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TECHNICAL NOTE R-45

A FORTRAN SUBROUTINE TO CALCULATE AMBIENT PROPERTIES AT VARIOUS ALTITUDES

Prepared by
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April, 1964

BROWN
ENGINEERING COMPANY INC.
HUNTSVILLE, ALABAMA
A Fortran Subroutine to Calculate Ambient Properties at Various Altitudes

April, 1963

Prepared For
DIRECTORATE OF MISSILE INTELLIGENCE
ARMY MISSILE COMMAND

By
SCIENTIFIC RESEARCH LABORATORIES
BROWN ENGINEERING COMPANY, INC.

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Prepared By
W. B. Warren
ABSTRACT

This subroutine uses geometric altitude either in Metric or English units to calculate the corresponding atmospheric pressure, density, temperature in both Rankine and Kelvin, speed of sound, and acceleration due to gravity.

This subroutine will compute in either English or Metric units. A control card is used to make this choice. The program is written in FORTRAN II. This program may be obtained from the Scientific Programming Section; Program No. SP32.

Approved By:

Charles F. Ostner
Chief, Missile and Space Intelligence Branch
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LIST OF SYMBOLS

\( b \) - Subscript indicating basic or reference level

\( C_s \) - Speed of Sound

\( G \) - Local acceleration due to gravity

\( g_o \) - Effective acceleration of gravity at 45°32'40", 
\( g_o = 9.80665 \text{ m sec}^{-2} \)

\( H \) - Geopotential altitude

\( L'_M \) - Molecular-scale temperature gradient

\( M \) - Molecular Weight

\( m \) - Geometric meter

\( m^1 \) - Geopotential meter

\( o \) - Subscript indicating sea level value

\( P \) - Atmospheric pressure

\( Q \) - Constant \( \frac{GM_o}{R} \)

\( R^\circ \) - Universal gas constant \( = 8.31439 \times 10^3 \text{ joules (oK)}^{-1} \text{(K)}^{-1} \)

\( r \) - Average radius of earth \( r = 6,371,239.9 \text{ meters}. \)

\( T \) - Real kinetic temperature

\( T_M \) - Molecular scale temperature where \( T_M = \frac{M_o}{M}T \)

\( Z \) - Altitude in geometric units
\( \rho \) - Atmospheric density

\( \gamma \) - Ratio of specific heats of air \( \frac{C_p}{C_V} = 1.4 \)
<table>
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<th>Symbols</th>
<th>Computer Symbols</th>
<th>Units Metric</th>
<th>English</th>
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<tr>
<td>G</td>
<td>GRAV</td>
<td>meters/sec$^2$</td>
<td>ft/sec$^2$</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>meters</td>
<td>ft</td>
</tr>
<tr>
<td>ALT</td>
<td>ALT</td>
<td>meters</td>
<td>ft</td>
</tr>
<tr>
<td>$T_M$</td>
<td>ATEMK</td>
<td>$^o$K</td>
<td>$^o$R</td>
</tr>
<tr>
<td>$T_R$</td>
<td>ATEMR</td>
<td>Newtons/meters$^2$</td>
<td>lb/ft$^2$</td>
</tr>
<tr>
<td>P</td>
<td>APNMM</td>
<td>K/meter$^3$</td>
<td>Slugs/ft$^3$</td>
</tr>
<tr>
<td>DEN</td>
<td></td>
<td>Slugs/ft$^3$</td>
<td></td>
</tr>
<tr>
<td>$C_S$</td>
<td>SOS</td>
<td>meters/sec</td>
<td>ft/sec</td>
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INTRODUCTION

This subroutine provides atmospheric density, pressure, temperature, acceleration due to gravity, and geopotential altitude in either Metric or English units. The density is forced to zero at an altitude of 400,000 feet. A card, referred to as units, permits this capability. If "units" ≠ 0, the units used are Metric. If "units" = 0, the units used are English. Caution: The units of the input must be the same as the desired output. CON50 must be equal to 0 prior to entering the subroutine the first time.

The program has been checked out and has less than 0.5% error where compared to Reference 1.

Library Functions Used:

EXPF
The equations listed below are extracted from Reference 1:

**Geopotential altitude, H**

\[
H = \frac{rz}{z + r}
\]

\[
G = \left(g_o \frac{r}{r + z}\right)^2
\]

\[
T_m = (T_m)_b + L_m (H - H_b)
\]

\[
P = P_b \left[ \frac{(T_m)_b}{T_m} \right] \frac{\mu_b}{\mu_m} \quad \text{when } L_m \neq 0
\]

\[
P = P_b \ e^{-\frac{Q (H - H_b)}{(T_m)_b}} \quad \text{when } L_m = 0
\]

\[
C = \frac{PM_0}{R^* T_m}
\]

\[
C_s = \left( \frac{\gamma R^*}{M_0 T_m} \right)^{1/2}
\]
DISCUSSION

The computer program is based on Reference 1. The functions used are those commonly used in main programs using this subroutine. Because of this only about 1400 digits of memory are required.

RESULTS

The results of the subroutine have been compared to the data in Reference 1. The error is less than 0.5%.
Start

CON50

0

11

Dimension
AP (9, 4)
CON50 = CON50 + 1

DO 12
I = 1, 9

12
Read 105

13
Units

Units = Metric

English

1000
Convert Alt & VL to Metric

500

(Page 5)
Enter 500 from Page 4

500
Compute Geopotential
Altitude & Gravity

DO 202
1 = 2, 9

H-AP(I, 1)

202
I = 10

203
J = 1-1

Compute
Temp $^\circ$K

204
Compute
Pressure

\[ I_m \]

206

(Page 6)
Enter 206 from Page 6

206
Compute
Density & SOS

Units
+ Metric

= English

502
Convert Gravity, Density, Pressure, Speed of Sound & Geopotential Altitude to English Units

501
Convert OK to OK

601
Alt - 4x10^5
English Units

600
Alt - 12144

508
Density = 0
Speed of Sound = 0

504
Return
FORTRAN RUN

C PROGRAMMED BY W B WARREN

C TRAJECTORY ATMOSPHERIC PROPERTIES

SUBROUTINE TAP %GRAV, ALT, ATEMK, APNM, DEN, SOS, ATEMRO

IF %CON50%11, 11, 13

11 DIMENSION AP%9, 4

CON50 # CON50 & 1.

DO 12 I = 1, 9

12 READ 105, AP%1, 10, AP%2, AP%3, 30, AP%4

105 FORMAT %4E15.8

READ 100, UNITS

100 FORMAT %15.8

13 IF %UNIT5%500, 1000, 500

1000 ALT # ALT/3.28083989

VL # VL/3.28083989

500 GRAV #9.80665*6371239.9/6371239.9 & ALT**2

H # ALT*6371239.9/6371239.9 & ALT

DO 202 I = 2, 9

IF %H - AP%1, 100203, 202, 202

202 CONTINUE

I # 10

203 J = I - 1

ATEMK # AP%J, 204*H - AP%J, 100*AP%J, 30

IF %AP%J, 204=204, 205, 204

204 APNM#AP%J, 40*AP%J, 0/ATEMK**%0.03416479/AP%J, 30

GO TO 206

APNM # APNM **%1020*2.705n / 3.281**200

205 APNM#AP%J, 40/EXP%0.0341647 40*H - AP%J, 100/AP%J, 200
206 DEN #&% .0034838394#APNMM/ATEMK#
SOS #20.046333#ATEMK#2.5
IF%UNITS%501,502,501
502 GRAV # GRAV*3.28083989
ALT # ALT * 3.2808389
H # H * 3.2808389
DEN # DEN * %&2.205/#3.28083989**3#0/32.174#
SOS # SOS * 3.28283989
501 ATEMR # ATEMK-273.16#%9./5. & 491.69
IF %UNITS#600,601,600
601 IF %ALT-400000.0504,504,505
600 IF %ALT -121914.0504,504,505
505 DEN # 0.
SOS # 0.
504 RETURN
END
REFERENCES