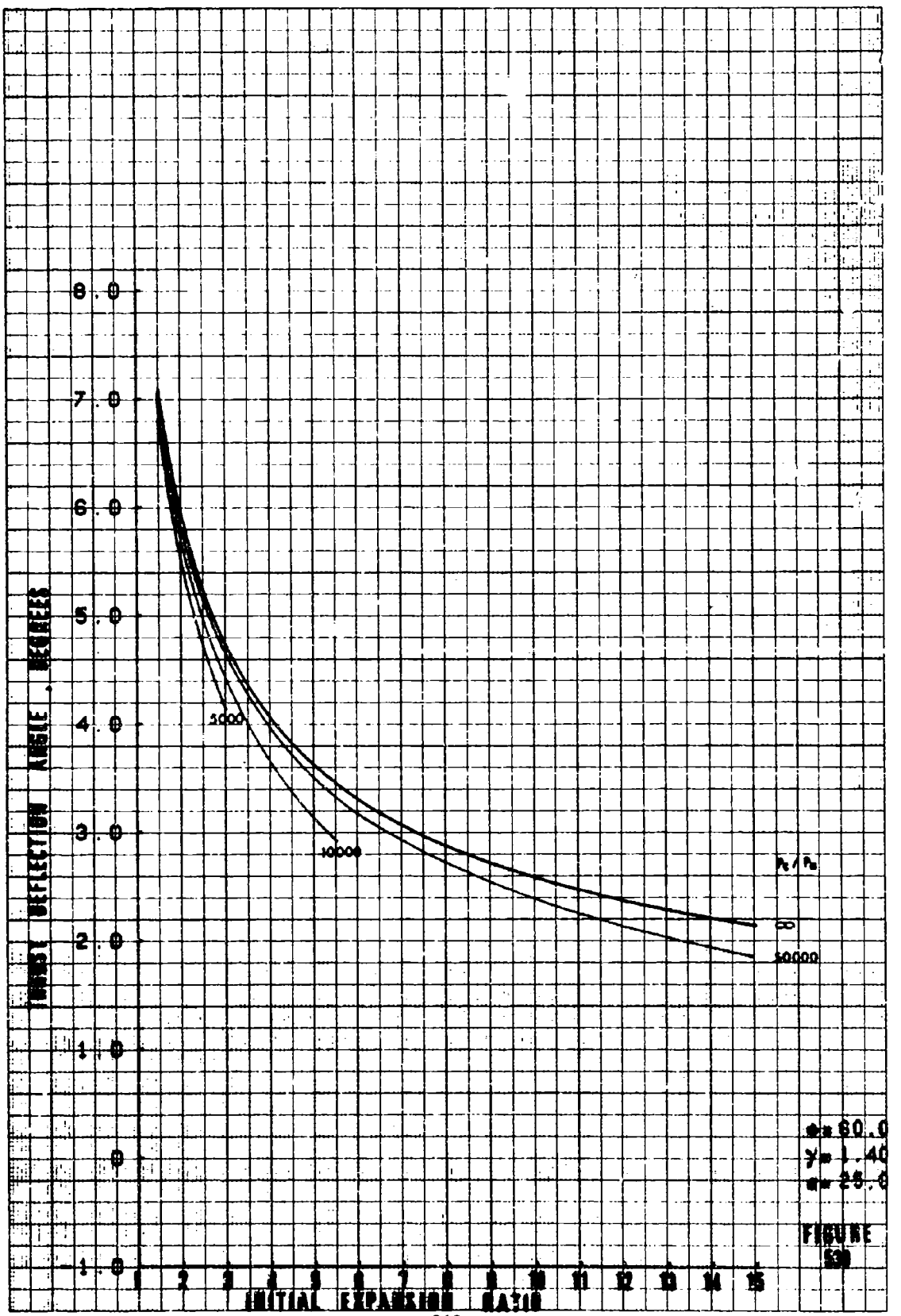
FIGURE 535


THRUST DEFLECTION ANGLE, DEGREES
70
60
50
40
30
20
10
0
10
500
1000
2000
P_c/P_a
∞
INITIAL EXPANSION RATIO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

FIGURE

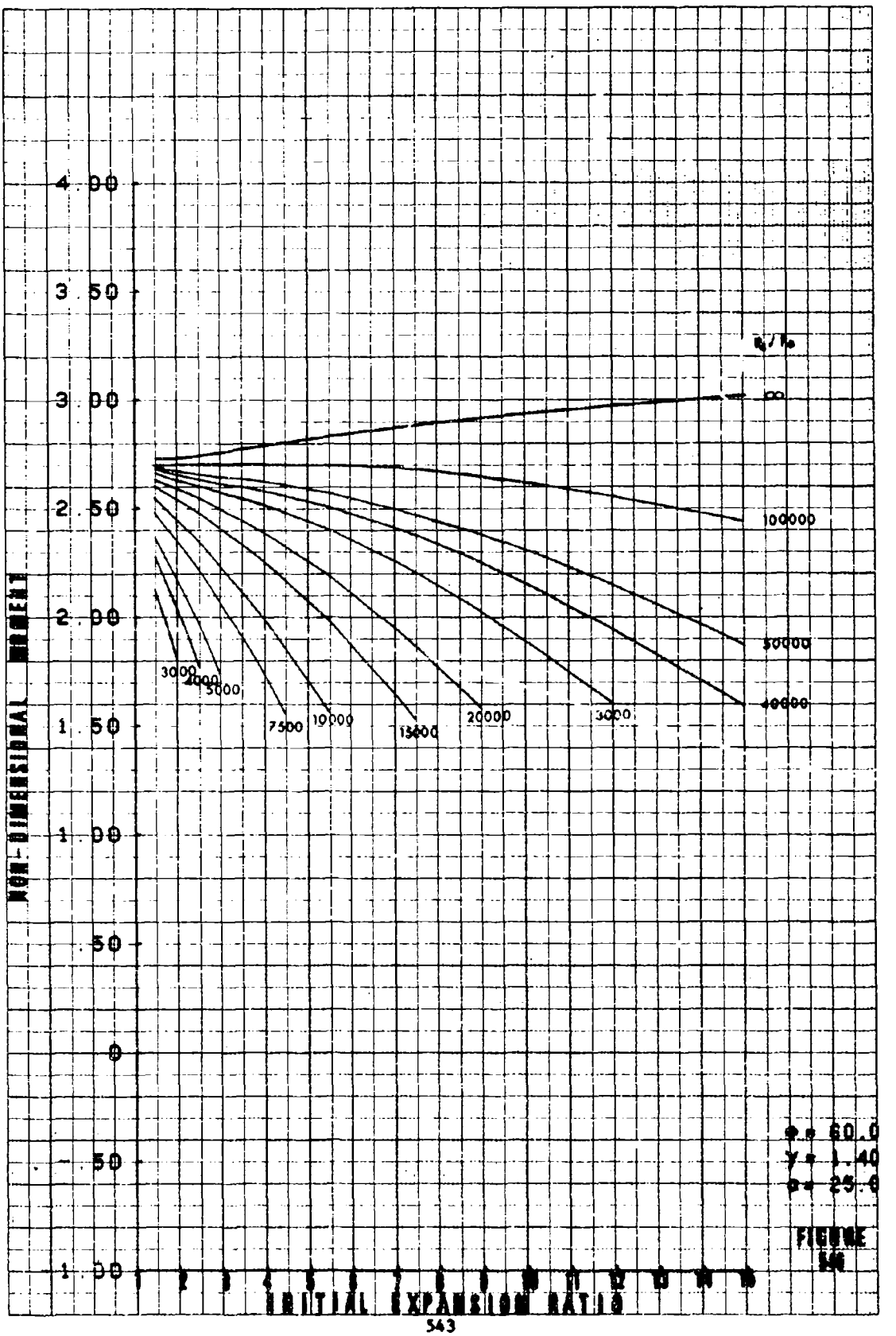

2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
-.25
-.50
∞
20000
10000
7500
5000
4000
3000
2000
1500
1000
500
INITIAL EXPANSION RATIO
FIGURE


THRUST COEFFICIENT
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO
10000
5000
y=1.40
FIGURE



8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
THRUST DEFLECTION ANGLE, DEGREES
5000
10000
∞
50000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INITIAL EXPANSION RATIO

FIGURE 530



4.00
3.50
3.00
2.50
2.00
1.50
1.00
.50
0
-.50
-1.00
NON-DIMENSIONAL MOMENT
INITIAL EXPANSION RATIO
∞
100000
50000
40000
3000
4000
5000
7500
10000
15000
20000
3000
φ = 60.0
γ = 1.40
α = 25.0

FIGURE 546