Thermal and mechanical properties of nitrogen

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THERMAL AND MECHANICAL PROPERTIES OF NITROGEN

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Abstract. Routines for the physical properties of nitrogen liquid and gas (1 to 6 bar) are presented.

The approximations are polynomials worked out by the least squares method. The fitted expressions have been compared with experimental data, and the accuracy is about one percent.

INIS descriptors: GASES, LIQUIDS, NITROGEN, POLYNOMIALS, SURFACE TENSION, THERMODYNAMIC PROPERTIES, VISCOSITY.

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CONTENTS

1. INTRODUCTION

In connection with Per Ottosen's experimental work (ref. 6) some physical properties of nitrogen have been found from different sources (ref. 1, 2, 3 and 4) and the authors of this report present the results here, expecting that they possibly might be of interest in other connections.

Most of the approximations are 4th-degree polynomials worked out by the least squares method by means of an HP-30 programme (ref. 5). The valid ranges of the approximations and the tables are seen from the first and the last variable stated in the table in question.

The accuracy is about one percent.

2. APPROXIMATIONS

The following properties are described:

Property	Conventional symbol	Symbol used in the present report	Dimension	Table no.
Temperature	T	T	K	1
Pressure	P	P	N/m^2	2
Latent heat of evaporation	h_{lg}	HLG	J/kg	3
Gas enthalpy	h_g	HG	J/kg	4
- density	ρ_g	RG	kg/m^3	5
- heat capacity	c_{pg}	CPG	J/kgK	6
- conductivity	k_g	KG	W/mK	7
- dynamic viscosity	μ_g	MYG	Ns/m^2	8
Liquid enthalpy	h_l	HL	J/kg	9
- density	ρ_l	RL	kg/m^3	10
- heat capacity	c_{pl}	CPL	J/kgK	11
- conductivity	k_l	KL	W/mK	12
- dynamic viscosity	μ_l	MYL	Ns/m^2	13
Surface tension	σ	S	N/m	14

HG has been chosen as independent variable in the approximations corresponding to Tables 5, 6, 7, 8, and HL has been chosen as independent variable in the approximations corresponding to Tables 10, 11, 12, 13, 14.

This is due to the original construction of the approximations in a manner suited to the programme RISQUE-T (ref. 7). T might be used as independent variable by convenient choice of "subroutines".

In the description below the following operators are used:

A^B : A↑B

AB : A*B

$\frac{A}{B}$: A/B

$\log_{10}$: LOG

10^n : En

and +, -, =, in their usual notation.

Three different types of functions are used:

$f(x_1,x_2)$: a function described with one or two variables.

$g(x)$: a 4th-degree polynomial with one variable. Coefficients A0, A1, A2, A3, A4 given.

$g(x_1, x_2)$: a 4th-degree polynomial with two variables; the first one (x_1) to find A0, A1, A2, A3, A4; the last (x_2) being variable in the polynomial.

Description:

Table 1: TSAT = f(PSAT). Ref. [1].

```
T = (-304.494)/(LOG(P/1.013E5)-3.93352)
```

Table 2: PSAT = f(TSAT). Ref. [1].

```
P = 1.013E5 * 10↑(3.93352-(304.494/T))
```

Table 3: HLG = g(PSAT). Ref. [2].

```
A0 = 2.112E5
A1 = -1.571E-1
A2 = 3.004E-7
A3 = -3.358E-13
A4 = 1.350E-19
```

Table 4: HG = g(P,T). Ref. [2].

```
A0 = -0.1129 * P      -3.667E2
A1 = 1.633E-3 * P     +1.054E3
A2 = -0.9327E-5 * P   -0.1632
A3 = 0.2385E-7 * P    +0.6011E-3
A4 = -0.2271E-10 * P  -0.7100E-6
```

Table 5: RG = f(P, HG). Ref. [2] and [3].

A1 = -8.668022E-4
A2 = -9.0406019E-10
A3 = -5.7967079
B1 = 7.9632344E-9
B2 = -3.50343556E-15
B3 = 0.28550768
RG = 1/(A1+A2*P+A3/P+HG*(B1+B2*P+B3/P))

Table 6: CPG = g(P, HG). Ref. [2].

A0 = (1.409+P*(4.496E-6+P*(-1.591E-11+1.750E-17*P)))*1E3
A1 = -7.754E-3+P*(-6.390E-8+P*(2.702E-13-3.043E-19*P))
A2 = (5.170E-5+P*(2.594E-10+P*(-1.343E-15+1.569E-21*P)))*1E-3
A3 = (-1.092E-7+P*(-2.520E-13+P*(1.891E-18-2.348E-24*P)))*1E-
A4 = 0

Table 7: KG (at 1 bar) = g(HG). Ref. [4].

A0 = 2.688E-3
A1 = 3.722E-8
A2 = 4.114E-13
A3 = -1.445E-18
A4 = 1.644E-24

Table 8: MYG = g(P, HG). Ref. [2].

A0 = P*6.403E-12 +5.457E-7
A1 = P*(-7,684E-17) +4.666E-11
A2 = P*3.486E-22 +2.557E-16
A3 = P*(-5.700E-28) -1.389E-21
A4 = P*7.333E-35 +2.188E-27

Table 9: HL = g(P). Ref. [2].

A0 = -1.448E5
A1 = 2.836E-1
A2 = -6.076E-7
A3 = 6.687E-13
A4 = -2.661E-19

Table 10: RL = g(HL). Ref. [2].

A0	5.027E2
A1	-1.929E-3
A2	1.548E-8
A3	1.185E-13
A4	2.538E-19

Table 11: CPL = g (HL). Ref. [2].

A0	4.975E3
A1	7.796E-2
A2	7.668E-7
A3	3.426E-12
A4	5.830E-18

Table 12: KL = g(HL). Ref. [4].

A0	5.523E-2
A1	-2.469E-7
A2	4.988E-12
A3	-1.190E-17
A4	0

Table 13: MYL = g(HL). Ref. [2].

A0	1.731E-4
A1	3.633E-9
A2	4.211E-14
A3	2.300E-19
A4	1.003E-24

Table 14: S = g(HL). Ref. [2].

A0	-8.295E-4
A1	-4.373E-8
A2	3.300E-13
A3	2.371E-19
A4	0

The approximations are tabulated in Section 4. The temperature T and pressure P have been preferred as independent variables. This means that one has to use up to three "subroutines". F.ex. Table 10, RL:

P is found by inserting T in "subroutine Table 2".
HL - - - - P - " - - 9".
RL - - - - HL - " - - 10".

It should be noted that N_2 gas can be considered as an ideal gas for temperatures $T \geq 350K$ and pressures $P \leq 10$ bar. In this way Table 5, RG versus P and T, can be extended beyond T = 350K. The molecular weight is M = 28.016 kg/kmol. The gas constant is R = 8314.3 J/ K·kmol. We then have the law for an ideal gas:

$$RG = (P/T)*(M/R) = (P/T)*0.0033696 \ [kg/m^3]$$

The comparison between the values calculated by the above formula, values calculated by the present approximations and table values from ref. 2, are shown in the Table below:

N_2 gas density [kg/m^3] at T = 350K

P bar	Calculated by the law of an ideal gas	Calculated by the present approximations	Table values from ref. 2.
1	0.963	0.962	0.962
2	1.93	1.92	1.92
3	2.89	2.88	2.89
4	3.85	3.84	3.85
5	4.81	4.80	4.81
6	5.78	5.77	5.77
7	6.74	6.74	
8	7.70	7.72	7.69
9	8.66	8.71	
10	9.63	9.70	9.62

The gas law is valid also for temperatures lower than 350K, but not near the saturation temperature. It should be emphasized - as mentioned in the introduction - that the present approximations in this case must not be used for variables larger than P = 10 bar and T = 350K.

3. REFERENCES

1. Landolt - Börnstein. Zahlenwerte und Funktionen aus Physik-Chemie-Astronomie-Geophysik und Tecknik. 6. Auflage IV Band, Tecknik 4. Teil Wärmetecknik. Springer Verlag 1967.

2. Vargaftik N.B. Tables on the Thermophysical Properties of Liquid and Gases.
   John Wiley & Sons.

3. Larsen, A.M. Steam and Water Property Routines Received from the THOR group at Brookhaven National Laboratory, NORHAV-D-030, Nov. 1976.

4. Handbook of Chemistry and Physics. 57th edition 1976-1977.

5. Dietrich, O.W. and Rathmann, O.S. Hewlett-Packard Keyboard. Vol. 7, No. 4, p. 4-6.

6. Ottosen, P. Inverted Annular Film Boiling In Liquid Nitrogen Flow. Risø National Laboratory. NORHAV-D-71. May 1979.

7. Eget, L. and Andersen, P.S. The RISQUE-T Computer Programme. Research Establishment Risø. NORHAV-D-035. February 1977.

4. TABLES

The approximations are tabulated in the following 14 tables. As mentioned the valid ranges of the approcimations are given by the first and the last variable stated in the table in question. The temperatures T and pressure P have been chosen as independent variables (see page 10).

5. FIGURES

The approximations (analytical fits) have been compared with the experimental data (table values from the references) on the following 12 figures, which give an impression of the accuracy. As mentioned on page 6 the entalpies have been chosen as independent variables in most cases.

TABLE NO. 1.

N2 SATURATION TEMPERATURE TSAT V. PRESSURE PSAT.

PSAT(N/M2)	TSAT(K)
.250E 5	67.0
.500E 5	71.8
.750E 5	74.9
.100E 6	77.2
.125E 6	79.2
.150E 6	80.9
.175E 6	82.3
.200E 6	83.6
.225E 6	84.8
.250E 6	85.9
.275E 6	87.0
.300E 6	87.9
.325E 6	88.8
.350E 6	89.6
.375E 6	90.4
.400E 6	91.2
.425E 6	91.9
.450E 6	92.6
.475E 6	93.3
.500E 6	93.9
.525E 6	94.5
.550E 6	95.1
.575E 6	95.7
.600E 6	96.3
.625E 6	96.8
.650E 6	97.4
.675E 6	97.9
.700E 6	98.4
.725E 6	98.9
.750E 6	99.3
.775E 6	99.8
.800E 6	100.2
.825E 6	100.7
.850E 6	101.1
.875E 6	101.5
.900E 6	102.0
.925E 6	102.4
.950E 6	102.8
.975E 6	103.2
.100E 7	103.6

TABLE NO. 2.

N2 SATURATION PRESSURE PSAT V. TEMPERATURE TSAT.

TSAT(K)	PSAT(N/M2)
68	.289E 5
69	.335E 5
70	.388E 5
71	.447E 5
72	.512E 5
73	.586E 5
74	.667E 5
75	.757E 5
76	.856E 5
77	.965E 5
78	.108E 6
79	.121E 6
80	.135E 6
81	.151E 6
82	.168E 6
83	.186E 6
84	.206E 6
85	.227E 6
86	.250E 6
87	.274E 6
88	.301E 6
89	.329E 6
90	.359E 6
91	.391E 6
92	.426E 6
93	.462E 6
94	.500E 6
95	.541E 6
96	.585E 6
97	.630E 6
98	.679E 6
99	.730E 6
100	.783E 6
101	.840E 6
102	.899E 6
103	.961E 6
104	.102E 7

TABLE NO. 3.

N2 LATENT HEAT OF EVAPORATION HLG V. TEMPERATURE TSAT.

TSAT(K)	HLG(J/KG)
68	.206E 6
69	.206E 6
70	.205E 6
71	.204E 6
72	.203E 6
73	.202E 6
74	.201E 6
75	.200E 6
76	.199E 6
77	.198E 6
78	.197E 6
79	.195E 6
80	.194E 6
81	.193E 6
82	.191E 6
83	.190E 6
84	.188E 6
85	.187E 6
86	.185E 6
87	.184E 6
88	.183E 6
89	.181E 6
90	.180E 6
91	.178E 6
92	.177E 6
93	.175E 6
94	.174E 6
95	.172E 6
96	.170E 6
97	.168E 6
98	.166E 6
99	.164E 6
100	.161E 6
101	.159E 6
102	.156E 6
103	.154E 6
104	.153E 6

TABLE NO. 4 (continues).

N2 GAS ENTHALPY HG (J/KG) V.TEMP. T AND PRESSURE P.

P(N/M2)	.100E 6	.200E 6	.300E 6	.400E 6	.500E 6
T(K)					
80	.801E 5				
85	.855E 5	.827E 5			
90	.910E 5	.884E 5	.858E 5		
95	.964E 5	.940E 5	.917E 5	.894E 5	.870E 5
100	.101E 6	.996E 5	.975E 5	.954E 5	.932E 5
105	.107E 6	.105E 6	.103E 6	.101E 6	.994E 5
110	.112E 6	.110E 6	.108E 6	.107E 6	.105E 6
115	.117E 6	.116E 6	.114E 6	.113E 6	.111E 6
120	.123E 6	.121E 6	.120E 6	.118E 6	.117E 6
125	.128E 6	.127E 6	.125E 6	.124E 6	.123E 6
130	.133E 6	.132E 6	.131E 6	.130E 6	.128E 6
135	.139E 6	.137E 6	.136E 6	.135E 6	.134E 6
140	.144E 6	.143E 6	.142E 6	.141E 6	.140E 6
145	.149E 6	.148E 6	.147E 6	.146E 6	.145E 6
150	.154E 6	.153E 6	.153E 6	.152E 6	.151E 6
155	.160E 6	.159E 6	.158E 6	.157E 6	.156E 6
160	.165E 6	.164E 6	.163E 6	.163E 6	.162E 6
165	.170E 6	.169E 6	.169E 6	.168E 6	.167E 6
170	.175E 6	.175E 6	.174E 6	.173E 6	.173E 6
175	.181E 6	.180E 6	.179E 6	.179E 6	.178E 6
180	.186E 6	.185E 6	.185E 6	.184E 6	.183E 6
185	.191E 6	.190E 6	.190E 6	.189E 6	.189E 6
190	.196E 6	.196E 6	.195E 6	.195E 6	.194E 6
195	.201E 6	.201E 6	.200E 6	.200E 6	.199E 6
200	.207E 6	.206E 6	.206E 6	.205E 6	.205E 6
205	.212E 6	.211E 6	.211E 6	.210E 6	.210E 6
210	.217E 6	.217E 6	.216E 6	.216E 6	.215E 6
215	.222E 6	.222E 6	.221E 6	.221E 6	.220E 6
220	.227E 6	.227E 6	.227E 6	.226E 6	.226E 6
225	.233E 6	.232E 6	.232E 6	.231E 6	.231E 6
230	.238E 6	.237E 6	.237E 6	.237E 6	.236E 6
235	.243E 6	.243E 6	.242E 6	.242E 6	.241E 6
240	.248E 6	.248E 6	.247E 6	.247E 6	.247E 6
245	.253E 6	.253E 6	.253E 6	.252E 6	.252E 6
250	.259E 6	.258E 6	.258E 6	.258E 6	.257E 6
255	.264E 6	.264E 6	.263E 6	.263E 6	.262E 6
260	.269E 6	.269E 6	.268E 6	.268E 6	.268E 6
265	.274E 6	.274E 6	.274E 6	.273E 6	.273E 6
270	.280E 6	.279E 6	.279E 6	.279E 6	.278E 6
275	.285E 6	.284E 6	.284E 6	.284E 6	.284E 6
280	.290E 6	.290E 6	.289E 6	.289E 6	.289E 6
285	.295E 6	.295E 6	.295E 6	.294E 6	.294E 6
290	.300E 6	.300E 6	.300E 6	.300E 6	.299E 6
295	.306E 6	.305E 6	.305E 6	.305E 6	.305E 6
300	.311E 6	.311E 6	.310E 6	.310E 6	.310E 6
305	.316E 6	.316E 6	.316E 6	.315E 6	.315E 6
310	.321E 6	.321E 6	.321E 6	.321E 6	.320E 6
315	.327E 6	.326E 6	.326E 6	.326E 6	.326E 6
320	.332E 6	.332E 6	.331E 6	.331E 6	.331E 6
325	.337E 6	.337E 6	.337E 6	.336E 6	.336E 6
330	.342E 6	.342E 6	.342E 6	.342E 6	.341E 6
335	.347E 6	.347E 6	.347E 6	.347E 6	.347E 6
340	.353E 6	.352E 6	.352E 6	.352E 6	.352E 6
345	.358E 6	.358E 6	.357E 6	.357E 6	.357E 6
350	.363E 6	.363E 6	.363E 6	.362E 6	.362E 6

TABLE NO. 4 (continued).

N2 GAS ENTHALPY HG (J/KG) V. TEMP. T AND PRESSURE P.

P(N/M2)	.600E 6	.700E 6	.800E 6	.900E 6	.100E 7
T(K)					
80					
85					
90					
95					
100	.911E 5				
105	.974E 5	.955E 5	.935E 5	.916E 5	.896E 5
110	.103E 6	.101E 6	.100E 6	.983E 5	.965E 5
115	.109E 6	.108E 6	.106E 6	.104E 6	.103E 6
120	.115E 6	.114E 6	.112E 6	.111E 6	.109E 6
125	.121E 6	.120E 6	.119E 6	.117E 6	.116E 6
130	.127E 6	.126E 6	.125E 6	.123E 6	.122E 6
135	.133E 6	.132E 6	.131E 6	.130E 6	.128E 6
140	.139E 6	.138E 6	.137E 6	.136E 6	.135E 6
145	.144E 6	.143E 6	.142E 6	.141E 6	.141E 6
150	.150E 6	.149E 6	.148E 6	.147E 6	.146E 6
155	.156E 6	.155E 6	.154E 6	.153E 6	.152E 6
160	.161E 6	.160E 6	.160E 6	.159E 6	.158E 6
165	.167E 6	.166E 6	.165E 6	.164E 6	.164E 6
170	.172E 6	.171E 6	.171E 6	.170E 6	.169E 6
175	.177E 6	.177E 6	.176E 6	.176E 6	.175E 6
180	.183E 6	.182E 6	.182E 6	.181E 6	.180E 6
185	.188E 6	.188E 6	.187E 6	.186E 6	.186E 6
190	.193E 6	.193E 6	.192E 6	.192E 6	.191E 6
195	.199E 6	.198E 6	.198E 6	.197E 6	.197E 6
200	.204E 6	.204E 6	.203E 6	.203E 6	.202E 6
205	.209E 6	.209E 6	.208E 6	.208E 6	.208E 6
210	.215E 6	.214E 6	.214E 6	.213E 6	.213E 6
215	.220E 6	.220E 6	.219E 6	.219E 6	.218E 6
220	.225E 6	.225E 6	.224E 6	.224E 6	.224E 6
225	.231E 6	.230E 6	.230E 6	.229E 6	.229E 6
230	.236E 6	.235E 6	.235E 6	.235E 6	.234E 6
235	.241E 6	.241E 6	.240E 6	.240E 6	.239E 6
240	.246E 6	.246E 6	.246E 6	.245E 6	.245E 6
245	.252E 6	.251E 6	.251E 6	.250E 6	.250E 6
250	.257E 6	.257E 6	.256E 6	.256E 6	.255E 6
255	.262E 6	.262E 6	.261E 6	.261E 6	.261E 6
260	.267E 6	.267E 6	.267E 6	.266E 6	.266E 6
265	.273E 6	.272E 6	.272E 6	.272E 6	.271E 6
270	.278E 6	.278E 6	.277E 6	.277E 6	.277E 6
275	.283E 6	.283E 6	.283E 6	.282E 6	.282E 6
280	.289E 6	.288E 6	.288E 6	.288E 6	.287E 6
285	.294E 6	.294E 6	.293E 6	.293E 6	.293E 6
290	.299E 6	.299E 6	.299E 6	.298E 6	.298E 6
295	.304E 6	.304E 6	.304E 6	.304E 6	.303E 6
300	.310E 6	.309E 6	.309E 6	.309E 6	.309E 6
305	.315E 6	.315E 6	.314E 6	.314E 6	.314E 6
310	.320E 6	.320E 6	.320E 6	.320E 6	.319E 6
315	.325E 6	.325E 6	.325E 6	.325E 6	.325E 6
320	.331E 6	.331E 6	.330E 6	.330E 6	.330E 6
325	.336E 6	.336E 6	.336E 6	.335E 6	.335E 6
330	.341E 6	.341E 6	.341E 6	.341E 6	.340E 6
335	.346E 6	.346E 6	.346E 6	.346E 6	.346E 6
340	.352E 6	.351E 6	.351E 6	.351E 6	.351E 6
345	.357E 6	.357E 6	.356E 6	.356E 6	.356E 6
350	.362E 6	.362E 6	.361E 6	.361E 6	.361E 6

TABLE NO. 5 (continues).

N2 GAS DENSITY RG (KG/M3) V. TEMP. T AND PRESSURE P.

P(N/M2) T(K)	.100E 6	.200E 6	.300E 6	.400E 6	.500E 6
80	.437E 1				
85	.409E 1	.849E 1			
90	.385E 1	.794E 1	.123E 2		
95	.363E 1	.746E 1	.115E 2	.158E 2	.204E 2
100	.344E 1	.704E 1	.108E 2	.148E 2	.190E 2
105	.327E 1	.667E 1	.102E 2	.139E 2	.178E 2
110	.311E 1	.633E 1	.967E 1	.131E 2	.167E 2
115	.297E 1	.603E 1	.919E 1	.124E 2	.158E 2
120	.284E 1	.576E 1	.876E 1	.118E 2	.150E 2
125	.272E 1	.551E 1	.837E 1	.113E 2	.143E 2
130	.261E 1	.528E 1	.801E 1	.108E 2	.136E 2
135	.251E 1	.508E 1	.769E 1	.103E 2	.131E 2
140	.242E 1	.488E 1	.739E 1	.995E 1	.125E 2
145	.234E 1	.471E 1	.712E 1	.957E 1	.120E 2
150	.226E 1	.454E 1	.686E 1	.922E 1	.116E 2
155	.218E 1	.439E 1	.663E 1	.890E 1	.112E 2
160	.211E 1	.425E 1	.641E 1	.860E 1	.108E 2
165	.205E 1	.412E 1	.621E 1	.832E 1	.104E 2
170	.199E 1	.399E 1	.602E 1	.806E 1	.101E 2
175	.193E 1	.387E 1	.584E 1	.782E 1	.983E 1
180	.187E 1	.376E 1	.567E 1	.759E 1	.954E 1
185	.182E 1	.366E 1	.551E 1	.738E 1	.926E 1
190	.177E 1	.356E 1	.536E 1	.718E 1	.901E 1
195	.173E 1	.347E 1	.522E 1	.698E 1	.877E 1
200	.168E 1	.338E 1	.509E 1	.680E 1	.854E 1
205	.164E 1	.330E 1	.496E 1	.663E 1	.832E 1
210	.160E 1	.322E 1	.484E 1	.647E 1	.811E 1
215	.157E 1	.314E 1	.472E 1	.632E 1	.792E 1
220	.153E 1	.307E 1	.461E 1	.617E 1	.773E 1
225	.150E 1	.300E 1	.451E 1	.603E 1	.756E 1
230	.146E 1	.293E 1	.441E 1	.589E 1	.739E 1
235	.143E 1	.287E 1	.431E 1	.576E 1	.722E 1
240	.140E 1	.281E 1	.422E 1	.564E 1	.707E 1
245	.137E 1	.275E 1	.413E 1	.552E 1	.692E 1
250	.134E 1	.270E 1	.405E 1	.541E 1	.678E 1
255	.132E 1	.264E 1	.397E 1	.530E 1	.664E 1
260	.129E 1	.259E 1	.389E 1	.520E 1	.651E 1
265	.127E 1	.254E 1	.382E 1	.510E 1	.638E 1
270	.124E 1	.249E 1	.374E 1	.500E 1	.626E 1
275	.122E 1	.245E 1	.368E 1	.491E 1	.614E 1
280	.120E 1	.240E 1	.361E 1	.482E 1	.603E 1
285	.118E 1	.236E 1	.354E 1	.473E 1	.592E 1
290	.116E 1	.232E 1	.348E 1	.465E 1	.582E 1
295	.114E 1	.228E 1	.342E 1	.457E 1	.572E 1
300	.112E 1	.224E 1	.336E 1	.449E 1	.562E 1
305	.110E 1	.220E 1	.331E 1	.441E 1	.552E 1
310	.108E 1	.217E 1	.325E 1	.434E 1	.543E 1
315	.106E 1	.213E 1	.320E 1	.427E 1	.534E 1
320	.105E 1	.210E 1	.315E 1	.420E 1	.526E 1
325	.103E 1	.207E 1	.310E 1	.414E 1	.518E 1
330	.102E 1	.203E 1	.305E 1	.407E 1	.510E 1
335	.100E 1	.200E 1	.301E 1	.401E 1	.502E 1
340	.990E 0	.197E 1	.296E 1	.395E 1	.495E 1
345	.976E 0	.195E 1	.292E 1	.390E 1	.487E 1
350	.962E 0	.192E 1	.288E 1	.384E 1	.480E 1

TABLE NO. 5 (continued).

N2 GAS DENSITY RG (KG/M3) V. TEMP. T AND PRESSURE P.

P(N/M2)	.600E 6	.700E 6	.800E 6	.900E 6	.100E 7
T(K)					
80					
85					
90					
95					
100	.235E 2				
105	.219E 2	.263E 2	.309E 2	.359E 2	.412E 2
110	.206E 2	.246E 2	.288E 2	.333E 2	.381E 2
115	.194E 2	.231E 2	.270E 2	.311E 2	.354E 2
120	.183E 2	.218E 2	.254E 2	.292E 2	.332E 2
125	.174E 2	.207E 2	.240E 2	.276E 2	.312E 2
130	.166E 2	.197E 2	.228E 2	.261E 2	.295E 2
135	.159E 2	.188E 2	.217E 2	.248E 2	.280E 2
140	.152E 2	.179E 2	.208E 2	.237E 2	.267E 2
145	.146E 2	.172E 2	.199E 2	.227E 2	.255E 2
150	.140E 2	.165E 2	.191E 2	.217E 2	.244E 2
155	.135E 2	.159E 2	.184E 2	.209E 2	.235E 2
160	.130E 2	.153E 2	.177E 2	.201E 2	.226E 2
165	.126E 2	.148E 2	.171E 2	.194E 2	.218E 2
170	.122E 2	.143E 2	.165E 2	.187E 2	.210E 2
175	.118E 2	.139E 2	.160E 2	.181E 2	.203E 2
180	.115E 2	.135E 2	.155E 2	.176E 2	.197E 2
185	.111E 2	.131E 2	.150E 2	.170E 2	.191E 2
190	.108E 2	.127E 2	.146E 2	.165E 2	.185E 2
195	.105E 2	.123E 2	.142E 2	.161E 2	.180E 2
200	.102E 2	.120E 2	.138E 2	.156E 2	.175E 2
205	.100E 2	.117E 2	.135E 2	.152E 2	.170E 2
210	.977E 1	.114E 2	.131E 2	.148E 2	.166E 2
215	.954E 1	.111E 2	.128E 2	.145E 2	.162E 2
220	.931E 1	.109E 2	.125E 2	.141E 2	.158E 2
225	.910E 1	.106E 2	.122E 2	.138E 2	.154E 2
230	.889E 1	.104E 2	.119E 2	.135E 2	.150E 2
235	.869E 1	.101E 2	.116E 2	.132E 2	.147E 2
240	.851E 1	.996E 1	.114E 2	.129E 2	.144E 2
245	.833E 1	.975E 1	.111E 2	.126E 2	.141E 2
250	.815E 1	.954E 1	.109E 2	.123E 2	.138E 2
255	.799E 1	.935E 1	.107E 2	.121E 2	.135E 2
260	.783E 1	.916E 1	.105E 2	.118E 2	.132E 2
265	.768E 1	.898E 1	.103E 2	.116E 2	.129E 2
270	.753E 1	.881E 1	.101E 2	.114E 2	.127E 2
275	.739E 1	.864E 1	.990E 1	.111E 2	.124E 2
280	.725E 1	.848E 1	.972E 1	.109E 2	.122E 2
285	.712E 1	.833E 1	.954E 1	.107E 2	.120E 2
290	.699E 1	.818E 1	.937E 1	.105E 2	.117E 2
295	.687E 1	.803E 1	.920E 1	.103E 2	.115E 2
300	.675E 1	.789E 1	.904E 1	.102E 2	.113E 2
305	.664E 1	.776E 1	.889E 1	.100E 2	.111E 2
310	.653E 1	.763E 1	.874E 1	.986E 1	.109E 2
315	.642E 1	.750E 1	.860E 1	.970E 1	.108E 2
320	.632E 1	.738E 1	.846E 1	.954E 1	.106E 2
325	.622E 1	.727E 1	.832E 1	.939E 1	.104E 2
330	.612E 1	.716E 1	.819E 1	.924E 1	.103E 2
335	.603E 1	.705E 1	.807E 1	.910E 1	.101E 2
340	.594E 1	.694E 1	.795E 1	.896E 1	.999E 1
345	.585E 1	.684E 1	.783E 1	.883E 1	.984E 1
350	.577E 1	.674E 1	.772E 1	.871E 1	.970E 1

TABLE NO. 6.

N2 GAS HEAT CAPACITY CPG (J/KGK) V. TEMP. T AND PRESSURE P.

P(N/M2)	.100E 6	.200E 6	.300E 6	.400E 6	.500E 6
T(K)					
80	.113E 4				
82	.113E 4				
84	.112E 4				
86	.111E 4				
88	.111E 4	.116E 4			
90	.110E 4	.115E 4	.119E 4		
92	.109E 4	.114E 4	.118E 4		
94	.109E 4	.113E 4	.117E 4		
96	.108E 4	.113E 4	.117E 4	.120E 4	.125E 4
98	.108E 4	.112E 4	.116E 4	.120E 4	.124E 4
100	.107E 4	.111E 4	.115E 4	.119E 4	.123E 4
102	.107E 4	.111E 4	.114E 4	.118E 4	.122E 4
104	.107E 4	.110E 4	.114E 4	.117E 4	.121E 4
106	.106E 4	.110E 4	.113E 4	.117E 4	.120E 4
108	.106E 4	.109E 4	.112E 4	.116E 4	.119E 4
110	.106E 4	.109E 4	.112E 4	.115E 4	.119E 4
112	.105E 4	.108E 4	.111E 4	.115E 4	.118E 4
114	.105E 4	.108E 4	.111E 4	.114E 4	.117E 4
116	.105E 4	.107E 4	.110E 4	.113E 4	.116E 4
118	.104E 4	.107E 4	.110E 4	.113E 4	.116E 4
120	.104E 4	.107E 4	.109E 4	.112E 4	.115E 4
122	.104E 4	.106E 4	.109E 4	.112E 4	.114E 4
124	.104E 4	.106E 4	.109E 4	.111E 4	.114E 4
126	.104E 4	.106E 4	.108E 4	.111E 4	.113E 4
128	.104E 4	.105E 4	.108E 4	.110E 4	.113E 4
130	.104E 4	.105E 4	.108E 4	.110E 4	.112E 4
132	.103E 4	.105E 4	.107E 4	.110E 4	.112E 4
134	.103E 4	.105E 4	.107E 4	.109E 4	.111E 4
136	.103E 4	.105E 4	.107E 4	.109E 4	.111E 4
138	.103E 4	.104E 4	.106E 4	.109E 4	.110E 4
140	.103E 4	.104E 4	.106E 4	.108E 4	.110E 4
142	.103E 4	.104E 4	.106E 4	.108E 4	.110E 4
144	.103E 4	.104E 4	.106E 4	.108E 4	.109E 4
146	.103E 4	.104E 4	.106E 4	.107E 4	.109E 4
148	.103E 4	.104E 4	.105E 4	.107E 4	.109E 4
150	.103E 4	.104E 4	.105E 4	.107E 4	.108E 4
152	.103E 4	.104E 4	.105E 4	.107E 4	.108E 4
154	.103E 4	.104E 4	.105E 4	.106E 4	.108E 4
156	.103E 4	.104E 4	.105E 4	.106E 4	.107E 4
158	.103E 4	.104E 4	.105E 4	.106E 4	.107E 4
160	.104E 4	.104E 4	.105E 4	.106E 4	.107E 4
162	.104E 4	.104E 4	.105E 4	.106E 4	.107E 4
164	.104E 4	.104E 4	.105E 4	.106E 4	.106E 4
166	.104E 4	.104E 4	.104E 4	.105E 4	.106E 4
168	.104E 4	.104E 4	.104E 4	.105E 4	.106E 4
170	.104E 4	.104E 4	.104E 4	.105E 4	.106E 4

TABLE NO. 7.

N2 GAS CONDUCTIVITY KG AT 1 BAR V. TEMPERATURE T.

T(K)	KG(W/MK)
80	.787E-2
85	.829E-2
90	.871E-2
95	.913E-2
100	.956E-2
105	.100E-1
110	.104E-1
115	.108E-1
120	.113E-1
125	.117E-1
130	.122E-1
135	.126E-1
140	.130E-1
145	.135E-1
150	.139E-1
155	.144E-1
160	.148E-1
165	.152E-1
170	.157E-1
175	.161E-1
180	.165E-1
185	.170E-1
190	.174E-1
195	.178E-1
200	.182E-1
205	.186E-1
210	.190E-1
215	.194E-1
220	.199E-1
225	.203E-1
230	.207E-1
235	.210E-1
240	.214E-1
245	.218E-1
250	.222E-1
255	.226E-1
260	.230E-1
265	.233E-1
270	.237E-1
275	.241E-1
280	.245E-1
285	.248E-1
290	.252E-1
295	.256E-1
300	.260E-1
305	.263E-1
310	.267E-1
315	.271E-1
320	.275E-1
325	.279E-1
330	.282E-1
335	.286E-1
340	.290E-1
345	.294E-1
350	.298E-1

TABLE NO. 8 (continues).

N2 GAS DYN. VISCOSITY MYG (NS/M2) V. TEMP. T AND PRESS. P.

P(N/M2) T(K)	.100E 6	.200E 6	.300E 6	.400E 6	.500E 6
80	.552E-5				
85	.586E-5	.589E-5			
90	.620E-5	.623E-5	.628E-5		
95	.653E-5	.657E-5	.661E-5	.667E-5	.674E-5
100	.687E-5	.690E-5	.694E-5	.700E-5	.706E-5
105	.721E-5	.724E-5	.728E-5	.733E-5	.738E-5
110	.754E-5	.757E-5	.761E-5	.765E-5	.770E-5
115	.787E-5	.790E-5	.793E-5	.798E-5	.802E-5
120	.819E-5	.822E-5	.826E-5	.830E-5	.834E-5
125	.852E-5	.855E-5	.858E-5	.862E-5	.866E-5
130	.884E-5	.887E-5	.890E-5	.894E-5	.898E-5
135	.915E-5	.918E-5	.921E-5	.925E-5	.929E-5
140	.946E-5	.949E-5	.953E-5	.956E-5	.960E-5
145	.977E-5	.980E-5	.983E-5	.987E-5	.990E-5
150	.100E-4	.101E-4	.101E-4	.101E-4	.102E-4
155	.103E-4	.104E-4	.104E-4	.104E-4	.105E-4
160	.106E-4	.107E-4	.107E-4	.107E-4	.107E-4
165	.109E-4	.109E-4	.110E-4	.110E-4	.110E-4
170	.112E-4	.112E-4	.113E-4	.113E-4	.113E-4
175	.115E-4	.115E-4	.115E-4	.116E-4	.116E-4
180	.118E-4	.118E-4	.118E-4	.119E-4	.119E-4
185	.121E-4	.121E-4	.121E-4	.121E-4	.122E-4
190	.123E-4	.124E-4	.124E-4	.124E-4	.124E-4
195	.126E-4	.126E-4	.126E-4	.127E-4	.127E-4
200	.129E-4	.129E-4	.129E-4	.129E-4	.130E-4
205	.131E-4	.132E-4	.132E-4	.132E-4	.132E-4
210	.134E-4	.134E-4	.134E-4	.135E-4	.135E-4
215	.137E-4	.137E-4	.137E-4	.137E-4	.138E-4
220	.139E-4	.139E-4	.140E-4	.140E-4	.140E-4
225	.142E-4	.142E-4	.142E-4	.142E-4	.143E-4
230	.144E-4	.145E-4	.145E-4	.145E-4	.145E-4
235	.147E-4	.147E-4	.147E-4	.148E-4	.148E-4
240	.150E-4	.150E-4	.150E-4	.150E-4	.150E-4
245	.152E-4	.152E-4	.153E-4	.153E-4	.153E-4
250	.155E-4	.155E-4	.155E-4	.155E-4	.155E-4
255	.158E-4	.158E-4	.158E-4	.158E-4	.158E-4
260	.160E-4	.160E-4	.160E-4	.160E-4	.161E-4
265	.163E-4	.163E-4	.163E-4	.163E-4	.163E-4
270	.166E-4	.166E-4	.166E-4	.166E-4	.166E-4
275	.169E-4	.169E-4	.169E-4	.169E-4	.168E-4
280	.172E-4	.172E-4	.171E-4	.171E-4	.171E-4
285	.175E-4	.174E-4	.174E-4	.174E-4	.174E-4
290	.178E-4	.178E-4	.177E-4	.177E-4	.177E-4
295	.181E-4	.181E-4	.180E-4	.180E-4	.180E-4
300	.184E-4	.184E-4	.183E-4	.183E-4	.183E-4

TABLE NO. 8 (continued).

N2 GAS DYN. VISCOSITY MYG (NS/M2) V. TEMP. T AND PRESS. P.

P(N/M2) T(K)	.600E 6	.700E 6	.800E 6	.900E 6	.100E 7
80					
85					
90					
95					
100	.714E-5				
105	.745E-5	.753E-5	.762E-5	.772E-5	.783E-5
110	.777E-5	.783E-5	.791E-5	.800E-5	.810E-5
115	.808E-5	.814E-5	.821E-5	.829E-5	.837E-5
120	.839E-5	.845E-5	.851E-5	.858E-5	.866E-5
125	.871E-5	.876E-5	.881E-5	.888E-5	.894E-5
130	.902E-5	.907E-5	.912E-5	.917E-5	.923E-5
135	.933E-5	.937E-5	.942E-5	.947E-5	.952E-5
140	.963E-5	.967E-5	.972E-5	.976E-5	.981E-5
145	.994E-5	.998E-5	.100E-4	.100E-4	.101E-4
150	.102E-4	.102E-4	.103E-4	.103E-4	.103E-4
155	.105E-4	.105E-4	.106E-4	.106E-4	.106E-4
160	.108E-4	.108E-4	.108E-4	.109E-4	.109E-4
165	.111E-4	.111E-4	.111E-4	.112E-4	.112E-4
170	.114E-4	.114E-4	.114E-4	.115E-4	.115E-4
175	.116E-4	.117E-4	.117E-4	.117E-4	.118E-4
180	.119E-4	.119E-4	.120E-4	.120E-4	.120E-4
185	.122E-4	.122E-4	.123E-4	.123E-4	.123E-4
190	.125E-4	.125E-4	.125E-4	.126E-4	.126E-4
195	.127E-4	.128E-4	.128E-4	.128E-4	.128E-4
200	.130E-4	.130E-4	.131E-4	.131E-4	.131E-4
205	.133E-4	.133E-4	.133E-4	.133E-4	.134E-4
210	.135E-4	.135E-4	.136E-4	.136E-4	.136E-4
215	.138E-4	.138E-4	.138E-4	.139E-4	.139E-4
220	.140E-4	.141E-4	.141E-4	.141E-4	.141E-4
225	.143E-4	.143E-4	.143E-4	.144E-4	.144E-4
230	.145E-4	.146E-4	.146E-4	.146E-4	.146E-4
235	.148E-4	.148E-4	.148E-4	.149E-4	.149E-4
240	.151E-4	.151E-4	.151E-4	.151E-4	.151E-4
245	.153E-4	.153E-4	.153E-4	.154E-4	.154E-4
250	.156E-4	.156E-4	.156E-4	.156E-4	.156E-4
255	.158E-4	.158E-4	.158E-4	.158E-4	.159E-4
260	.161E-4	.161E-4	.161E-4	.161E-4	.161E-4
265	.163E-4	.163E-4	.163E-4	.163E-4	.163E-4
270	.166E-4	.166E-4	.166E-4	.166E-4	.166E-4
275	.168E-4	.168E-4	.168E-4	.168E-4	.168E-4
280	.171E-4	.171E-4	.171E-4	.171E-4	.171E-4
285	.174E-4	.174E-4	.174E-4	.173E-4	.173E-4
290	.177E-4	.176E-4	.176E-4	.176E-4	.176E-4
295	.179E-4	.179E-4	.179E-4	.179E-4	.178E-4
300	.182E-4	.182E-4	.182E-4	.181E-4	.181E-4

TABLE NO. 9.

N2 LIQUID ENTHALPY HL V. TEMPERATURE T

T(K)	HL(J/KG)
68	-.137E 6
69	-.135E 6
70	-.134E 6
71	-.133E 6
72	-.131E 6
73	-.130E 6
74	-.128E 6
75	-.126E 6
76	-.124E 6
77	-.122E 6
78	-.120E 6
79	-.118E 6
80	-.115E 6
81	-.113E 6
82	-.111E 6
83	-.109E 6
84	-.106E 6
85	-.104E 6
86	-.102E 6
87	-.100E 6
88	-.984E 5
89	-.965E 5
90	-.947E 5
91	-.930E 5
92	-.913E 5
93	-.896E 5
94	-.878E 5
95	-.860E 5
96	-.841E 5
97	-.819E 5
98	-.795E 5
99	-.769E 5
100	-.742E 5
101	-.714E 5
102	-.688E 5
103	-.668E 5
104	-.660E 5

TABLE NO. 10.

N2 LIQUID DENSITY RL V. TEMPERATURE T.

T(K)	RL(KG/M3)
68	.842E 3
69	.839E 3
70	.837E 3
71	.834E 3
72	.831E 3
73	.827E 3
74	.823E 3
75	.819E 3
76	.815E 3
77	.810E 3
78	.805E 3
79	.800E 3
80	.795E 3
81	.790E 3
82	.784E 3
83	.779E 3
84	.773E 3
85	.768E 3
86	.763E 3
87	.758E 3
88	.753E 3
89	.748E 3
90	.744E 3
91	.739E 3
92	.735E 3
93	.731E 3
94	.726E 3
95	.721E 3
96	.716E 3
97	.710E 3
98	.704E 3
99	.697E 3
100	.690E 3
101	.682E 3
102	.675E 3
103	.670E 3
104	.668E 3
105	.671E 3
106	.684E 3

TABLE NO. 11.

N2 LIQUID HEAT CAPACITY CPL. V. TEMPERATURE TSAT.

TSAT(K)	CPL(J/KGK)
68	.193E 4
69	.193E 4
70	.193E 4
71	.193E 4
72	.193E 4
73	.193E 4
74	.193E 4
75	.194E 4
76	.194E 4
77	.194E 4
78	.194E 4
79	.195E 4
80	.195E 4
81	.196E 4
82	.196E 4
83	.197E 4
84	.198E 4
85	.198E 4
86	.199E 4
87	.200E 4
88	.201E 4
89	.201E 4
90	.202E 4
91	.203E 4
92	.204E 4
93	.205E 4
94	.206E 4
95	.208E 4
96	.209E 4
97	.211E 4
98	.213E 4
99	.215E 4
100	.218E 4
101	.222E 4
102	.225E 4
103	.228E 4
104	.229E 4
105	.227E 4
106	.221E 4

TABLE NO. 12.

N2 LIQUID CONDUCTIVITY KL V. TEMPERATURE T.

T(K)	KL(W/MK)
68	.152E 0
69	.151E 0
70	.149E 0
71	.148E 0
72	.147E 0
73	.145E 0
74	.143E 0
75	.142E 0
76	.140E 0
77	.138E 0
78	.136E 0
79	.134E 0
80	.132E 0
81	.130E 0
82	.128E 0
83	.126E 0
84	.123E 0
85	.121E 0
86	.120E 0
87	.118E 0
88	.116E 0
89	.114E 0
90	.113E 0
91	.111E 0
92	.110E 0
93	.108E 0
94	.107E 0
95	.105E 0
96	.104E 0
97	.102E 0
98	.100E 0
99	.983E-1
100	.961E-1

TABLE NO. 13.

N2 LIQUID DYNAMIC VISCOSITY MYL V. TEMPERATURE T.

T(K)	MYL(NS/M2)
68	.228E-3
69	.222E-3
70	.215E-3
71	.208E-3
72	.201E-3
73	.194E-3
74	.186E-3
75	.178E-3
76	.170E-3
77	.163E-3
78	.155E-3
79	.147E-3
80	.140E-3
81	.133E-3
82	.127E-3
83	.121E-3
84	.115E-3
85	.110E-3
86	.106E-3
87	.101E-3
88	.982E-4
89	.950E-4
90	.920E-4
91	.894E-4
92	.870E-4
93	.848E-4
94	.827E-4
95	.807E-4
96	.787E-4
97	.768E-4
98	.749E-4
99	.732E-4
100	.718E-4

TABLE NO. 14.

N2 SURFACE TENSION S V. TEMPERATURE T.

T(K)	S(N/M)
68	.107E-1
69	.106E-1
70	.104E-1
71	.102E-1
72	.101E-1
73	.992E-2
74	.972E-2
75	.950E-2
76	.927E-2
77	.904E-2
78	.880E-2
79	.855E-2
80	.830E-2
81	.805E-2
82	.780E-2
83	.755E-2
84	.731E-2
85	.708E-2
86	.685E-2
87	.664E-2
88	.644E-2
89	.625E-2
90	.607E-2

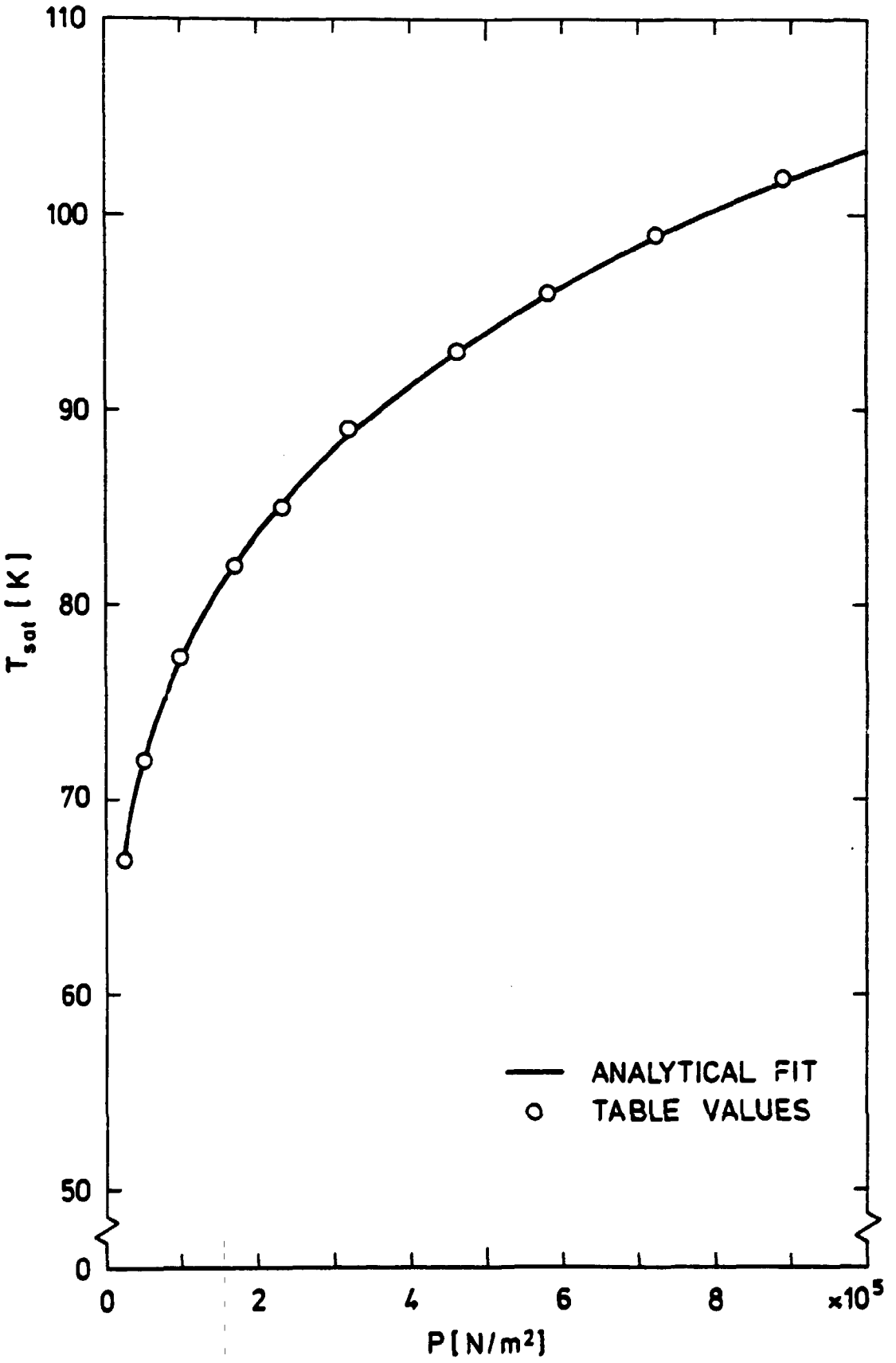

Fig. 1: N_2 saturation temperature T_{sat} versus pressure P.

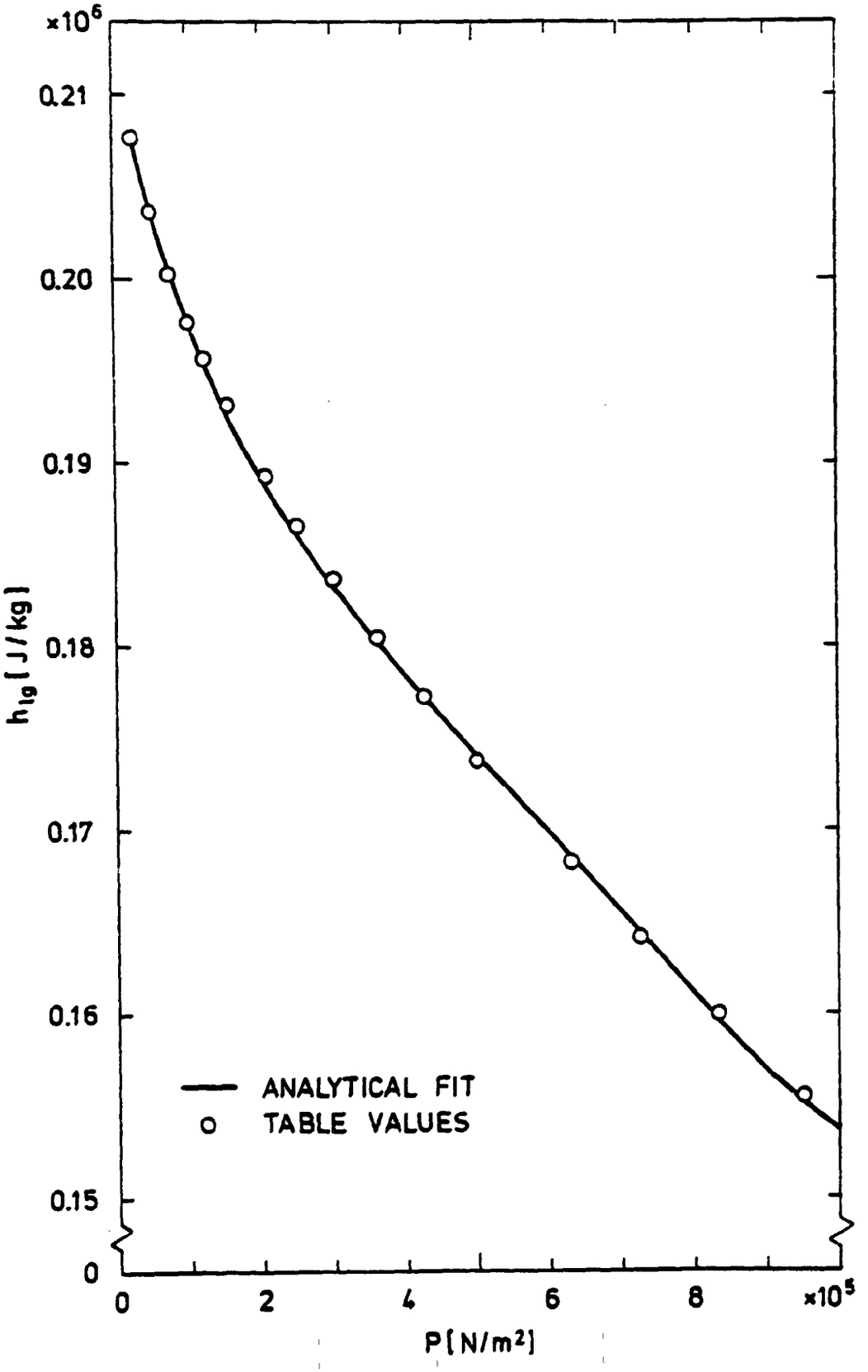

Fig 2: N_2 heat of evaporation h_{lg} versus pressure P.

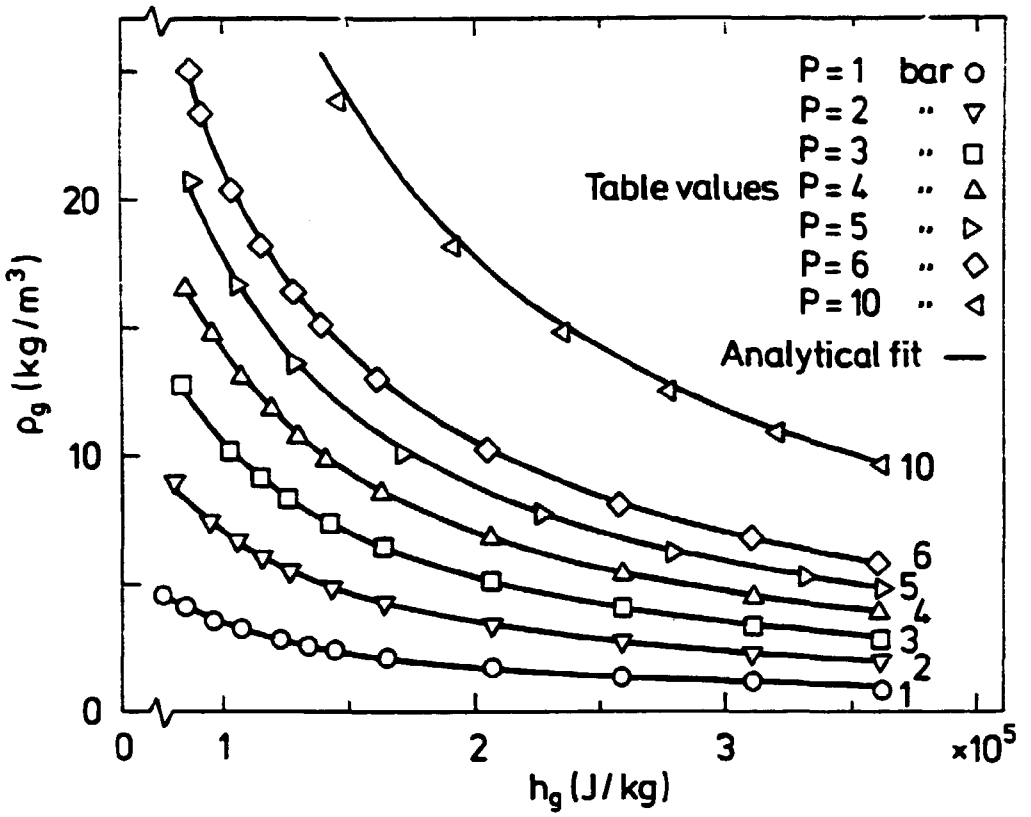

Fig. 3: N_2 gas density ρ_g versus entalphy h_g and pressure P.

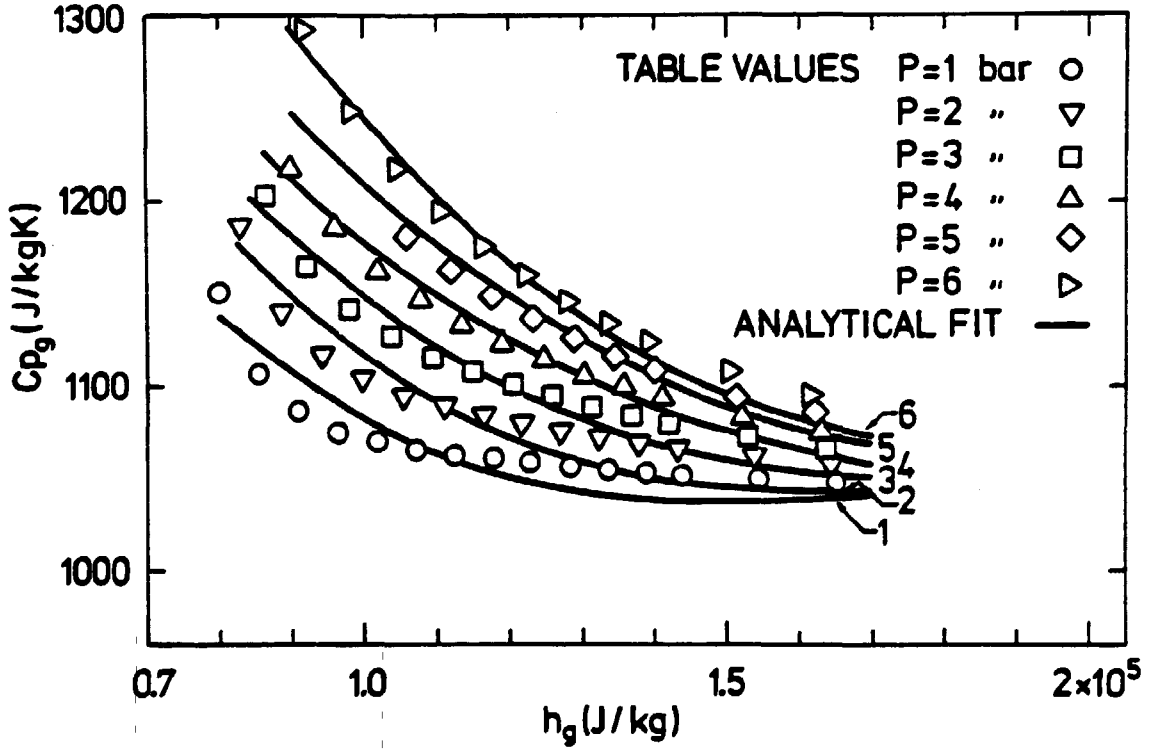

Fig. 4: N_2 gas heat capacity c_{pg} versus entalphy h_g and pressure P.

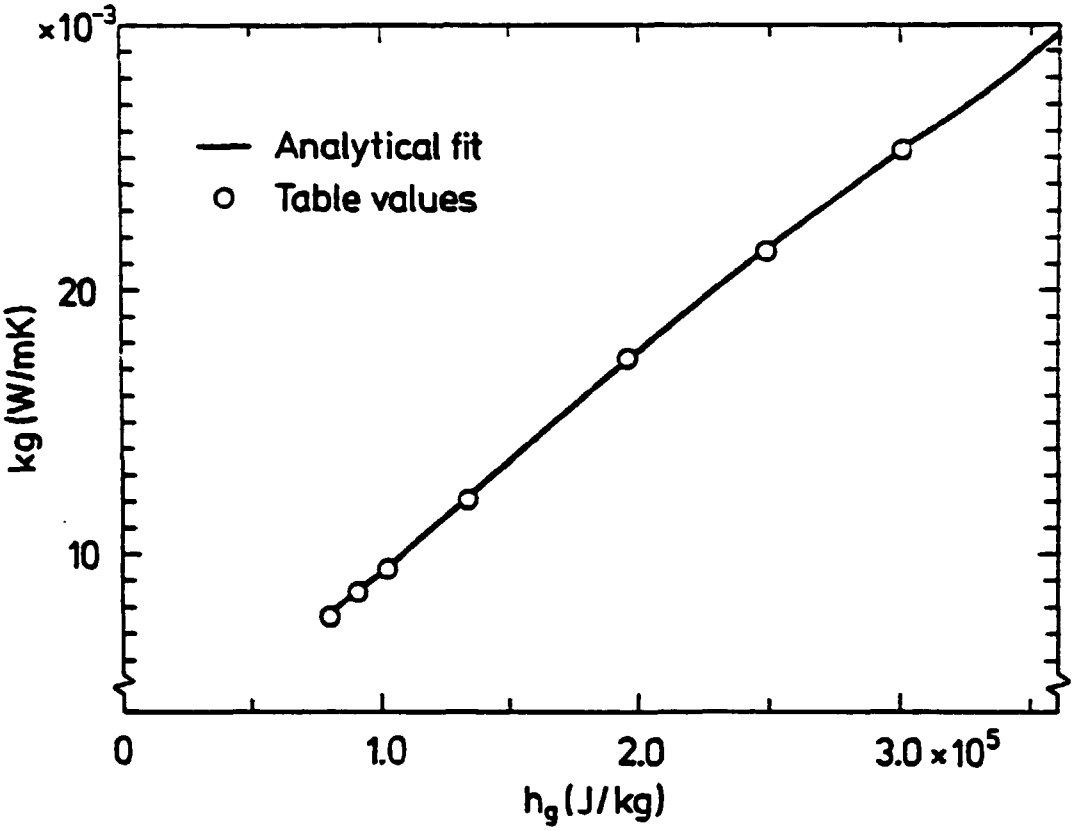

Fig. 5: N_2 gas conductivity k_g versus entalphy h_g.

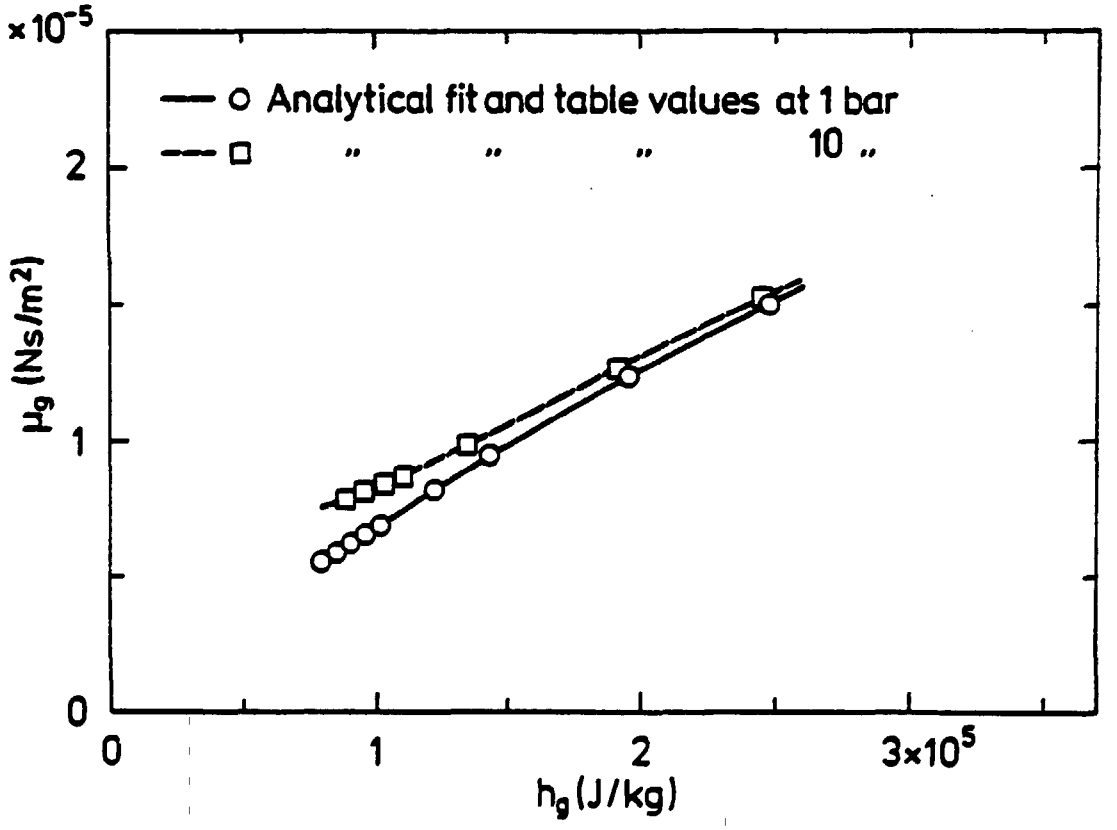

Fig. 6: N_2 gas dynamic viscosity μ_g versus entalphy h_g and pressure P.

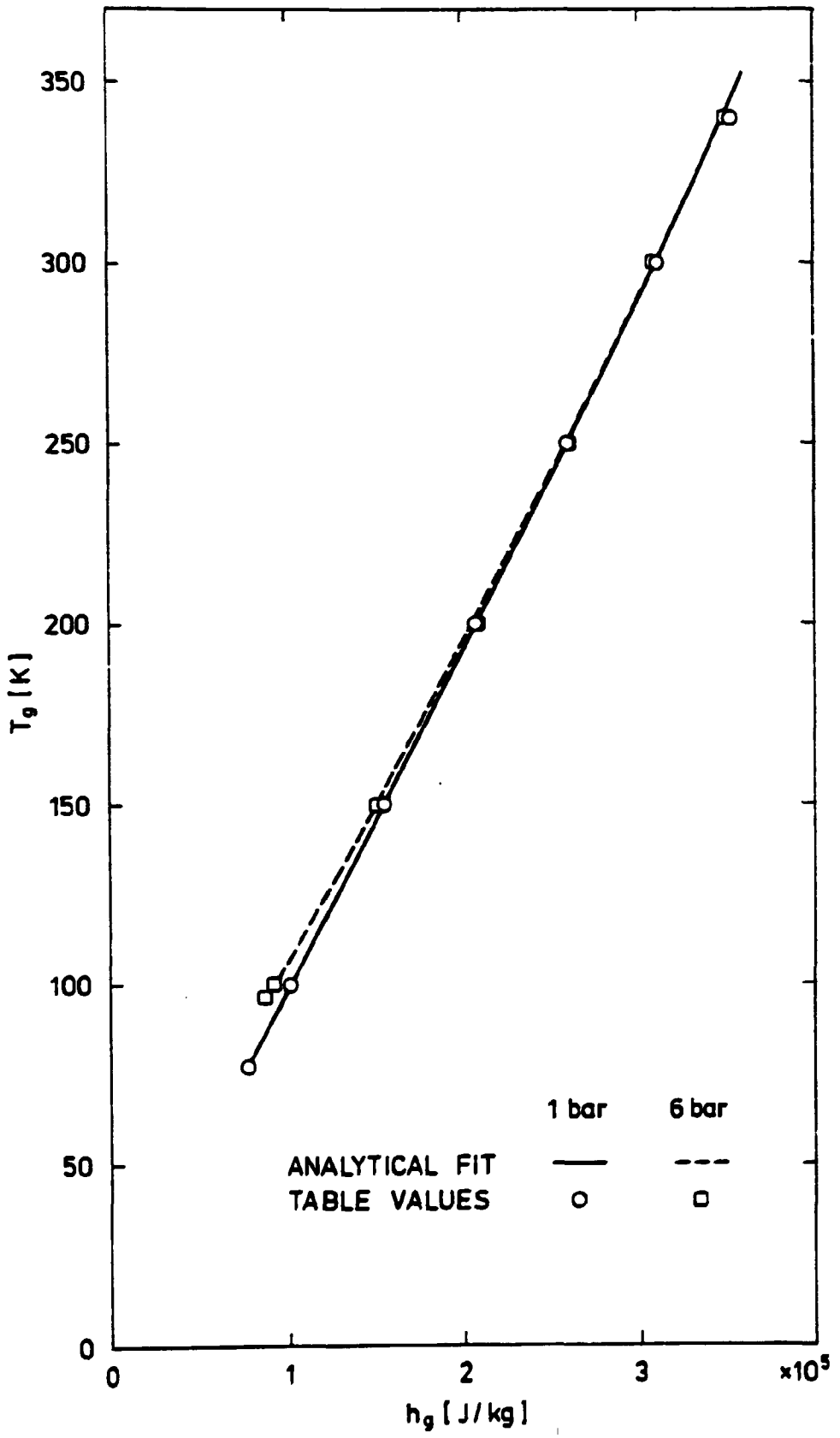

Fig. 7: N_2 gas temperature versus entalphy h_g and pressure P.

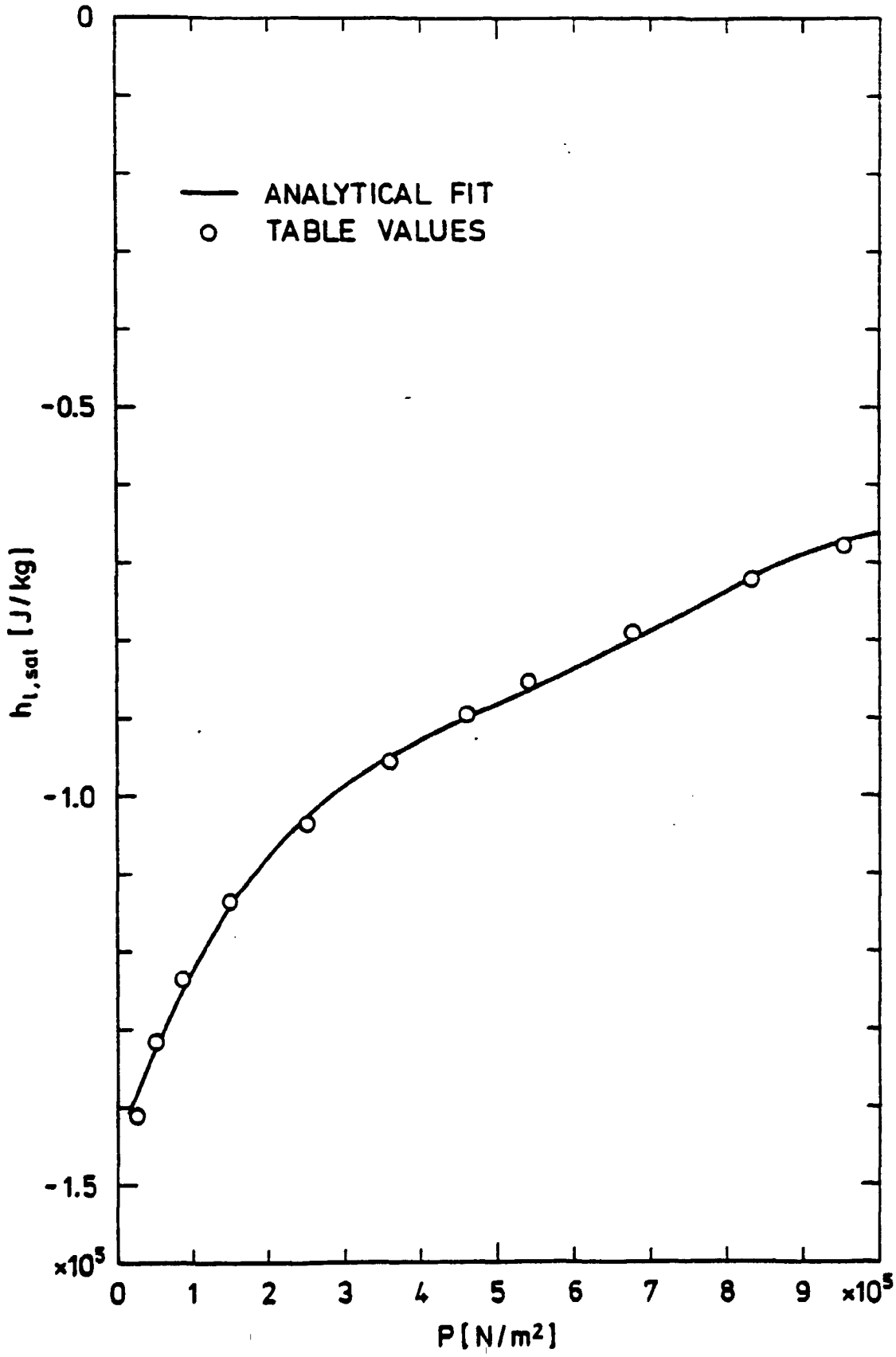

Fig. 8: N_2 liquid entalphy $h_{l,\,sat}$ versus pressure P.

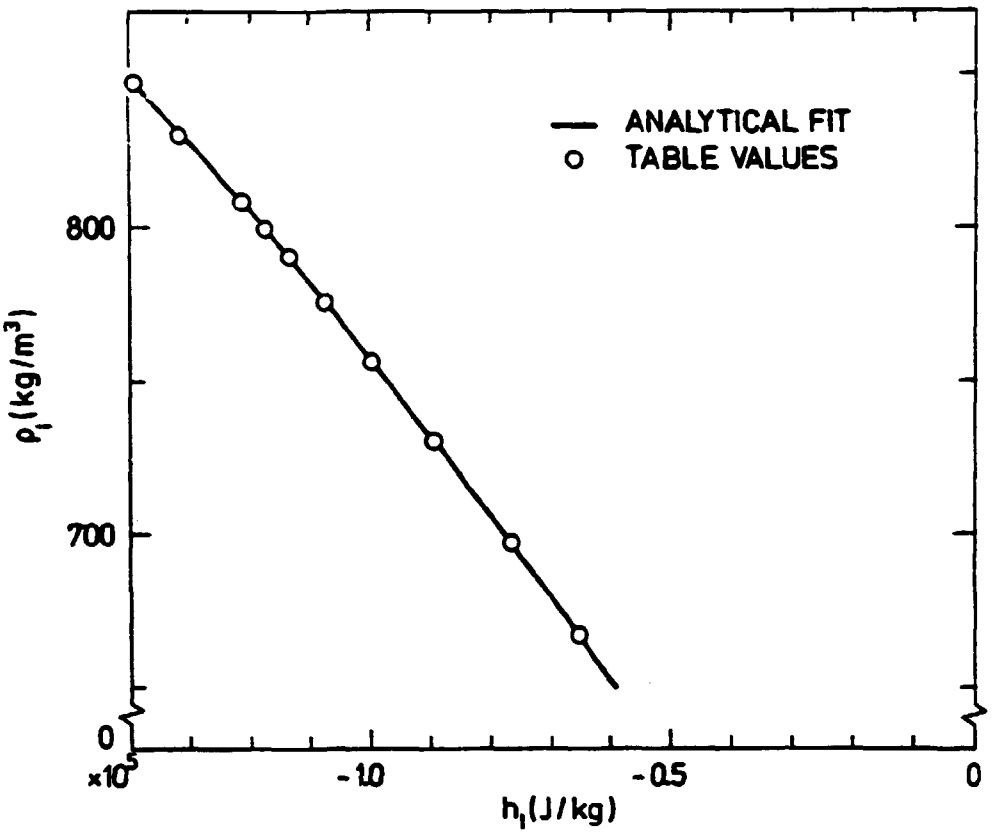

Fig. 9: N_2 liquid density ρ_ℓ versus entalphy h_ℓ.

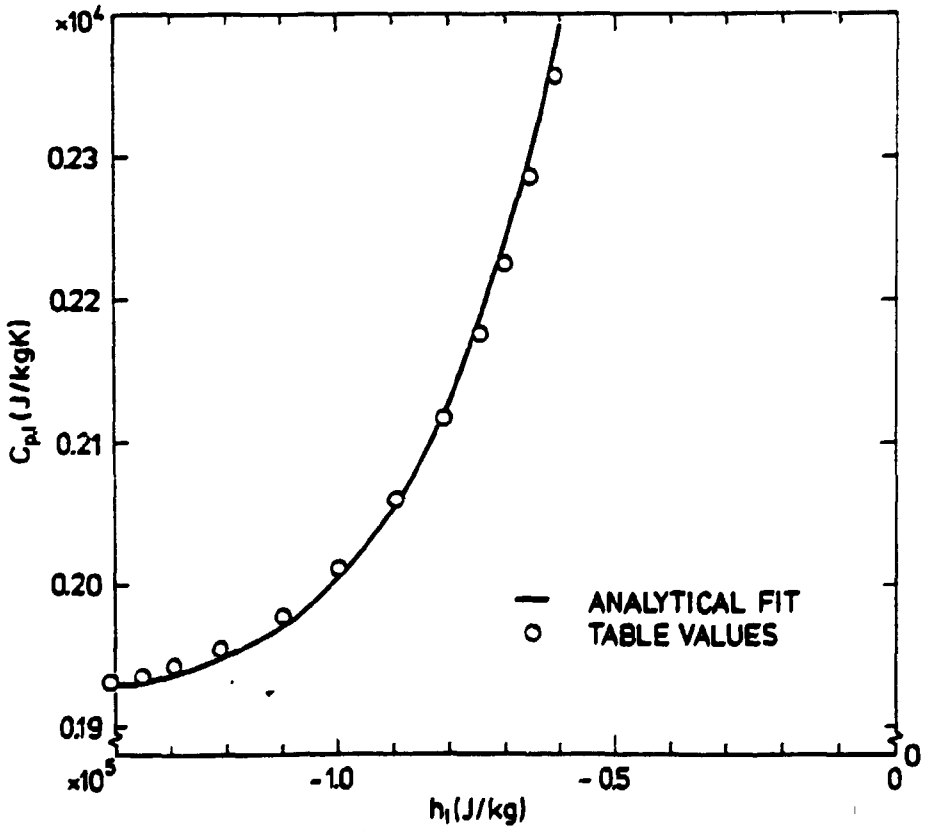

Fig. 10: N_2 liquid heat capacity $c_{p\ell}$ versus entalphy h_ℓ.

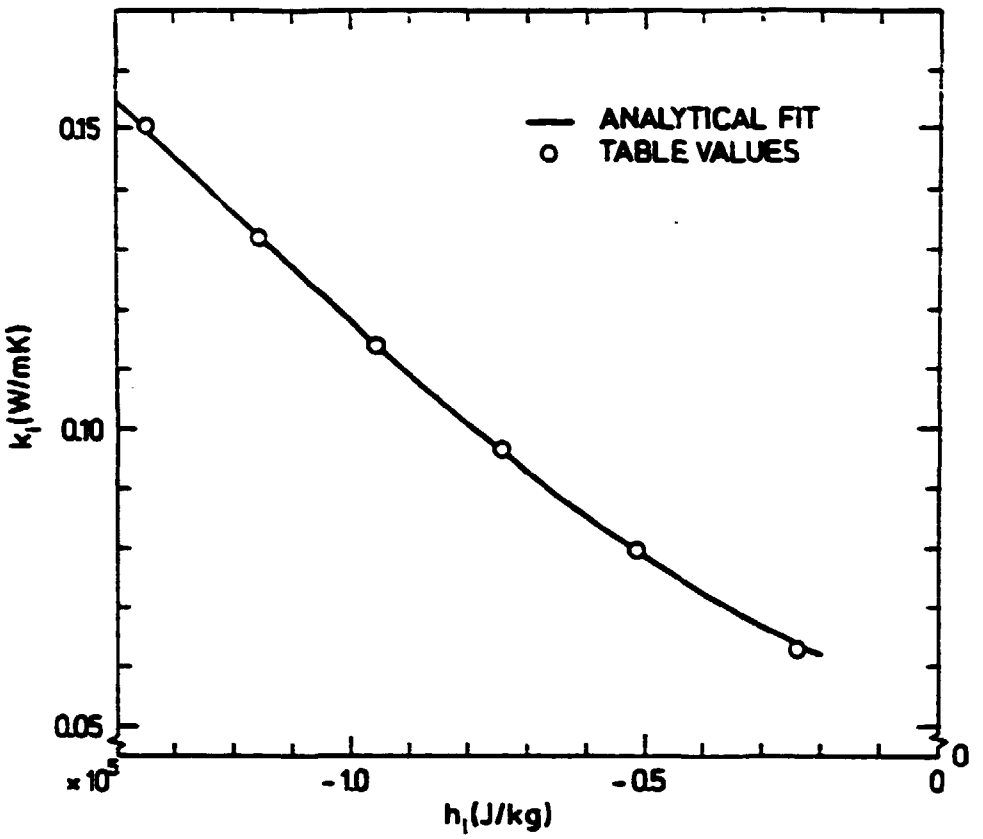

Fig. 11: N_2 liquid conductivity k_ℓ versus entalphy h_ℓ.

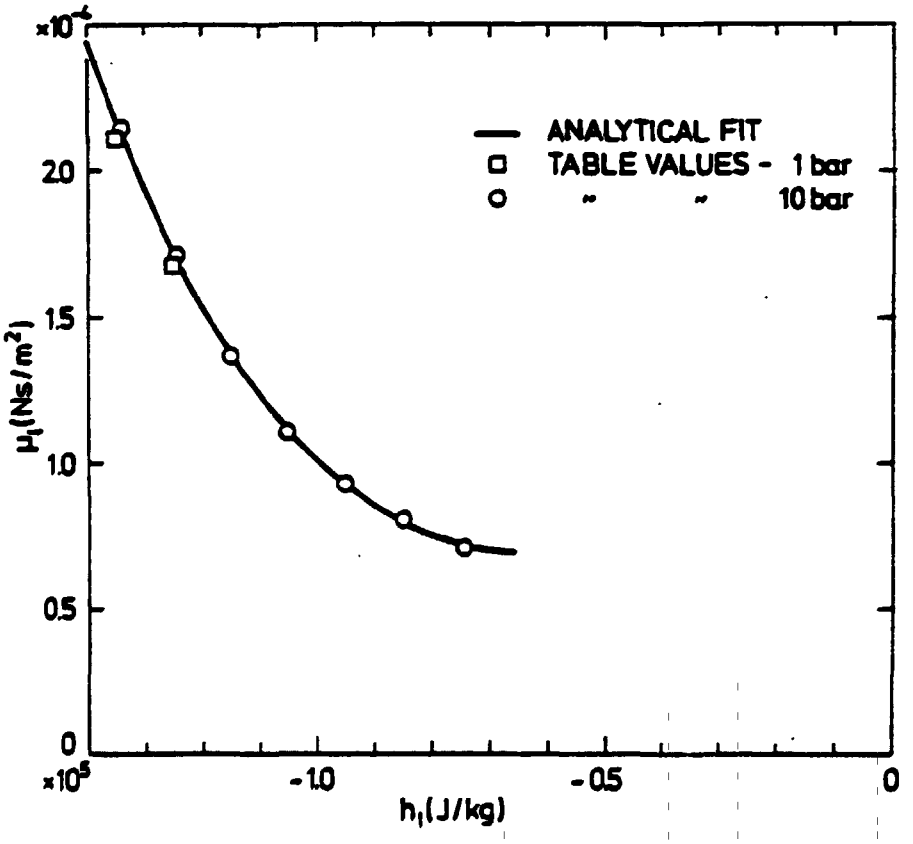

Fig. 12: N_2 liquid dynamic viscosity μ_ℓ versus entalphy h_ℓ.

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Thermal and Mechanical Properties of Nitrogen

P. Ottosen and G. Mannov

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Abstract

Routines for the physical properties of nitrogen liquid and gas (1 to 6 bar) are presented.

The approximations are polynomials worked out by the least squares method. The fitted expressions have been compared with experimental data, and the accuracy is about one percent.

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