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OPERATING ENVELOPE CHARTS FOR THE LANGLEY 0.3-METER TRANSONIC CRYOGENIC WIND TUNNEL

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Introduction

Operating a wind tunnel at reduced temperatures, first proposed by Margoulis (refs. 1 and 2) in 1920, offers an attractive means of increasing Reynolds number while avoiding many of the practical problems associated with testing at high Reynolds numbers in conventional ambient temperature pressure tunnels. Personnel of the NASA Langley Research Center have been studying the application of the cryogenic wind tunnel concept to various types of high Reynolds number transonic tunnels since the autumn of 1971. The usefulness of the concept (ref. 3) has been realized at Langley with the successful operation of the 0.3-meter Transonic Cryogenic Tunnel (0.3-m TCT) (refs. 4 and 5) since August 1973 and with the recent completion in 1982 of the U.S. National Transonic Facility (refs. 6 and 7).

To take full advantage of the unique Reynolds number capabilities of the 0.3-m TCT, it was designed to accomodate test sections other than the original, octagonal, three-dimensional test section. A 20- by 60-cm two-dimensional test section was installed in 1976 and was extensively used, primarily for airfoil testing, through the fall of 1984. The tunnel was inactive during 1985 so that a new test section and improved high speed diffuser could be installed in the tunnel circuit. The new test section has solid adaptive top and bottom walls to reduce or eliminate wall interference for two-dimensional testing. This new test section has a 33- by 33-cm cross section at the entrance and is 142 cm long.

During the planning and execution of past airfoil tests in the 0.3-m TCT, the use of operating envelope charts have proven very useful. These charts give the variation of total temperature and pressure with Mach number and Reynolds number. The operating total temperature range of the 0.3-m TCT is from about 78 K to 327 K with total pressures ranging from about 17.5 psia to 88 psia. This report presents the "tunnel empty" operating envelope charts for the 0.3-m TCT with the adaptive wall test section installed. These charts are intended to serve as a guide for users of the 0.3-m TCT.

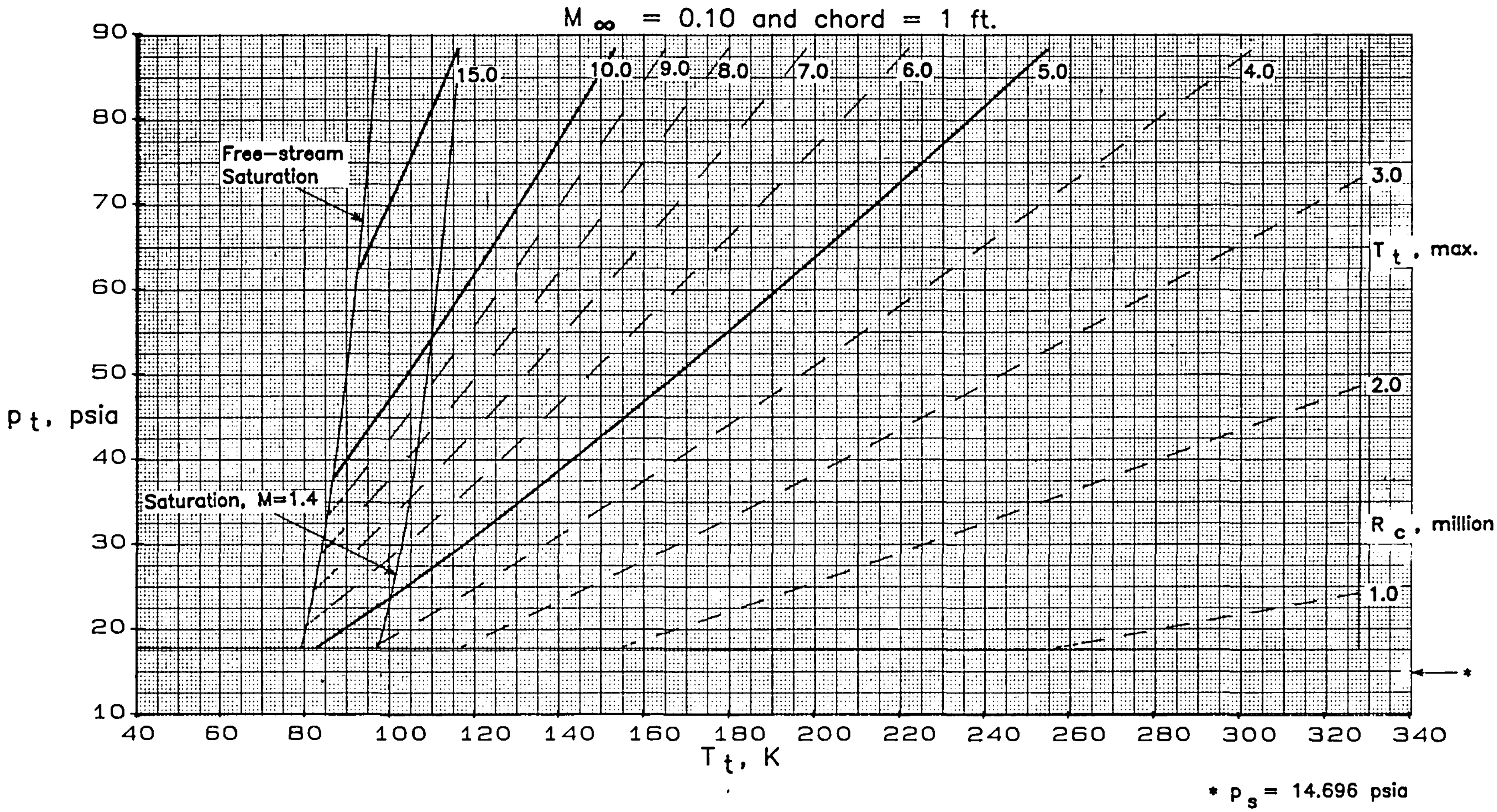
Symbols

M	Mach number
p	pressure, psia
R	Reynolds number
T	temperature, K
Subscripts:	
c	reference chord (c = 1 ft.)
max.	maximum
RPM	revolutions per minute (for tunnel drive motor)
s	static condition
t	total condition
∞	free-stream condition

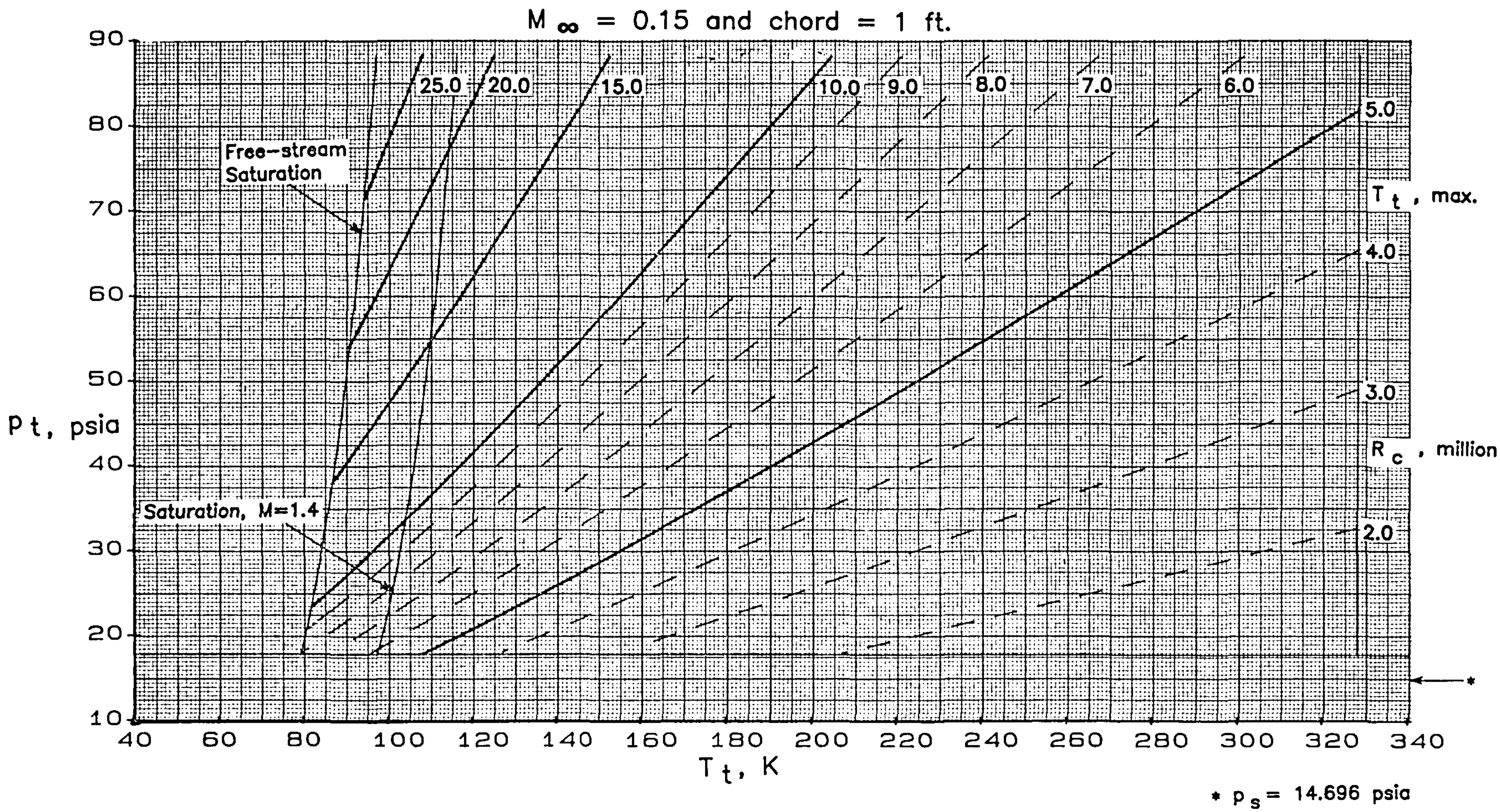
Discussion

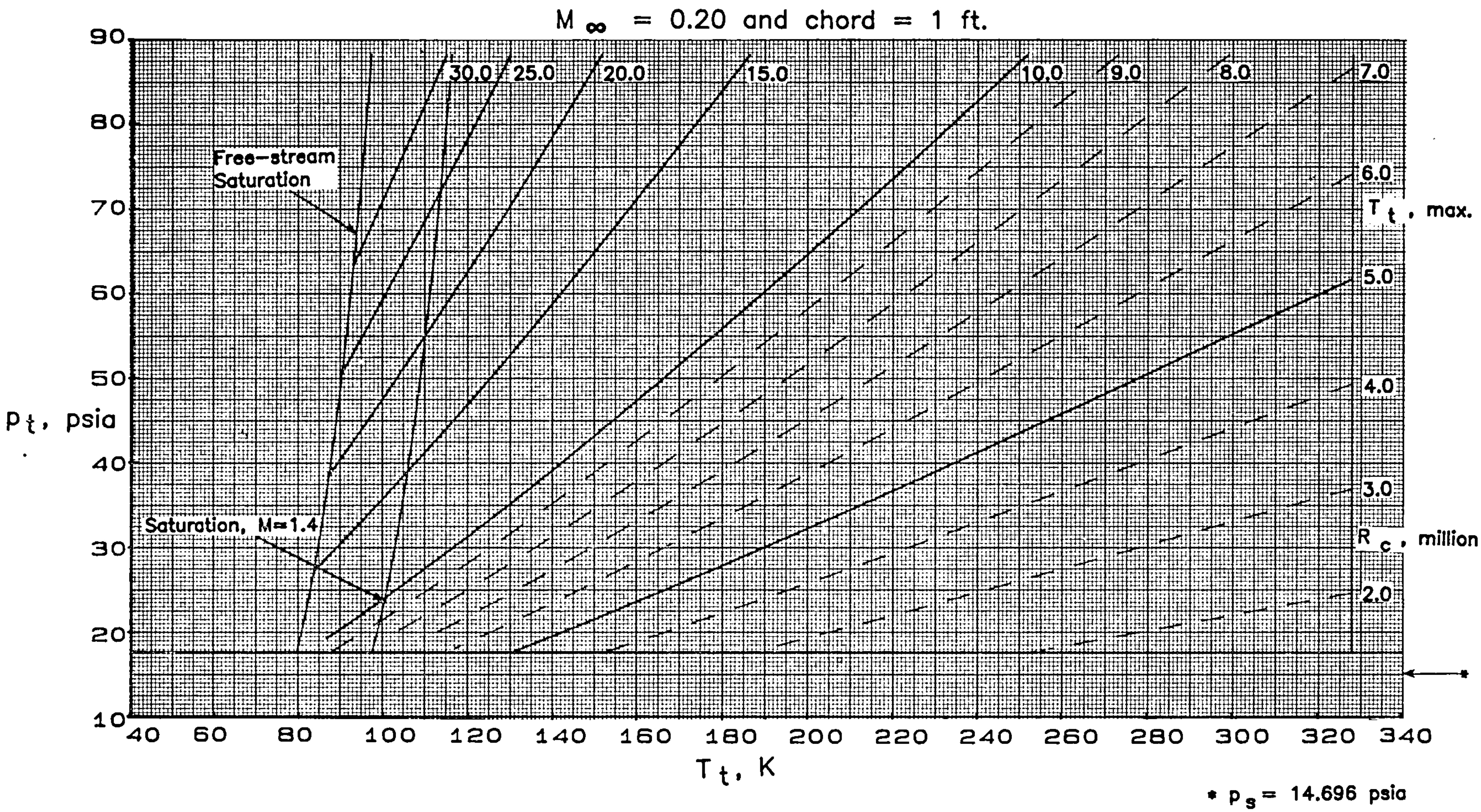
The charts in this report were generated using a computer code which is primarily based on the calculation procedures used in reference 8. The charts are based on a reference chord length of one foot. The Mach numbers vary from 0.10 to 0.95. Note that the lines in the charts labeled "Saturation, M = 1.4" are referring to local saturation of the flow at a local Mach number of 1.4.

A fan drive power limit is shown on the charts for Mach numbers greater than or equal to 0.70. This power limit is based on an approximate mathematical model for fan pressure ratio and fan speed developed by Balakrishna and Thibodeaux for the 0.3-m TCT with the 20- by 60-cm test section installed (ref. 9). To generate the charts for this report, the mathematical model was modified following the evaluation of "tunnel empty" data with the adaptive wall test section installed. This modified model gives a good approximation to the actual power limit. It should be noted that the fan drive power will generally increase due to the presence of a model in the test section.

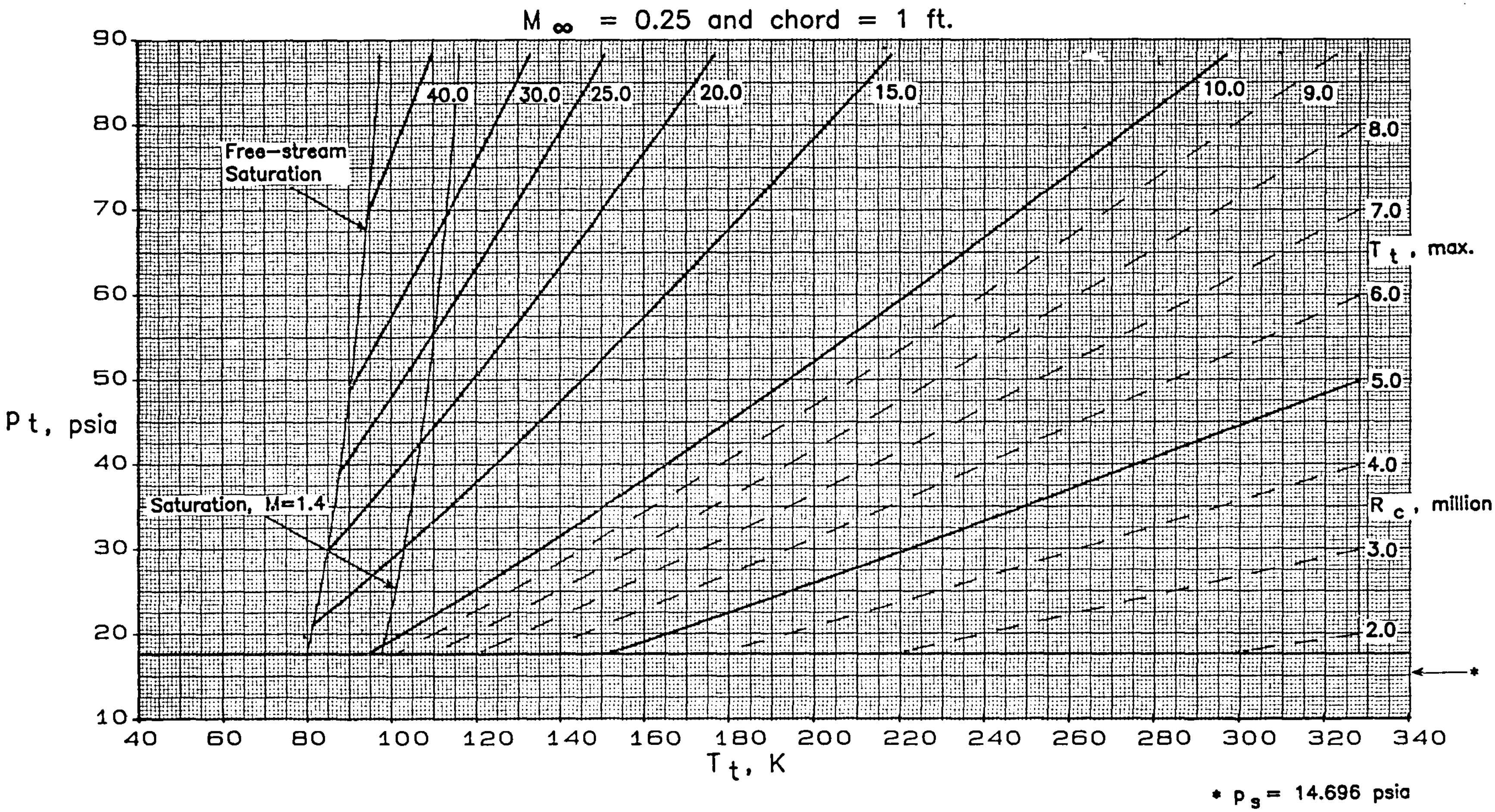


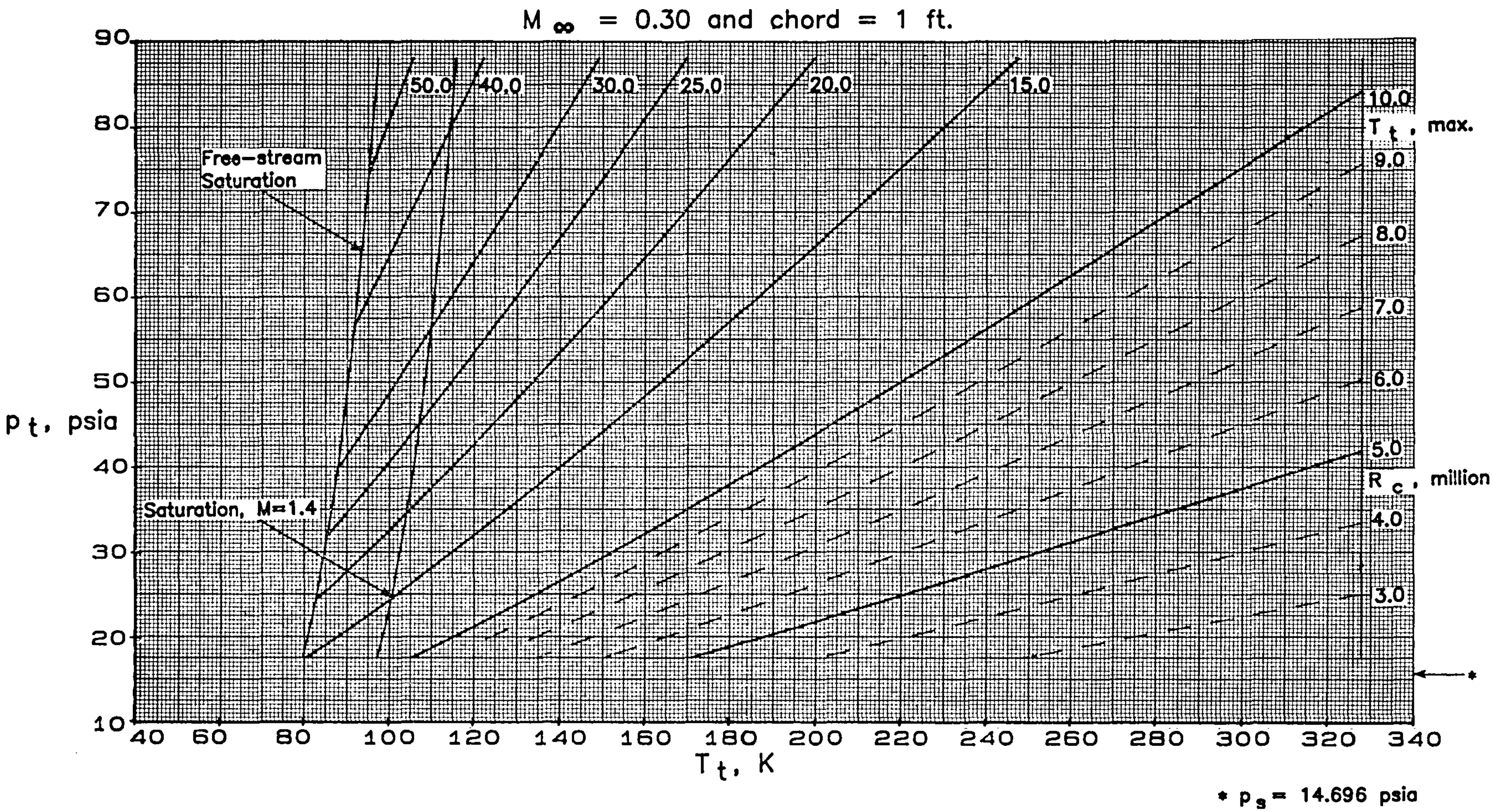
M ∞ = 0.10 and chord = 1 ft.
Free-stream Saturation
Saturation, M=1.4
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
T t , max.
R c , million
p t , psia
T t , K
10
20
30
40
50
60
70
80
90
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* p s = 14.696 psia


M ∞ = 0.15 and chord = 1 ft.
90
80
70
60
50
40
30
20
10
p t, psia
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
T t, K
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
Free–stream
Saturation
Saturation, M=1.4
T t, max.
R c, million
* p s = 14.696 psia

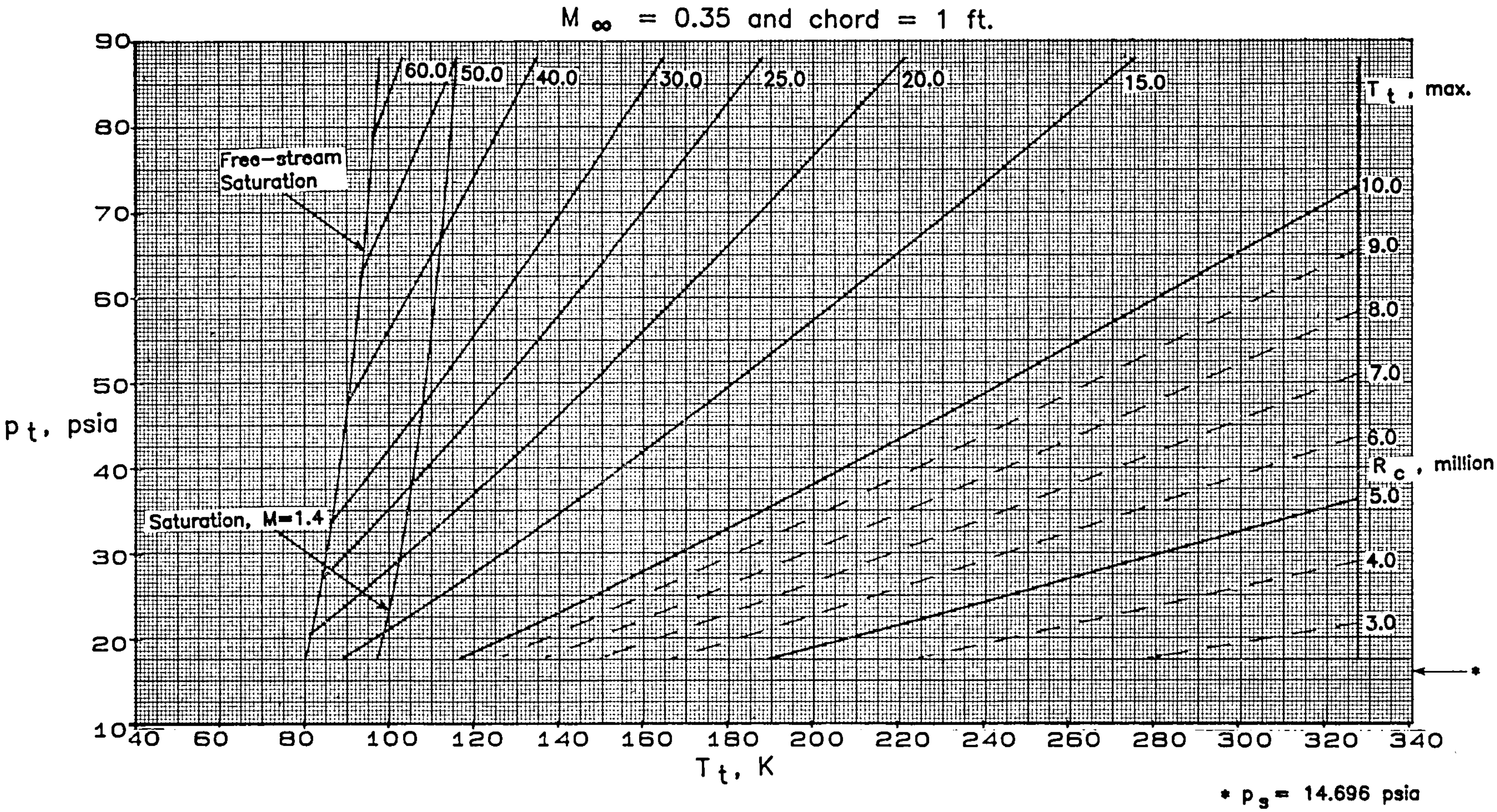


M ∞ = 0.20 and chord = 1 ft.
90
80
70
60
50
40
30
20
10
p t, psia
40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
T t, K
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
Free-stream
Saturation
Saturation, M=1.4
T t, max.
R c, million
* p s = 14.696 psia


M ∞ = 0.25 and chord = 1 ft.
90
80
70
60
50
40
30
20
10
P t , psia
40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
T t , K
Free–stream
Saturation
Saturation, M=1.4
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
T t , max.
6.0
5.0
4.0
R c , million
3.0
2.0
* p s = 14.696 psia

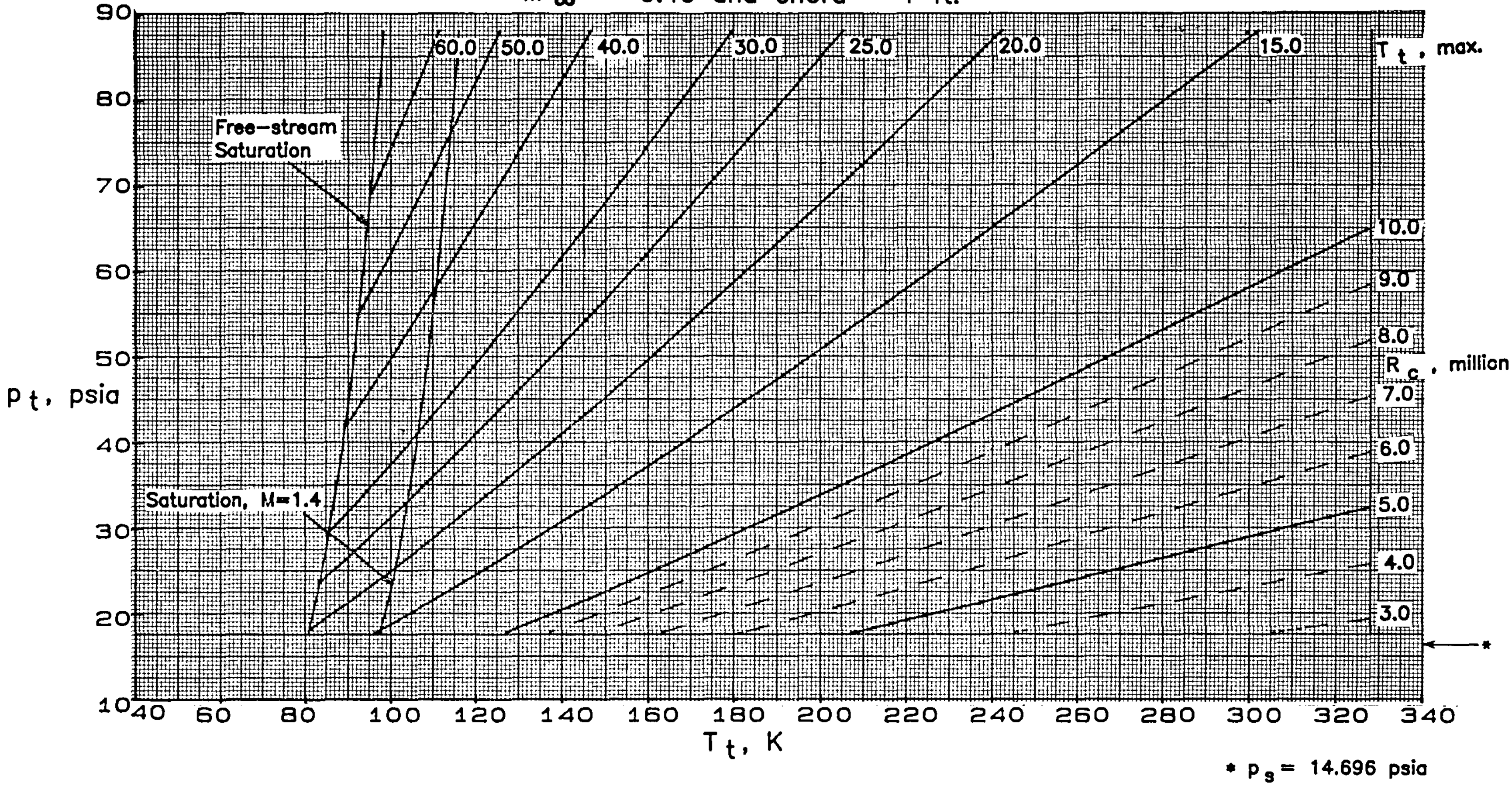

M ∞ = 0.30 and chord = 1 ft.
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
T t , max.
R c , million
Free-stream Saturation
Saturation, M=1.4
p t , psia
T t , K
* p s = 14.696 psia

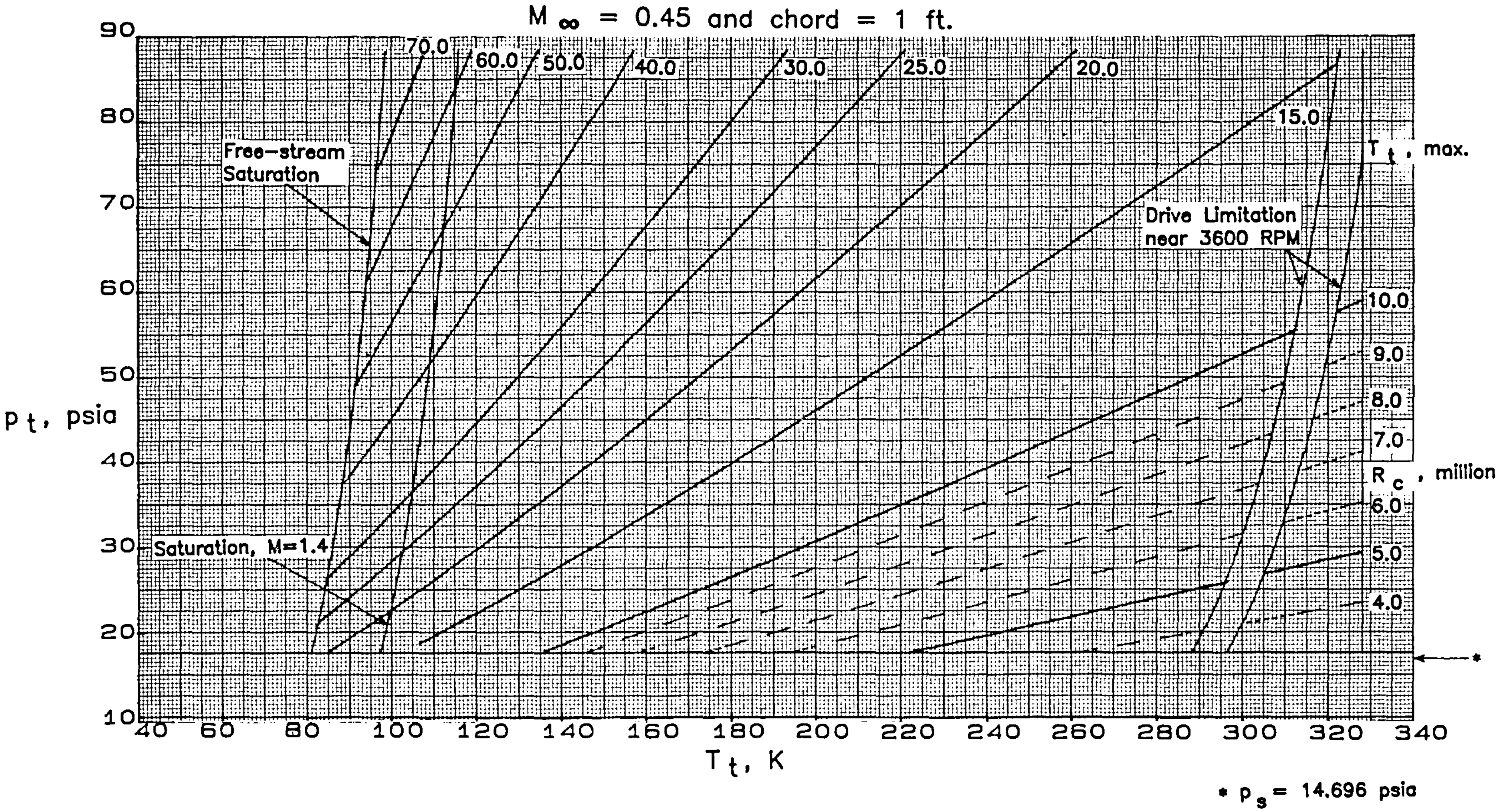
∞



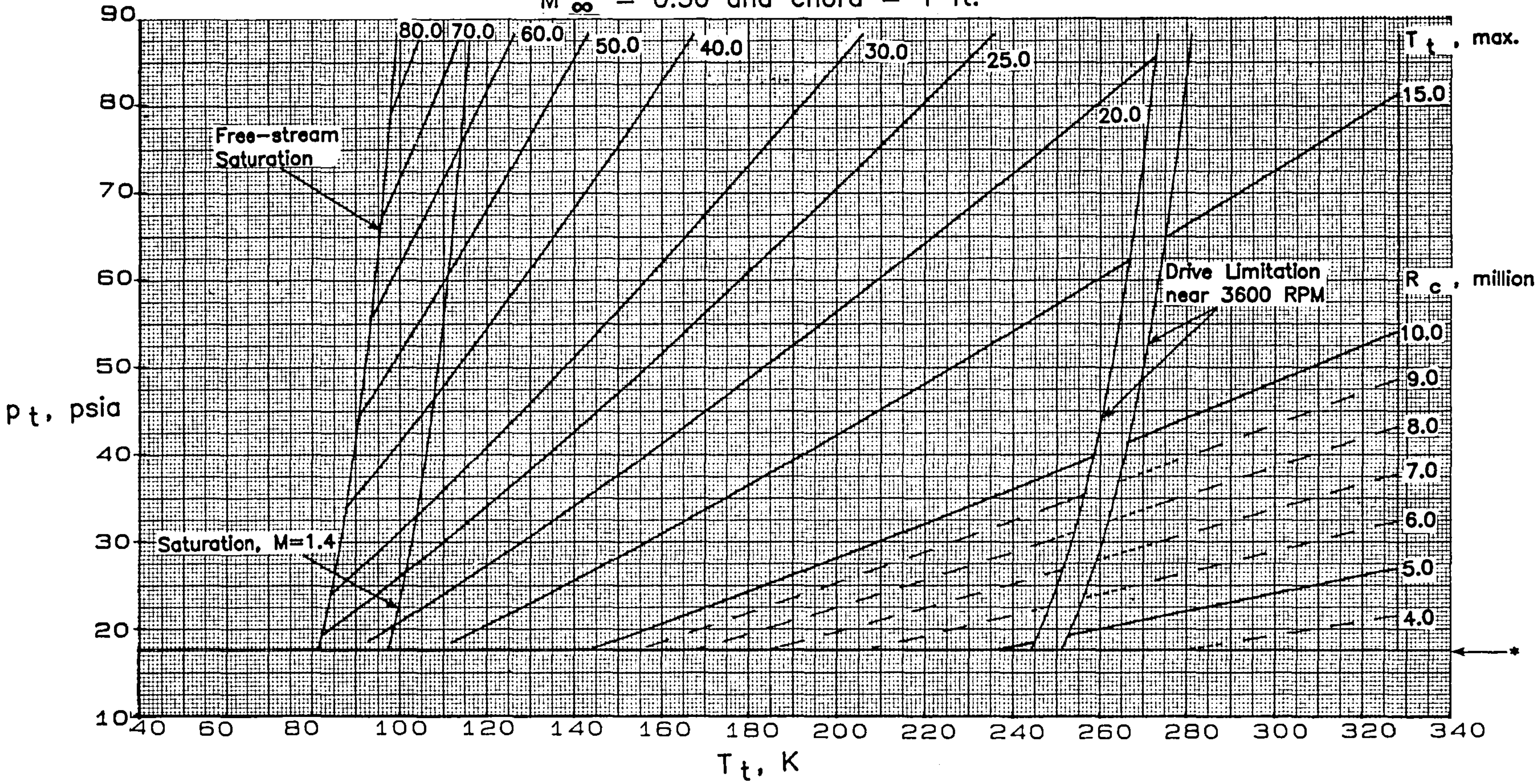
M ∞ = 0.35 and chord = 1 ft.
60.0
50.0
40.0
30.0
25.0
20.0
15.0
Tt, max.
10.0
9.0
8.0
7.0
6.0
Rc, million
5.0
4.0
3.0
Free-stream Saturation
Saturation, M=1.4
pt, psia
Tt, K
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* ps = 14.696 psia

$M_\infty = 0.40$ and chord = 1 ft.

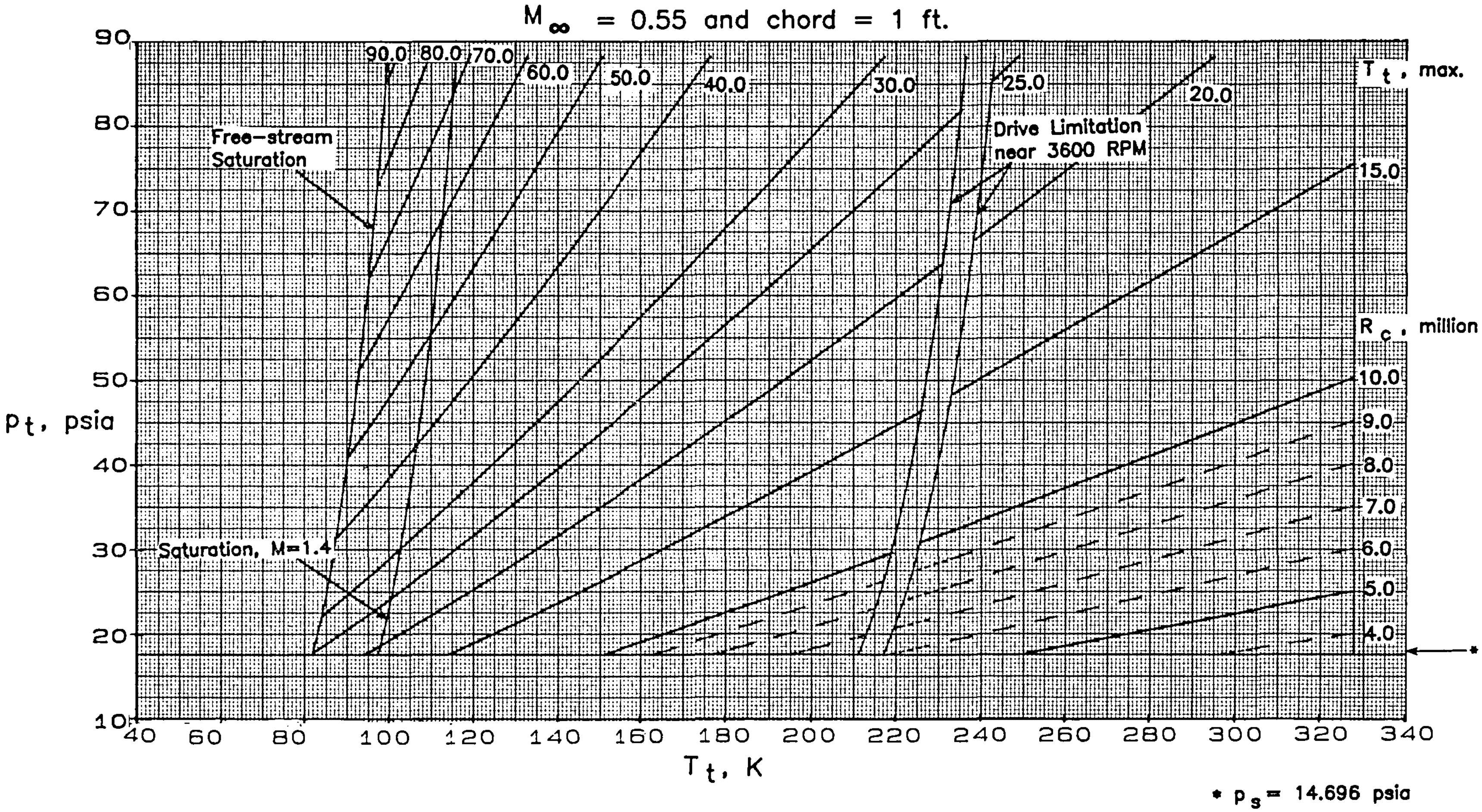


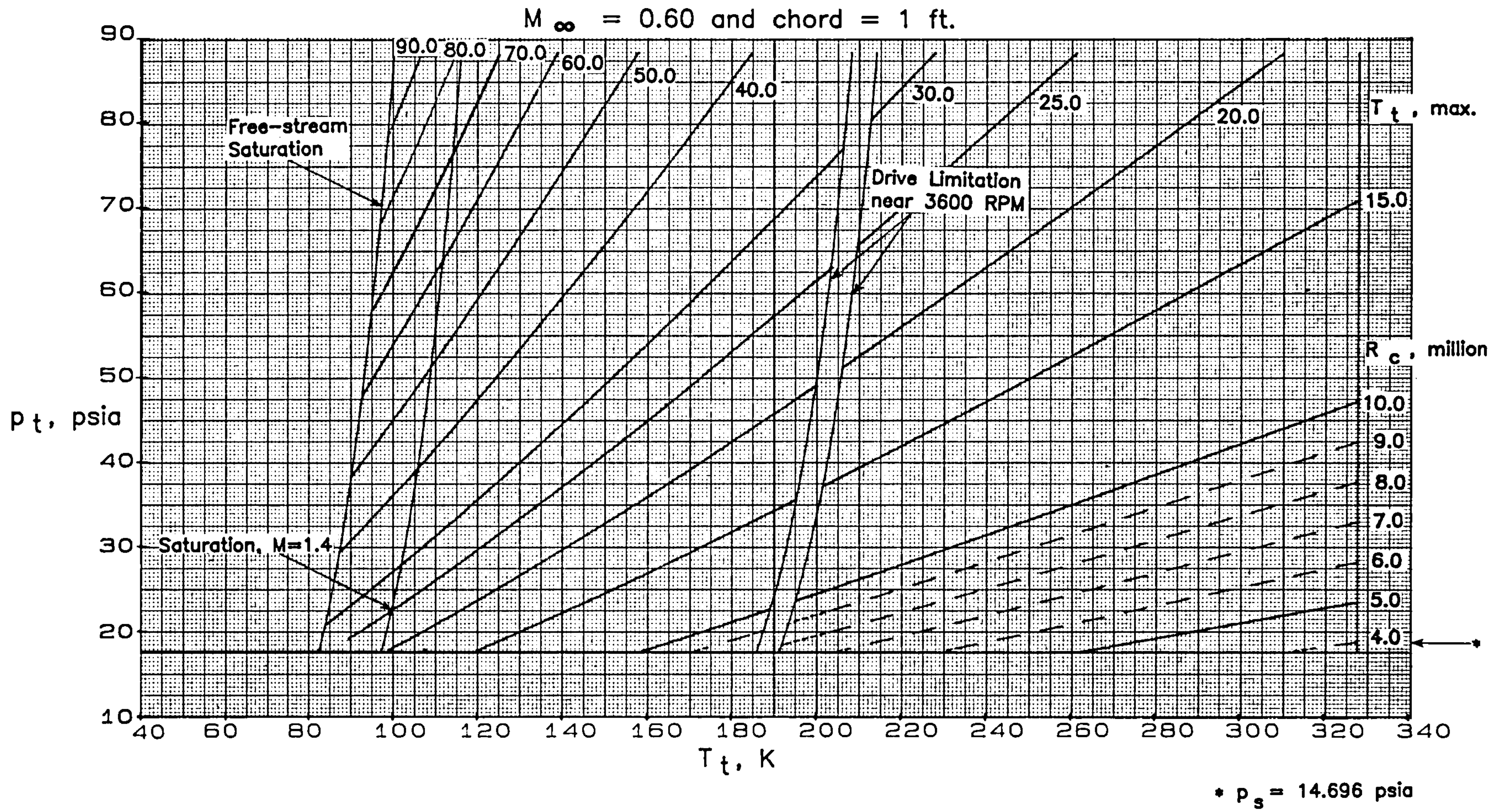

M ∞ = 0.45 and chord = 1 ft.
90
80
70
60
50
40
30
20
10
p t , psia
40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340
T t , K
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
R c , million
T t , max.
Free-stream Saturation
Saturation, M=1.4
Drive Limitation near 3600 RPM
* p s = 14.696 psia

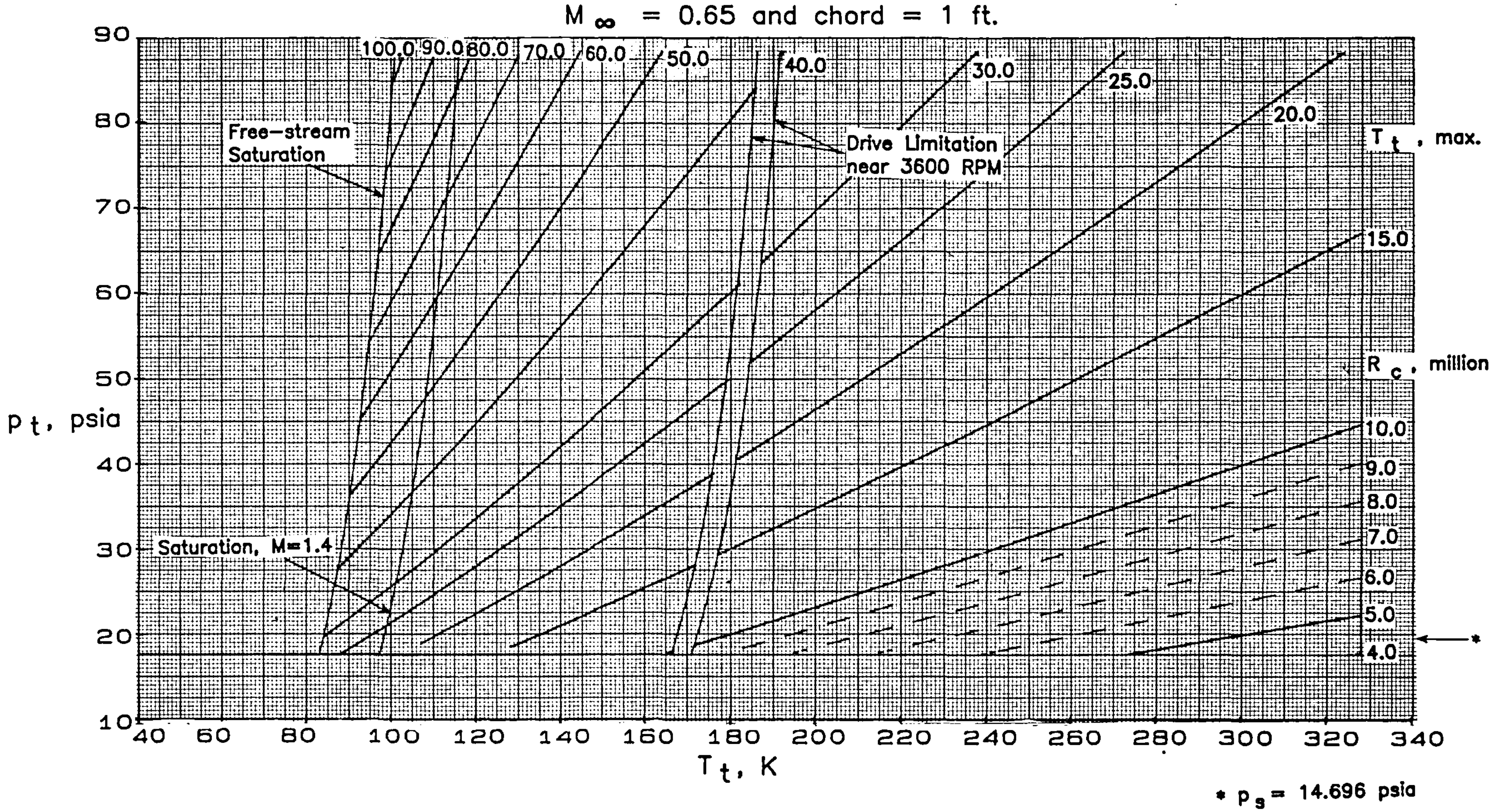
M_∞ = 0.50 and chord = 1 ft.

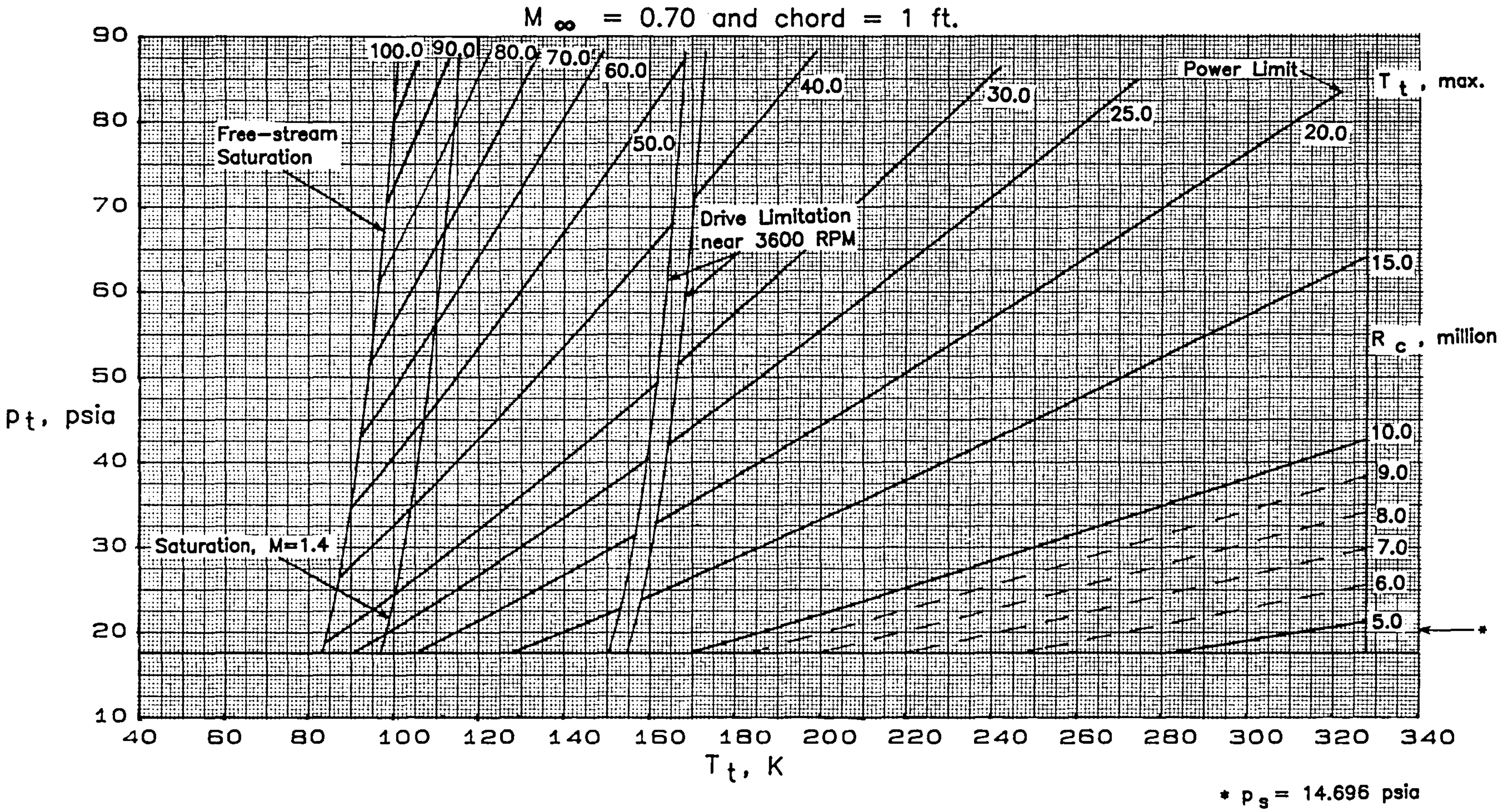


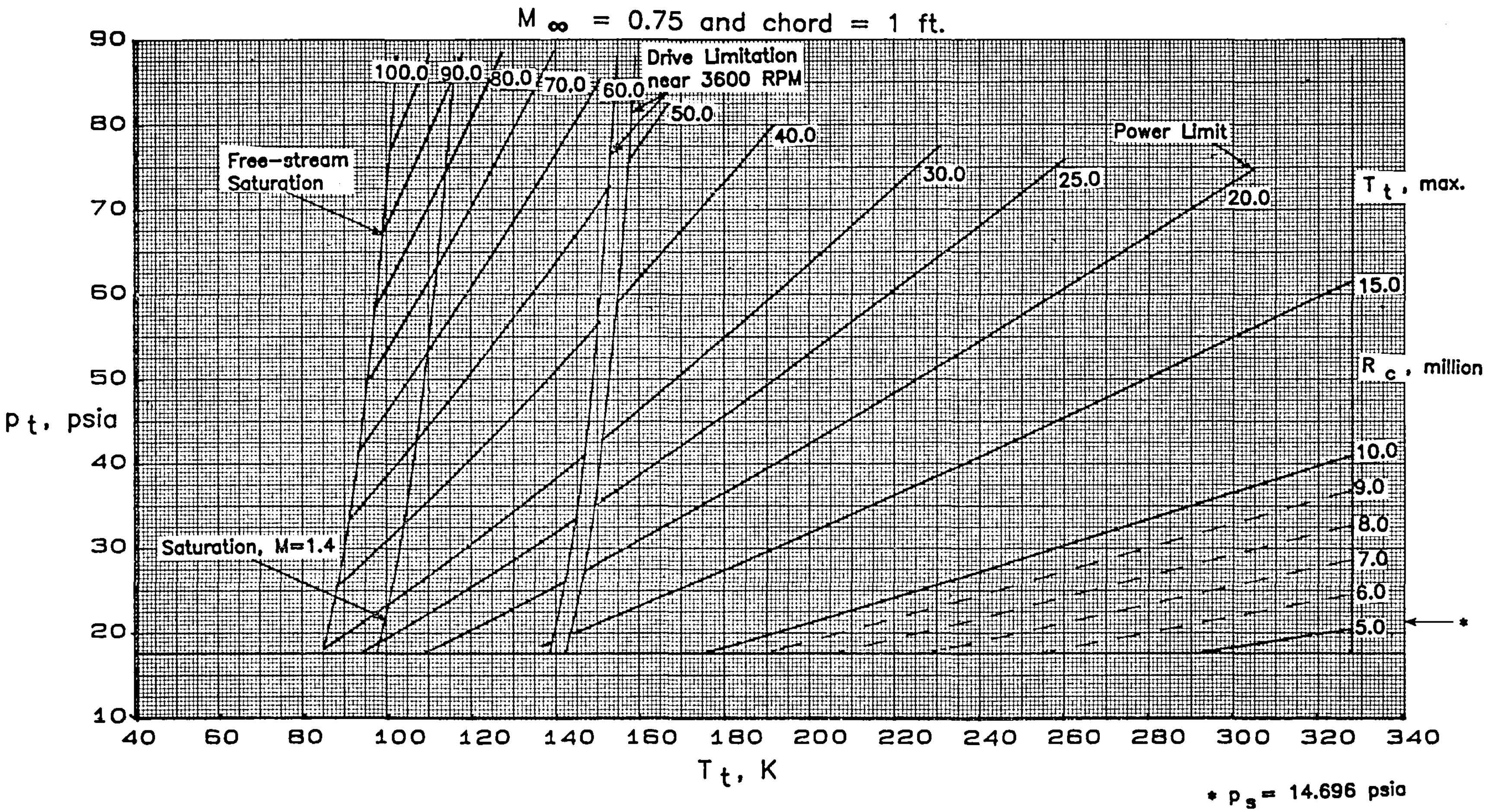
* p_s = 14.696 psia

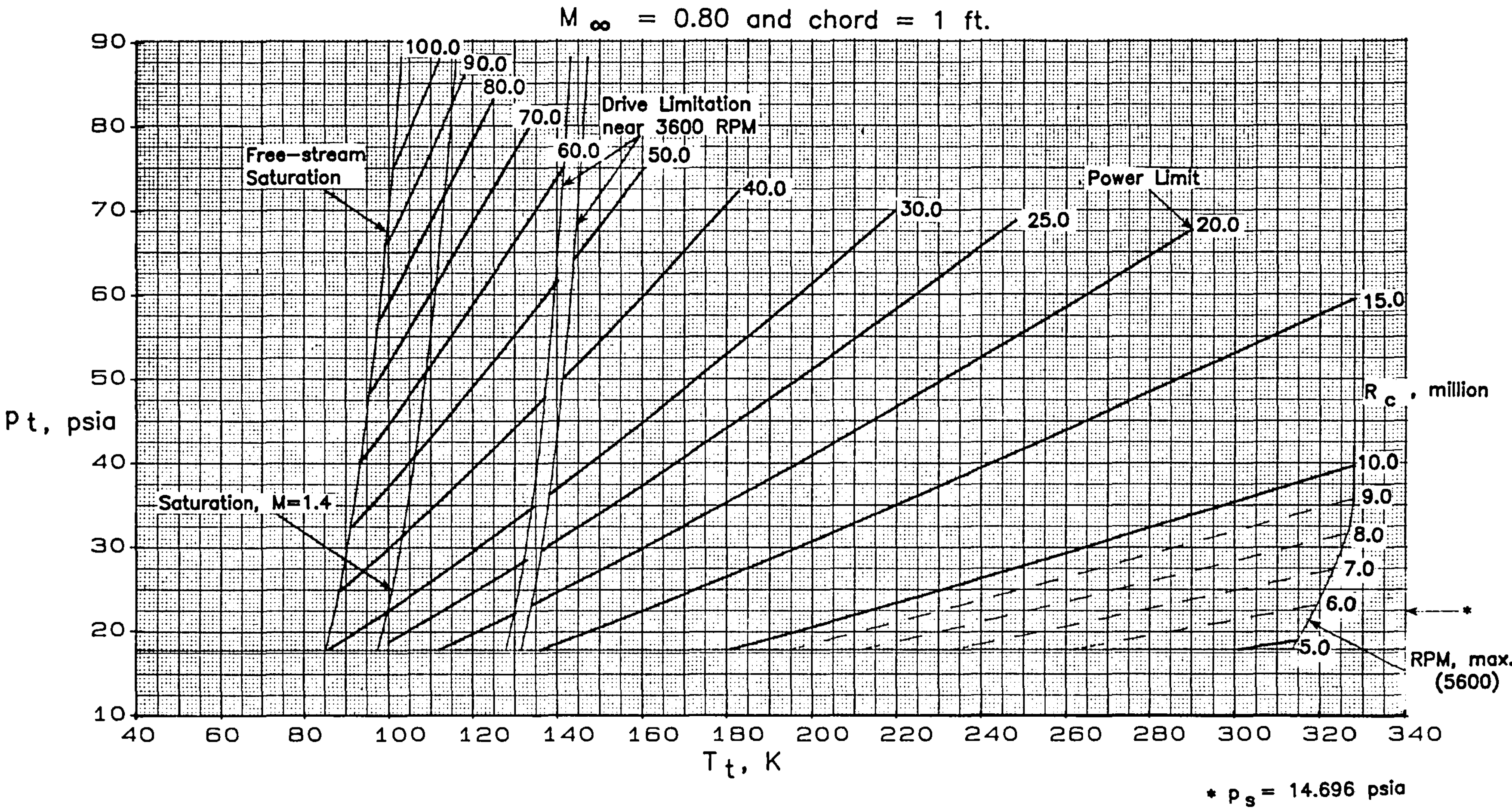

M∞ = 0.55 and chord = 1 ft.
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
Tt, max.
Rc, million
Free-stream Saturation
Saturation, M=1.4
Drive Limitation near 3600 RPM
pt, psia
Tt, K
10
20
30
40
50
60
70
80
90
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* ps = 14.696 psia

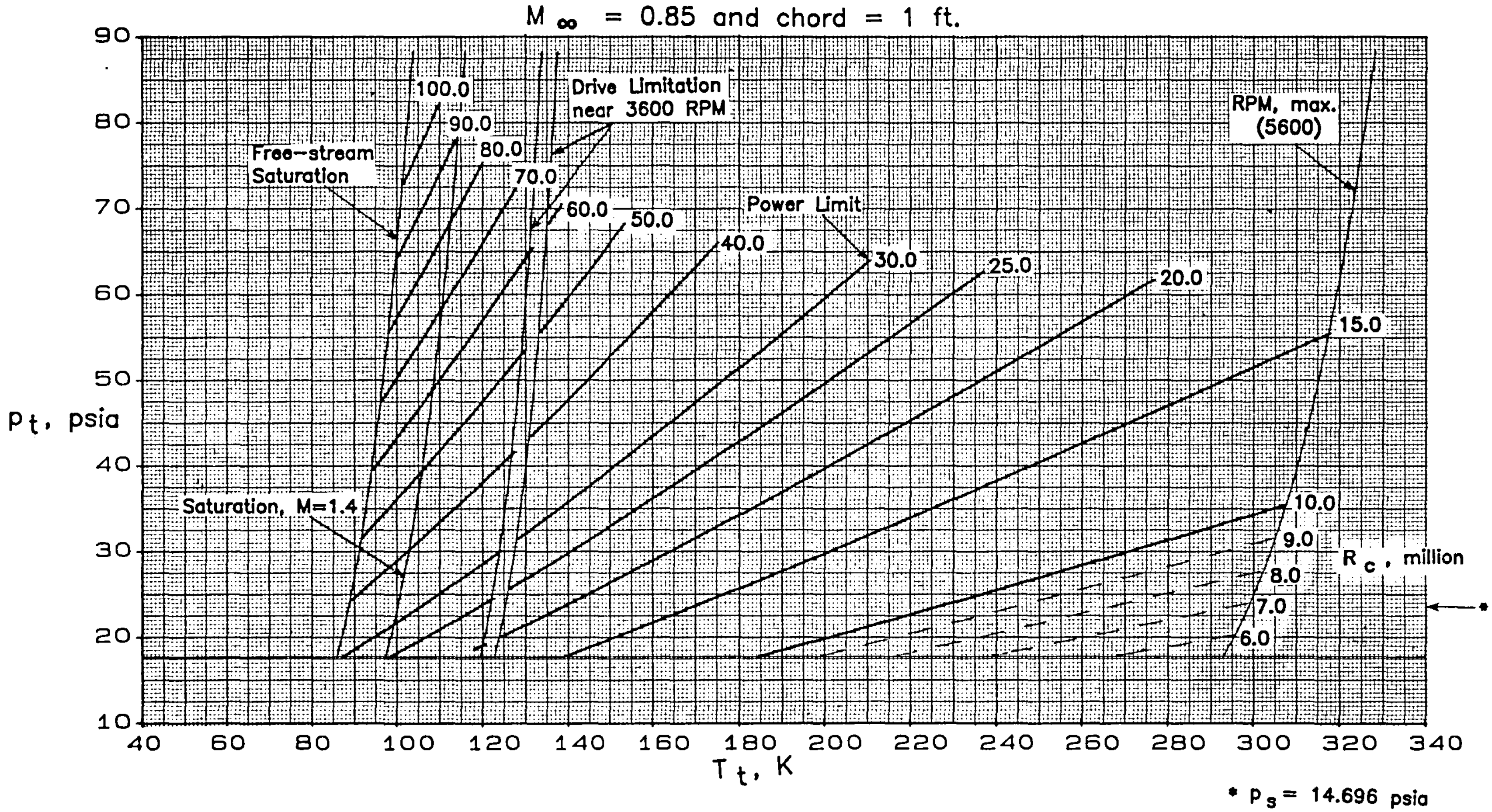

M ∞ = 0.60 and chord = 1 ft.
90
80
70
60
50
40
30
20
10
p t , psia
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
T t , K
Free-stream Saturation
Saturation, M=1.4
Drive Limitation near 3600 RPM
T t , max.
R c , million
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
* p s = 14.696 psia

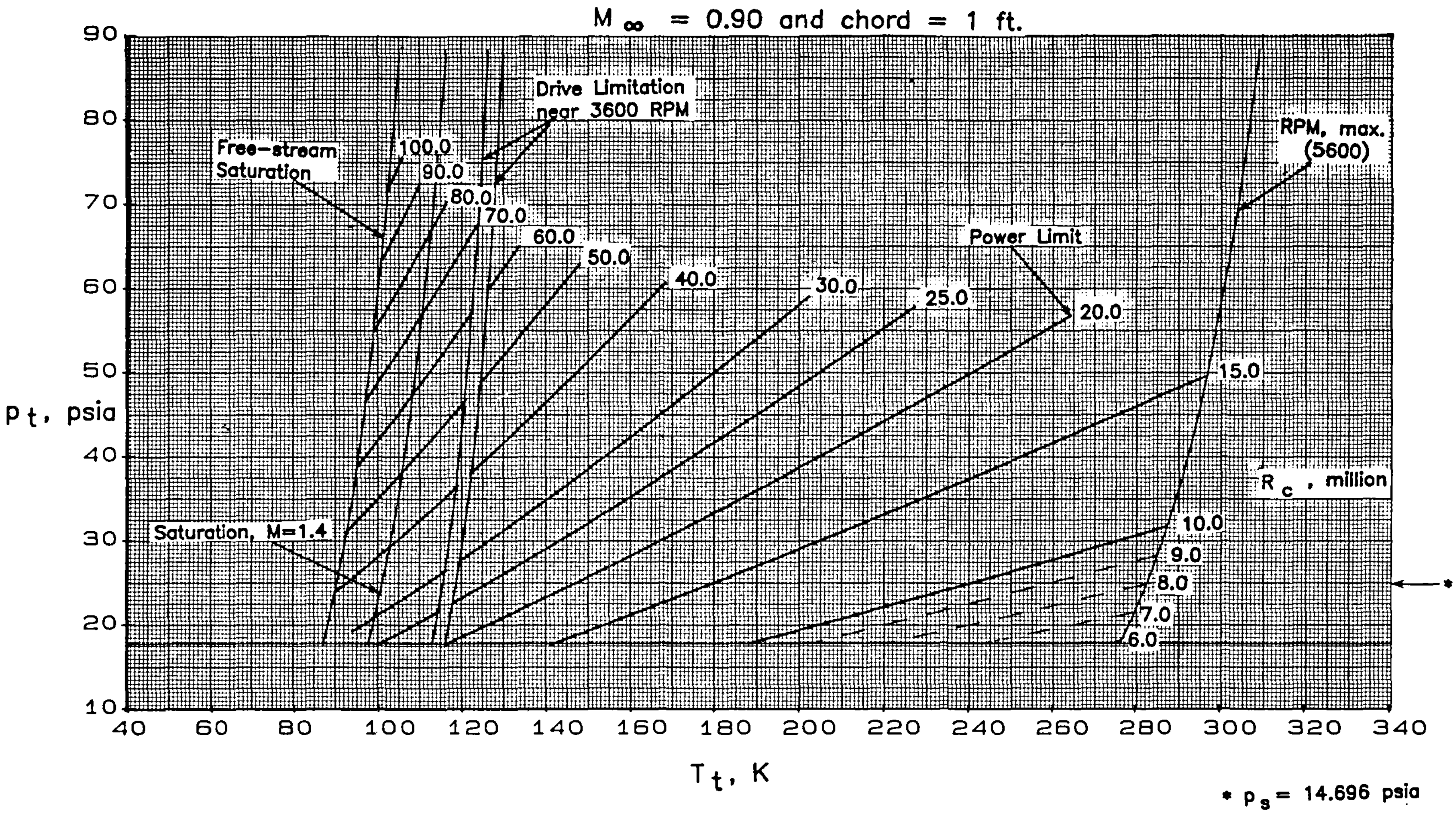

M ∞ = 0.65 and chord = 1 ft.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
Free-stream Saturation
Drive Limitation near 3600 RPM
Saturation, M=1.4
T t , max.
R c , million
p t , psia
T t , K
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* p s = 14.696 psia

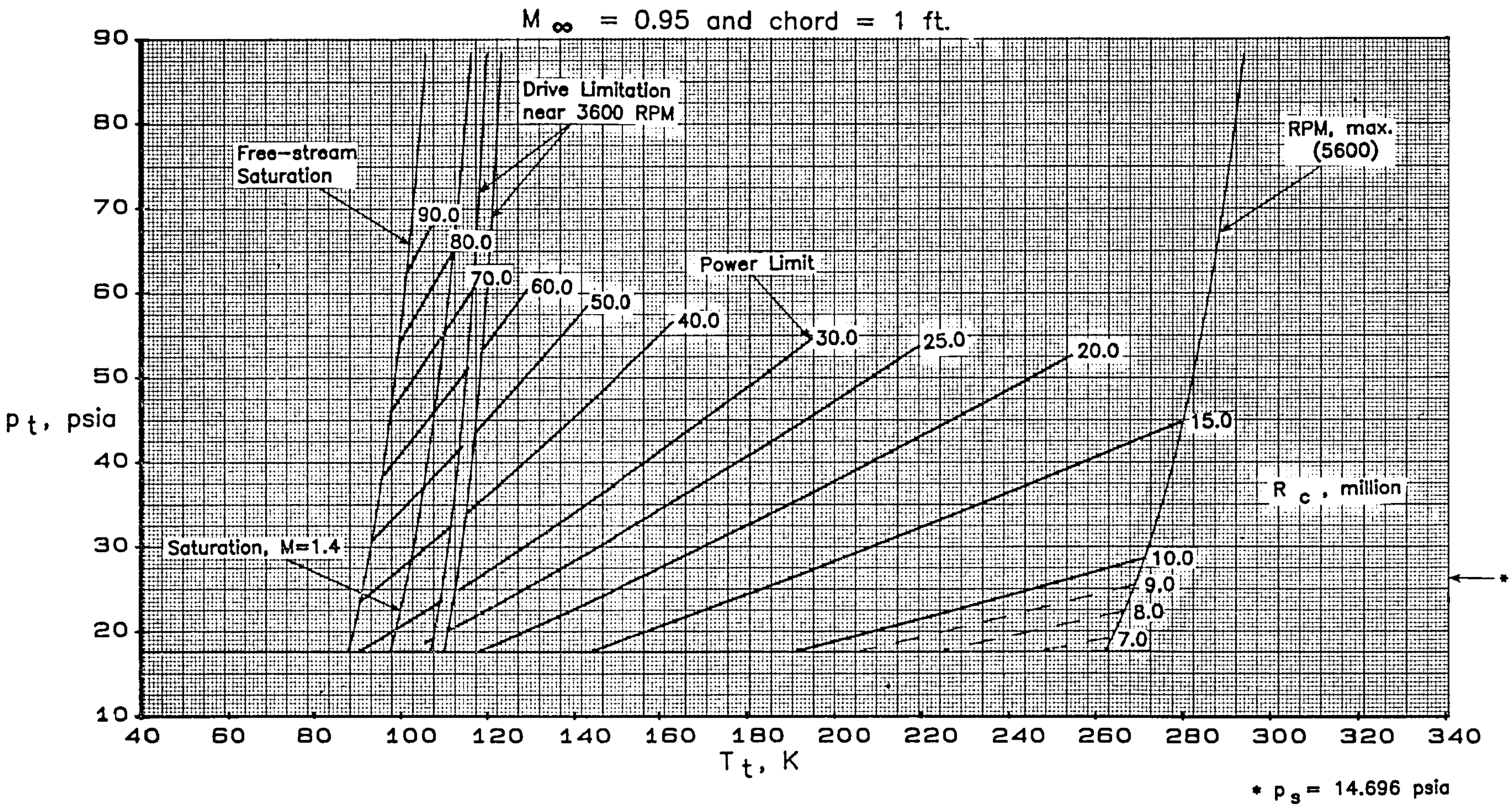

M ∞ = 0.70 and chord = 1 ft.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
Power Limit
T t , max.
R c , million
Free–stream Saturation
Drive Limitation near 3600 RPM
Saturation, M=1.4
p t , psia
T t , K
* p s = 14.696 psia
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340


M ∞ = 0.75 and chord = 1 ft.
p t , psia
T t , K
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
Drive Limitation
near 3600 RPM
Free-stream
Saturation
Saturation, M=1.4
Power Limit
T t , max.
R c , million
* p s = 14.696 psia


M ∞ = 0.80 and chord = 1 ft.
Pt, psia
Tt, K
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
Rc, million
Free-stream Saturation
Drive Limitation near 3600 RPM
Power Limit
Saturation, M=1.4
RPM, max. (5600)
* ps = 14.696 psia


M ∞ = 0.85 and chord = 1 ft.
Drive Limitation near 3600 RPM
Free-stream Saturation
Power Limit
RPM, max. (5600)
Saturation, M=1.4
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
R c , million
p t , psia
T t , K
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* p s = 14.696 psia


M ∞ = 0.90 and chord = 1 ft.
p t , psia
T t , K
Drive Limitation near 3600 RPM
Free-stream Saturation
Saturation, M=1.4
Power Limit
RPM, max. (5600)
R c , million
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
25.0
20.0
15.0
10.0
9.0
8.0
7.0
6.0
* p s = 14.696 psia



M ∞ = 0.95 and chord = 1 ft.
Drive Limitation near 3600 RPM
Free-stream Saturation
RPM, max. (5600)
90.0
80.0
70.0
60.0
50.0
40.0
Power Limit
30.0
25.0
20.0
15.0
R c, million
10.0
9.0
8.0
7.0
Saturation, M=1.4
p t, psia
T t, K
90
80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
* p s = 14.696 psia

References

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16. Abstract

To take full advantage of the unique Reynolds number capabilities of the 0.3-meter Transonic Cryogenic Tunnel (0.3-m TCT) at the NASA Langley Research Center, it was designed to accommodate test sections other than the original, octagonal, three-dimensional test section. A 20- by 60-cm two-dimensional test section was installed in 1976 and was extensively used, primarily for airfoil testing, through the fall of 1984. The tunnel was inactive during 1985 so that a new test section and improved high speed diffuser could be installed in the tunnel circuit. The new test section has solid adaptive top and bottom walls to reduce or eliminate wall interference for two-dimensional testing. The test section is 33- by 33-cm in cross section at the entrance and is 142 cm long.

In the planning and running of past airfoil tests in the 0.3-m TCT, the use of operating envelope charts have proven very useful. These charts give the variation of total temperature and pressure with Mach number and Reynolds number. The operating total temperature range of the 0.3-m TCT is from about 78 K to 327 K with total pressures ranging from about 17.5 psia to 88 psia. This report presents the operating envelope charts for the 0.3-m TCT with the adaptive wall test section installed. They were all generated based on a 1-foot chord model. The Mach numbers vary from 0.1 to 0.95.

17. Key Words (Suggested by Author(s))
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