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TECHNICAL NOTE R-45

A FORTRAN SUBROUTINE TO CALCULATE
AMBIENT PROPERTIES AT VARIOUS ALTITUDES

Prepared By

William B. Warren

April, 1963

BROWN

ENGINEERING COMPANY INC.
HUNTSVILLE, ALABAMA

1963

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AMBIENT PROPERTIES AT VARIOUS
ALTITUDES

April, 1963

Prepared For

DIRECTORATE OF MISSILE INTELLIGENCE
ARMY MISSILE COMMAND

By

SCIENTIFIC RESEARCH LABORATORIES
BROWN ENGINEERING COMPANY, INC.

Contract No. DA-01-009-ORD-1068

Prepared By

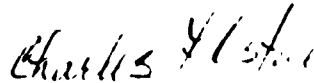
W. B. Warren

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'	-	Geopotential meter
o	-	Subscript indicating sea level value
P	-	Atmospheric pressure
Q	-	Constant $\frac{GM_o}{R}$
R^*	-	Universal gas constant = $8.31439 \times 10^3 \text{ joules}$ $(^{\circ}\text{K})^{-1} (\text{K}_g)^{-1}$
r	-	Average radius of earth $t = 6,371,239.9 \text{ meters.}$
T	-	Real kinetic temperature
T_M	-	Molecular scale temperature where $T_M = (\frac{M_o}{M})T$
Z	-	Altitude in geometric units

ρ	-	Atmospheric density
γ	-	Ratio of specific heats of air $C_P/C_V = 1.4$

PROGRAM SYMBOLS

<u>Symbols</u>	<u>Computer Symbols</u>		<u>Units</u>	
			<u>Metric</u>	<u>English</u>
G	GRAV	Local acceleration due to gravity	meters/sec ²	ft/sec ²
H	H	Geopotential altitude	meters	ft
ALT	ALT	Geometric altitude at which properties are desired	meters	ft
T _M	ATEMK	Temperature	°K	
T _R [°]	ATEMR	Temperature		°R
P	APNMM	Atmospheric pressure	Newtons/ meters ²	lb/ft ²
	DEN	Atmospheric density	K _g /meter ³	Slugs/ft ³
C _s	SOS	Speed of sound	meters/sec	ft/sec

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" $\neq$ 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

ANALYSIS

The equations listed below are extracted from Reference 1:

Geopotential altitude, H

$$H = \frac{rz}{z+r}$$

$$G = (g_0) \left(\frac{r}{r+z} \right)^2$$

$$T_m = (T_m)_b + L_m (H - H_b)$$

$$P = P_b \left[\frac{(T_m)_b}{T_m} \right]^{Q/L_m} \quad \text{when } L_m \neq 0$$

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

$$\rho = \frac{P M_0}{R^* T_m}$$

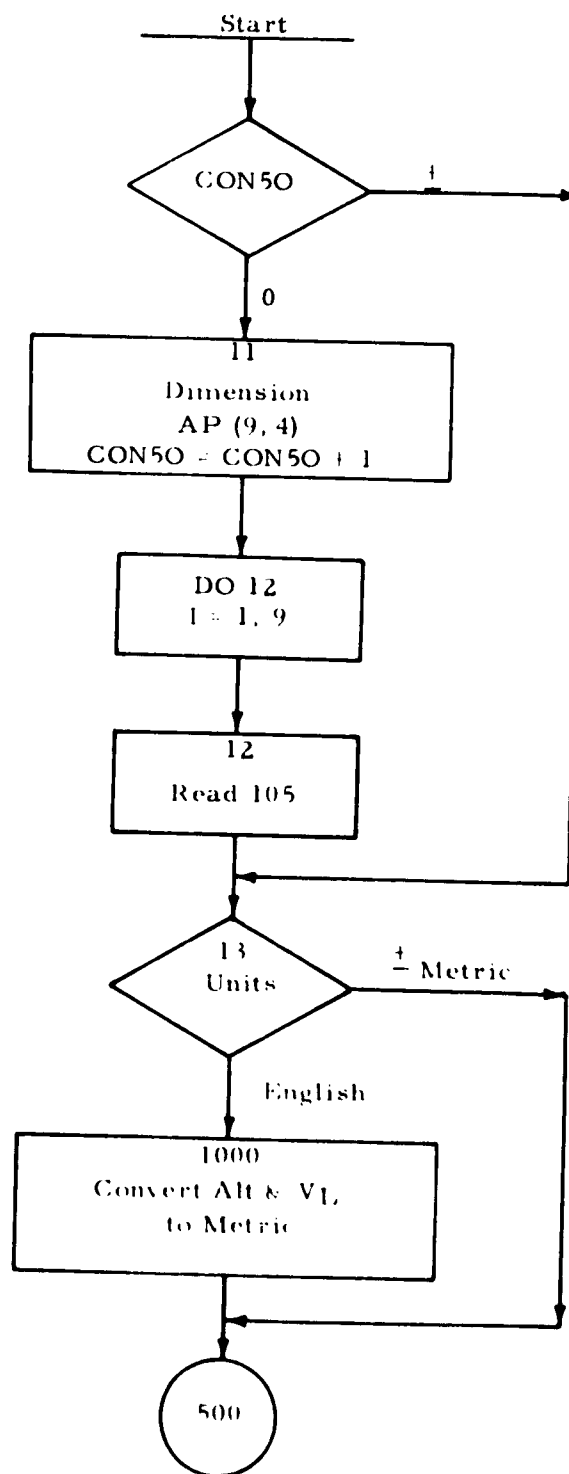
$$C_s = \left(\frac{\gamma R^*}{M_0} T_m \right)^{1/2}$$

DISCUSSION

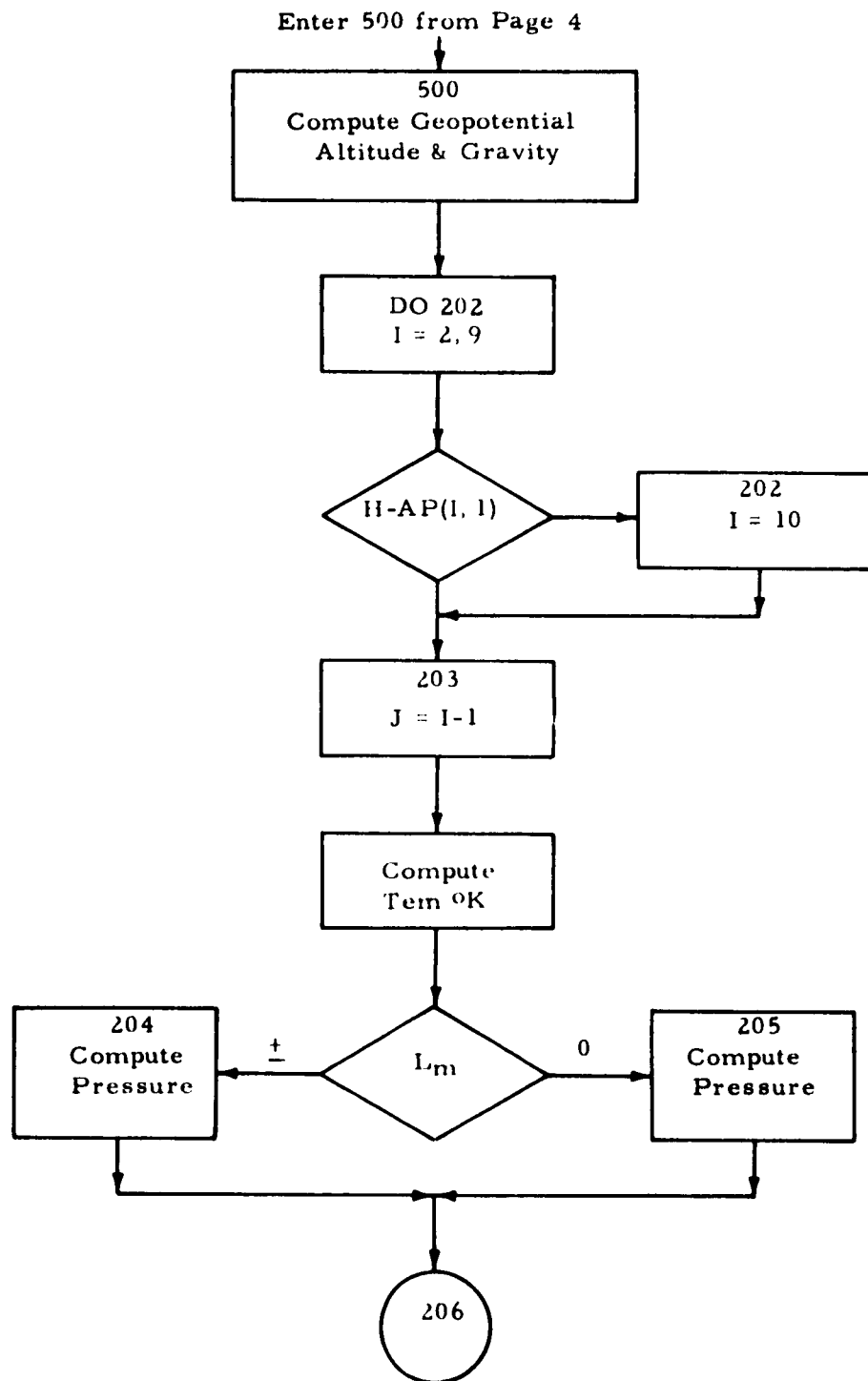
The computer program is based on Reference 1. The functions used are those commonly used in main programs using this subroutine. Because of this only about 1400 digits of memory are required.

RESULTS

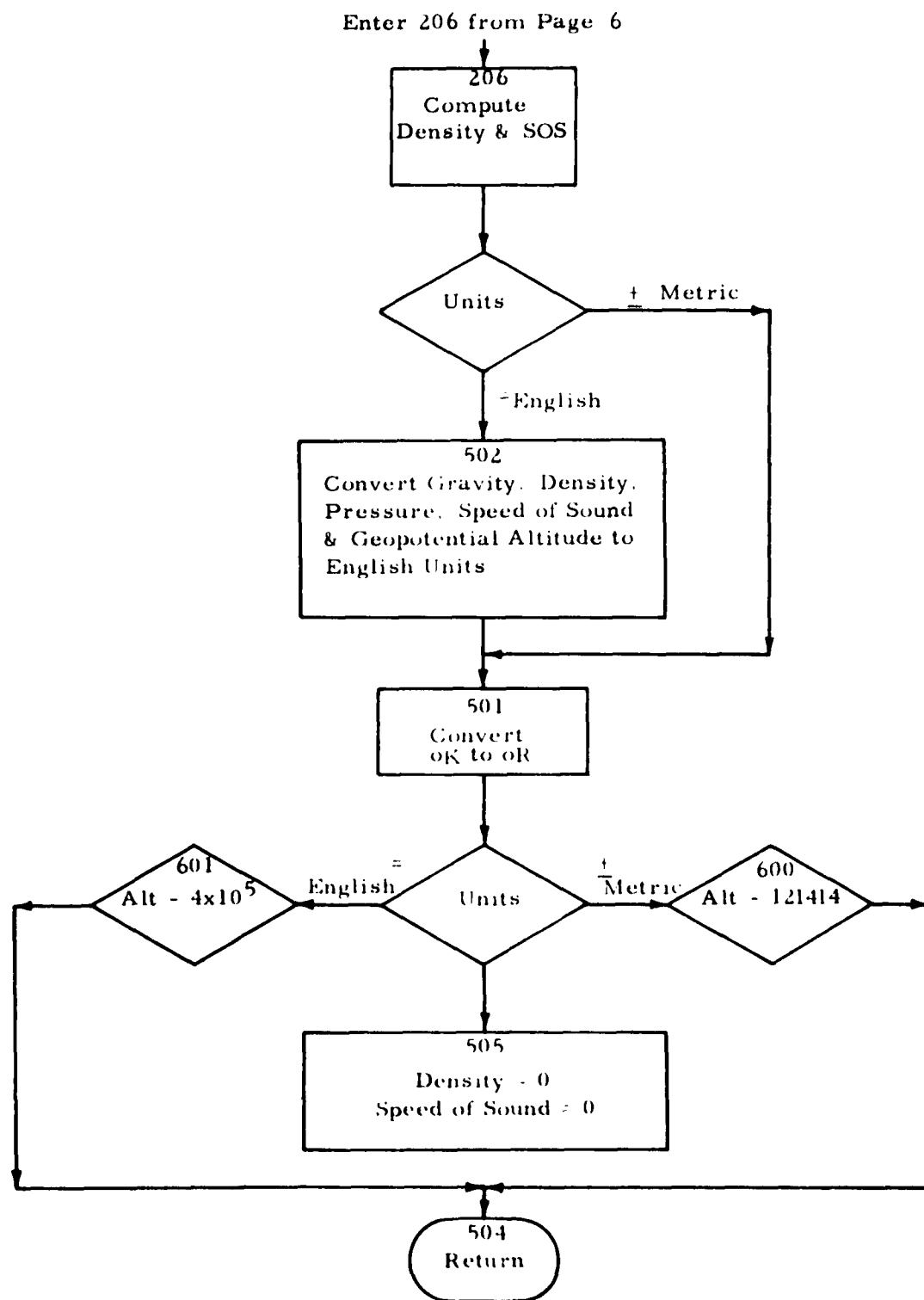
The results of the subroutine have been compared to the data in Reference 1. The error is less than 0.5%.



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      FORTRAN    RUN
C      PROGRAMMED BY W B WARREN
C      TRAJECTORY ATMOSPHERIC PROPERTIES
      SUBROUTINE TAP %GRAV,ALT,ATEMK,APNMM,DEN,SOS,ATEMRD
      IF %CON50=11,11,13
11  DIMENSION AP%9,4D
      CON50 # CON50 & 1.
      DO 12 I # 1,9
12  READ 105,AP%1,1D,AP%1,2D,AP%1,3D,AP%1,4D
105  FORMAT %4E15.8D
      READ 100,UNITS
100  FORMAT%4E15.8D
13  IF %UNITS=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%1,1D=203,202,207
202  CONTINUE
      I # 10
203  J # I-1
      ATEMK #AP%J,2D&%H-AP%J,1D+AP%J,3D
      IF %AP%J,3D=204,205,204
204  APNMM#AP%J,4D+%AP%J,2D/ATEMK=*.03416479/AP%J,3D
      GO TO 206
      APNMM # APNMM *%.1020*2.205D / %3.281*2D
205  APNMM#AP%J,4D/EXP%*.0341647 4D+%H-AP%J,1D/AP%J,2D

```

206 DEN ## .0034838394*APNMM/ATEMK
 SOS #20.046333*ATEMK*.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#/#32.174
 SOS # SOS * 3.28283989
 501 ATEM # %ATEMK-273.16*%9./5.# & 491.69
 IF %UNITS#600,601,600
 601 IF %ALT-400000.#504,504,505
 600 IF %ALT -121914.#504,504,505
 505 DEN # 0.
 SOS # 0.
 504 RETURN
 END

REFERENCES

1. U. S. Air Force, "Handbook of Geophysics ", The Macmillan Company, New York, pp 1 - 1 thru 1 - 35, 1961.