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**AIR DENSITIES FOR ATMOSPHERIC NUCLEAR TESTS AND  
MEDIAN AIR MASS DATA**

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## ABSTRACT

A tabulation is presented of ground-zero and burst altitudes and associated dry-air and water-vapor density data for U. S. atmospheric nuclear tests. Also presented are density data for a tropical (15°N) atmosphere up to 90 kilometers. A method for computing columnar air mass between two points at different altitudes for the Pacific Proving Ground area is presented. This method can be extended to any set of spatial points within the wide limits provided and can be used for other atmospheres. Where possible, information presented is based on original data.

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## SUMMARY

### The Problem

Weather data for atmospheric nuclear tests are available generally in four forms: (1) as handout sheets distributed at the tests, (2) as published volumes for a particular test series, (3) as part of the Report of the Test Director, and (4) as part of a nuclear detonation report concerned with aspects other than weather data. Similarly ground-zero and burst-altitude data are scattered in various documents. Generally, this unclassified information is found only in classified reports as are most nuclear data, and thus is available to a small select group. Compilation of this information into a single unclassified list with emphasis on the veracity of the data is one main objective of this report. The second and more significant objective is to provide a means of computing the average air density between source and receiver points in the atmosphere. This capability permits evaluation of radiation exposures for any burst. In such evaluations, air density is usually multiplied by slant range, and the product is termed columnar air mass in this report.\*

### The Findings

Albeit most information sought was available, some shot sites were a considerable distance from the Yucca Flat weather station at the Nevada Test Site and burst times did not necessarily correspond to times at which meteorological observations were taken. Therefore, some of the weather data gathered at the Yucca Flat weather station were merely indicative of the situation when applied to ground-zero and burst altitudes. Further, for the early testing days in Nevada, some ground-zero altitudes had to be adjusted when checked against topographical maps (circa 1952) of the Nevada Test Site areas (surveyed by the Army Map Service). Errors or discrepancies were found when several documents were consulted for the same data. Data in this report are best-estimate values.

\* So termed by Rand Corporation (RM-4142); also called "atmospheric depth" and "air mass in a column" by Air Force Cambridge Research Laboratories (AFCLR-62-260).

Wet (ambient) air densities varied little over the many years of testing in the Pacific Proving Ground area and had a mean value of 1.157 grams per liter at ground zero. Primarily this consistent value was due to choosing optimum conditions for detonation and to the influence of the large heat budget of the Pacific Ocean. Wet air density at the Nevada Test Site for ground zeros, irrespective of altitude variation, had a mean value of 1.072 grams per liter with maximum excursion of +14% and -8%.

A method is presented for calculating columnar air mass as a function of altitude and results are tabulated. The average air density between any two altitudes may be found by dividing the columnar air mass between these two altitudes by the distance between them. Data given for columnar air mass over any oceanic surface up to one kilometer when compared to other model atmospheres is estimated to be reliable within 7% or less. Application of these data for cases over the USA up to ten kilometers is estimated to be reliable within 2%. The model atmosphere used was chosen to correspond to the Pacific Test area but is also not too different from that of the Nevada Site. However, at other latitudes, the variation of air density with altitude shows marked departures from the chosen model.

#### Recommendation

It is recommended that this tabulation be used as a convenient basic source of air density and other pertinent facts for the study of effects associated with atmospheric nuclear bursts.

## CONTENTS

ADMINISTRATIVE INFORMATION . . . . .	Inside cover
ABSTRACT . . . . .	1
SUMMARY . . . . .	11
 SECTION 1 INTRODUCTION. . . . .	 1
1.1 THE PROBLEM . . . . .	1
1.2 OBJECTIVE AND SCOPE . . . . .	2
1.3 LIMITATIONS . . . . .	2
 SECTION 2 DISCUSSION OF THE DATA. . . . .	 3
2.1 TABLE 1 DATA: AIR DENSITIES FOR NUCLEAR ATMOSPHERIC BURSTS . . . . .	3
2.2 TABLE 2 DATA: COLUMNAR AIR MASS AS A FUNCTION OF GEOMETRIC ALTITUDE . . . . .	4
2.3 COMPUTATION OF COLUMNAR AIR MASS. . . . .	6
 SECTION 3 CONCLUSIONS . . . . .	 10
 REFERENCES . . . . .	 11
 TABLES	
1 AIR DENSITIES FOR NUCLEAR ATMOSPHERIC BURSTS. . . . .	13
2 COLUMNAR AIR MASS AS A FUNCTION OF GEOMETRIC ALTITUDE FOR A TROPICAL MODEL ATMOSPHERE. . . . .	23
 FIGURES	
1 AIR DENSITY vs GEOMETRIC ALTITUDE . . . . .	25
2 REMAINING VERTICAL COLUMNAR AIR MASS <u>vs</u> ALTITUDE. . . . .	26

## SECTION 1

### INTRODUCTION

#### 1.1 THE PROBLEM

An important factor associated with the study of nuclear effects is that of air density. Air density significantly influences the rate and partition of energy released from nuclear burst in the atmosphere, the energy transport by neutrons, gamma rays, x-rays, thermal radiation, and blast effects. An error in the value used for air density directly affects the accuracy of radiation- and blast-effects analyses and thus can result in errors of equal or larger magnitude in predictions based on such analyses. Accurate knowledge of ambient air densities is therefore required. Weather data from which such air densities are obtained are found with difficulty in a variety of materials such as handout sheets distributed at the tests, the Reports of the Test Directors, weather reports for test series, and other reports not directly concerned with weather data. The situation is similar for ground-zero and burst altitudes. Thus, with a considerable amount of data (in many cases conflicting) in reports of varying classification, a need for carefully compiled and verified information issued as a single unclassified document has long existed.

For competent prediction of radiation and blast effects of nuclear atmospheric bursts, a rapid means of evaluation of air density is needed. However, air density is usually multiplied by slant range in effects calculations. This product is termed columnar air mass in this report.\* The concept of columnar air mass applies primarily to the transmission or absorption of particulate and electromagnetic radiation emitted during an atmospheric nuclear burst. Therefore, a method for calculation of columnar air mass and a tabulation of results would facilitate predictions of nuclear burst effects.

\* So termed by Rand Corporation (RM-4142); also called "atmospheric depth" and "air mass in a column" by Air Force Cambridge Research Laboratories (AFCRL-62-260).

## 1.2 OBJECTIVE AND SCOPE

The objective of this report is to provide accurate data on air densities, ground-zero and burst altitudes of atmospheric nuclear tests, and a capability for computing columnar air masses between selected points at different altitudes and horizontal distances over various geographical areas. A literature survey has been conducted and available data selected, compared and tabulated. Sources are referenced and in most cases provide considerably more information than is given in the limited scope of this presentation. Only U.S. atmospheric nuclear bursts are considered. Where the tabulation of basic data is incomplete, it is due to one of three reasons:

- (1) non-availability of the data,
- (2) security classification of all information concerning a particular shot or,
- (3) inapplicability of available air density to the particular shot.

Data on which columnar air mass calculations can be based have been tabulated and a calculational method is presented. Results are given as a function of geometric altitude.

## 1.3 LIMITATIONS

Aside from the limited scope of presentation as described in the previous section, computation of columnar air mass is at best a hopeful endeavor. Indeed, as in many natural situations, annual, daily and moment-to-moment microscopic and macroscopic variation in the condition of the atmosphere render inaccurate all attempts at precise quantification. However, for the intended use of columnar mass, namely the study of effects associated with atmospheric nuclear bursts, the data and computational method are considered satisfactory within 7% up to one kilometer when applied over any oceanic surface. Application of these data for cases over the USA up to ten kilometers is estimated to be reliable within 2%. The model atmosphere used was chosen to correspond to the Pacific Test area but is also not too different from that of the Nevada Site. However, at other latitudes, the variation of air density with altitude shows marked departures from the chosen model.

## SECTION 2

### DISCUSSION OF THE DATA

#### 2.1 TABLE 1 DATA: AIR DENSITIES FOR NUCLEAR ATMOSPHERIC BURSTS

Compilation of all available data for ground-zero and burst-height altitudes and computed dry-air and water-vapor densities appears in Table 1. This information was gathered through an extensive literature search in an effort to provide reliable data for the analysis and prediction of nuclear detonation effects. Tabulation of this information became necessary during the task of analyzing copious amounts of nuclear-weapons test data from many operations. This tabulation has been extended beyond the minimum necessary to air density determinations since a compendium of this sort may easily have uses other than originally intended.

Operations and the nuclear tests composing each operation are listed in chronological order with associated times of detonation in Greenwich Civil Time (GCT). To translate GCT to Pacific Proving Ground (PPG) local time, add 12 hours. Nevada Test Site (NTS) local time may be found by subtracting 8 hours from GCT. However, it should be noted that for shots in Nevada, Daylight Saving Time was in effect for tests occurring between the beginning of May and October.

For all detonations in Nevada, the site is listed as NTS. For detonations in the Pacific, the atoll on, near, or over which the test took place is listed as the site. For the tower shots, burst heights are not exact. Elevations listed are for nominal tower heights and do not include the additional height from the center of mass of the device to the cab floor. In addition, for the Trinity shot the ground zero altitude measurement was actually 800 yards from true ground zero and was taken from an altimeter calibrated at Kirtland, New Mexico, as part of the 100-ton pre-nuclear test shot. However, it is believed that to make additional corrections would be of little consequence for this tabulation.

References 1-18 are the sources used for Table 1 weather data. In general, pressure measurements are probably good to one millibar ( $10^3$  dynes/cm<sup>2</sup>) and temperatures to one degree centigrade. Consequently,

density data are assumed accurate to within 1/2%. In Operation Sandstone, burst-altitude weather data for Shot X-ray were taken from Ref. 3 and, for the rest of the Operation, from Ref. 4. In most cases, weather data were taken a few minutes to a few hours before or after the particular shot. Furthermore, in many cases, data were taken at various altitudes other than the exact burst heights. Therefore, in those cases, a linear interpolation was made to estimate weather data corresponding to a specific time and burst altitude.

No data for air-density computations similar to those obtained at the preceding operations were available for Operation Dominic. However, some data were taken in the upper atmosphere by a rocket-launched free-falling-sphere method (see Ref. 19). Upon examination, measurements were found to be similar to the values of air density vs altitude given in Ref. 20 (presented in Table 2).

All data computed in Table 1 are based on constants and equations found in the Smithsonian Meteorological Tables.<sup>21</sup> Dew-point measurements are converted to vapor-pressure using the tabulation, 'Saturated Vapor Pressure Over Water' (pg. 351), even when the dew-point is below freezing temperature. Detailed explanations for this procedure can be found on pg. 358, Handbook of Meteorology,<sup>22</sup> and on pg. 348 in the Smithsonian Tables. When the dew-point was unavailable, vapor pressure was found as a function of air temperature and then multiplied by the relative humidity to obtain the values used. Vapor density was found by dividing vapor pressure by air temperature and then multiplying by the appropriate gas constant. Dry air density was found by dividing air pressure minus vapor pressure by air temperature and then multiplying by the appropriate gas constant. Wet air density (ambient air density) was found by summing vapor density and dry air density.

## 2.2 TABLE 2 DATA: COLUMNAR AIR MASS AS A FUNCTION OF GEOMETRIC ALTITUDE

Input data of Table 2 listed in column 2 were taken from Ref. 20 and represent a model tropical atmosphere up to 90 kilometers at 15° North latitude. This model atmosphere was chosen for three reasons:

- (1) it corresponds to PPG atmosphere for tests at which data were taken,
- (2) it is similar to the NTS (U.S.) atmosphere with a minimum of correction, and
- (3) in comparison to other model atmospheres in Ref. 20, it seems to be better suited for naval applications.

Vertical columnar air mass, column 3 of Table 2, was found by point-to-point numerical integration using the equation:

$$\int_{H_1}^{H_2} \rho \Delta y = (\rho_1 - \rho_2) (H_2 - H_1) / \log_e (\rho_1 / \rho_2) \quad (1)$$

where  $\rho_1$  and  $\rho_2$  are the model air densities at their respective geometric heights,  $H_1$  and  $H_2$ . If we assume

$$\rho = \rho_0 e^{-by}$$

then

$$\begin{aligned} \int_{H_1}^{H_2} \rho \Delta y &= \int_{H_1}^{H_2} \rho_0 e^{-by} dy \\ &= \frac{1}{b} \left[ \rho_0 e^{-bH_1} - \rho_0 e^{-bH_2} \right] \\ &= (\rho_1 - \rho_2) / b \end{aligned}$$

but

$$(H_2 - H_1)b = \log_e (\rho_1 / \rho_2)$$

which, when substituted in the preceding equation, gives us Eq. 1. This form of integration was used (between consecutive kilometers) because of the generally semi-logarithmic dependence of air density on geometric altitude. Remaining columnar air mass (columnar air mass above a given altitude), column 4 of Table 2, was computed simply by subtracting values of column 3 (rounded off numbers appear in the table) from the value 1937.898876000 g/cm<sup>2</sup>, which represents a total columnar air mass,  $M_0$ , applicable to an infinite geometric altitude. An estimate of this "total" was derived by requiring that the ratio of air density to remaining columnar air mass for the last two entries (89 and 90 km) be equal, i.e.

$$\frac{RM_{89}}{\rho_{89}} = \frac{RM_{90}}{\rho_{90}}$$

thus the equations:

$$M_{\infty} - M_{89} = RM_{89}$$

$$M_{\infty} - M_{90} = RM_{90}$$

may be solved for  $M_{\infty}$  (see next section for definitions). The "total" columnar air mass value thus is an extrapolated value based on the semi-logarithmic nature of the function integrated. The use of this "total" in the computations preserves the shape of the 'Remaining Columnar Air Mass' curve; i.e., in the region of 90 km and beyond the curve continues with a constant slope.

Air density vs geometric altitude is plotted in Fig. 1. Remaining vertical columnar air mass vs geometric altitude is plotted in Fig. 2.

### 2.3 COMPUTATION OF COLUMNAR AIR MASS

The method for computing columnar air mass is derived in the following paragraphs. The equation for columnar air mass (M) between two points separated in altitude and horizontal distance can be expressed (in g/cm<sup>2</sup>) as:

$$M = \frac{RM_1 - RM_2}{H_2 - H_1} \times \frac{\rho_a}{\rho_m} \times SR \quad (2)$$

where

$RM_1$  = remaining columnar air mass (g/cm<sup>2</sup>) above the altitude  $H_1$  (km)

$RM_2$  = remaining columnar air mass (g/cm<sup>2</sup>) above the altitude  $H_2$  (km)

$\rho_a$  = ambient air density (g/l) at any altitude between  $H_1$  and  $H_2$

$\rho_m$  = model atmosphere air density (g/l) at the same altitude as  $\rho_a$

SR = slant range (km)

At other than integral altitudes linear interpolation between values in the table is sufficiently accurate (variation < .13% between 0 and 1 km). Equation 2 and subsequent equations could also be expressed in terms of the difference in columnar air mass, i.e.  $M_1 - M_2$ , but this would necessitate an inordinate number of digits in these terms (to accomplish the same task) particularly at high altitudes.

The difference:

$$RM_1 - RM_2 \quad (3)$$

represents the vertical columnar air mass between two altitudes,  $H_1$  and  $H_2$ .

The function:

$$\frac{RM_1 - RM_2}{H_2 - H_1} \quad (4)$$

is the average vertical columnar air mass per kilometer of altitude. In the special case where  $H_2 = H_1$  for a horizontal path M can be expressed as:

$$M = \rho_H \times \frac{\rho_a}{\rho_m} \times SR \times 10^2 \quad (2a)$$

in the units previously given. The ratio  $\rho_a/\rho_m$  corrects the value from that of the model atmosphere to that of the ambient atmosphere. Use of ambient air density data in the neighborhood of  $H_1$  and  $H_2$  is the desirable procedure. If such data are not available a close approximation to the actual columnar air mass may be obtained by substituting for  $\frac{\rho_a}{\rho_m}$  the ratio  $\frac{\rho_{sl}}{\rho_{msl}}$ ,

where  $\rho_{sl}$  = ambient (wet) air density at sea level

$\rho_{msl}$  = model atmosphere air density at sea level (1.16655 in Table 2)

If  $\rho_{sl}$  is not known, the following values are recommended for the ratio

of  $\rho_{sl}$  to  $\rho_{msl}$ :

Area/Season	$\rho_{sl}/\rho_{msl}$
USA (if season/location not specified)	1.05011
30° N July	.99369
30° N Jan	1.05678
45° N July	1.02177
45° N Jan	1.11524
60° N July	1.04566
60° N Jan	1.17637
75° N July	1.08404
75° N Jan	1.21446

No model-atmosphere data are available for the Southern Hemisphere. However, it is estimated (based on latitude pressure dependence) that applicable values of the  $\rho_{sl}/\rho_{msl}$  ratio for the Northern Hemisphere could be used, i.e., 30° N July for 30° S Jan.

A correction for the curvature of the earth is ignored. Its inclusion changes the slant range less than one percent with 1500 km and introduces an error of less than one percent in the columnar air mass within 100 km horizontal range. However, the error between the 'flat-earth' and 'round-earth' case increased rapidly for horizontal (ground) ranges greater than 100 km. Other useful manipulations are:

$$\bar{\rho} = \frac{RM_1 - RM_2}{H_2 - H_1} \times \frac{\rho_a}{\rho_m} \times 10^{-2} \text{ g/l} \quad (5)$$

and

$$\text{Rel} = \frac{RM_1 - RM_2}{H_2 - H_1} \times \frac{\rho_a}{\rho_m} \times \frac{10^{-2}}{\rho_{std}} \quad (6)$$

where  $\bar{\rho}$  = average ambient vertical air density (g/l)

$\rho_{std}$  = any arbitrarily selected standard for sea level air density (two standards frequently employed are 1.2923 g/l, STP and 1.2255 g/l, density at 1 atmosphere and 15°C)

$$\text{Rel} = \frac{\bar{\rho}}{\rho_{\text{std}}} = \text{average relative air density (a dimensionless number)}$$

The following examples illustrate the use of Table 2 or Figs. 1 and 2:

Example 1: What is the columnar air mass (Eq. 2) between two points at 1 km and 0 km altitudes, separated by 1 km horizontal ground distance, where the ambient sea level air density is 1.150 g/l? From Table 2;  $RM_2$  is  $9.26428 \times 10^2$ \*,  $RM_1$  is  $1.03790 \times 10^3$ \*, and  $\rho_{\text{msl}}$  is 1.16655. Slant range, SR, is 1.41421,  $H_1$  is 0,  $H_2$  is 1, and  $\rho_{\text{sl}}$  is 1.150. Thus, the columnar air mass is:

$$M = \frac{1.03790 \times 10^3 - 9.26428 \times 10^2}{1 - 0} \times \frac{1.150}{1.16655} \times 1.41421$$

or

$$M = 155.408 \text{ g/cm}^2$$

Example 2: Using the conditions in Ex. 1, what is the average relative air density (Eq. 6) where the standard air density,  $\rho_{\text{std}}$ , is 1.2923 g/l? The relative air density is:

$$\text{Rel} = \frac{1.03790 \times 10^3 - 9.26428 \times 10^2}{1 - 0} \times \frac{1.150}{1.16655} \times \frac{10^{-2}}{1.2923} = 0.85035$$

\* +2, +3, etc. stand for powers of 10 in Table 2

## SECTION 3

### CONCLUSIONS

The data presented in Table 1 are the most reliable that are available at NRDL. In general, Table 1 pressure measurements are probably good to one millibar and temperatures to one degree centigrade. Consequently, density data are assumed accurate to within 1/2%.

Columnar air mass computations based on data in Table 2 and the method given in the text generate values sufficiently accurate for use in the study of nuclear weapons effects. Comparison of the air density values in Table 2 with other model atmospheres in Ref. 20 indicates that, when the actual sea-level air density is known, the computation of columnar air mass is valid (within 7% or less) over oceanic surfaces other than the Pacific Proving Ground area at low altitudes (~ 1 km). At altitudes higher than 1 km, other model atmospheres vary considerably from the model chosen; thus the air densities of Table 2 are not in close agreement. Computations for the USA appear to be good to 2% up to 10 km. However, for extreme altitude differences, error in columnar air mass due to curvature tends to be minimized by the averaging effect of columnar mass tabulations. All columnar air mass computations should be confined to 100 km horizontal (ground) range to achieve 1% computational accuracy. Further discussion of accuracy may be found in Sec. 1.3.

In conclusion, this report provides a useful source of basic data on pertinent air densities, altitude and columnar air masses for the study of effects of atmospheric nuclear bursts.

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Operation	Name	Date (OCT)	Time (OCT)	Location of Shot	Ground Zero Alt MSL (feet)	Burst Alt MSL (feet)	Height of Burst (feet)	Type of Burst	Air Pressure		Air Temperature	
									Ground Zero (mb)	Burst Height (mb)	Ground Zero (°C)	Burst Height (°C)
Trinity		16/7/45	1230	Alamogordo New Mexico	4979	5079	100	Tower	851.7		20	
Crossroads	Able	30/6/46	2201	Bikini	0	518	518	Air	1012.2		30	
Sandstone	X-ray	14/4/48	1817	Eniwetok	0	200	200	Tower	1011.8	1009	27.2	27
	Yoke	30/4/48	1809	"	0	200	200	"	1010.5	1003.7	27.0	26.5
	Zebra	14/5/48	1804	"	0	200	200	"	1008.0	1001.3	27.0	26.0
Ranger	Able	27/1/51	1345	NIS	3140	4200	1060	Air	903	868	- 2.0	6.1
	Baker	23/1/51	1352	"	3140	4220	1080	"	899	864	- 2.8	7.4
	Easy	1/2/51	1347	"	3140	4220	1080	"	919	879	- 11.5	- 5.1
	Baker-2	2/2/51	1349	"	3140	4240	1100	"	920	881	- 9.2	- 2.6
	Fox	6/2/51	1347	"	3140	4575	1435	"	909	862	- 2.0	7.5
Greenhouse	Dog	7/4/51	1834	Eniwetok	0	300	300	Tower	1012.2	1002.2	26.1	26.1
	Easy	20/4/51	1827	"	0	300	300	"	1010.2	1000.2	26.7	26.7
	George	8/5/51	2130	"	0	200	200	"	1007.1	1000.4	27.2	27.2
	Item	24/5/51	1817	"	0	200	200	"	1011.9	1005.2	26.7	26.7
Buster - Jeagle	Able	22/10/51	1400	NIS	4169	4269	100	Tower	874	870	5.8	5.9
	Baker	28/10/51	1520	"	4193	5311	1118	Air	877	840	11.4	9.8
	Charlie	30/10/51	1500	"	4193	5325	1132	"	872	835	5.3	11.2
	Dog	1/11/51	1530	"	4193	5610	1417	"	876	832	15.5	12.0
	Easy	5/11/51	1630	"	4224	5538	1314	"	878	838	11.3	8.4
	Sugar	19/11/51	1700	"	4223	4217	4	Surface	871.5		1.0	
Tumbler - Snapper	Able	1/4/52	1700	NIS	3078	3871	793	Air	914	888.5	14.44	13.61
	Baker	15/4/52	1730	"	4193	5302	1109	"	878	842	11.56	8.89
	Charlie	22/4/52	1730	"	4193	7640	3447	"	873	770	18.94	7.39
	Dog	1/5/52	1630	"	4193	5233	1040	"	877	845	17.11	15.0
	Easy	7/5/52	1215	"	4240	4540	300	Tower	865	856	15.83	17.67
	Fox	25/5/52	1200	"	4310	4610	300	"	868	858	13.94	19.44
	George	1/6/52	1155	"	4027	4327	300	"	872	862	11.44	14.11
	How	5/6/52	1155	"	4492	4793	300	"	863	854	17.78	20.39
Ivy	Mike	31/10/52	1915	Eniwetok	0	20	20	Tower	1011		29.4	
	King	15/11/52	2330	"	0	1480	1480	Air	1011	962	28.0	25.4
Upshot - Knothole	Annie	17/3/53	1320	NIS	4025	4325	300	Tower	876	866	2.7	7.9
	Nancy	24/3/53	1310	"	4308	4608	300	"	870	860	9.9	13.3
	Ruth	31/3/53	1300	"	4164	4464	300	"	873	863	4.4	8.2

TABLE 1  
Air Densities for Nuclear  
Atmospheric Bursts

(\* terms defined at end of Table)

Type of Burst	Air Pressure		Air Temperature		Dew Point		Relative Humidity		Vapor Pressure		Vapor Density	
	Ground Zero (mb)	Burst Height (mb)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)
Tower	851.7		20		16.1				18.3		.0135	
Air	1012.2		30									
Tower	1011.8	1009	27.2	27	24.6		68	81	29.3	28.9	.0209	.0209
"	1010.5	1003.7	27.0	26.5			76.5	75	30.9	27.3	.0223	.0188
"	1008.0	1001.3	27.0	26.0			81	80	28.9	26.0	.0197	.0188
Air	903	868	- 2.0	6.1			73	55	3.85	5.18	.00306	.00402
"	899	864	- 2.8	7.4			87	57	4.33	5.87	.00347	.00453
"	919	879	-11.5	- 5.1			89	65	2.26	2.72	.00187	.00220
"	920	881	- 9.2	- 2.6			79	61	2.43	3.08	.00199	.00247
"	909	862	- 2.0	7.5			85	53	4.48	5.49	.00358	.00424
Tower	1012.2	1002.2	26.1	26.1	21.7	21.7			26.0	26.0	.0188	.0188
"	1010.2	1000.2	26.7	26.7	21.1	21.1			25.0	25.0	.0181	.0181
"	1007.1	1000.4	27.2	27.2	25.0	25.0			31.7	31.7	.0229	.0229
"	1011.9	1005.2	26.7	26.7	22.8	22.8			27.7	27.7	.0200	.0200
Tower	874	870	5.8	5.9			22	23	2.03	2.13	.00158	.00165
Air	877	840	11.4	9.8			28	27	3.77	3.27	.00287	.00250
"	972	855	5.3	11.2			14	14	1.25	1.86	.000973	.00142
"	876	832	15.5	15.0			43	58	7.57	8.13	.00568	.00618
"	878	838	11.3	8.4			17	18	2.28	1.98	.00174	.00154
Surface	871.5		1.0		- 9.5				2.98		.00236	
Air	914	888.5	14.44	13.61			28	30	4.56	4.67	.00344	.00353
"	878	842	11.56	8.89			30	30	4.10	3.42	.00312	.00263
"	873	770	18.94	7.39			30	47	6.55	4.84	.00486	.00374
"	877	845	17.11	15.0			47	50	9.16	8.52	.00684	.00641
Tower	868	850	15.83	17.57			40	37	5.18	7.49	.00440	.00558
"	868	858	13.94	19.44			41	41	6.51	9.23	.00491	.00684
"	872	862	11.44	14.11			48	50	6.47	8.04	.00493	.00606
"	863	854	17.78	20.39			45	50	9.27	11.98	.00603	.00884
Tower	1011		29.4		23.8				29.5		.0411	
Air	1011	962	28.0	25.4	23.5	22.2			28.9	26.6	.0208	.0195
Tower	876	866	2.7	7.9	- 8.5	- 5.4			3.22	4.09	.00253	.00315
"	870	860	9.9	13.3	- 3.6	- 3.2			4.68	4.83	.00358	.00365
"	873	863	4.4	8.3	- 5.3	- 7.4			4.12	3.51	.00322	.00270

2

(\* terms defined at end of Table)

Relative Humidity *	Vapor Pressure *		Vapor Density *		Dry Air Density *		Wet Air Density *		References	
	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)		
		18.3		.0135		.970		1.004	1	
		29.3		.0209		1.130		1.150	2	
	81	30.9	28.9	.0223	.0209	1.138	1.138	1.160	1.158	3, 4
	75	27.3	26.0	.0177	.0188	1.141	1.137	1.161	1.155	4
	80	26.9	26.9	.0209	.0195	1.136	1.135	1.157	1.154	4
	55	3.85	5.18	.00306	.00402	1.148	1.076	1.151	1.080	5
	57	4.33	5.87	.00347	.00453	1.153	1.066	1.156	1.070	5
	65	2.26	2.72	.00187	.00220	1.221	1.139	1.222	1.141	5
	61	2.43	3.08	.00199	.00247	1.211	1.130	1.213	1.133	5
	53	4.48	5.49	.00358	.00424	1.162	1.063	1.166	1.067	5
		26.0	26.0	.0188	.0188	1.148	1.136	1.167	1.155	6
		25.0	25.0	.0181	.0181	1.145	1.133	1.163	1.151	6
		31.7	31.7	.0227	.0229	1.131	1.124	1.154	1.146	6
		27.7	27.7	.0200	.0200	1.143	1.136	1.163	1.156	6
	23	2.03	2.13	.00158	.00165	1.089	1.083	1.091	1.085	7
	27	3.77	3.27	.00287	.00250	1.067	1.030	1.072	1.033	7
	14	1.25	1.86	.000973	.00142	1.089	1.021	1.090	1.022	7
	58	7.57	8.13	.00568	.00618	1.048	1.007	1.054	1.013	7
	18	2.28	1.98	.00174	.00152	1.073	1.034	1.074	1.036	7
		2.98		.00236		1.104		1.106		8
	30	4.56	4.67	.00344	.00353	1.102	1.074	1.105	1.077	9
	30	4.10	3.42	.00312	.00263	1.069	1.036	1.072	1.038	9
	47	6.55	4.84	.00486	.00374	1.035	.950	1.040	.954	9
	50	9.16	8.52	.00684	.00641	1.042	1.011	1.048	1.018	9
	37	3.18	7.49	.00240	.00558	1.049	1.019	1.044	1.024	9
	41	6.51	9.23	.00491	.00684	1.045	1.011	1.050	1.017	9
	50	6.47	8.04	.00493	.00606	1.060	1.036	1.064	1.042	9
	50	9.17	11.98	.00683	.00884	1.022	.999	1.029	1.008	9
		29.5		.0211		1.130		1.151		10
		28.9	26.8	.0208	.0195	1.136	1.091	1.157	1.111	10
		3.22	4.09	.00253	.00315	1.102	1.068	1.105	1.072	11
		4.68	4.83	.00358	.00365	1.065	1.040	1.069	1.044	11
		4.12	3.51	.00322	.00270	1.091	1.064	1.094	1.067	11

3

Operation	Name	Date (OCT)	Time (OCT)	Location of Shot	Ground Zero Alt MSL (feet)	Burst Alt MSL (feet)	Height of Burst (feet)	Type of Burst	Air Pressure		Air Gross Zero
									Ground Zero (mb)	Burst Height (mb)	
Upshot- Knothole (Cont.)	Dixie	6/4/53	1530	NTS	4191	10211	6020	Air	861	886	15.5
	Ray	11/4/53	1245	"	4240	4340	100	Tower	869	866	- .1
	Bradgar	18/4/53	1235	"	4492	4792	300	"	862	852	7.7
	Simon	25/4/53	1230	"	4838	4938	300	"	870	860	11.7
	Encore	8/5/53	1530	"	3078	5503	2425	Air	900	825	16.7
	Harry	19/5/53	1205	"	4009	4309	300	Tower	874	864	14.3
	Grable	25/5/53	1530	"	3078	3606	524	Gun	901	884	14.8
Climax	4/6/53	1115	"	4210	5544	1334	Air	867	824	13.3	
Castle	Bravo	28/2/54	1845	Bikini	10.0	17.0	7	Surface	1006.1		26.7
	Romeo	26/3/54	1830	"	7.2	14.2	7	Barge	1012.4		26.7
	Koon	6/4/54	1820	"	8.0	21.6	13.6	Surface	1009.7		27.2
	Union	25/4/54	1810	"	5.8	12.8	7	Barge	1007.4		27.2
	Yankee	4/5/54	1810	"	6.6	13.6	7	"	1010.8		27.1
	Nectar	13/5/54	1820	Eniwetok	7.2	14.2	7	"	1006.4		26.7
Teapot	Wasp	18/2/55	2000	NTS	4195	4997	762	Air	870	845	- 3.5
	Moth	22/2/55	1345	"	4026	4326	300	Tower	879	870	- 7.7
	Teala	1/3/55	1330	"	4201	4501	300	"	876	866	- 4.2
	Turk	7/3/55	1320	"	4491	4991	500	"	870	854	5.0
	Hornet	12/3/55	1320	"	4007	4307	300	"	881	872	- 1.0
	Bee	22/3/55	1305	"	4245	4745	500	"	875	860	1.0
	Apple-1	29/3/55	1255	"	4309	4809	500	Tower	867	852	8.0
	Wasp	29/3/55	1800	"	4195	4935	740	Air	871	849	13.4
	HA	6/4/55	1800	"	4030	36,620	32,590	"	883	222	10.2
	Fret	9/4/55	1230	"	4236	4536	300	Tower	875	865	4.2
	Met	15/4/55	1915	"	3078	3478	400	"			
	Apple-2	5/5/55	1210	"	4236	4736	500	"	871	855	9.6
	Zucchini	15/5/55	1200	"	4245	4745	500	"	866	852	3.0
	Redring	Lacrosse	4/5/56	1825	Eniwetok	0	17	17	Surface	1008.5	
Cherokee		20/5/56	1751	Bikini	0	4320	4320	Air	1009.0	870	27.2
Zuni		27/5/56	1756	"	0	9	9	Surface	1010.5		27.2
Eric		30/5/56	1815	Eniwetok	0	300	300	Tower	1009.1	1003	26.8
Seminole		6/6/56	0055	"	0	4.5	4.5	Surface	1010.5		30.5
Flathead		11/6/56	1826	Bikini	0	15	15	Barge	1012.9		27.8
Blackfoot		11/6/56	1826	Eniwetok	0	200	200	Tower	1012.5	1006	27.3
Cage		16/6/56	0114	"	0	680	680	Air	1008.5		29.9
Dakota		25/6/56	1806	Bikini	0	0	0	"	1009.1		27.8
Apache		8/7/56	1806	Eniwetok	0	0	0	Barge	1010.5		26.8
Navajo		10/7/56	1756	Bikini	0	15	15	"	1010.2		27.3
Tewa		20/7/56	1746	"	0	15	15	"	1009.3		27.8
Huron		21/7/56	1816	Eniwetok	0	15	15	"	1007.8		27.4

TABLE 1 (Cont.)

(\* terms defined at end of Table)

Sight #	Type of Sight	Air Pressure		Air Temperature		Dew Point		Relative Humidity		Vapor Pressure		Vapor Density	
		Ground Zero (mb)	Burst Height (mb)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)
280	Air	861	886	15.5	- .6	- 4.1	-13.7			4.51	2.13	.00338	.0016
100	Tower	869	866	- .3	- .1	-11.3	-11.7			2.58	2.50	.00205	.0015
300	"	862	852			- 7.7	- 7.2			4.58	4.51	.00353	.0034
300	"	870	860			- 7.7	- 7.3			3.53	4.31	.00268	.0032
405	Air	900	865	16.7	8.0	- 7.0	-12.5			3.62	2.34	.00270	.0012
300	Tower	874	854	14.3	18.3	- .6	4.5			5.85	8.42	.00441	.0068
384	Gun	901	864	14.8	13.1	- 3.8	- 7.2			4.61	3.56	.00347	.0026
134	Air	867	864	13.3	12.2	- 3.9	- 1.5			4.58	5.47	.00346	.0041
7	Surface	1006.1		26.7		22.2				26.8		.0194	
7	Barge	1012.4		26.7		22.2				26.8		.0194	
13.6	Surface	1009.7		27.2		23.9				29.7		.0214	
7	Barge	1007.4		27.2		24.4				30.6		.0221	
7	"	1010.8		27.1		23.9				29.7		.0214	
7	"	1006.4		26.7		23.9				29.7		.0214	
762	Air	870	845	- 3.5	- 6.4	-16.6	-19.0			1.67	1.37	.00134	.0011
300	Tower	879	870	- 7.7	- 4.4	-15.1	-13.0			1.90	2.25	.00155	.0012
300	"	876	866	- 4.2	- 1.1	-15.2	-14.5			1.88	1.99	.00152	.0015
300	"	870	854	5.0	5.9	- 9.8	- 8.5			2.91	3.22	.00227	.0022
300	"	881	872	- 1.0	2.5	- 7.6	- 4.1			3.45	4.51	.00275	.0035
300	"	875	860	1.0	4.5	-14.1	-13.5			2.06	2.16	.00163	.0016
300	Tower	867	852	8.0	9.3	- 1.4	- 0.9			5.51	5.72	.00425	.0041
740	Air	871	849	13.4	12.6	- 1.5	1.5			5.47	5.47	.00414	.0041
2,590	"	863	822	10.2	-47.8	- 8.0				3.35		.00256	
300	Tower	875	865	4.2	8.7	- 9.8	- 9.7			2.91	4.00	.00227	.0030
400	"												
300	"	871	855	9.6	14.2	- 5.2	- 3.0			4.15	4.90	.00318	.0036
300	"	866	852	3.0	2.1	- 8.5	- 8.9			3.22	3.12	.00253	.0024
17	Surface	1008.5		27.2		25.0				31.7		.0229	
380	Air	1009.0	870	27.2	15.5	22.8	10.8			27.7	12.9	.0200	.0096
9	Surface	1010.5		27.2		24.4				30.6		.0221	
300	Tower	1009.1	1003	26.8	26.6	23.1	22.0			28.3	26.4	.0204	.0191
4.5	Surface	1010.5		30.5		24.7				31.1		.0222	
15	Barge	1012.9		27.8		24.4				30.6		.0220	
200	Tower	1012.5	1006	27.3	26.6	24.3	23.8			30.4	29.5	.0219	.0211
580	Air	1008.5		29.9		24.8				31.3		.0224	
0	Barge	1009.1		27.8		23.0				29.7		.0214	
C	"	1010.5		26.8		23.8				29.5		.0213	
15	"	1010.2		27.3		23.3				28.6		.0206	
15	"	1009.3		27.8		25.0				31.7		.0228	
15	"	1007.8		27.4		24.6				30.9		.0223	

2

(\* terms defined at end of Table)

Relative Humidity		Vapor Pressure		Vapor Density		Dry Air Density		Wet Air Density		References
Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)	Burst Height (g/l)	
	4.51		2.13	.00336	.00169	1.034	.874	1.037	.876	
	2.58		2.50	.00205	.00198	1.106	1.108	1.108	1.104	11
	4.58		4.51	.00353	.00348	1.064	1.053	1.067	1.057	11
	3.53		4.31	.00268	.00324	1.060	1.033	1.062	1.037	11
	3.62		2.34	.00270	.00180	1.077	1.019	1.080	1.021	11
	5.85		8.42	.00441	.00626	1.052	1.023	1.057	1.029	11
	4.61		3.56	.00347	.00269	1.084	1.072	1.088	1.074	11
	4.58		5.47	.00346	.00415	1.049	.999	1.052	1.003	11
	86.8			.0194		1.138		1.157		12
	86.8			.0194		1.145		1.164		12
	89.7			.0214		1.137		1.158		12
	30.6			.0221		1.133		1.155		12
	89.7			.0214		1.138		1.160		12
	89.7			.0214		1.133		1.155		12
	1.67	1.37		.00134	.00111	1.122	1.102	1.123	1.103	13
	1.90	2.25		.00155	.00181	1.151	1.125	1.153	1.127	13
	1.88	1.99		.00152	.00158	1.133	1.106	1.135	1.108	13
	2.91	3.22		.00227	.00250	1.086	1.062	1.088	1.065	13
	3.45	4.51		.00275	.00355	1.123	1.096	1.126	1.100	13
	2.06	2.16		.00163	.00169	1.109	1.076	1.111	1.078	13
	5.51	5.72		.00425	.00439	1.067	1.044	1.072	1.048	13
	5.47	5.47		.00414	.00415	1.052	1.028	1.056	1.033	13
	3.35			.00296		1.082	.943	1.084	.943	13
	2.91	4.00		.00227	.00308	1.095	1.064	1.098	1.067	13
	4.15	4.90		.00318	.00369	1.068	1.031	1.071	1.034	13
	3.22	3.12		.00253	.00246	1.088	1.074	1.091	1.077	13
	31.7			.0229		1.133		1.156		14
	27.7	12.9		.0200	.00968	1.138	1.034	1.158	1.044	14
	30.6			.0221		1.137		1.159		14
	28.3	26.4		.0204	.0191	1.139	1.135	1.160	1.154	14
	31.1			.0222		1.124		1.146		14
	30.6			.0220		1.137		1.159		14
	30.4	29.5		.0219	.0213	1.139	1.135	1.161	1.156	14
	31.3			.0224		1.123		1.146		14
	29.7			.0214		1.134		1.155		14
	29.5			.0213		1.139		1.161		14
	28.6			.0206		1.138		1.159		14
	31.7			.0228		1.132		1.154		14
	30.9			.0223		1.132		1.155		14

Operation	Name	Date (OCT)	Time (OCT)	Location of Shot	Ground Zero Alt MSL (feet)	Burst Alt MSL (feet)	Height of Burst (feet)	Air Pressure		Air Zero		
								Type of Burst	Ground Zero (mb)		Burst Height (mb)	
Flumbob	Boltzman	28/5/57	1155	NTS	4235	4735	500	Tower	867	854	18.	
	Franklin	2/6/57	1155	"	4025	4325	300	"	878	869	14.	
	Lassen	5/6/57	1145	"	4230	4730	500	Balloon	872	855	23.	
	Wilson	18/6/57	1145	"	4230	4730	500	"	882	864	17.	
	Priscilla	24/6/57	1330	"	3076	3776	700	"	909.5	886.7	17.	
	Hood	5/7/57	1140	"	4230	4730	500	"	875	819	21.	
	Diablo	15/7/57	1130	"	4469	4969	500	Tower	864	849	23.	
	John	19/7/57	1400	"	4280	19, 110	14, 830	Rocket	870	824	21.	
	Kepler	24/7/57	1130	"	4309	4809	500	Tower	865	854	21.	
	Owens	25/7/57	1330	"	4215	4715	500	Balloon	871	854	20.	
	Stokes	7/8/57	1225	"	4186	5686	1500	"	872	827	15.	
	Shasta	18/8/57	1200	"	4387	4887	500	Tower	866	852	26.	
	Doppler	23/8/57	1230	"	4186	5686	1500	Balloon	877	832	21.	
	Franklin	30/8/57	1240	"	4186	4936	750	"	868	844	11.	
	Smoky	31/8/57	1230	"	4479	5179	700	Tower	856	844	14.	
	Galileo	2/9/57	1240	"	4235	4735	500	"	878	862	15.	
	Wheeler	6/9/57	1245	"	4215	4715	500	Balloon	876	861	20.	
	LaPlace	8/9/57	1300	"	4186	4936	750	"	874	849	19.	
	Fisheu	14/9/57	1645	"	3997	4497	500	Tower	880	865	25.	
	Newton	16/9/57	1250	"	4186	5686	1500	Balloon	862	820	13.	
	Whitney	23/9/57	1230	"	4486	4986	500	Tower	867	851	16.	
	Charleston	28/9/57	1300	"	4215	4715	500	Balloon	876	829	18.	
	Morgan	7/10/57	1300	"	4215	4715	500	"	869	854	7.	
	Hardtack-I	Yucca	26/4/58	0240	Bikini †	0	85,000	85,000	Balloon	1010.5		30.0
		Cactus	5/5/58	1815	Eniwetok	0	3	3	Surface	1010.5		27.5
		Fir	11/5/58	1750	Bikini	0	9.88	9.88	Barge	1009.2		26.7
		Butternut	11/5/58	1815	Eniwetok	0	10.13	10.13	"	1008.1		27.1
		Koa	12/5/58	1830	"	0	3	3	Surface	1010.2		27.1
		Holly	20/5/58	1830	"	0	13.06	13.06	Barge	1010.2		27.1
		Mutmag	21/5/58	2120	Bikini	0	12.11	12.11	"	1009.9		26.7
Yellowwood		26/5/58	0200	Eniwetok	0	10.52	10.52	"	1011.9		30.0	
Magnolia		26/5/58	1800	"	0	13.88	13.88	"	1010.5		26.7	
Tobacco		37/5/58	0215	"	0	9.06	9.06	"	1011.2		30.0	
Sycamore		31/5/58	0300	Bikini	0	11.64	11.64	"	1009.4		27.5	
Rose		2/6/58	1845	Eniwetok	0	15.43	15.43	"	1008.1		27.5	
Maple		10/6/58	1730	Bikini	0	11.58	11.58	"	1010.7		27.1	
Aspen		14/6/58	1730	"	0	10.82	10.82	"	1011.0		27.1	
Walnut		14/6/58	1830	Eniwetok	0	7.21	7.21	"	1010.8		26.7	
Linden		18/6/58	0300	Bikini	0	8.25	8.25	"	1009.9		27.5	
Redwood		27/6/58	1730	"	0	10.79	10.79	"	1010.1		27.1	
Elder	27/6/58	1830	Eniwetok	0	9.17	9.17	"	1008.5		27.1		

† 60 miles west of Bikini

• data for Eniwetok

TABLE 1 (Cont.)

(\* terms defined at end of Table)

ght Burst ft)	Type of Burst	Air Pressure		Air Temperature		Dew Point		Relative Humidity		Vapor Pressure		Vapor Density	
		Ground Zero (mb)	Burst Height (mb)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)
0	Tower	867	854	18.5	21.3	4.5	3.4			8.42	7.79	.00626	.00577
0	"	878	869	14.8	21.2	3.5	6.4			7.85	9.61	.00591	.00707
0	Balloon	872	855	23.9	27.2	9.9	8.9			12.2	11.4	.00890	.00828
0	"	882	864	17.1	20.5	3.0	3.2			7.58	7.68	.00566	.00568
0	"	909.5	886.7	17.5	24.0	-0.6	-0.2			5.85	6.02	.00436	.00439
0	"	875	819	21.3	26.8	-3.4	-3.6			4.75	4.68	.00350	.00338
0	Tower	864	849	23.1	23.8	-0.8	-0.3			5.76	5.98	.00421	.00438
830	Rocket	870	424	21.8	-17.4	1.2				6.66		.00489	
0	Tower	865	854	21.0	21.0	-5.0	-2.7			4.21	5.01	.00310	.00364
0	Balloon	871	854	20.0	23.1	-3.6	-0.8			4.68	5.76	.00346	.00421
0	"	872	827	15.7	18.4	-5.8	-0.9			3.97	5.72	.00298	.00428
0	Tower	866	852	26.4	26.5	8.9	8.0			11.4	10.7	.00825	.00771
0	Balloon	877	832	21.4	22.0	13.9	10.4			15.9	12.6	.0117	.00928
0	"	868	844	11.0	14.3	-3.7	0.2			4.65	6.20	.00355	.00467
0	Tower	856	844	14.0	15.2	-3.6	-1.2			4.68	5.60	.00353	.00421
0	"	878	862	15.8	18.8	-1.5	-0.5			5.47	5.89	.00410	.00437
0	Balloon	876	861	20.0	23.8	-1.1	2.3			5.64	7.21	.00417	.00526
0	"	874	849	19.0	25.4	1.2	1.7			6.66	6.90	.00494	.00501
0	Tower	880	865	25.1	22.0	-1.5	-3.0			5.47	4.90	.00377	.00360
0	Balloon	862	820	13.2	17.9	-5.6	-5.3			4.03	4.12	.00305	.00307
0	Tower	867	851	16.1	17.0	-3.7	-3.7			4.65	4.65	.00348	.00347
0	Balloon	876	829	18.1	18.5	0.9	1.7			6.52	6.90	.00485	.00513
0	"	869	854	7.3	11.9	-5.9	-5.0			3.94	4.21	.00304	.00322
000	Balloon	1010.5		30.0		22.2				26.8		.0191	
0	Surface	1010.5		27.2		23.3				26.6		.0206	
0.88	Barge	1009.2		26.7		22.8				27.7		.0200	
0.13	"	1008.1		27.2		22.8				27.7		.0200	
0	Surface	1010.2		27.2		23.3				26.6		.0206	
0.06	Barge	1010.2		27.2		23.9				29.7		.0212	
2.11	"	1009.9		26.7		22.2				26.8		.0194	
0.52	"	1011.9		30.0		22.2				26.8		.0192	
0.88	"	1010.5		26.7		22.2				26.8		.0194	
0.06	"	1011.2		30.0		23.9				29.7		.0212	
0.64	"	1009.4		27.5		22.8				27.7		.0200	
0.43	"	1008.1		27.2		23.3				26.6		.0206	
0.58	"	1010.7		27.2		23.3				26.6		.0206	
0.82	"	1011.0		27.2		23.3				26.6		.0206	
0.21	"	1010.8		26.7		23.9				29.7		.0212	
0.29	"	1009.9		27.5		22.5				27.2		.0196	
0.79	"	1010.1		27.2		26.1				33.8		.0244	
0.17	"	1008.5		27.2		23.3				26.6		.0206	

(\* terms defined at end of Table)

Relative Humidity		Vapor Pressure		Vapor Density		Dry Air Density		Wet Air Density		References
Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)	Burst Height (g/l)	Ground Zero (g/l)	Burst Height (g/l)	
	8.42		7.79	.00626	.00973	1.026	1.001	1.032	1.007	15
	7.85		9.61	.00591	.00707	1.053	1.017	1.059	1.024	15
	12.2		11.4	.00890	.00822	1.008	.978	1.017	.987	15
	7.58		7.68	.00566	.00567	1.050	1.016	1.055	1.022	15
	5.85		6.02	.00436	.00439	1.083	1.032	1.087	1.037	15
	4.75		4.68	.00350	.00338	1.030	.946	1.033	.949	15
	5.76		5.98	.00421	.00436	1.009	.989	1.013	.993	15
	6.66			.00489		1.020	.978	1.025	.978	15
	4.21		5.01	.00310	.00369	1.019	1.005	1.023	1.009	15
	4.68		5.76	.00346	.00421	1.030	.997	1.033	1.002	15
	3.97		5.72	.00298	.00425	1.047	.981	1.050	.986	15
	11.4		10.7	.00425	.00774		.994	1.002	.986	15
	15.9		12.6	.0117	.00925	1.018	.967	1.030	.976	15
	4.65		6.20	.00355	.00467	1.058	1.015	1.062	1.020	15
	4.68		5.60	.00353	.00421	1.033	1.013	1.036	1.017	15
	5.47		5.89	.00410	.00437	1.052	1.022	1.056	1.026	15
	5.64		7.21	.00417	.00526	1.034	1.002	1.038	1.007	15
	6.66		6.90	.00494	.00501	1.034	.983	1.039	.988	15
	5.47		4.90	.00397	.00360	1.021	1.015	1.025	1.019	15
	4.03		4.12	.00305	.00307	1.044	.977	1.047	.980	15
	4.65		4.65	.00348	.00347	1.039	1.016	1.042	1.020	15
	6.52		6.90	.00485	.00513	1.040	.982	1.045	.987	15
	3.94		4.21	.00304	.00320	1.075	1.039	1.078	1.042	15
	26.8			.0191		1.130		1.150*		16
	28.6			.0206		1.139		1.160		16
	27.7			.0200		1.140		1.160		16
	27.7			.0200		1.137		1.157		16
	28.6			.0206		1.139		1.159		16
	29.7			.0214		1.137		1.159		16
	26.8			.0194		1.142		1.162		16
	26.8			.0192		1.132		1.151		16
	26.8			.0194		1.143		1.162		16
	29.7			.0212		1.128		1.149		16
	27.7			.0200		1.138		1.157		16
	28.6			.0206		1.136		1.157		16
	28.6			.0206		1.139		1.160		16
	28.6			.0206		1.139		1.149		16
	29.7			.0215		1.140		1.161		16
	27.2			.0196		1.139		1.158		16
	33.8			.0244		1.132		1.157		16
	28.6			.0206		1.137		1.157		16



Operation	Name	Date (OCT)	Time (OCT)	Location of Shot	Ground Zero Alt MSL (feet)	Burst Alt MSL (feet)	Height of Burst (feet)	Type of Burst	Air Pressure	
									Ground Zero (mb)	Burst Height (mb)
Hardtack-I (Cont.)	Oak	25/6/58	1930	Eniwetok	0	6.5	6.5	Barge	1008.5	
	Hickory	25/6/58	0000	Bikini	0	12.11	12.11	"	1009.3	
	Sequoia	1/7/58	1830	Eniwetok	0	6.5	6.5	"	1007.1	
	Cedar	2/7/58	1730	Bikini	0	10.84	10.84	"	1008.5	
	Dogwood	5/7/58	1830	Eniwetok	0	12.25	12.25	"	1008.8	
	Poplar	12/7/58	0330	Bikini	0	11.66	11.66	"	1011.8	
	Juniper	22/7/58	0420	"	0	12.11	12.11	"	1009.0	
	Oliver	22/7/58	2030	Eniwetok	0	8.0	8.0	"	1008.5	
	Pine	26/7/58	2030	"	0	8.0	8.0	"	1008.6	
	Teak	1/8/58	1050	JT*	0	250,000	250,000	Rocket		
	Orange	12/8/58	1030	JT*	0	141,000	141,000	"		
	Fig	18/8/58	1600	Eniwetok				Surface		
	Hardtack-II	Eddy	19/9/58	1400	WTB	4186.5	4686.5	900	Balloon	875
Mor.		29/9/58	1405	"	4186.5	4686.5	1900	"	874	826
Quay		10/10/58	1430	"	4248.6	4348.6	100	Tower	876	870
Lee		13/10/58	1320	"	4186.5	4686.5	1500	Balloon	878	831
Hamilton		15/10/58	1600	"	3082.3	3132.3	50	Tower		
Dona Ana		16/10/58	1420	"	4186.5	4636.5	450	Balloon	380	862
Rio Arriba		18/10/58	1425	"	4009.6	4082.1	72.5	Tower	879	878
Socorro		22/10/58	1330	"	4186.5	4636.5	1450	Balloon	874	836
Wrangell		22/10/58	1650	"	3076.7	4576.7	1500	"		863
Rushmore		22/10/58	2340	"	4214.2	4714.2	500	"	873	877
Sandford		26/10/58	1020	"	3076.7	4776.7	1500	"		864
DeBacon		26/10/58	1600	"	4186.5	4686.5	1500	"	879	829
Humbolt		29/10/58	1445	"	4028.7	4053.7	25	Tower	885	
Santa Fe		30/10/58	0300	"	4186.5	4686.5	1500	Balloon	876	828
Sun Beam	Little - Feller II	7/7/62	1900	WTB	5129.2	5132.2	3	Tower	845	
	Johany Boy	11/7/62	1645	"	5153.5	5151.5	~ -2	Sub Surf.	848	
	Small Boy	14/7/62	1830	"	3077.8	3077.8	10	Tower	906	
	Little - Feller I	17/7/62	1700	"	5193.6	5196.6	3	Rocket	844	
Dominic +	Adobe	25/4/62	1546	CT*	0					
	Artec	27/4/62	1602	"	0					
	Arkansas	2/5/62	1802	"	0					
	Queets	4/5/62	1905	"	0					
	Frigate- Bird	6/5/62	2330	"	0					
	Yukon	8/5/62	1801	"	0					
	Mesilla	9/5/62	1701	"	0					

- \* Johnston Island
- + Christmas Island
- + No meteorological data available for  
Dominic

TABLE 1 (Cont.)

(\* terms defined at end)

Alt (ft)	Height of Burst (feet)	Type of Burst	Air Pressure		Air Temperature		Dew Point		Relative Humidity		Vapor Pressure		Vapor Zero (g/l)
			Ground Zero (mb)	Burst Height (mb)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (°C)	Burst Height (°C)	Ground Zero (%)	Burst Height (%)	Ground Zero (mb)	Burst Height (mb)	
.5	6.5	Barge	1008.5		26.7		24.4				30.6		.0221
.11	12.11	"	1009.3		27.8		27.2				36.1		.0260
.5	6.5	"	1007.1		27.2		23.9				29.7		.0214
.84	10.84	"	1008.5		27.2		24.4				30.6		.0221
.25	12.25	"	1008.8		27.2		25.0				31.7		.0229
.66	11.66	"	1011.8		30.0		24.4				30.6		.0219
.11	12.11	"	1009.0		27.8		25.0				31.7		.0228
.0	8.0	"	1008.5		26.7		24.4				30.6		.0221
.0	8.0	"	1008.8		27.2		25.0				31.7		.0229
100	250,000	Rocket											
100	141,000	"											
		Surface											
5	900	Balloon	875	858	14.2	21.4	-7.9	-3.2			3.37	4.83	.00254
5	1900	"	874	866	11.8	17.3	6.5	5.0			9.67	8.72	.00735
6	100	Tower	876	870	15.3	15.6	-2.7	-2.9			5.01	4.93	.00376
5	1900	Balloon	878	831	13.4	18.3	-4.3	-1.0			4.44	5.68	.00336
3	50	Tower											
5	490	Balloon	380	862	13.7	19.9	-2.7	-.7			5.01	5.80	.00378
1	72.5	Tower	879	878	9.3	5.4	-10.3	-10.7			2.80	2.71	.00215
5	1490	Balloon	874	836	4.7	9.3	-14.7				1.96		.00153
7	1500	"		863		11.1							
2	900	"	873	877	17.8	16.3							
7	1900	"		864		9.4		3.7					
5	1500	"	879	389	8.3	7.6	5.1	2.1			8.78	9.15	.00701
7	25	Tower	885		7.4		3.2				7.68	7.11	.00676
5	1500	Balloon	876	828	12.1	11.6	-7.4	-11.3			3.51	2.58	.00287
2	3	Tower	845		26.5								
5	~-2	Sub Surf.	848		24.3				12		3.64		.00265
3	10	Tower	906		35.0		4.0				8.13		.00771
5	3	Rocket	844		25.0		.2				6.20		.00449

2

(\* terms defined at end of Table)

Relative Humidity e		Vapor Pressure e		Vapor Density e		Dry Air Density e		Wet Air Density e		References
Ground	Burst	Ground	Burst	Ground	Burst	Ground	Burst	Ground	Burst	
Zero	Height	Zero	Height	Zero	Height	Zero	Height	Zero	Height	
(%)	(%)	(mb)	(mb)	(g/l)	(g/l)	(g/l)	(g/l)	(g/l)	(g/l)	
		30.6		.00221		1.136		1.158		16
		36.1		.00260		1.127		1.153		16
		89.7		.00214		1.134		1.155		16
		30.6		.00221		1.134		1.156		16
		31.7		.00229		1.133		1.156		16
		30.6		.00219		1.128		1.149		16
		31.7		.00228		1.131		1.154		16
		30.6		.00221		1.136		1.158		16
		31.7		.00229		1.133		1.156		16
		3.37	4.83	.00254	.00248	1.077	1.011	1.059	1.013	17
		9.67	8.72	.00735	.00690	1.077	.980	1.064	.987	17
		3.01	4.93	.00376	.00370	1.052	1.044	1.056	1.047	17
		4.44	3.68	.00336	.00422	1.062	.987	1.065	.991	17
										17
		3.01	3.80	.00378	.00429	1.063	1.018	1.066	1.022	17
		2.80	2.71	.00215	.00228	1.081	1.079	1.083	1.081	17
		1.96		.00153		1.093		1.095		17
										17
			9.15	.00701		1.054		1.061		17
		8.78	7.11	.00676	.00549	1.077	1.020	1.084	1.025	17
		7.68		.00593		1.089		1.095		17
		3.31	2.98	.00267	.00196	1.066	1.010	1.068	1.012	17
										18
12		3.64		.00265		.989		.992		18
		8.13		.00771		1.015		1.021		18
		6.20		.00449		.979		.983		18

TABLE 1 (Cont.)

Operation	Name	Date (GCT)	Time (GCT)	Location of Shot	Ground Zero Alt MSL (feet)	Burst Alt MSL (feet)
Dominic + (Cont.)	Muskegon	11/5/62	1537	CI**	0	
	Encino	12/5/62	1703	"	0	
	Swanee	14/5/62	1*22	"	0	
	Chetco	19/5/62	1537	"	0	
	Tanana	25/5/62	1609	"	0	
	Nembo	27/5/62	1703	"	0	
	Alma	8/6/62	1703	"	0	
	Truckee	9/6/62	1537	"	0	
	Yaso	10/6/62	1601	"	0	
	Harlem	12/6/62	1537	"	0	
	Rinconada	15/6/62	1601	"	0	
	Dulce	17/6/62	1601	"	0	
	Petit	19/6/62	1501	"	0	
	Otowi	22/6/62	1601	"	0	
	Bighorn	27/6/62	1519	"	0	
	Bluestone	30/6/62	1521	"	0	
	Starfish	9/7/62	0900	JI*	0	400.09 KM
	Sunset	10/7/62	1633	CI**	0	
	Familco	11/7/62	1537	"	0	
	Androscoffin	2/10/62	1618	JI*	0	
	Bumping	6/10/62	1603	"	0	
	Chama	18/10/62	1601	"	0	
	Checkmate	20/10/62	0830	"	0	
	Bluegill	26/10/62	1000	"	0	
	Calamity	27/10/62	1546	"	0	
	Housetonic	30/10/62	1602	"	0	
	Kingfish	1/11/62	1210	"	0	
	Tightrope	4/11/62	0730	"	0	

- \* Johnston Island
- \*\* Christmas Island
- + No meteorological data available for  
Dominic

## DEFINITION OF TERMS

1. Dew Point is that temperature to which moist air must be cooled in order that it be water-saturated at the same initial pressure.
2. Relative Humidity of moist air is the ratio of the actual water vapor pressure to the saturated vapor pressure at the same temperature. (Saturated vapor pressure is the maximum possible vapor pressure of moist air at a given temperature.)
3. Vapor pressure is the pressure exerted by vapor in moist air and is equal to the total air pressure minus the dry air pressure.
4. Vapor density is the density of water (excluding dry air) in moist air.
5. Dry air density is the density of air (excluding water) in moist air.
6. Wet air density is the sum of vapor density and dry air density and is thus the density of moist air.

TABLE 2  
Columnar Air Mass as a Function  
of Geometric Altitude  
For a Tropical Model Atmosphere

(1)	(2)	(3)	(4)	(1)	(2)	(3)
Geometric Altitude (km)	Model Air Density (g/l)	Vertical Columnar Air Mass (g/cm <sup>2</sup> )	Remaining Columnar Air Mass (g/cm <sup>2</sup> )	Geometric Altitude (km)	Model Air Density (g/l)	Vertical Columnar Air Mass (g/cm <sup>2</sup> )
0	1.16655	0.0	1.03790+3*	40	4.18106-3	1.03474+3
1	1.05443	1.11471+2	9.26428+2	41	3.63279	1.03513
2	9.68876-1	2.13262	8.24837	42	3.16106	1.03546
3	8.79708	3.05213	7.32686	43	2.75339	1.03576
4	7.99068	3.88687	6.40212	44	2.40137	1.03602
5	7.19873	4.64372	5.73527	45	2.09671	1.03624
6	6.50142	5.32813	5.09086	46	1.83298	1.03644
7	5.89483	5.94528	4.43361	47	1.60416	1.03661
8	5.25844	6.50051	3.87848	48	1.41124	1.03676
9	4.70827	6.99834	3.38065	49	1.24627	1.03689
10	4.20069	7.44341	2.93558	50	1.10073	1.03701
11	3.73951	7.84034	2.53865	51	9.72185-4	1.03711
12	3.3157	8.19229	2.18870	52	8.61481	1.03721
13	2.92928	8.50414	1.87485	53	7.65886	1.03729
14	2.57790	8.77913	1.59986	54	6.80308	1.03736
15	2.25967	9.02066	1.35833	55	6.03762	1.03742
16	1.97234	9.23193	1.14706	56	5.35416	1.03748
17	1.67966	9.41393	9.65061+1	57	4.74377	1.03753
18	1.38041	9.56636	8.12627	58	4.19912	1.03758
19	1.14482	9.69235	6.86639	59	3.71353	1.03761
20	9.51540-2	9.79687	5.82119	60	3.28711	1.03765
21	7.93821	9.88390	4.95089	61	2.91711	1.03768
22	6.64484	9.95662	4.22365	62	2.58481	1.03771
23	5.61892	1.00178+3	3.61192	63	2.28621	1.03773
24	4.76296	1.00696	3.09402	64	2.01883	1.03775
25	4.04495	1.01135	2.65460	65	1.77976	1.03777
26	3.44184	1.01509	2.28110	66	1.56592	1.03779
27	2.93175	1.01827	1.96314	67	1.37534	1.03780
28	2.50193	1.02098	1.69202	68	1.20976	1.03782
29	2.13835	1.02329	1.46048	69	1.05483	1.03783
30	1.83099	1.02527	1.26843	70	9.21004-5	1.03784
31	1.56940	1.02697	1.09277	71	8.08445	1.03785
32	1.34739	1.02843	9.47211+0	72	6.97712	1.03789
33	1.15839	1.02968	8.22160	73	6.05184	1.03786
34	9.97425-3	1.03075	7.14970	74	5.23773	1.03787
35	8.99978	1.03168	6.21869	75	4.52286	1.03787
36	7.42960	1.03248	5.41886	76	3.89581	1.03788
37	6.41909	1.03317	4.72785	77	3.34702	1.03788
38	5.93687	1.03377	4.13008	78	2.85869	1.03788
39	4.81718	1.03429	3.61226	79	2.45048	1.03788

U.S. 2  
 Mass as a Function  
 metric Altitude  
 Standard Model Atmosphere

(3)	(4)	(1)	(2)	(3)	(4)
Vertical Columnar Air Mass (g/cm <sup>2</sup> )	Remaining Columnar Air Mass (g/cm <sup>2</sup> )	Geometric Altitude (km)	Model Air Density (g/l)	Vertical Columnar Air Mass (g/cm <sup>2</sup> )	Remaining Columnar Air Mass (g/cm <sup>2</sup> )
1.03474+3	3.16310+0	80	2.08818-5	1.03789+3	1.17226-2
1.03513	2.77305	81	1.74940	1.03789	9.80879-3
1.03546	2.43350	82	1.46075	1.03789	8.20805
1.03576	2.13685	83	1.21973	1.03789	6.87143
1.03608	1.88131	84	1.01847	1.03789	5.75535
1.03634	1.65875	85	8.50423-6	1.03789	4.82343
1.03654	1.46076	86	7.10235	1.03789	4.04520
1.03661	1.28896	87	5.93156	1.03790	3.39526
1.03676	1.13840	88	4.95377	1.03790	2.85246
1.03689	1.00969	89	4.13793	1.03790	2.39910
1.03711	8.88493-1	90	3.45646	1.03790**	2.02040
1.03711	7.84980				
1.03721	6.93408				
1.03729	6.12133				
1.03736	5.39908				
1.03742	4.75781				
1.03748	4.18890				
1.03753	3.68462				
1.03758	3.23803				
1.03761	2.84290				
1.03765	2.49330				
1.03768	2.18346				
1.03771	1.90869				
1.03773	1.66545				
1.03775	1.45047				
1.03777	1.26080				
1.03779	1.09374				
1.03780	9.46888-2				
1.03782	8.18013				
1.03783	7.05152				
1.03784	6.06512				
1.03785	5.20475				
1.03785	4.45590				
1.03786	3.80554				
1.03787	3.24205				
1.03787	2.75489				
1.03788	2.33474				
1.03788	1.97389				
1.03788	1.66364				
1.03788	1.39871				

Note: +2, -1 etc. denote powers of 10. Succeeding entries have same exponent until a new exponent is noted.

\*1037.898876000 \*\*1037.896855597

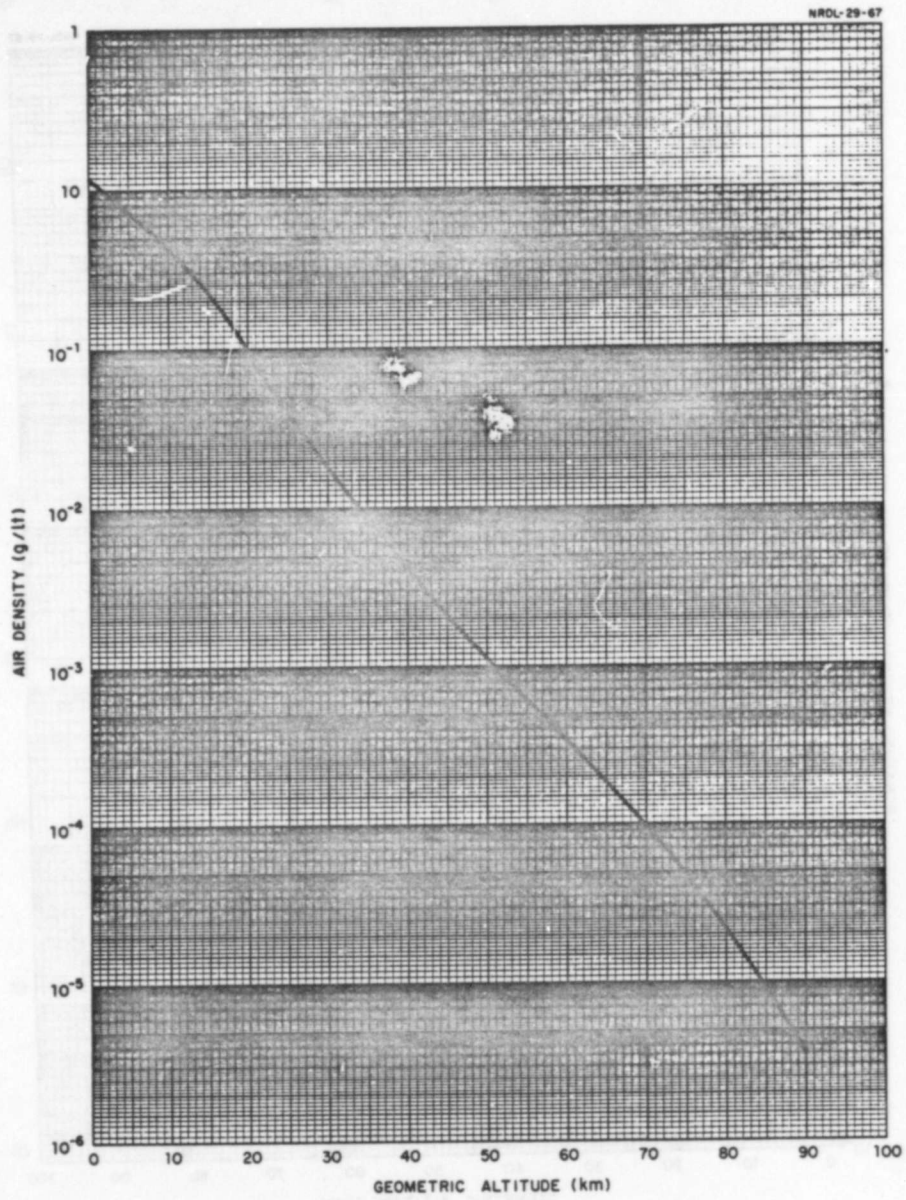


Fig. 1 Air Density vs Geometric Altitude

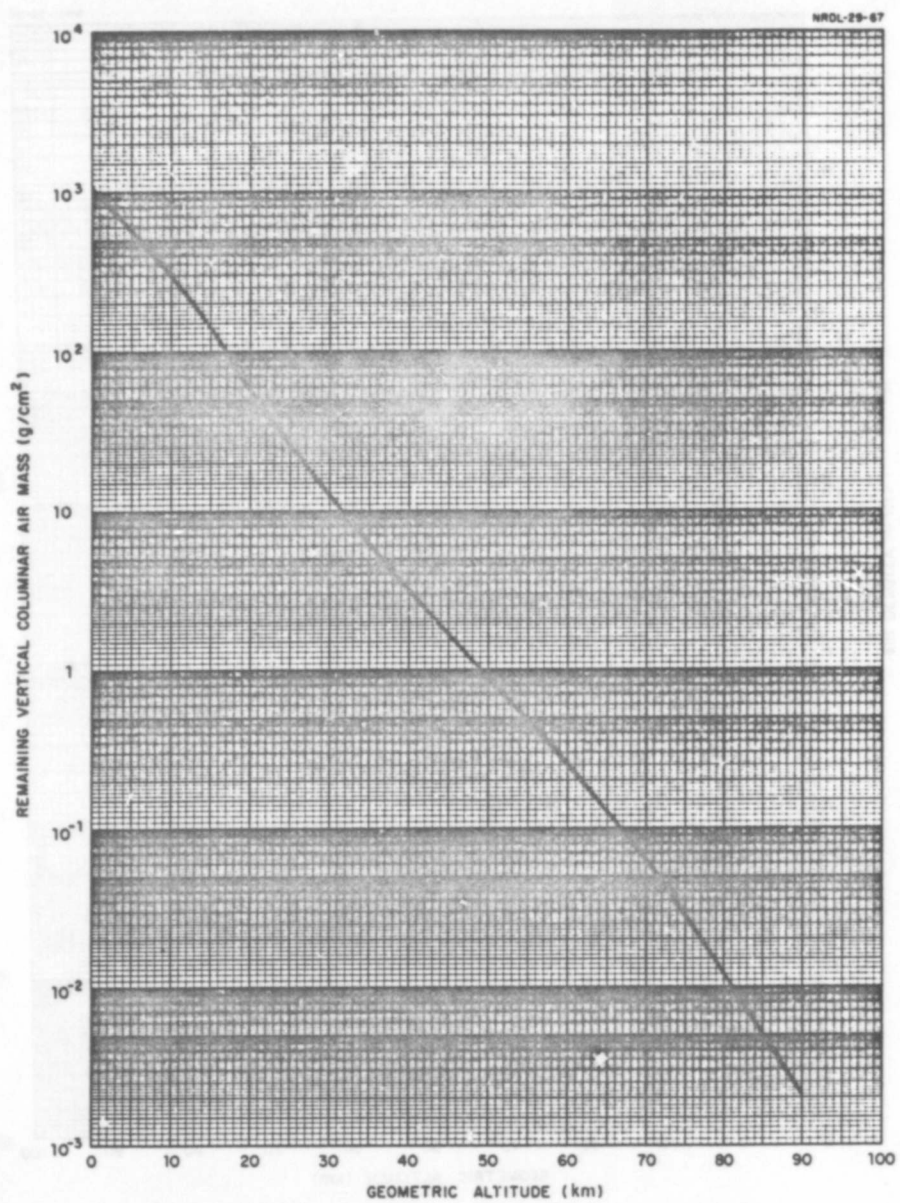


Fig. 2 Remaining Vertical Columnar Air Mass vs Altitude

<p>Naval Radiological Defense Laboratory USNRDL-TR-67-20 AIR DENSITIES FOR ATMOSPHERIC NUCLEAR TESTS AND COLUMNAR AIR MASS DATA, by T. A. Alexander 2 February 1967 32 p. tables illus. UNCLASSIFIED</p> <p>A tabulation is presented of ground-zero and burst altitudes and associated dry-air and water-vapor density data for U. S. atmospheric nuclear tests. Also presented are density data for a tropical (15°N) atmosphere up to 90 kilometers. A method for computing columnar air mass between two points at different altitudes for the Pacific Proving Ground area is presented. This method can be (over)</p>	<p>1. Air mass analysis 2. Nuclear explosions 3. Air - density</p> <p>I. Alexander, T. A. II. Title III. SF 011 05 12</p>	<p>1. Air mass analysis 2. Nuclear explosions 3. Air - density</p> <p>I. Alexander, T. A. II. Title III. SF 011 05 12</p> <p>UNCLASSIFIED</p>	<p>1. Air mass analysis 2. Nuclear explosions 3. Air - density</p> <p>I. Alexander, T. A. II. Title III. SF 011 05 12</p> <p>UNCLASSIFIED</p>
<p>extended to any set of spatial points within the wide limits provided and can be used for other atmospheres. Where possible, information presented is based on original data.</p>	<p>extended to any set of spatial points within the wide limits provided and can be used for other atmospheres. Where possible, information presented is based on original data.</p>	<p>extended to any set of spatial points within the wide limits provided and can be used for other atmospheres. Where possible, information presented is based on original data.</p>	<p>extended to any set of spatial points within the wide limits provided and can be used for other atmospheres. Where possible, information presented is based on original data.</p>

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13. ABSTRACT

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