An Investigation of Instantaneous Plume Rise
From Rocket Exhaust

THESIS

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AFIT/GEE/ENC/96D-01

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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Masters of Science in Engineering and Environmental Management

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PREFACE

This thesis studied the phenomenon of instantaneous buoyant plume rise associated with rocket exhaust. Modifications were made to the Rocket Exhaust Effluent Diffusion Model (REEDM) FORTRAN program and the results compared to the original program. The modifications used more accurate calculations of stability and buoyancy and well as changing the behavior associated with the entrainment coefficient.

This area of research was chosen because of Capt Sand's interest in space launches and his previous knowledge of fluid mechanics. Further knowledge of realistic effects these launches have on the environment was desired, so that accurate predictions of human health risks could be determined. This research may contribute to an improvement of the current REEDM model and help provide launch safety officers with improved insight into the effect the entrainment coefficient has on the human health risk predictions. It may also point to areas for future improvement of the model.

Acknowledgments

Most of all, I want to thank God for giving me the many opportunities and gifts that I have experienced, and allowing me to finish this thesis and this Masters degree. The old adage came true: "With God, anything (including this thesis) is possible."

Next I thank my parents for their continuing support and prayers.

I am deeply grateful and indebted to my Thesis Committee Chairman and Advisor, Dr. Dennis Quinn. He has helped me gain the knowledge and understanding necessary to complete this thesis.

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Lastly, I thank Pat, Pam, Kathy, Gwen and the other AFIT librarians, who have cheerfully endured my many requests for literature. Their friendship and help have brightened many a bad day. They are certainly much appreciated by many AFIT students.

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ABSTRACT

Rocket launches at Vandenburg Air Force Base and Cape Canaveral Air Station produce exhaust clouds containing several toxic by-products, including HCl and Al_2O_3. These clouds rise to atmospheric stabilization heights, and then start dispersing and diffusing through the air. Upon reaching the ground, concentration levels of the toxins may present a human health risk. To predict these risks and concentration levels, range officials use a computer program titled the Rocket Effluent Exhaust Diffusion Model (REEDM). The version currently in use has been shown to underpredict the stabilization height of the exhaust cloud. This thesis examines the theory and algorithms used in REEDM that govern buoyant cloud rise. Further, modifications that improved the physics of the algorithms and changed an entrainment assumption were implemented and tested in REEDM.

Stabilization heights predicted by REEDM using these modifications increased and in some cases closely agreed with observed heights. However, in some circumstances, predicted heights exceeded those observed.

I. Introduction

Overview

When launching large space vehicles, such as the Titan IV rocket, commanders at Vandenburg AFB and the launch facility at Cape Canaveral Air Station must assess the health and environmental risks associated with toxic elements of the exhaust cloud. Such elements include hydrochloric acid (HCl), carbon monoxide (CO), nitrogen oxides (NO and NO_2) and aluminum perchlorate (Al_2O_3) (1: 532). Of primary concern is the ground level concentration of HCl (2: 64, 3).

To help commanders decide whether or not to launch, the safety personnel at both locations employ computer modeling programs that predict the location and concentration of toxic exhaust by-products. The area where the ground-level concentration of these toxins is predicted to be at such a level as to present a human health risk is termed the toxic hazard corridor. The toxic hazard corridor is that ground area predicted to experience concentrations of exhaust elements possibly harmful to human health. Figure 1-1 shows an example of a toxic hazard corridor predicted for HCl for a particular Titan IV launch. If this hazard corridor is predicted to fall over populated areas, launch commanders must hold the launch, which results in great financial and operational costs to the Air Force (4: 3). Compounding this problem is the acceptance by the Air Force of guidance lowering the allowed maximum concentration levels, typically described in terms of exposure limits. These new levels increase the probability that the launch must be postponed or even canceled due to the predicted concentration levels exceeding the guidance levels (5:5-6).

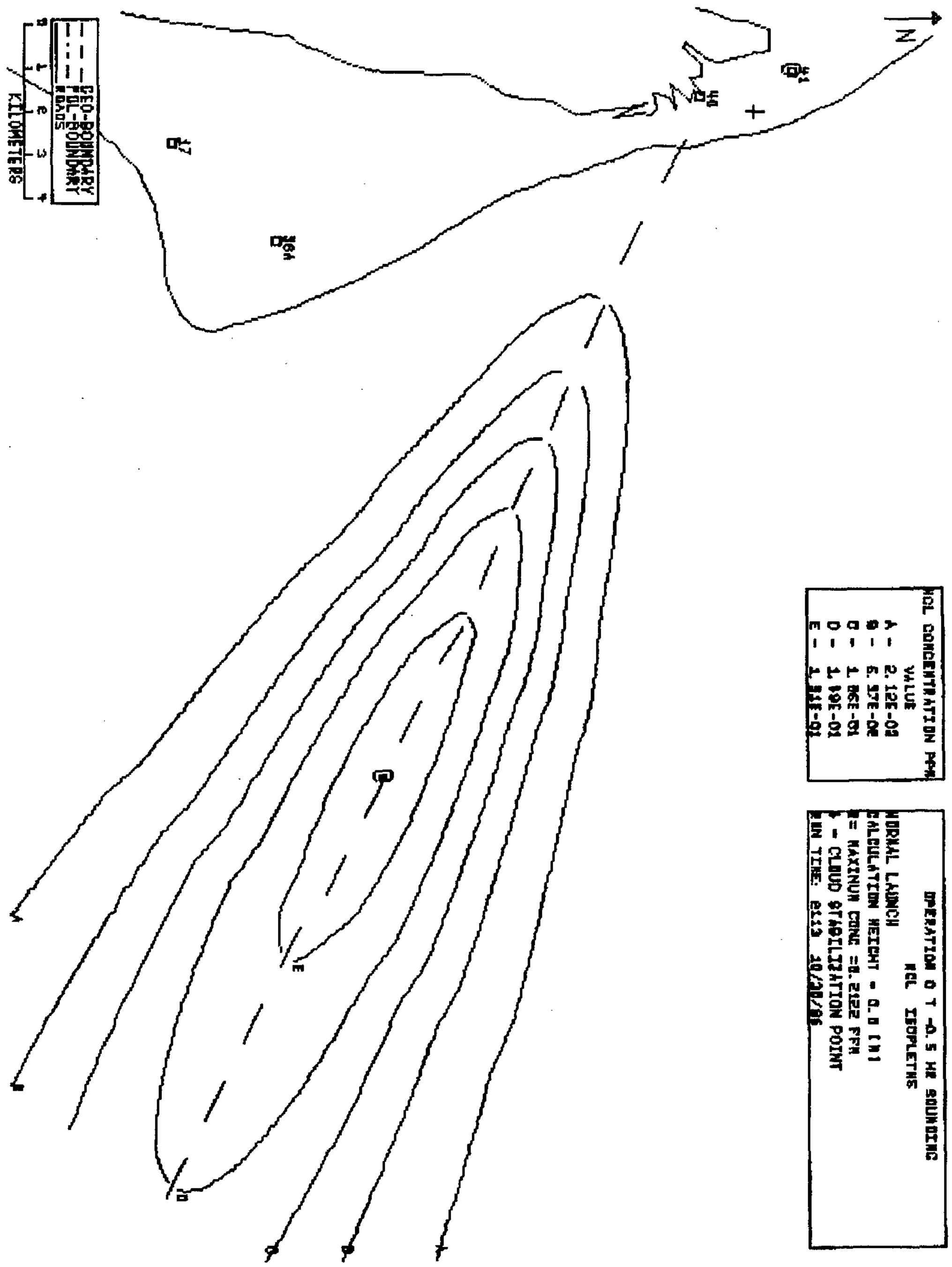

Figure 1-1: Example of a Toxic Hazard Corridor for HCl

Two atmospheric dispersion models are currently employed at the launch ranges. Vandenburg AFB uses a model called the Launch Area Toxic Risk Analysis Program(LATRA). This model incorporates and was developed out of a previous computer model entitled the Rocket Exhaust Effluent Diffusion Model (REEDM). LATRA is a probabilistic model using Monte Carlo simulations of the REEDM code to calculate risk profiles and casualty expectations (**6**: 1-4).

One of the main problems with REEDM has been that the model has never been fully validated. Since it has never been validated, conservative launch criteria is required to be used in the model. Because of these criteria, predicted ground level concentrations of toxic hazards may be higher than what actually may occur in reality (**8**: 1-1). A principle factor behind these predicted high concentrations is an inaccurate prediction of the stabilization height of the toxic ground cloud through the low-level atmosphere. Stabilization height is defined as the height where the ground cloud reaches equilibrium with its surroundings and stops rising. The intent of this thesis is to examine the physics and calculations used in REEDM for predicting instantaneous cloud rise and modifying the model with more accurate, realistic equations.

Problem Description

The rise and eventual stabilization of the toxic ground cloud resulting from the rocket exhaust is inherently linked to ground level concentrations of toxic substances. After reaching the stabilization height, the cloud disperses and spreads due to the prevailing winds, diluting the concentration of the toxins. Eventually part of the cloud reaches the ground, where the concentration levels may or may not present a health risk. The higher the cloud rises, the more the effluent is dispersed, reducing the ground-level concentration of the toxins. Additionally, if all or most of the cloud penetrates an atmospheric inversion layer, the toxins will in effect be contained above the inversion and pose little or no threat to ground-level populations.

Through the use of cloud imagery techniques, data on heights of exhaust clouds have been gathered. Comparing these data from actual launches to the heights predicted by REEDM shows a disturbing tendency for REEDM to underpredict the cloud heights. For example, in observations with four Titan III launches, REEDM underestimated the cloud heights by an average of 40% with a range of 21% to 55% (9:20). Similar results were found with Titan IV launches (12). This inaccuracy can give inappropriate and much higher predictions of ground level concentration (as much as 1100% with a 55% error), thereby giving cause a launch hold when no toxic hazard would result from the launch.

Scope of Study

The goal of this thesis is to reduce the error involved in the prediction of instantaneous cloud stabilization heights resulting from the exhaust of large rocket launches. This will involve understanding the assumptions and physical equations used in REEDM's plume rise algorithm along with the classical theory of buoyant plume rise. Supported by the literature search, changes to the code will be presented and implemented. Actual measured cloud stabilization heights will be compared to heights predicted by the computer model in its original form and by the model when the changes are included.

Three versions of the REEDM computer program will be used in this analysis, the original REEDM code and two modified versions. The modified versions will incorporate changes suggested by the literature and by contractors currently working with the REEDM code (15). The changes will involve the buoyancy calculations, the stability calculations and the entrainment calculations. The stabilization heights predicted by these modified REEDM versions will be compared to the original version and to observed stabilization heights. The cloud rise parameters of height and velocity will also be analyzed with respect to the time from launch to further compare and contrast the three models.

Cloud rise data from rocket launches from Cape Canaveral Air Station and Vandenburg AFB will be compared with model predictions. The Titan IV rocket is the vehicle to be used in the study since this is the only space vehicle from which cloud stabilization heights have been measured. The rawinsonde meteorological data associated with the observed launches are used in this study. In this thesis, the rise and stabilization of the toxic ground cloud is examined. Transport, diffusion and deposition of the cloud toxins are not examined. The predicted ground-level concentrations from these launches is not considered.

Only three subroutines out of many in the program are modified in this thesis. The affected subroutines are those involving calculations for the buoyancy of the cloud, the atmospheric stability and the rise of the instantaneous ground cloud rise calculations. Not affected are subroutines relating to the transport and diffusion mechanism and the chemical reactions occurring within the exhaust cloud.

Thesis Statement

The REEDM computer program used to predict toxic hazard corridors from rocket and space vehicle launches has not been validated. Observations of stabilization heights of the instantaneous ground clouds from launches of the Titan IV rocket have indicated that the current model underpredicts these heights, resulting in large toxic hazard corridors. The hypothesis of this thesis is the changes to the calculations of REEDM affecting the rise of the instantaneous exhaust cloud will more closely match measured cloud stabilization heights.

Thesis Structure

This thesis is organized into five chapters. The first chapters introduces and provides an overview of the problem of the study. The second chapter is the Background and Literature Review. This chapter presents the theory involved in buoyant instantaneous sources as described in the literature and gives a detailed description of the calculations involved in the REEDM computer program. The third chapter is the Approach which describes how this thesis study was carried out. Presented here are the changes implemented in the code. The fourth chapter is entitled Results. Here the results of the changes implemented are presented and discussed. The fifth chapter is the Conclusions, where the results are summarized, recommendations made, and possible follow-on research is suggested.

II. Background

Chapter Overview

In this chapter, background information related to this thesis study is presented. Included is the history of the development of the REEDM program, followed by theory central to atmospheric modeling and the rising of buoyant, instantaneous plumes. (The toxic ground cloud generated by the rocket's exhaust is modeled as a spherical, buoyant, instantaneous plume.) The formula predicting the final stabilization height of the ground cloud is then derived.

History of REEDM

Atmospheric diffusion models to predict the behavior of rocket exhaust clouds were first developed during the late 1960's by the Marshall Space Flight Center of the National Aeronautics and Space Administration (NASA). These models were needed to help NASA assess any environmental effects resulting from rocket exhaust products. Subsequently, multi-layer atmospheric dispersion models for these applications were developed and implemented (11: 1). Work on these models continued throughout the 1970's. Eventually the Rocket Exhaust Effluent Diffusion Model (REEDM) computer code was developed in 1982 out of a contract awarded to the H. E. Cramer Company, Inc. after a NASA program identified the need for "real-time dispersion prediction capability" (11:1). Since REEDM's initial conception, changes and revisions have occurred such that this program has undergone seven major modifications. The current program is title REEDM 7.07. Additional contracts awarded to ACTA Inc. expanded and improved the capabilities of REEDM.

The three main sections of the REEDM computer program include the meteorological model, the cloud rise model, and the multilayer diffusion model. The latter model includes concentration, dosage and precipitation deposition algorithms. Input information includes launch vehicle data, atmospheric meteorological data (in the form of rawinsonde files), and user-supplied information (11: 6, 2: 22). This thesis study focuses on the algorithms included in the subroutine which calculates cloud rise. This portion of the program calculates the stabilization height of the instantaneous exhaust cloud, and several parameters of the cloud such as the radius, velocity, buoyancy, time from launch, and position from the launch pad.

REEDM Development

With the passing of the National Environmental Protection Act and the Clean Air Act and its subsequent amendments the National Aeronautics and Space Administration (NASA) had to better understand the environmental effects of rocket launches. The expected increase in space vehicle launches, especially those planned with the space shuttle, increased the urgency for this knowledge. To comply, environmental assessments of aerospace operations were conducted in the early to mid-1970s. These assessments included efforts to model the transport of rocket exhaust which includes the various chemical reactions involved and the turbulent effects experienced. Of particular concern was the down-wind ground-level concentrations of HCl and Al_2O_3 (2: 1-4). These modeling efforts resulted in the NASA/Marshall Space Flight Center (MSFC) Rocket Exhaust Effluent Diffusion (REED) computer program. Subsequent contract work resulted in the REEDM code.

Meteorological Model

The meteorological model uses rawinsonde (also referred to as radiosonde) data as inputs to model the local atmospheric layers. These data include wind speed, wind direction, relative humidity, dew point, and other meteorological measurements. The rawinsonde data files used in this thesis can be found in Appendix 2.

The meteorological model divides the atmosphere into several multiple layers, each typically about 1000 feet in depth. These layers are assumed to be homogeneous, with the meteorological parameters being constant in the layer. These layers are usually grouped into two main regions, the lower surface transport layer and the high altitude layer. An inversion layer, if one exists, separates the two regions. Cloud rise calculations are performed by the program within each of these homogeneous meteorological layers, independent of the other layers.

Theory of Cloud Rise

REEDM's cloud rise algorithm uses fundamental conservation equations and thermodynamic relationships. The theory for instantaneous sources was developed in 1956 by Morton, Taylor, and Turner (19), as well as with individual works by Turner (20), Briggs (18), and Gebhart et.al. (21). The conservation equations involved in REEDM's plume rise algorithm are the conservation of mass (continuity equation), momentum, and buoyancy. To understand these conservation equations, some discussion on atmospheric parcel theory is in order.

Air and gas movement in the troposphere can be thought of as "parcels" that travel up or down, depending on their relationship with the ambient atmospheric surroundings. This can be represented by the Archimedean principle stating that the net vertical force on the parcel equals the difference in mass between the parcel (M_p) and the air displaced by this parcel (M) multiplied by the gravitational constant of acceleration, g (9.807 m/s²):

$$F_B = g\,(M-M_p) \tag{2-1}$$

Equating this to Newton's second law gives the acceleration of the parcel:

$$F_B = M_p\frac{d^2z}{dt^2} = g\,(M-M_p) \tag{2-2}$$

Since density (ρ) is mass divided by volume, dividing (2-2) by the volume of the parcel and rearranging gives the following equation (22:70, 23: C-9):

$$\frac{d^2z}{dt^2} = b \tag{2-3}$$

where

$$b = g\left(\frac{\rho-\rho_p}{\rho_p}\right) \tag{2-4}$$

is the buoyancy acceleration (22: 70). Therefore, the parcel will accelerate upward if the density of the parcel is smaller than the density of the surrounding air. Next, two assumptions are made to simplify the derivation of equations pertaining to b:

(1) the pressure of the parcel is identical to the surrounding atmosphere at any height z, and

(2) the parcel moves isentropically, so that no heat gain or loss occurs with its surroundings and therefore has constant potential temperature ($\partial\theta/\partial z = 0$).

Applying the ideal gas law to the above equation, (2-3) can be expressed in terms of temperature (22: 69-70, 23: C-10) :

$$\frac{d^2z}{dt^2} = g\left(\frac{T_p-T}{T}\right) = g\left(\frac{\theta_p-\theta}{\theta}\right) \tag{2-5}$$

Here, θ is used to describe the atmospheric parameter of potential temperature.

Potential temperature is a calculated atmospheric parameter that takes into account pressure changes with temperature as an air parcel rises through the atmosphere. More accurately, potential temperature is the temperature a parcel of dry air at a certain pressure p, would exhibit if brought adiabatically to some reference pressure, p_0 (16:457). Mathematically, potential temperature is defined by Poisson's equation (22: 49) as

$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_p} \tag{2-6}$$

where:

p is the pressure at the altitude of concern

p_0 equals 1000 mbars

R/c_p = .286 in air [17: 329].

The preceding discussion has introduced the concepts of buoyancy, acceleration, and potential temperature in relation to atmospheric parcels of air. These concepts and equations will be used in the following sections to derive expressions for stability and the cloud stabilization height involved with hot, buoyant gases such as rocket exhaust.

Stability Parameter

The following describes the derivation of the stability parameter, s, used in the REEDM computer program. If z_0 is taken to be the initial height of a parcel and θ_0 is the potential temperature θ_p of the parcel at this height, the difference between the parcel's potential temperature and that of its surroundings can be expanded using Taylor's theorem (22: 71):

$$\theta - \theta_0 = \frac{\partial \theta}{\partial z}(z - z_0) + \left(\frac{\partial^2 \theta}{\partial z^2}\right)\frac{(z - z_0)^2}{2!} + . \quad . \quad . \tag{2-7}$$

Therefore for small intervals of $z - z_0$, 2-5 can be written as:

$$\frac{d^2(z - z_0)}{dt^2} = -g\left(\frac{\theta - \theta_0}{\theta}\right) \cong -\frac{g}{\theta}\left(\frac{\partial \theta}{\partial z}\right)(z - z_0) \tag{2-8}$$

Substituting η for $z - z_0$, the linear homogeneous second order differential equation results:

$$\frac{d^2\eta}{dt^2} + \left(\frac{g}{\theta}\frac{\partial \theta}{\partial z}\right)\eta = 0 \tag{2-9}$$

This has a solution of the form $\eta = Ae^{\lambda t}$, with a characteristic equation of

$$\lambda^2 + \left(\frac{g}{\theta}\frac{\partial \theta}{\partial z}\right) = 0 \tag{2-10}$$

Solving for λ gives:

$$\lambda = \pm\left[\left(\frac{g}{\theta}\frac{\partial \theta}{\partial z}\right)_0\right]^{.5} = \pm\omega \quad \text{for } \partial\theta/\partial z < 0 \tag{2-11}$$

$$\lambda = \pm i\left[\left(\frac{g}{\theta}\frac{\partial \theta}{\partial z}\right)_0\right]^{.5} = \pm i\omega \text{ for } \partial\theta/\partial z > 0 \quad (i = \sqrt{-1}) \tag{2-12}$$

Equation (2-11) relates to an unstable atmospheres where the parcel wants to continue its upward motion and equation (2-12) relates to a stable atmosphere where the parcel wants to stop rising and remain at its current height. The term ω is defined as the Brunt-Väisälä frequency, depicting the frequency of oscillation the parcel experiences about the stabilization height (22: 71, 23: C-12). The square of this frequency is termed the stability parameter, s. (In Vers7.07 of REEDM, this term is expressed as $\frac{g}{T}\frac{\partial \theta}{\partial z}$ instead of the correct form $\frac{g}{\theta}\frac{\partial\theta}{\partial z}$. This is corrected in Chapter III.) Now, using equations (2-5) and (2-7) the buoyancy force in equation (2-2) can be expressed as:

$$F_B = M_p \frac{d^2z}{dt^2} = -M_p \frac{g}{\theta}\frac{\partial\theta}{\partial z}(z - z_0) \tag{2-13}$$

Cloud Height Solution

The REEDM instantaneous cloud rise equation is derived using Newton's second law, which in our case states that the force experienced by the instantaneous cloud is equal to the time derivative of the vertical momentum (19, 23: C-21)

$$F_B = \frac{d(M_c w)}{dt} \tag{2-14}$$

where

$w = \frac{dz}{dt}$, the vertical velocity and

M_c is the mass of the cloud.

In equation (2-14), $M_c = \frac{4}{3}\pi r^3 \rho_c$, where r is the radius of the spherical cloud, while in equation (2-1), $F_B = g(M - M_c) = g\left(\frac{4}{3}\pi r^3 \rho - \frac{4}{3}\pi r^3 \rho_c\right)$. Consequently, equation (2-14) may be rewritten as:

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho_c w\right) = \frac{4}{3}\pi r^3 g(\rho - \rho_c) \tag{2-15}$$

or, dividing out $\frac{4}{3}\pi$,

$$\frac{d}{dt}\left(r^3 w \rho_c\right) = r^3 g(\rho - \rho_c) \tag{2-16}$$

where r is the radius of the spherical cloud. This equation is the conservation of momentum equation presented in Morton, Taylor, and Turner (19: 15, 23: C-22). Dividing both sides of (2-16) by ρ_c gives the following equation:

$$\frac{1}{\rho_c}\frac{d}{dt}\left(\rho_c r^3 w\right) = r^3\left(\frac{\rho - \rho_c}{\rho_c}\right) \tag{2-17}$$

Employing the product rule on the left hand side of (2-16) yields:

$$r^3 w \frac{1}{\rho_c}\frac{d}{dt}\rho_c + \frac{d}{dt}\left(rw^3\right) = r^3 g\left(\frac{\rho - \rho_c}{\rho_c}\right) \tag{2-18}$$

Consistent with the nondimensionalization of Morton, Taylor, and Turner's equation (18)ii, the term $r^3 w \frac{1}{\rho_c}\frac{d}{dt}\rho_c$ is considered second order and is negligible (19: 16), which yields the following equation:

$$\frac{d}{dt}\left(rw^3\right) = r^3 g\left(\frac{\rho - \rho_c}{\rho_c}\right) \tag{2-19}$$

This is the basic equation used in REEDM.

Equation (2-19) must now be related to stability and potential temperature in order to be solved for z. Using equations (2-2) and (2-5) results in:

$$F_B = M_c g\left(\frac{\theta_c - \theta}{\theta}\right) = M_c g\left(\theta_c \theta^{-1} - 1\right)$$

Consequently,

$$\frac{dF_B}{dz} = -M_c g \theta_c \theta^{-2}\frac{d\theta}{dz} = -M_c g\frac{\theta_c}{\theta^2}\frac{d\theta}{dz} \cong -M_c \frac{g}{\theta}\frac{d\theta}{dz} \tag{2-20}$$

Here, the mass of the cloud is assumed constant and the rise is isentropic. Next, applying the chain rule and substituting the volume and density relationship for mass gives:

$$\frac{dF_B}{dt}=\frac{dF_B}{dz}\frac{dz}{dt}=-\frac{4}{3}\pi r^3\rho_c\frac{g}{\theta}\frac{d\theta}{dz}w\approx-\frac{4}{3}\pi r^3\rho_c sw \tag{2-21}$$

where $s=\frac{g}{\theta}\frac{d\theta}{dz}$. Because $F_B=\frac{4}{3}\pi r^3 g(\rho-\rho_c)$ (see equations (2-1) and (2-14)), equation (2-21) can be written as:

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 g(\rho-\rho_c)\right)=-\frac{4}{3}\pi r^3\rho_c sw \tag{2-22}$$

The left hand side of (2-22) can be rewritten as $\frac{d}{dt}\left[\rho_c\frac{4}{3}\pi r^3 g\left(\frac{\rho-\rho_c}{\rho_c}\right)\right]$ which equals

$$\rho_c\frac{d}{dt}\left[\frac{4}{3}\pi r^3 g\left(\frac{\rho-\rho_c}{\rho}\right)\right]+\frac{4}{3}\pi r^3 g\left(\frac{\rho-\rho_c}{\rho_c}\right)\frac{d}{dt}\rho_c.$$

Again, consistent with Morton, Taylor, and Turner, the term involving $\frac{d}{dt}\rho_c$ is assumed negligible, so equation (2-22) becomes

$$\rho_c\frac{d}{dt}\left[\frac{4}{3}\pi r^3 g\left(\frac{\rho-\rho_c}{\rho_c}\right)\right]=-\frac{4}{3}\pi r^3\rho_c sw \tag{2-23}$$

Dividing by $\frac{4}{3}\pi\rho_c$, (2-23) becomes:

$$\frac{d}{dt}\left(r^3 g\frac{\rho-\rho_c}{\rho_c}\right)=-r^3 sw \tag{2-24}$$

Using $b=g\left(\frac{\rho-\rho_c}{\rho_c}\right)$ in equations (2-19) and (2-24) respectively yields

$$\frac{d}{dt}\left(wr^3\right) = r^3 b \tag{2-25}$$

and

$$\frac{d}{dt}\left(r^3 b\right) = -r^3 sw \tag{2-26}$$

An alternate derivation of equation (2-26) is shown in Appendix F. Differentiating (2-25) with respect to t yields:

$$\frac{d^2}{dt^2}\left(wr^3\right) = \frac{d}{dt}\left(r^3 b\right) \tag{2-27}$$

Substituting (2-26) into (2-27) yields

$$\frac{d^2}{dt^2}\left(wr^3\right) = -swr^3 \tag{2-28}$$

The authors of REEDM make an assumption that b can be approximated by:

$b = g\left(\frac{\rho - \rho_c}{\rho}\right)$ instead of the more accurate form $b = g\left(\frac{\rho - \rho_c}{\rho_c}\right)$. An approach to correct this is presented in the Chapter III.

REEDM calculates the cloud stabilization height by solving the conservation of momentum equation in the form given in equation 2-19:

$$\frac{d^2(wr^3)}{dt^2} = -swr^3 \tag{2-29}$$

This is a second order differential equation that has the solution:

$$wr^3 = \begin{cases} F_m \cos\left(\sqrt{s}t\right) + \frac{F_0}{\sqrt{s}}\sin\left(\sqrt{s}t\right) & (s > 0) \\ F_m \cosh\left(\sqrt{-s}t\right) + \frac{F_0}{\sqrt{-s}}\sinh\left(\sqrt{-s}t\right) & (s < 0) \end{cases} \tag{2-30}$$

where the initial conditions, F_m and F_0 are (23: C-23; 11: 17):

$$F_m = w_0 r_0^3$$

$$F_0 = b r_0^3 \approx \frac{3gQ_0}{4C_p \pi \rho T} \quad \text{(buoyancy flux)}$$

Q_0 = the initial heat released to create the buoyant cloud

The solution and initial buoyancy equation is similar in form to that presented by Briggs (17: 341, 334).

Now, the growth of the plume as it rises must be accounted for. The cloud grows as it rises due to entrainment of outside air. This entrainment is caused by the turbulent nature of the cloud. The relationship between entrainment and cloud growth has been developed by Taylor and states that the cloud grows linear with height at some constant rate (20: 3-4):

$$r = r_0 + \gamma z \tag{2-31}$$

where γ is an empirical entrainment coefficient and r_0 is the initial cloud radius (72 m in REEDM). This follows from equation 16(i) of Morton, Taylor, and Turner which is $4\pi r^2 \frac{dr}{dt} = 4\pi r^2 \gamma \frac{dz}{dt}$. Dividing by $4\pi r^2$ yields $\frac{dr}{dt} = \gamma \frac{dz}{dt}$, which when integrated results in equation (2-31). The authors of REEDM have used a default value of .64 for γ. No clear reason why this value is used is known.

Substituting equation (2-31) into equation (2-30), using dz/dt = w and rearranging terms gives:

$$\frac{dz}{dt} = \frac{F_m}{(r_0 + \gamma z)^3} \cos\left(\sqrt{s}t\right) + \frac{F_0}{\sqrt{s}(r_0 + \gamma z)^3} \sin\left(\sqrt{s}t\right) \quad (s > 0) \tag{2-32}$$

Integrating this equation from the initial time, t_0 to the cloud's final time, t_f results in the final solution used in the REEDM code (11: 18):

$$
z = \begin{cases} \left[\dfrac{4F_m}{\gamma^3 \sqrt{s}} \sin\left(\sqrt{s}t\right) + \dfrac{4F_0}{\gamma^3 s}\left(1 - \cos(\sqrt{s}t\right) + \left(\dfrac{r_0}{\gamma}\right)^4 \right]^{1/4} - \dfrac{r_0}{\gamma} & (s > 0) \\ \left[\dfrac{4F_m}{\gamma^3 \sqrt{-s}} \sinh\left(\sqrt{-s}t\right) + \dfrac{4F_0}{\gamma^3 s}\left(1 - \cosh\left(\sqrt{-s}t\right)\right) + \left(\dfrac{r_0}{\gamma}\right)^4 \right]^{1/4} - \dfrac{r_0}{\gamma} & (s < 0) \end{cases} \tag{2-33}
$$

Note that the following assumptions still apply:

1. The mass of the original cloud parcel is constant.
2. The cloud rises isentropically.
3. No water vapor phase change.
4. The entrainment coefficient (γ) is constant. (23: C-24)

This last assumption is challenged in Chapter III and an alternate method is proposed.

REEDM Calculation Method

In REEDM, the meteorological profile is divided up into layers, which are assumed to be homogeneous in the typical atmospheric parameters such as pressure, temperature, and density. In each of these layers REEDM calculates the cloud characteristics using values from the previous layers. The characteristics include height, radius, buoyancy, density, vertical velocity and stability. As the cloud rises to a new level, the values from the previous level are used as the starting values for the calculations in the current level. The instantaneous cloud calculation method is depicted in Figure 2-1.

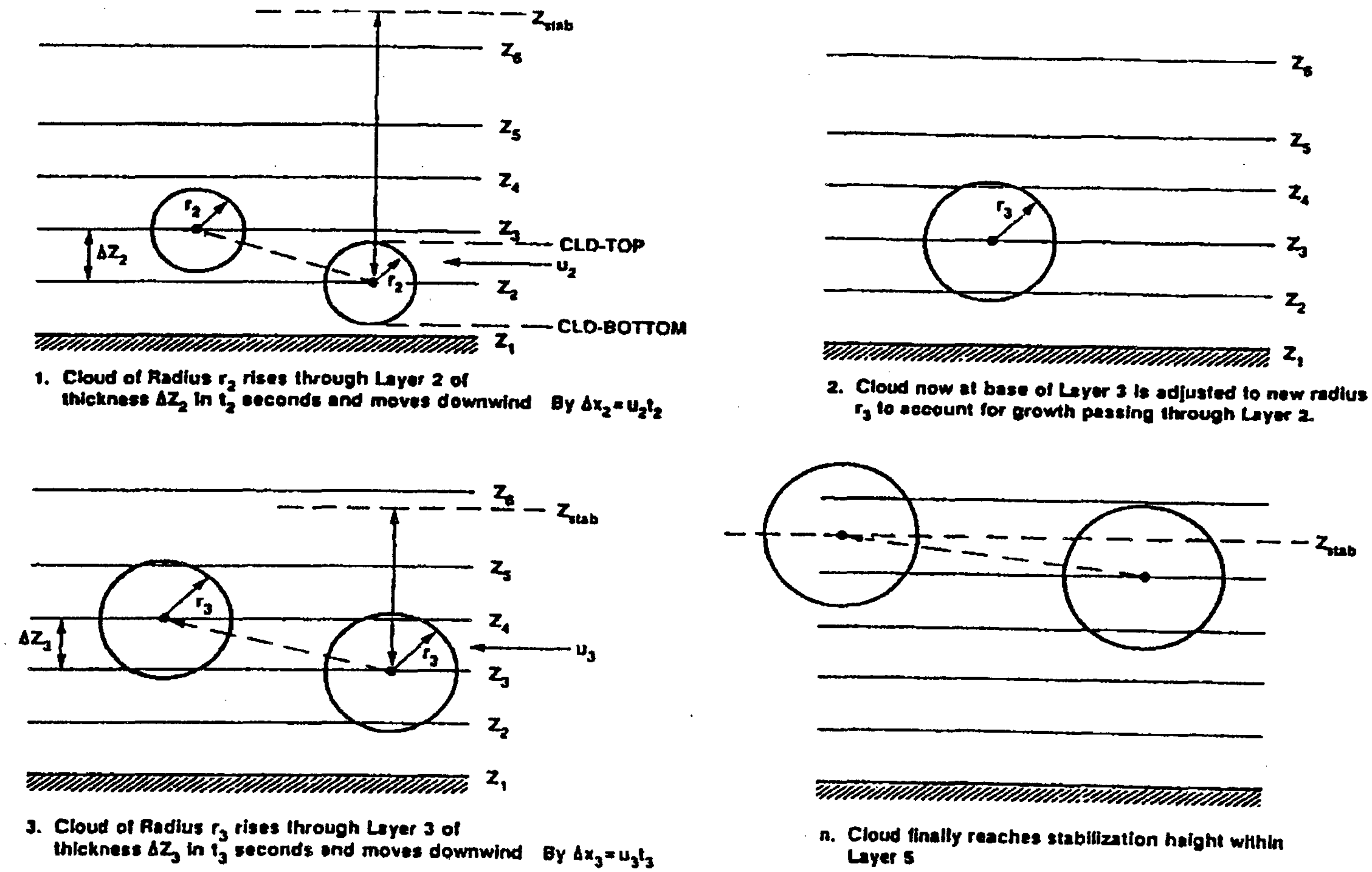

Figure 2-1: REEDM's Cloud Rise Calculation Method

III. APPROACH

Introduction

The analysis for investigating the instantaneous ground cloud rise uses three different versions of the REEDM computer program. The first version is an unchanged version of the program, called Vers7.07. This is the version currently used at the launch sites to predict ground-level concentrations of toxic effluents. This version will serve as the baseline for this study. The second version incorporates changes recommended by engineers at Aerospace Corporation, called AM7.07 in this thesis. The third version further modifies the program by changing the behavior of the entrainment coefficient, γ, from a constant into a piecewise linear function. This modification makes γ a linear function at the beginning of the rise and a constant after reaching a certain height. The assumption here is that the rate of air entrainment changes with altitude, with the rate being small in the early stages of rise, and greater in the later stages (19). This version is entitled Mod2 and contains this change in the entrainment coefficient assumption in addition to those changes made in AM7.07. For each variable of interest, the results from the different models were compared to one another. For the calculated cloud stabilization heights, results were also compared to values measured at launch sites.

Output Generation

All three versions have been modified to write variables of interest to two files called instcld.out and stab.out. Variables pertaining to the instantaneous cloud are saved to instcld.out. Those included in the variables saved to instcld.out are the meteorological layer (k, a positive integer beginning with 1), the altitude height of that the bottom of the layer (althgt(k) in meters), the radius of the cloud at that layer (R and cldrad(k), both in meters), the velocity of the cloud at that layer (ww, in meters/second), the buoyancy force at that layer (boyncy, in meters^4/seconds^2), the time from launch (ristim, in seconds) and the height the instantaneous cloud experienced in the previous layer (cldhgt, in meters). The actual height of the cloud is then the value of cldhgt in this layer added to the value of althgt of the previous layer. For the sake of clarity, the term rise hgt is used in Appendix D to refer to the height of the cloud in the previous layer while cld hgt is used to refer to the actual height of the cloud from the ground. The variables in instcld.out are the primary ones of interest in this study.

Variables pertaining to the atmospheric and stability conditions of the meteorological layer were included in the file stab.out. Values for each of these variables at each meteorological layer are sent to these files so the behavior of the cloud rise and the atmospheric conditions can be understood and analyzed.

Selection of Test Cases

In order to determine the impact of these changes to the calculations, launch cases were analyzed for cases which measured, observed clouds heights existed. Through a contract with the Space and Environment Technology Center of Aerospace Corp., visual and infrared observations of eight Titan IV launches have been conducted. Six of these observed launches were chosen to be test cases in this study, since data needed for the study were available for these cases and not the remaining two. Four of these six launches occurred at Cape Canaveral while the remaining two were at Vandenburg. The launches at Cape Canaveral are termed K-23, K-19, K-21, and K-16. The Vandenburg launches are termed K-15 and K-22. At present, only one technical report (for K-23) and two technical memorandums (for K-21 and K-19) exist detailing the imagery work conducted by Aerospace (8, 13, 14). However, summary data of all six launch observations were provided so comparisons to the different codes could be made. These summary data are shown in Table 3-1.

Mission (*range*)	*K-23* (*cape*)	*K-19* (*cape*)	*K-21* (*cape*)	*K-15* (*vafb*)	*K-16* (*cape*)	*K-22* (*vafb*)
Hgt(m) Visible	1149	1640	N/A	899	1023	827
Hgt(m) Infrared	N/A	1913	1375	N/A	N/A	866
Date	5/14/95	7/10/95	11/6/95	12/5/95	4/24/96	5/12/96
time (local)	0945	0838	0015	1318	1937	1432

Table 3-1: Measured Titan VI Cloud Heights (Visible and Infrared Observations)

REEDM Program Changes

AM7.07

AM7.07 incorporates two changes based on recommendations from the Aerospace Corporation's Environmental Systems Directorate (15). The first change modifies the method for calculating the average stability of the meteorological layers (found in the subroutine rdatm which is in file sor2.for). Originally, the average ambient temperature of each layer was used as the denominator in the variable ssa:

$$ssa = \frac{\theta_k - \theta_{k-1}}{.5(T_k + T_{k-1})} \tag{3-1}$$

where:

k refers to the meteorological layer the calculation is being made,

θ is the potential temperature at that layer, and

T is the ambient temperature at the given layer.

This is used in the calculation of the array of stability parameters (avgstb). The recommended change uses the potential temperature, instead of the ambient temperature:

$$\text{ssa} = \frac{\theta_k - \theta_{k-1}}{.5(\theta_k + \theta_{k-1})} \tag{3-2}$$

This modification more accurately characterizes the stability of the atmosphere since potential temperature is a better atmospheric parameter at higher altitudes than ambient temperature. Potential temperature was defined in Chapter II.

The second modification involves the buoyancy calculation (found in the subroutine plume). The original formula used the atmospheric density, ρ_a in the calculation for buoyancy while the modification uses an estimate of the surface cloud density: $\rho_c = \rho_a + \Delta\rho$. $\Delta\rho$ is calculated by the equation:

$$\Delta\rho = -\frac{Q}{T \cdot c_p V_c} \tag{3-3}$$

where:

Q is the heat output in calories,

V_c is the cloud volume: $\frac{4}{3}\pi r^3$,

T is the ambient temperature in K, and

c_p is the specific heat of air (.24 cal/g K)

The buoyancy force, F_b, is then calculated by:

$$F_B = \frac{3gQ}{4\pi c_p \rho_c T} \qquad (2\text{: } 28). \tag{3-4}$$

Since the buoyancy term relates to the characteristics of the surface cloud, it was appropriate to replace the ambient density with the cloud density. The result of this modification is to decrease the calculated density of the cloud, making it more buoyant than before. A more buoyant cloud rises higher, and hence would have a higher predicted stabilization height.

Mod2

The second modification of the REEDM program, Mod2 involves changing the behavior of the entrainment coefficient, γ. Entrainment is the introduction of ambient fluid into the cloud plume, mainly due to the vortices and turbulent motion present in plumes and is responsible for the growth of the plume (7: 30, 17: 61).

In Morton, Taylor and Turner, there is an observation of the motion of an atomic bomb, where

> "there is strongly turbulent interior motion confined within a surface which is relatively smooth during the early stages of the ascent....Indeed, in the early stages of its motion the atomic bomb cloud behaves more as a bubble of air in water, in which case there is no entrainment at all..." (19: 21).

The previous versions of REEDM all kept γ constant throughout the cloud rise. In Mod2, γ is made a piecewise linear function such that

$$\gamma = \frac{\left(\gamma^{*} - .01\right)}{z^{*}} \cdot z + .01 \quad \text{when } z < z^{*}$$

$$\gamma = \gamma^{*} \quad \text{otherwise} \tag{3-6}$$

where z is the height of the bottom of the current meteorological layer and the value of z^* was set to a height of 150 meters. This height was chosen to be within the height that heat is added to the instantaneous cloud from the continuous exhaust cloud of the rocket. (REEDM adds an incremental amount of heat in each meteorological layer up to 200 meters.) γ^* is equal to its original value of .64 but can be varied when REEDM calculations are performed using the "research" or "diagnostic" modes.

This modification of γ developed out of a previous modification (not included in this study) where γ was modeled as a step function, with γ being one distinct constant value in one range and a different constant value (γ^*) in another range. Results from this modification were not included here because nonconservative cloud heights were obtained and the behavior of the cloud as it rose did not agree with what was occurring in nature. The actual code changes for AM7.07, and Mod2 can be found in Appendix A

Input Files

Six individual rawinsonde input files were used as input files with each of the four different versions of REEDM. These files were titled K23_1327.raw, K19_0838.raw, K21_6Nov.raw, K15_2103.raw, K16_2310.raw, and K22_2117.raw, corresponding to the K-23, K-19, K-21, K-15, K-16 and K-22 launches of the Titan IV rocket respectively. These files contain the most recent meteorological data of the atmosphere for the day of the launch. Information contained in these files include altitude, wind direction, wind speed, temperature, dewpoint, pressure, relative humidity, absolute humidity, and density data. These rawinsonde files are found in Appendix B.

The other two files of interest concern the location of the launch area, namely Vandenburg AFB or Cape Canaveral Air Station. These files, entitled rdmbase.mas for Vandenburg and rdmbase.ksc for Cape Canaveral, contain geographical data used by REEDM to calculate concentration and dosage levels and plot the concentration isopleths.

Entrainment Coefficient Values

Calculations using each of the six cases were performed using these different models of REEDM in the research mode. (This allows default values of certain parameters in the program to be changed.) For this study, the only parameter changed was the entrainment coefficient, γ. Values of .64 (the default), .57, and .5 were used for γ for each of the launch cases. Some calculations were performed with $\gamma = .4$, but these resulted in overpredicting cloud height as compared to the observed height for most of the launch cases.

Chapter Summary

The chapter presented the two variations of REEDM that were compared to the original version. Modifications incorporated in each model were shown and discussed, along with the launch cases to be used in the study, and the values used for the entrainment coefficient, γ. The following chapter will examine the results from these modifications, examining the cloud heights predicted by each model at the various γs and comparing them to observed heights. Also the behavior predicted of the cloud radius and cloud velocity with each of these models will be analyzed. Lastly, results from a simple formula will be discussed.

IV. RESULTS

Introduction

The following sections will discuss the results of the six launch cases using the three different models of REEDM discussed in Chapter III. The results will compare the cloud heights predicted by the models to the observed imagery data and discuss if the changes implemented in the AM7.07 and Mod2 programs improved REEDM's ability to predict stabilized cloud height. Also, the effects on the cloud's vertical velocity by these changes will be discussed. Included in this discussion will be the effect of changing the entrainment coefficient (γ). Lastly, a derived formula for cloud height from the literature will be presented and compared to the six launch cases.

Stabilized Cloud Height Results

For each of the six launches, the stabilized height predicted by each of the models was compared directly to the observed stabilized height. Since imagery was conducted using both visible and infrared observing equipment, two sets of observed cloud heights existed for some cases. In all cases except one, the visible imagery data was more conservative and so this value of cloud height was used in the comparison. The exception was for launch K-21 which was conducted at night and therefore visible imagery was unable to be conducted. The results of all the launch cases for each model are tabulated in Table 4-1. These results are also shown pictorially shown in Figures 4-3 through 4-8, located at the end of the chapter. The entire table of results and graphs showing height and velocity profiles for all cases with each model can be found in Appendix D.

Launch: K-23 Date: 14 May 95 Location: CCAS				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	787.86	922.80	1031.52	1640.00
Gamma=.57	879.36	1033.74	1155.27	1640.00
Gamma=.5	1021.20	1201.61	1329.29	1640.00
Launch: K-19 Date: 10 July 95 Location: CCAS				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	851.30	997.60	1108.14	1774.00
Gamma=.57	973.72	1117.15	1219.60	1774.00
Gamma=.5	1096.78	1243.06	1337.57	1774.00
Launch: K-21 Date: 6 Nov 95 Location: CCAS				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	1131.99	1210.51	1259.82	1375.00
Gamma=.57	1214.16	1295.91	1340.60	1375.00
Gamma=.5	1302.87	1386.28	1429.79	1375.00
Launch: K-15 Date: 5 Dec 95 Location: VAFB				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	514.76	629.40	761.20	899.00
Gamma=.57	581.66	739.05	895.58	899.00
Gamma=.5	695.90	874.65	1023.91	899.00
Launch: K-16 Date: 24 Mar 96 Location: CCAS				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	756.80	854.19	936.55	1023.00
Gamma=.57	810.94	917.76	999.50	1023.00
Gamma=.5	881.25	995.39	1080.65	1023.00
Launch: K-22 Date: 12 May 96 Location: VAFB				
REEDM Version	Vers707 (m)	AM707 (m)	MOD 2 (m)	Observed (m)
Gamma=.64	438.26	528.10	633.30	827.00
Gamma=.57	470.67	564.69	671.77	827.00
Gamma=.5	509.37	611.83	727.82	827.00

Table 4-1: Cloud Height Results for Launch Cases

Effect of Entrainment Coefficient

The overall trend of lowering the value of γ was an increase in the cloud stabilization height when comparing results from the same model. The trend held across the six cases for all three models, increasing cloud height by approximately an average of 11% for each decrease by .07 in γ. The range for this average is 7% to 20%. This trend was expected since a smaller γ reduces the entrainment of ambient air into the instantaneous cloud resulting in a smaller, more buoyant cloud. This naturally should result in a higher stabilization height. The percentage increase was also consistent for each model used within each case. For example, every model in launch K-21 experienced a 6%-7% increase in cloud height with each smaller γ used. It also appears that the greater the original difference from the observed (using Vers7.07), the greater the increase resulted using a γ.

The results do show support that a smaller value of γ should be used in the model, as opposed to the default value of .64. However, how low this value should go was not determined by the launch cases used in this study. For three of the cases, (K-21, K-15, and K-16) a value of .57 very closely matched the observed stability height. The smaller value of .50 resulted in a higher stability height than observed, which would lead to a non-conservative estimate of the ground level concentrations of the toxic chemicals. On the other hand, the remaining three cases still underpredicted the cloud height using a value of .5, some by a sizable margin (over 300 meters). Here an argument for a smaller γ could be made.

A smaller γ has the most notable effects early in the cloud's ascent through the atmosphere. As can be seen by the graph of cloud height vs. time from launch on Figure 4-1 (using the Vers7.07 model with the K-23 case), the cloud typically experiences a very rapid rise within the first 100 seconds and then asymptotically levels off to its predicted stabilization height. By decreasing the value of γ, the cloud's ascent increases just slightly, most often after the initial, rapid rise has occurred (typically after 50-60 seconds). The smaller γs decrease the time required to traverse from one atmospheric layer to the next, which agrees with the theory that less entrainment is occurring and therefore the cloud is more buoyant and rising faster. But this still can have a large discrepancy as compared to the observed height. Just decreasing γ appears to be only a partial solution to the problem with REEDM's ability to predict stabilization height.

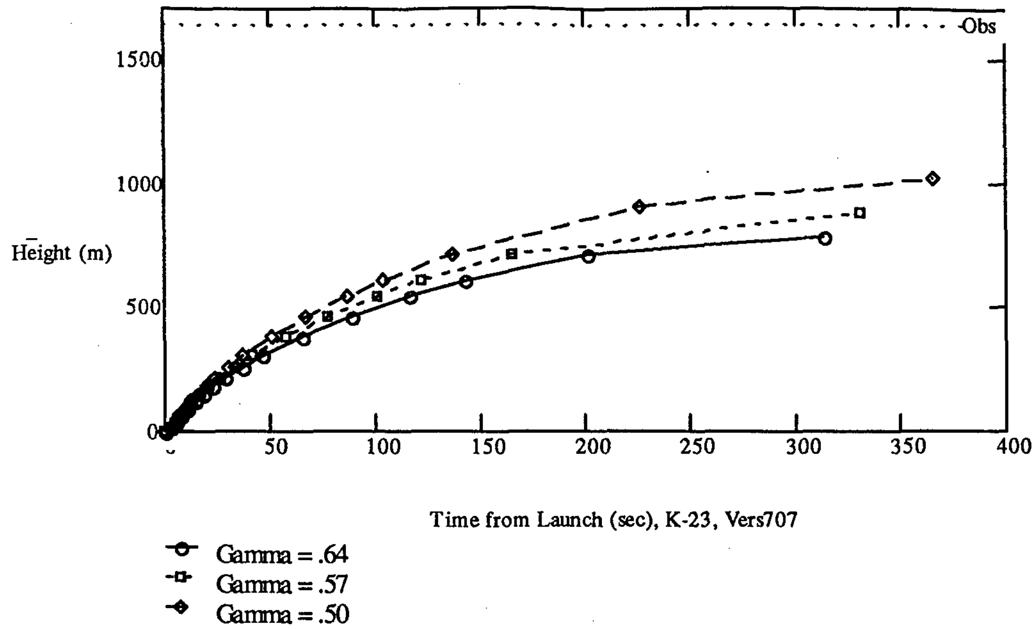

Figure 4-1. Comparison of Stability Heights with different γ's

AM7.07 Model

This model improved the cloud height predictions of REEDM for all cases. The average improvement compared to the Vers7.07 model was 15%, with a range of 6% to 27%. These correspond to actual height improvements of 83 meters to 157 meters. The cloud heights, in fact, were generally directly at the midpoint between the heights predicted by Vers7.07 and those by Mod2, such that a linear relationship seems to exist between the three results. This relationship can also be seen from the graphs of cloud height vs. time in Appendix D. For every launch case, the cloud height for this model throughout its rise was almost always directly in the middle of the heights given by the other two models.

Also, the percentage change with this model was almost identical as the γ was decreased. This behavior was also seen with the Mod2 version. For four of the cases, only 1% difference or less resulted with every .07 decrease in γ. For the two other cases, K-19 and K-15, the differences between the maximum percentage change and the smallest were 4 and 5% respectively. Thus, it is likely that cloud heights at various γ's with this model can be predicted using the stabilization height predicted by the Vers707 model at a certain γ and only one cloud height result from the AM7.07 model.

Examining the graphs of the cloud velocities vs. time in Appendix D, it is found that the cloud in the AM7.07 model experiences a faster ascent during the early stages of its rise compared to that of the Vers7.07 model. The maximum vertical velocities were all in the range of 13-16 m/s. After reaching its maximum velocity, it moderately slows down to zero in almost the same fashion seen by the Vers7.07 model. This increase in velocity was expected because the modification to the buoyancy equation increased the buoyancy of the cloud which directly increases the vertical velocity of the cloud. It is this increase in vertical velocity that most likely accounts for the increase in cloud height.

Mod2 Model

The results of this model had a significant impact on the cloud stabilization height. The cloud heights from the six models had an average percentage increase of 31% as compared to the Vers7.07 model, with a range from 10% to 54%. These correspond to height improvement ranging from 126 m to 328 m.

The cloud heights were also more consistent within each of the launch cases. For all but two of the launch cases, only one or two percentage points separated the percentage change experienced by the MOD2 model at the various γ's when compared to results from Vers7.07 using the same γ. The other two cases (K-19 and K-15) had differences of only 8% and 7% between highest change and lowest percentage change.

A comparison was made of the cloud radii predicted by MOD2 throughout the cloud's rise to that predicted by theory using the new behavior of γ seen in this model. The data points were taken at various predicted heights from the ground. These results are seen in Figure 4-2. Results from the model matched very closely to the line predicted by theory, thereby lending credence that the model is working properly.

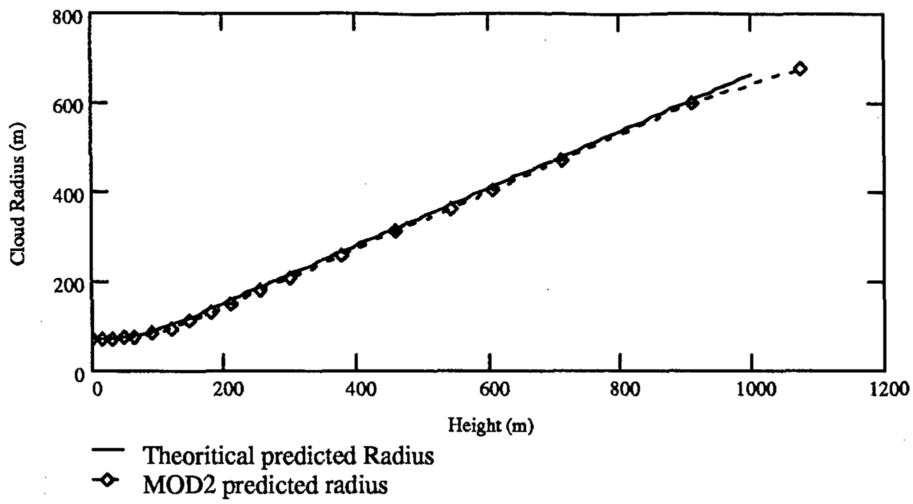

Figure 4-2: Comparison of Theoretical and MOD2 Predicted Radii with Height

The velocity profiles generated by this model were different from the previous models. With this model, the maximum cloud velocities was much greater than those of the AM7.07 and Vers7.07 models. Typical maximum velocities for the Mod2 trials ranged around 25-27 m/s for all cases regardless of the value of γ. These maximum velocities were approximately 1.8 times greater than those seen with the AM7.07 model and 2.5 times greater than those of the Vers7.07. However, the cloud quickly lost this upward velocity and started dramatically slowing down. This can been seen with the sharper peaks in the velocity profiles for this model.

Higher velocities were expected with this model because of the behavior of the entrainment coefficient. Since, in this model, the γ is kept small in the beginning of the cloud's rise and is gradually and linearly increased until it reaches 150 meters, where it then becomes a constant, the cloud's buoyancy is directly being increased. What wasn't expected was the large deceleration that occurred after reaching maximum velocity.

Two launch cases deserve special attention here. Even using the Mod2 model with a γ of .50, the predicted stabilization heights for the K-23 and K-19 launches still had large deviations from the observed stabilized cloud heights. There are possibly several reasons why the model is underpredicting these heights, however only one is currently evident. Comparing these launches to the other two at Kennedy Space Center, it is found that the K-23 and K-19 clouds are transported east out over the ocean, whereas K-21 and K-16 travel over land. Possible land-sea effects affecting the wind and atmospheric stability therefore may be contributing to the inaccuracy of the model. The accuracy's of the observed heights were not reported, but it is thought that the other launch cases would have a similar error, thus this does not account for these differences. It is likely some further modification of the REEDM code is needed.

Formula Prediction

The final aim of this study was to determine if a some type of easy formula could be used to predict the final cloud height of the rocket exhaust. Several formulas exist for continuous sources. (For example see Briggs' *Plume Rise* (1969) (25), Hanna, Briggs and Hosker's *Handbook on Atmospheric Diffusion* (1982) (24:14-17), and Seinfeld's *Atmospheric Chemistry and Physics of Air Pollution* (1986) (16:579).) However only one formula was discovered for instantaneous sources given in terms of the heat released. This formula taken from Morton, Taylor and Turner (1956) is:

$$H = 1.87\ Q^{1/4}$$

where Q is the rate of release of heat in joules and H is the final height in meters (19:21). Converting joules to calories (used in REEDM) this equation becomes:

$$H = 2.675\ Q^{1/4}$$

As can be seen by Table 4-2, this formula yielded favorable results for three of the launch cases, but gave higher heights than observed for the remaining three. Because predicted heights greater than actual heights are nonconservative, these prediction are unacceptable from a public health standpoint. Therefore it is unknown if a formula, empirical or derived, can be developed that can work well in every launch case. The derivation of such a formula is a topic for future research and is mentioned in the next chapter.

Launch Case	Q (cal)	Formula Result (m)	Observed (m)
K-23	6.21×10^{10}	1335	1640
K-19	6.24×10^{10}	1337	1774
K-21	6.17×10^{10}	1333	1375
K-15	6.07×10^{10}	1328	899
K-22	6.06×10^{10}	1327	827
K-16	6.18×10^{10}	1334	1023

Table 4-2: Formula Results

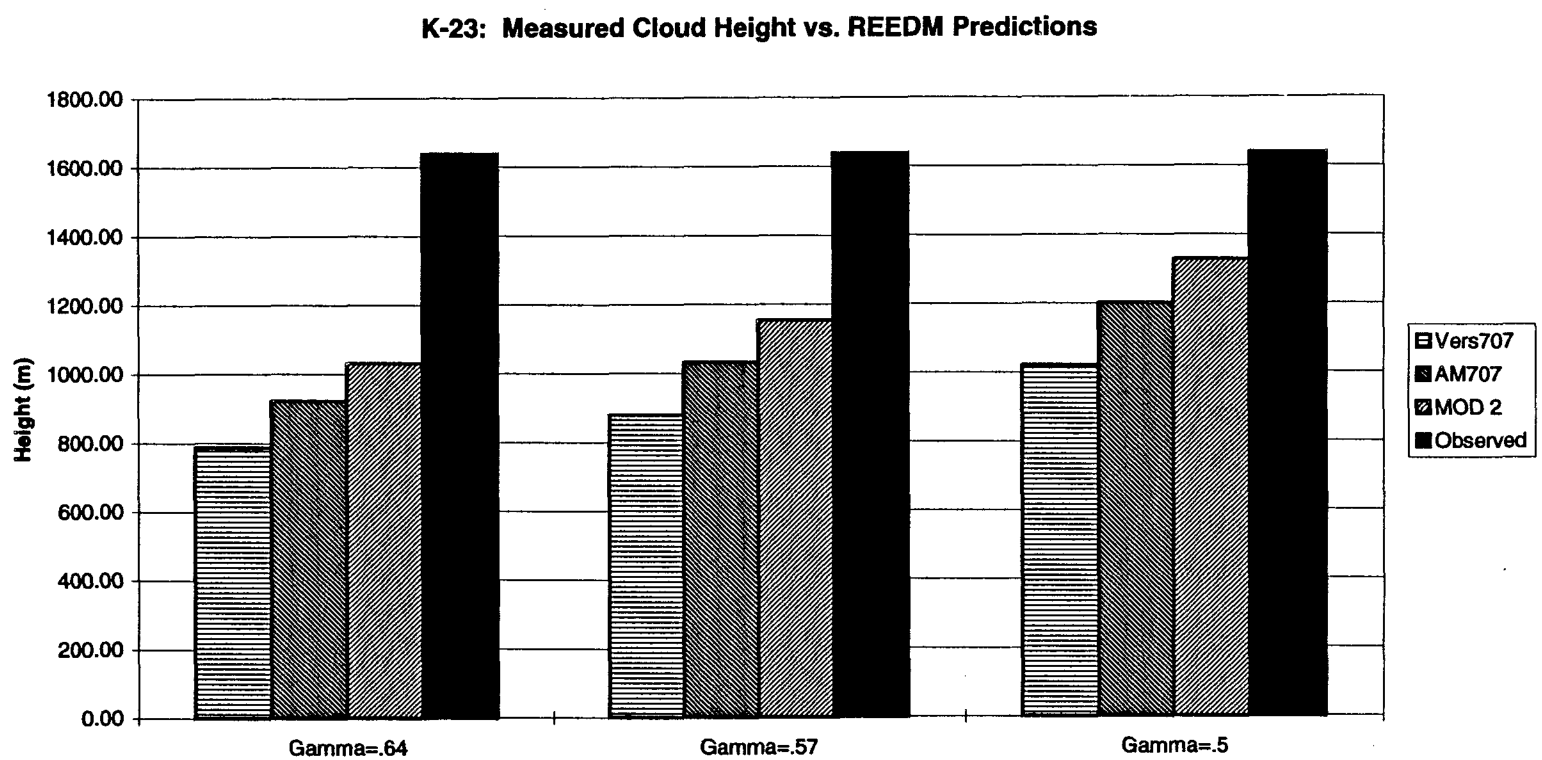

Figure 4-3: Comparison of Cloud Heights for Launch K-23 (Cape Canaveral AS)

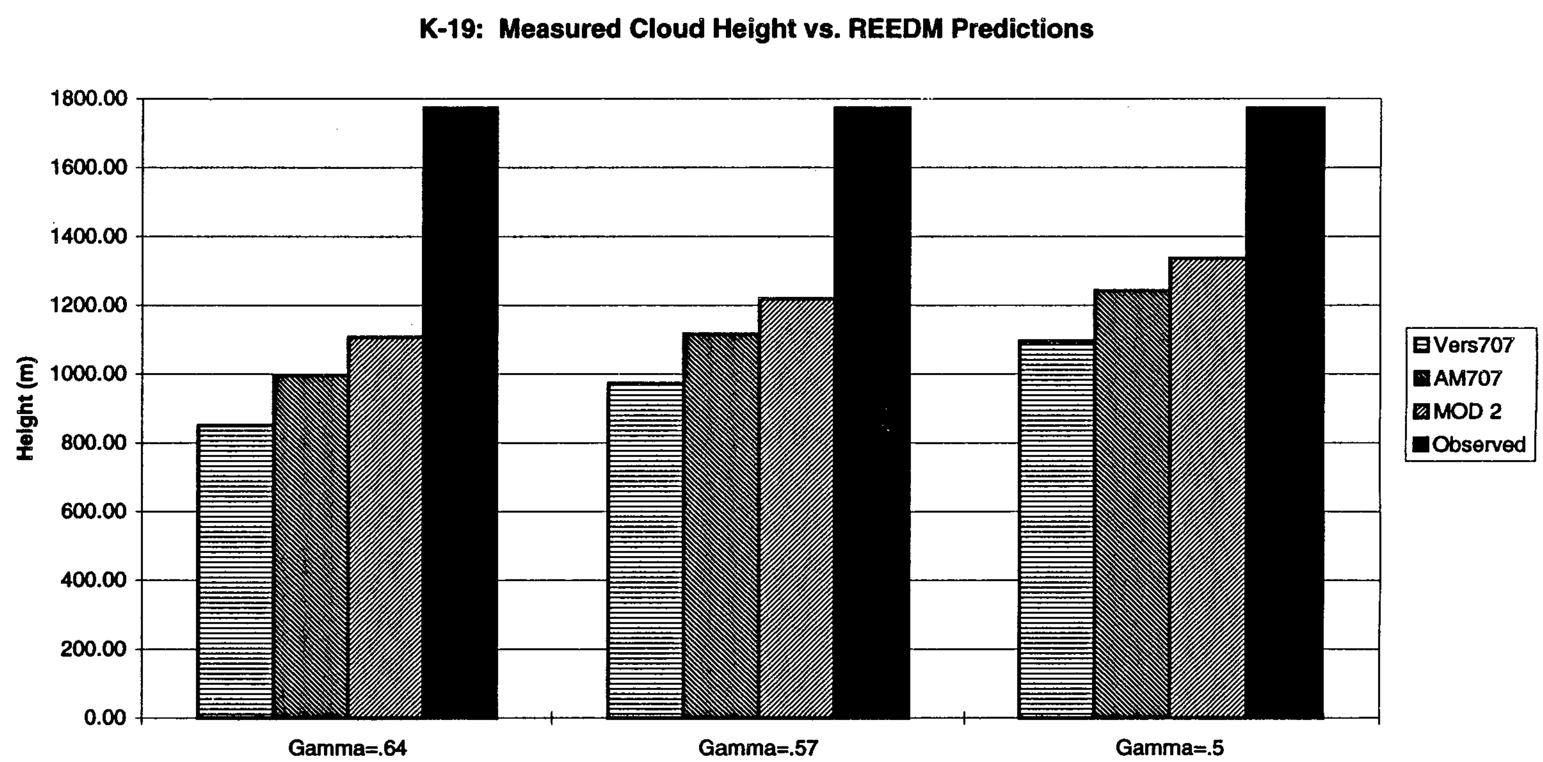

Figure 4-4: Comparison of Cloud Heights for Launch K-19 (Cape Canaveral AS)

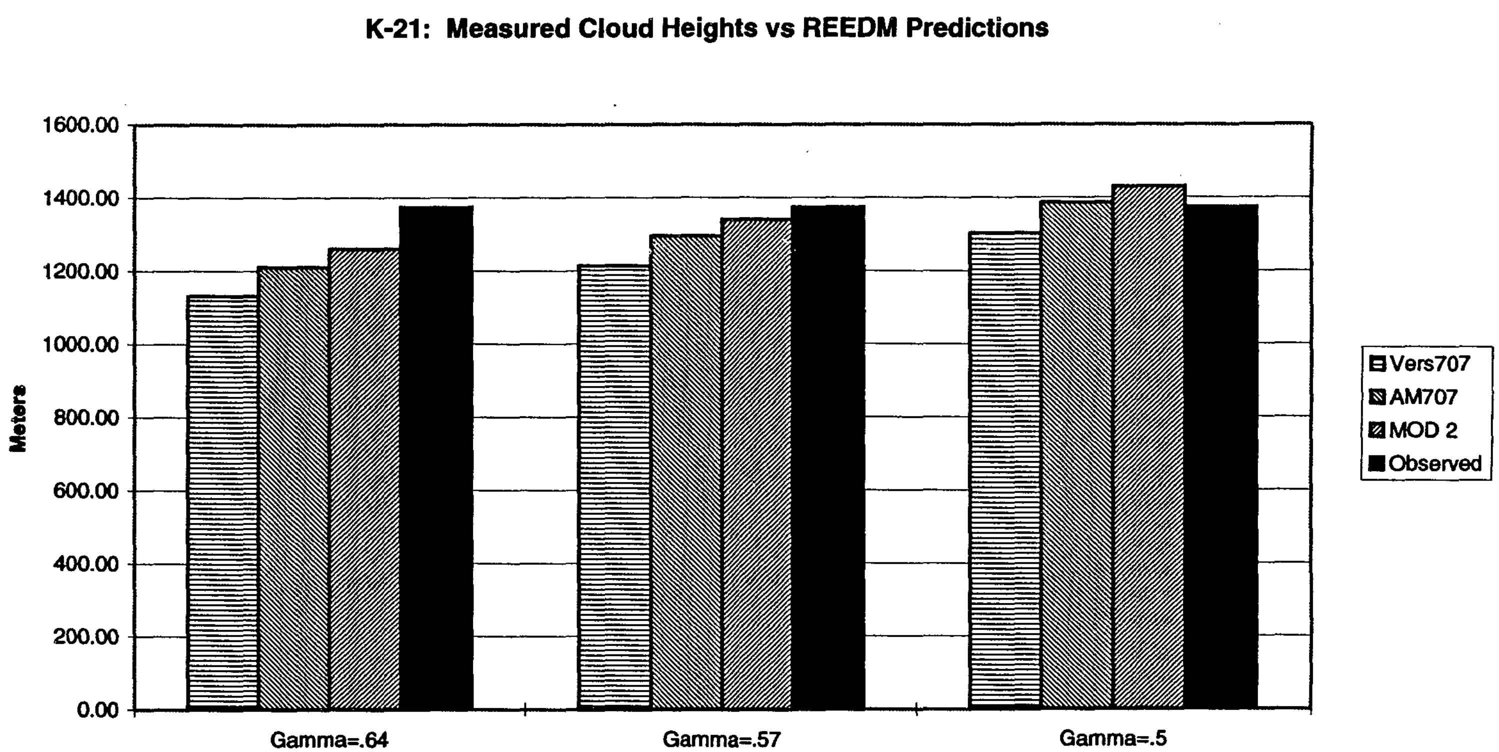

Figure 4-5: Comparison of Cloud Heights for Launch K-21 (Cape Canaveral AS)

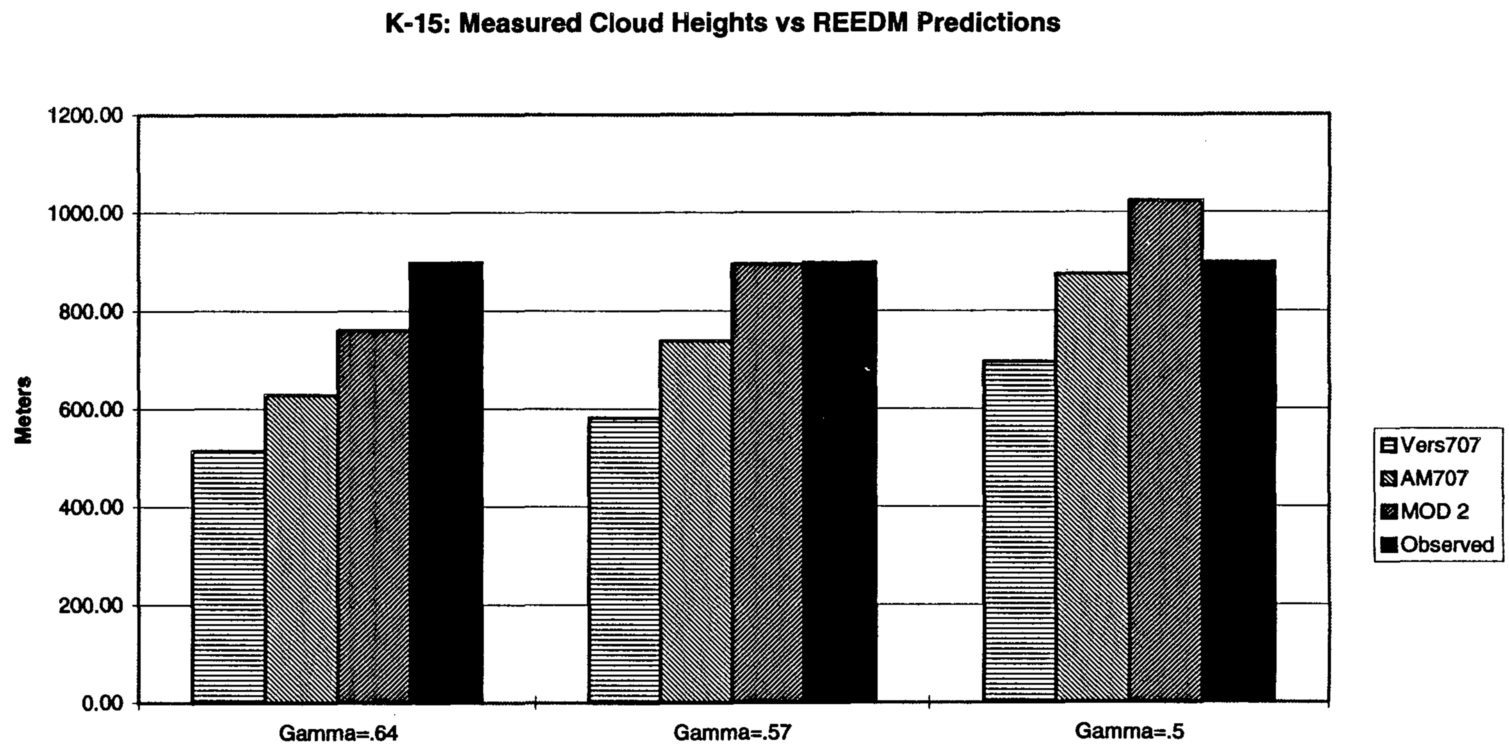

Figure 4-6: Comparison of Cloud Heights for Launch K-15 (Vandenburg AFB)

K-16: Measured Cloud Height vs REEDM Predictions

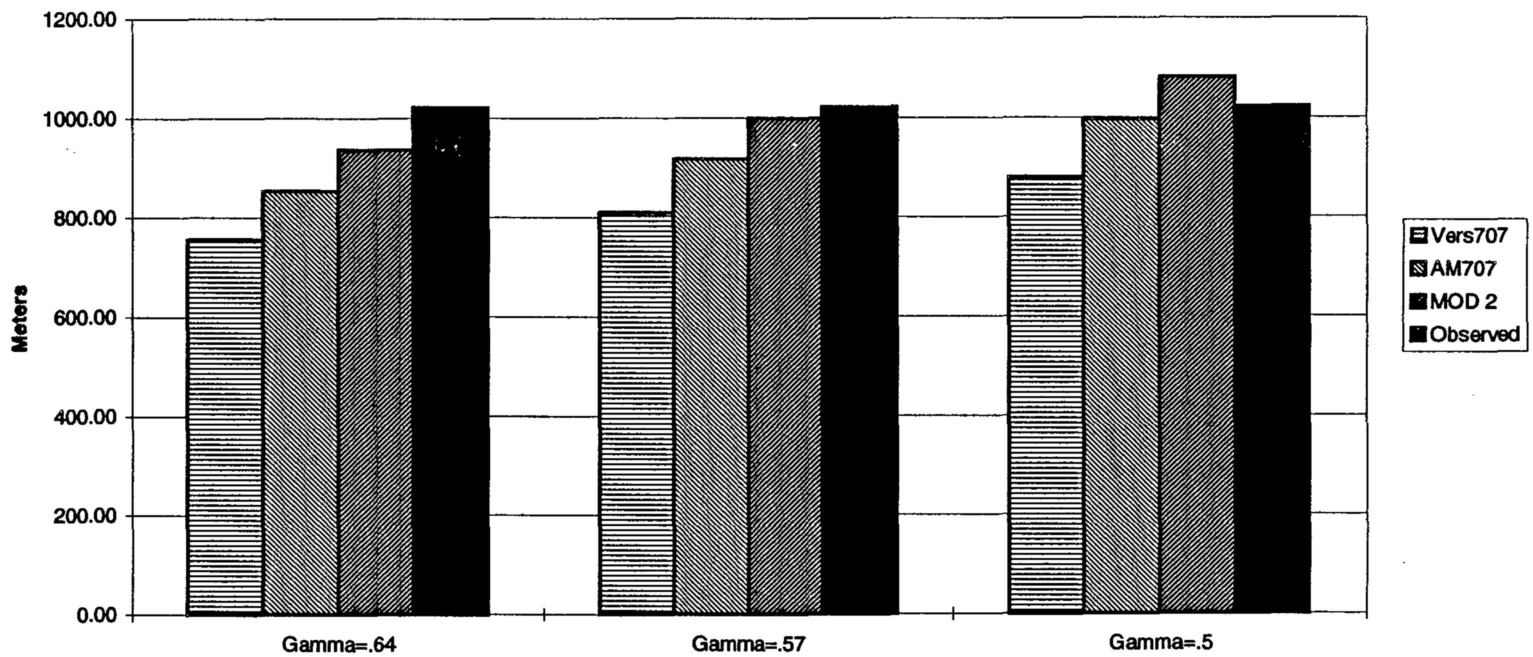

Figure 4-7: Comparison of Cloud Heights for Launch K-16 (Cape Canaveral AS)

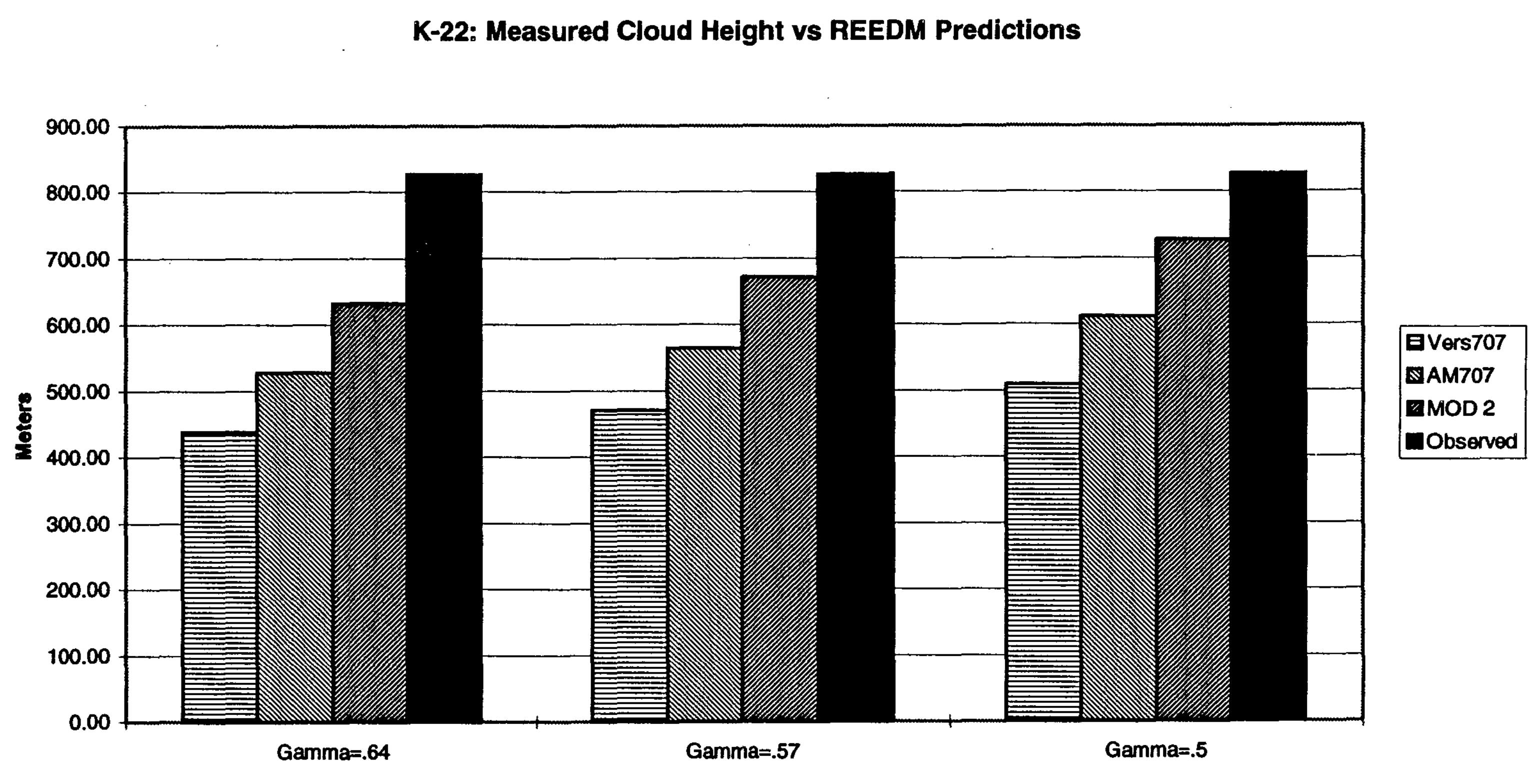

Figure 4-8: Comparison of Cloud Heights for Launch K-22 (Vandenburg AFB)

V. CONCLUSIONS

Introduction

Conservation laws and an entrainment assumption provide the theory for predicting stabilization heights of instantaneous buoyant clouds resulting from exhausts of large launch vehicles such as the Titan IV. This theory is converted into the FORTRAN code REEDM Vers7.07. Two modifications of this original code have been presented in this study. The first model, the AM7.07 version of REEDM, changes certain equations and thereby removes certain assumptions made by the authors of REEDM. The second version, Mod2, introduces a new hypothesis pertaining to the entrainment coefficient while also incorporating the changes in AM7.07. Both models improved the cloud height predictions for the six launch cases when compared to the original version of REEDM.

Further, a small study examining the effect the entrainment coefficient, γ, has on stabilization heights of the instantaneous cloud was performed. It was found decreasing the value of γ increased the stabilization height of the instantaneous cloud. However, the study did not indicate that a single value of γ was appropriate to use in all launch cases.

Model Conclusions

Evidence presented in the results of this study gives weight to adoption of some of the changes made to the REEDM code. The AM7.07 model improved the cloud heights of the six cases by various amounts with an average percentage increase of 15%. This height improvement is accompanied by an increase in the cloud's vertical velocity. The two changes made in this model have a very sound base in the theory of plume rise, and therefore enables the code to accurately model the phenomenon of buoyant, rising instantaneous exhaust clouds. It is recommended that launch commanders and decision-makers associated with Cape Canaveral Air Station and Vandenburg Air Force Base adopt these changes in the code.

The Mod2 model presented in this study also improves the predictive capabilities of the REEDM code in regards to cloud stabilization heights. This model introduces a different assumption into the theory of entrainment used in REEDM. A 31% improvement in cloud stabilization heights as compared to those of the Vers7.07 code resulted. A fairly dramatic increase in the cloud's velocity accompanied these results. The assumption presented in this model is theoretical at this point and has not been independently validated by experimental data. However the results do seem to support the assumption that the entrainment coefficient is not constant throughout the cloud's entire movement through the atmospheric layers and therefore some additional theory is warranted.

The results of both modified versions were not unexpected. All the changes made were theoretically predicted to improve the predicted cloud rise. The AM7.07 model increased the predicted stabilization heights by mainly increasing the calculated buoyancy of the cloud. The modification in the Mod2 version directly inhibited the initial calculated growth of cloud, thereby indirectly increasing the predicted cloud's vertical velocity. Coupled with this theoretical result was the increase in buoyancy predicted from the AM7.07 model. Therefore the greatest increase in cloud stabilization height was expected with this model.

Entrainment Coefficient Conclusions

As alluded to earlier, no one value of the entrainment coefficient appeared to correctly predict the observed cloud stability heights for the six cases examined. Decreasing the coefficient somewhat improved the models' ability to correctly predict the stability height, but with only six cases to study, it would be difficult to make a recommendation concerning a correct value for γ. Based on the results of this study with the original Vers7.07 code, it would appear that a γ of .50 or less may be appropriate to use with this model. However, if the changes made in the AM7.07 model are adopted, a γ of .50 should be the lower limit for this parameter. Any smaller value may overpredict stability heights, thereby introducing a possible environmental threat due to high ground-level concentrations of toxic exhaust by-products. A value such as .53 may be even more appropriate and safer in terms of protecting the public for exposure to toxins than .50. Overall, this study does seem to indicate that the current value of .64 for γ is unrealistic and greatly underpredicts the stability height of the cloud.

Recommended Follow-On Research

The phenomenon of plume rise from instantaneous sources is an interesting and challenging area. Many assumptions are made in the development of the theory and in the development of the REEDM code. The physics surrounding entrainment certainly warrant additionally study. Specifically:

1) Does the entrainment coefficient behave in a linear fashion as proposed in Mod2? If so, how steep should the slope be?
2) There is some research in the literature relating entrainment to atmospheric conditions. Gebhart, et. al. describes a relationship between the nondimensional Froude number and entrainment (21: 672-679). Can such a relationship be applied to the REEDM

code, or can some other modification of the REEDM code be developed that accounts for such non-constant parameters such as wind speed and atmospheric stability?

3) The number of cases examined in this thesis was limited. As more data becomes available, additional cases should be examined with the models used here to help validate the conclusions presented here. Eventually it is hoped that enough launches will be observed to allow some type statistical analysis on the models' results.
4) The deflagration and conflagration modes available in the REEDM program were not used in this study. Therefore it is unknown what effect the changes implemented in the AM7.07 model and the Mod2 model would have in these modes.
5) The formula derived by Morton, Taylor, and Turner was inaccurate for half of the launch cases used in this study. How is the accuracy of this formula affected by meteorological conditions? Is there a method to determine when it will predict nonconservative results?
6) In a previous study involving REEDM, a modification was made to the program that involved an improved averaging method for the meteorological model (26). It is possible that predictions of ground-level concentrations of toxic rocket exhaust by-products may be further improved by using the modifications presented in this thesis with this improved averaging method.

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APPENDIX A

FORTRAN Program changes implemented in AM7.07 and Mod2

AM7.07 Modifications

File: SOR2.FOR

Subroutine: RDATM

The following shows the modification to change the stability factor calculation, using potential temperature instead of ambient temperature. This modified the subroutine RDATM found in file SOR2.FOR.

```
CC      Change denom. from amtemp to potemp- see fax from aerospace      090396
C       SSA = 2.0*(POTEMP(I)-POTEMP(IM1))/(AMTEMP(I)+AMTEMP(IM1))
        SSA = 2.0*(POTEMP(I)-POTEMP(IM1))/(POTEMP(I)+POTEMP(IM1))        090396
CC           REDUCE INFLUENCE OF THE LOWEST LAYERS (BELOW 60.0 M)
        IF (ALTHGT(IM1) .LE. 60.0) THEN
          FLUIM1 = 0.01666667*ALTHGT(IM1)
          FLUI = AMIN1(0.01666667*ALTHGT(I),1.0)
          RATIOI = ((AMAX1(60.0,ALTHGT(I))-60.0)+0.5*(AMIN1(60.0,
     *              ALTHGT(I)-ALTHGT(IM1)))*FLUI+FLUIM1)/(ALTHGT(I)-
     *              ALTHGT(IM1))
          SSA = RATIOI*(FLUIM1+FLUI)*SSA
        END IF
        SUMSA = SUMSA+SSA
        AVGSTB(I) = SUMSA
```

The following shows the modification made to the buoyancy calculation of the exhaust cloud. This is found in the subroutine PLUME located in the file SUB4.FOR.

```
CC      ORIGINAL CODE
C       BOYNCY = (3.0*GRAV/(4.0*PIRADN*CP))*Q0/(AMTEMP(1)*SURDEN)
C       Modified code following Aerospace's recommendations              090396
        cp=0.24
        r03=r0**3
        fourpio3=(4.0/3.0)*(4.0*Atan(1.0))
        delden=-Q0/(cp*Amtemp(1)*r03*fourpio3)
        sfcldn=surden+delden
CC      REPLACE CONSTANT TERM WITH COMPONENTS(3G/4*PI*CP)=9.7552         091396
        BOYNCY = (3.0*GRAV/(4.0*PIRADN*CP))*Q0/(AMTEMP(1)*sfcldn)        091396
CC      END OF CHANGES                                                   090396
```

MOD2 Modifications

File: SUB4.FOR

Subroutine: PLUME

The following shows part of the subroutine PLUME contained in File SUB4.FOR. This part shows the buoyancy modification from AM707 and the entrainment modification (gamma) of MOD2.

```
CC       INSTANTANEOUS
        NM1 = NUMLM1
        H3 = ALTHGT(NUMLRS)
        Z0 = CLDDZI
        W0 = CLDVLI
        CLDHZ0 = 0.0
        TR0 = gctime
cc      ENHGT is height where entrainment will start.
        ENHGT = 150.00                                                  101596
cc      Calculate Lapse rate for print out later (comparison purposes)
cc        CALL LEAST(ALTHGT,POTEMP,DPOVDZ,K,0,0.0,0.0,DUMY)
cc        IF (DPOVDZ .LT. 3.322E-4) DPOVDZ = 3.322E-4
cc        alapse(K)=dpovdz                                              101596
cc        write(*,*) ' line 791 ',dpovdz
        IF (ifnorm .EQ. 3) THEN
          Z0 = ALTHGT(IHTDFL)
          IF (IHTDFL .EQ. NUMLRS.AND.HGTDFL .GT. ALTHGT(NUMLRS))
     *        Z0 = HGTDFL
        END IF
        CLDVEL(1) = CLDVLI
        CLDRAD(1) = CLDRDI
        R0 = CLDRDI
        IF (ifnorm .ne. 3) THEN
          Q0 = TR0*XDUMY
        ELSE
          Q0 = DFLHET
        END IF
        write(35,7200)Q0                                                092296
 7200   FORMAT(73X,'Initial heat (Q0) = ',G13.6,' cal')                 092296
CC      ORIGINAL CODE
C       BOYNCY = (3.0*GRAV/(4.0*PIRADN*CP))*Q0/(AMTEMP(1)*SURDEN)
C       Modified code following Aerospace's recommendations             090396
        cp=0.24
        r03=r0**3
        fourpio3=(4.0/3.0)*(4.0*Atan(1.0))
        delden=-Q0/(cp*Amtemp(1)*r03*fourpio3)
        sfcldn=surden+delden
CC      REPLACE CONSTANT TERM WITH COMPONENTS(3G/4*PI*CP)=9.7552        091396
        BOYNCY = (3.0*GRAV/(4.0*PIRADN*CP))*Q0/(AMTEMP(1)*sfcldn)       091396
CC      END OF CHANGES                                                  090396
        ICTOP = 2
        ICBOT = 2
CC-DEBUGS
        IF (IFRUND .EQ. 3) THEN
          JP = ITITL(0,4,0,4)
          WRITE (IOTFIL,9000) NM1,H3,CLDVLI,
     *                        CLDRDI,gctime,Z0,CLDHZ0,Q0,G3,
     *                        BOYNCY,sfcldn,GAMMAT
        END IF
CC-DEBUGE
        DO 50 K=1,NM1
CC      Modified code starting entrainment of air after a certain       101696
CC      height.  Entrainment coefficient will be a linear function
CC      of height with height being from 0 to ENHGT.
CC      GAMMAN is new variable for entrainment.
```

```
      If (Althgt(k) .lt. ENHGT) THEN                                   101696
        GAMMAN =((GAMMAT-.01)/ENHGT)*ALTHGT(K)+.01
      ELSE
        GAMMAN = GAMMAT
      ENDIF                                                            101696
cc    END GAMMA MODIFICATIONS
```

APPENDIX B

Rawinsonde input files for:

K-23
K-19
K-21
K-15
K-22
K-16

K-23 Rawinsonde file (K23_1327.RAW)

S011341327
TEST NBR E7597 WS8 5070
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
1327Z 14 MAY 95

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	270	6.0	.000	29.5	23.9	1016.70	72	21.26	1157.37	382	682	29.69	0
1000	256	8.8	.006	26.1	22.5	982.95	81	19.75	1132.39	369	678	27.27	6
2000	239	9.5	.005	25.2	20.1	949.70	73	17.08	1098.48	346	676	23.51	12
3000	231	9.3	.002	22.8	18.2	917.37	75	15.28	1070.54	329	674	20.87	16
4000	237	7.8	.003	20.2	17.2	885.85	83	14.53	1043.08	320	670	19.67	21
5000	253	5.2	.005	18.3	14.8	855.18	80	12.54	1014.51	302	668	16.87	25
6000	276	2.8	.005	17.1	11.8	825.39	71	10.35	984.40	282	666	13.86	29
7000	283	2.0	.001	15.5	3.2	796.44	45	5.96	957.76	250	663	7.94	31
8000	266	2.7	.002	13.2	4.2	768.29	54	6.26	930.99	246	661	8.28	33
9000	278	2.6	.001	11.5	3.1	740.96	56	5.82	903.41	237	659	7.65	34
10000	336	3.5	.005	10.3	-4.1	714.44	36	3.49	875.93	217	657	4.57	36
11000	356	5.1	.004	9.0	-7.3	688.74	31	2.71	848.72	206	655	3.52	37
12000	11	5.7	.003	7.3	-9.5	663.84	29	2.31	823.25	198	653	2.99	38
13000	24	7.1	.003	4.9	-11.6	639.66	29	1.96	800.14	191	651	2.52	38
14000	17	8.1	.002	2.4	-14.7	616.16	27	1.54	778.09	183	647	1.96	39
15000	6	9.7	.004	.5	-16.5	593.34	27	1.33	754.61	177	645	1.68	39
16000	2	11.6	.003	-1.8	-19.2	571.19	25	1.08	732.67	170	642	1.35	40
17000	357	12.3	.002	-3.4	-24.1	549.71	18	.70	709.45	163	640	.87	40
18000	359	12.4	.001	-5.7	-24.2	528.91	22	.70	688.43	158	638	.86	40
19000	360	12.9	.001	-7.6	-24.8	508.73	24	.67	667.06	153	635	.82	40
20000	353	13.7	.003	-9.5	-25.6	489.17	26	.63	646.12	148	633	.76	40
21000	348	14.4	.002	-11.8	-27.3	470.23	26	.54	626.44	143	630	.65	41
22000	348	15.8	.002	-13.5	-30.7	451.89	22	.39	606.13	138	628	.47	41
23000	349	16.8	.002	-16.1	-32.4	434.11	23	.34	588.07	133	625	.40	41
24000	350	18.6	.003	-17.5	-35.2	416.91	20	.26	568.04	128	623	.30	41
25000	352	21.0	.004	-20.2	-37.1	400.26	20	.21	551.17	124	620	.25	41
26000	354	21.7	.002	-22.6	-39.0	384.11	21	.18	534.06	120	617	.21	41
27000	354	18.6	.005	-25.0	-40.9	368.48	21	.15	517.24	116	614	.17	41
28000	353	15.4	.005	-27.8	-42.8	353.32	22	.12	501.52	113	611	.14	41
29000	352	13.4	.003	-30.5	-44.7	338.63	23	.10	486.21	109	607	.11	41
30000	351	12.0	.002	-33.1	-46.5	324.40	25	.08	470.77	105	604	.09	41
31000	352	10.1	.003	-36.0	-48.6	310.61	26	.07	456.24	102	600	.07	41
32000	357	9.4	.002	-38.4	-51.4	297.27	23	.05	441.06	99	597	.05	41
33000	353	9.1	.001	-40.8	-53.3	284.37	24	.04	426.32	95	594	.04	41
34000	339	8.7	.004	-43.4	-55.4	271.90	25	.03	412.27	92	591	.03	41
35000	325	10.8	.005	-46.0	-57.5	259.86	25	.02	398.50	89	588	.02	41
36000	328	17.2	.011	-48.3	-59.3	248.21	26	.02	384.64	86	584	.02	41
37000	333	23.9	.012	-49.4	-60.4	237.01	26	.02	369.09	82	583	.02	41
38000	338	28.3	.008	-52.0	-62.7	226.23	26	.01	356.43	79	580	.01	41
39000	342	27.2	.004	-54.9	-65.2	215.82	26	.01	344.57	77	576	.01	41
40000	342	23.9	.006	-57.1	-67.0	205.77	26	.01	331.76	74	573	.01	41
41000	335	21.6	.006	-58.6	-68.3	196.10	27	.01	318.44	71	571	.01	41
42000	321	23.6	.010	-60.3	99.9	186.84	999	99.99	305.78	68	569	.00999	
43000	316	29.5	.011	-61.7	99.9	177.94	999	99.99	293.13	65	567	.00999	
44000	314	32.9	.006	-63.1	99.9	169.41	999	99.99	281.02	63	565	.00999	
45000	314	34.0	.002	-65.1	99.9	161.23	999	99.99	270.02	60	562	.00999	
46000	316	32.7	.003	-66.2	99.9	153.39	999	99.99	258.23	58	561	.00999	
47000	321	29.5	.007	-67.4	99.9	145.88	999	99.99	247.06	55	559	.00999	
48000	319	26.8	.005	-68.2	99.9	138.71	999	99.99	235.82	53	558	.00999	
49000	313	27.2	.005	-68.4	99.9	131.88	999	99.99	224.37	50	558	.00999	

50000	309	29.8	.006	-68.2	99.9	125.39	999	99.99	213.11	47 558	.00999
51000	307	32.2	.004	-69.4	99.9	119.21	999	99.99	203.81	45 556	.00999
52000	307	34.2	.003	-69.6	99.9	113.30	999	99.99	193.96	43 556	.00999
53000	309	34.6	.002	-70.3	99.9	107.68	999	99.99	184.96	41 555	.00999
54000	312	32.0	.006	-71.1	99.9	102.32	999	99.99	176.44	39 554	.00999
55000	311	28.6	.006	-71.9	99.9	97.21	999	99.99	168.30	37 553	.00999
56000	306	26.5	.006	-72.5	99.9	92.33	999	99.99	160.31	36 552	.00999
57000	302	24.6	.004	-71.3	99.9	87.70	999	99.99	151.39	34 554	.00999
58000	302	21.9	.005	-71.6	99.9	83.32	999	99.99	143.98	32 553	.00999
59000	304	19.4	.004	-71.1	99.9	79.16	999	99.99	136.48	30 554	.00999
60000	300	15.1	.007	-70.2	99.9	75.22	999	99.99	129.14	29 555	.00999
61000	282	12.4	.009	-70.3	99.9	71.49	999	99.99	122.76	27 555	.00999
62000	272	14.0	.004	-71.1	99.9	67.93	999	99.99	117.15	26 554	.00999
63000	279	14.9	.003	-68.2	99.9	64.57	999	99.99	109.74	24 558	.00999
64000	295	13.9	.007	-65.7	99.9	61.41	999	99.99	103.12	23 561	.00999
65000	305	11.0	.006	-63.4	99.9	58.44	999	99.99	97.08	22 565	.00999
66000	312	7.8	.006	-62.1	99.9	55.65	999	99.99	91.84	20 566	.00999
67000	317	4.9	.005	-62.8	99.9	52.99	999	99.99	87.75	20 565	.00999
68000	358	3.4	.005	-61.4	99.9	50.46	999	99.99	83.00	18 567	.00999
69000	39	5.5	.006	-61.6	99.9	48.06	999	99.99	79.13	18 567	.00999
70000	44	7.2	.003	-60.7	99.9	45.77	999	99.99	75.04	17 568	.00999
71000	36	9.5	.004	-59.1	99.9	43.61	999	99.99	70.98	16 570	.00999
72000	38	13.3	.006	-59.0	99.9	41.56	999	99.99	67.59	15 570	.00999
73000	45	14.5	.004	-59.4	99.9	39.60	999	99.99	64.55	14 570	.00999
74000	55	11.4	.006	-58.7	99.9	37.74	999	99.99	61.31	14 571	.00999
75000	52	5.9	.009	-56.0	99.9	35.98	999	99.99	57.73	13 574	.00999
76000	51	3.0	.005	-54.7	99.9	34.31	999	99.99	54.72	12 576	.00999
77000	89	2.5	.003	-54.6	99.9	32.73	999	99.99	52.17	12 576	.00999
78000	102	3.1	.001	-54.2	99.9	31.22	999	99.99	49.69	11 577	.00999
79000	79	2.2	.002	-53.7	99.9	29.79	999	99.99	47.29	11 577	.00999
80000	33	4.3	.005	-52.4	99.9	28.42	999	99.99	44.86	10 579	.00999
81000	39	8.3	.007	-52.1	99.9	27.13	999	99.99	42.75	10 580	.00999
82000	52	11.8	.007	-51.5	99.9	25.89	999	99.99	40.70	9 580	.00999
83000	59	12.0	.003	-52.2	99.9	24.71	999	99.99	38.96	9 579	.00999
84000	68	10.6	.004	-52.4	99.9	23.59	999	99.99	37.23	8 579	.00999
85000	78	9.1	.004	-51.7	99.9	22.51	999	99.99	35.42	8 580	.00999
86000	84	9.0	.001	-51.0	99.9	21.49	999	99.99	33.70	8 581	.00999
87000	85	8.9	.000	-49.3	99.9	20.52	999	99.99	31.93	7 583	.00999
88000	81	9.4	.001	-47.4	99.9	19.60	999	99.99	30.25	7 586	.00999
89000	82	12.3	.005	-45.3	99.9	18.73	999	99.99	28.64	6 588	.00999
90000	90	15.7	.007	-44.5	99.9	17.90	999	99.99	27.28	6 589	.00999
91000	103	16.6	.006	-43.7	99.9	17.11	999	99.99	25.99	6 590	.00999
92000	125	14.7	.011	-42.1	99.9	16.37	999	99.99	24.68	5 592	.00999
93000	153	12.4	.012	-40.6	99.9	15.65	999	99.99	23.45	5 594	.00999
94000	182	11.1	.010	-38.9	99.9	14.98	999	99.99	22.28	5 597	.00999
95000	197	9.9	.005	-38.8	99.9	14.33	999	99.99	21.31	5 597	.00999
96000	210	8.4	.004	-38.4	99.9	13.72	999	99.99	20.36	5 597	.00999
97000	225	7.3	.004	-38.1	99.9	13.13	999	99.99	19.46	4 598	.00999
98000	234	7.6	.002	-39.3	99.9	12.57	999	99.99	18.72	4 596	.00999
99000	242	8.3	.002	-38.4	99.9	12.03	999	99.99	17.85	4 597	.00999
100000	248	8.0	.001	-36.3	99.9	11.51	999	99.99	16.93	4 600	.00999
101000	255	6.3	.003	-36.6	99.9	11.02	999	99.99	16.23	4 600	.00999
102000	243	5.2	.003	-35.3	99.9	10.55	999	99.99	15.46	3 601	.00999
103000	220	6.7	.005	-34.7	99.9	10.11	999	99.99	14.77	3 602	.00999
104000	209	8.4	.004	-34.8	99.9	9.68	999	99.99	14.15	3 602	.00999
105000	200	8.1	.002	-34.5	99.9	9.27	999	99.99	13.53	3 602	.00999
106000	180	7.3	.005	-34.5	99.9	8.88	999	99.99	12.97	3 602	.00999
107000	156	9.8	.007	-35.1	99.9	8.51	999	99.99	12.45	3 601	.00999
108000	999	999.0	.999	-34.6	99.9	8.15	999	99.99	11.90	3 602	.00999

TERMINATION 108243 GEOPFT 32992 GEOPM 7.8 MBS

TROPOPAUSE 47757 FEET 140.43 MB -68.3 C 99.9 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
499	274	9	26.0	23.1	1000.0	84
1988	239	9	25.2	20.1	950.0	73
3542	234	9	21.3	17.6	900.0	80
5163	256	5	18.2	14.2	850.0	78
6863	284	2	15.7	4.9	800.0	50
8650	269	3	12.1	2.3	750.0	51
10538	350	5	9.8	-6.6	700.0	31
12543	21	6	6.0	-10.8	650.0	29
14673	10	9	1.2	-16.1	600.0	26
16948	357	12	-3.4	-24.0	550.0	18
19396	357	13	-8.6	-24.6	500.0	26
22050	348	16	-13.8	-31.0	450.0	22
24950	352	21	-20.3	-37.1	400.0	20
28145	353	15	-28.3	-43.2	350.0	22
31699	356	9	-37.9	-50.9	300.0	24
35731	327	16	-48.2	-59.2	250.0	26
40455	340	22	-58.2	-68.0	200.0	27
43188	315	31	-62.1	99.9	175.0	999
46276	318	31	-67.0	99.9	150.0	999
49871	308	30	-68.2	99.9	125.0	999
54229	312	30	-71.7	99.9	100.0	999
58545	304	20	-71.1	99.9	80.0	999
61145	274	13	-71.3	99.9	70.0	999
64178	300	13	-64.9	99.9	60.0	999
67867	9	4	-60.9	99.9	50.0	999
72436	44	15	-59.2	99.9	40.0	999
78440	86	2	-53.8	99.9	30.0	999
82309	58	12	-52.1	99.9	25.0	999
87067	82	9	-48.3	99.9	20.0	999
93412	181	11	-38.9	99.9	15.0	999
102594	216	7	-34.7	99.9	10.0	999

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	270	6	29.5	23.9	1016.7	382	72
221	289	9	26.5	22.1	1009.6	372	77
707	263	9	25.7	23.9	992.9	382	90
1253	251	9	26.4	21.2	974.4	357	73
1795	241	9	25.7	20.5	956.4	349	73
2349	234	10	24.4	19.4	938.3	340	74
3921	236	8	20.4	17.3	888.3	320	83
4462	243	7	19.2	16.7	871.6	314	85
7259	281	2	15.0	-.5	789.1	239	35
7839	267	3	13.4	5.1	772.8	249	57
8982	277	3	11.5	3.2	741.4	237	56
9543	309	3	10.4	2.2	726.4	232	57
10052	338	4	10.3	-4.8	713.1	215	34
10613	351	5	9.7	-6.8	698.6	209	31
16743	357	12	-3.1	-23.6	555.2	164	19
17217	357	12	-3.6	-24.4	545.2	161	18
23836	349	18	-17.1	-34.9	419.7	129	19
35693	326	15	-48.1	-59.1	251.7	87	26
40542	340	22	-58.2	-68.0	200.5	72	27
45176	314	34	-65.5	99.9	159.8	60	999
47757	321	27	-68.3	99.9	140.4	53	999

52833	308	35	-70.4	99.9	108.6	42	999
54510	312	30	-71.8	99.9	99.7	38	999
56393	303	26	-72.7	99.9	90.5	35	999
61420	274	13	-71.3	99.9	70.0	27	999
65193	307	10	-62.8	99.9	57.9	21	999
71379	35	11	-58.4	99.9	42.8	15	999
73335	48	14	-59.7	99.9	39.0	14	999
75765	47	3	-54.8	99.9	34.7	12	999
84189	70	10	-52.5	99.9	23.4	8	999
92627	141	13	-40.9	99.9	15.9	5	999
93885	180	11	-38.9	99.9	15.1	5	999
102390	233	5	-34.5	99.9	10.4	3	999
108963	999	999	-34.9	99.9	7.8	3	999

TERMINATION
NNNN

K-19 Rawinsonde file (K19_0838.raw)

RS011911138 95191 120
RAWINSONDE DATA FROM PRIMARY WINDS SOURCE
TEST NBR E7587 WS6 1620
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
1138Z 10 JUL 95

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	170	3.0	.000	25.1	22.8	1014.80	87	20.17	1173.08	380	677	27.76	0
1000	254	14.6	.025	25.6	20.1	981.02	72	17.07	1133.60	353	677	23.53	6
2000	245	16.0	.005	23.5	17.5	947.65	69	14.63	1103.91	333	674	20.03	10
3000	232	18.0	.007	21.6	15.1	915.18	66	12.60	1074.00	315	672	17.14	14
4000	224	19.5	.005	19.8	13.9	883.61	69	11.75	1043.54	303	669	15.89	18
5000	218	20.0	.003	17.7	13.3	852.94	76	11.38	1014.88	295	667	15.28	22
6000	215	20.2	.002	15.8	10.8	823.09	73	9.75	986.61	279	665	13.00	25
7000	214	19.7	.001	13.7	6.4	794.08	61	7.28	959.93	258	662	9.63	27
8000	216	18.1	.003	12.4	-1.3	765.88	40	4.35	931.76	234	660	5.73	29
9000	218	15.9	.004	11.3	-10.5	738.56	21	2.10	903.39	214	658	2.76	30
10000	221	14.9	.002	9.4	-12.1	712.03	21	1.86	876.82	207	656	2.43	31
11000	226	16.4	.003	7.3	-10.5	686.27	27	2.14	851.23	203	653	2.77	31
12000	228	19.8	.006	5.4	-16.1	661.28	19	1.36	826.34	193	651	1.74	32
13000	228	22.4	.004	4.2	-16.7	637.07	20	1.30	799.31	186	650	1.67	32
14000	228	23.3	.001	1.6	-10.9	613.59	39	2.10	776.88	187	647	2.66	33
15000	226	23.4	.001	-.6	-10.7	590.79	46	2.16	753.84	182	644	2.72	33
16000	225	22.3	.002	-2.2	-14.9	568.69	37	1.54	730.33	173	642	1.93	34
17000	223	19.9	.004	-4.1	-19.2	547.27	30	1.09	707.97	165	640	1.35	34
18000	216	17.1	.006	-6.1	-24.0	526.51	23	.71	686.33	158	637	.88	35
19000	209	15.9	.004	-8.1	-26.2	506.39	22	.59	665.31	152	635	.72	35
20000	212	16.2	.001	-9.4	-30.2	486.91	17	.41	642.94	146	633	.50	35
21000	223	17.2	.006	-11.0	-31.8	468.09	16	.35	621.89	141	631	.42	35
22000	232	19.8	.007	-13.2	-33.6	449.87	16	.30	602.82	136	629	.35	35
23000	237	22.0	.005	-14.6	-29.3	432.23	30	.49	582.22	133	627	.58	35
24000	242	22.0	.004	-17.2	-23.0	415.17	60	.81	564.59	131	624	.96	35
25000	253	22.1	.007	-19.0	-37.6	398.64	18	.21	546.28	123	622	.24	36
26000	260	22.5	.005	-21.2	-39.5	382.64	17	.17	528.91	119	619	.19	36
27000	262	23.4	.002	-23.5	-41.2	367.15	18	.14	512.20	115	616	.16	36
28000	264	24.5	.002	-25.7	-43.0	352.16	18	.12	495.73	111	613	.13	36
29000	265	25.8	.002	-28.4	-44.5	337.64	19	.10	480.52	108	610	.11	36
30000	264	25.4	.001	-31.0	-44.2	323.58	26	.11	465.39	104	607	.12	36
31000	999	999.0	.999	-33.4	-45.2	309.96	29	.09	450.41	101	604	.10	36
32000	999	999.0	.999	-36.1	-48.5	296.77	26	.07	436.19	98	600	.07	36

TERMINATION 32186 GEOPFT 9810 GEOPM 293.1 MBS
TROPOPAUSE 0 FEET .00 MB .0 C .0 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
442	255	13	26.2	21.8	1000.0	77
1926	246	16	23.6	17.8	950.0	70
3472	228	19	20.8	14.8	900.0	68
5088	218	20	17.4	13.1	850.0	76
6782	214	20	14.1	7.4	800.0	64
8561	217	17	12.1	-8.0	750.0	24
10443	223	15	8.2	-9.5	700.0	28
12436	228	21	4.8	-17.6	650.0	18
14561	227	23	.2	-9.2	600.0	49
16833	223	20	-3.9	-18.6	550.0	31

19279	209	16	-8.6	-27.7	500.0	20
21938	232	20	-13.2	-33.6	450.0	16
24851	252	22	-18.9	-35.7	400.0	24
28069	265	25	-26.0	-43.2	350.0	18
31658	999	999	-35.6	-47.7	300.0	27

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	170	3	25.1	22.8	1014.8	380	87
219	255	13	25.9	23.1	1007.7	380	85
624	255	14	26.5	20.7	993.8	359	71
5024	218	20	17.6	13.3	852.2	295	76
5602	216	20	16.4	11.9	834.9	286	75
6153	214	20	15.5	10.4	818.6	277	72
8400	217	17	12.4	-6.9	754.9	222	25
10102	221	15	9.2	-12.3	709.4	206	20
10666	224	15	7.6	-7.9	694.8	208	32
11755	228	19	5.7	-15.0	667.4	195	21
12913	228	22	4.5	-17.4	639.2	186	18
14675	227	23	.0	-9.0	598.1	185	51
17708	219	18	-5.5	-23.6	532.5	159	22
19623	209	16	-9.0	-29.2	494.2	148	18
20871	221	17	-10.7	-31.5	470.5	141	16
22077	233	20	-13.4	-33.7	448.5	136	16
22693	236	22	-14.0	-34.5	437.6	133	16
23263	238	22	-15.2	-24.9	427.7	133	43
23825	241	22	-16.7	-22.5	418.1	132	60
24430	246	22	-18.4	-24.2	408.0	129	60
25014	253	22	-19.0	-37.9	398.4	123	17
25614	258	22	-20.3	-38.9	388.8	121	17
29671	265	26	-29.9	-44.6	328.2	105	22
31595	999	999	-35.2	-47.2	302.1	99	28
32282	999	999	-36.8	-49.4	293.1	97	25

TERMINATION
043 043
NNNN

K-21 Rawinsonde file (K21_6Nov.raw)

RS013100435
TEST NBR A1546 W8 R4 4380
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
0435Z 06 NOV 95

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	20	3.0	.000	17.3	15.0	1021.80	86	12.73	1217.84	348	666	17.07	0
1000	74	7.2	.010	20.6	15.6	987.17	73	13.07	1162.98	337	670	17.71	4
2000	82	5.8	.003	17.4	14.5	952.90	83	12.33	1135.17	328	667	16.52	8
3000	115	3.6	.006	14.4	13.7	919.48	95	11.82	1106.66	319	663	15.69	12
4000	225	.9	.007	12.0	11.2	886.91	95	10.12	1077.35	302	660	13.31	15
5000	304	8.0	.013	11.5	.5	855.27	48	4.96	1043.73	263	659	6.51	17
6000	298	16.3	.014	11.0	-7.1	824.70	27	2.73	1009.61	242	658	3.57	18
7000	289	20.4	.009	9.6	-10.4	795.06	23	2.15	978.35	231	656	2.80	19
8000	284	23.2	.006	7.5	1.7	766.35	67	5.35	948.05	245	654	6.93	20
9000	284	24.9	.003	6.8	2.9	738.58	76	5.83	915.56	241	653	7.53	22
10000	286	25.1	.002	5.0	.6	711.69	73	4.98	888.22	229	651	6.40	24
11000	288	25.0	.001	3.6	-3.4	685.64	60	3.72	860.81	215	649	4.75	25
12000	291	26.3	.003	1.6	-2.0	660.39	77	4.16	834.78	213	647	5.28	26
13000	297	29.3	.007	.0	-3.1	635.90	80	3.86	808.80	205	645	4.86	27
14000	303	32.7	.008	-.9	-5.2	612.22	72	3.29	781.50	195	644	4.14	28
15000	307	37.7	.009	-2.5	-7.3	589.30	70	2.84	756.96	187	642	3.54	29
16000	308	43.5	.010	-3.5	-14.4	567.14	43	1.61	731.72	174	641	2.00	30
17000	305	47.6	.008	-6.0	-13.1	545.67	57	1.80	710.39	170	638	2.22	30
18000	301	48.5	.006	-7.9	-13.7	524.82	63	1.73	688.23	165	635	2.12	31
19000	296	48.0	.007	-8.6	-16.7	504.70	52	1.36	663.86	157	634	1.66	31
20000	291	47.7	.007	-9.9	-25.3	485.26	27	.65	641.69	147	633	.79	32
21000	288	48.5	.004	-12.4	-26.5	466.44	29	.58	622.75	143	630	.70	32
22000	289	50.5	.003	-14.8	-27.0	448.18	34	.56	603.93	138	627	.66	32
23000	291	52.2	.004	-17.4	-26.8	430.48	44	.57	586.03	134	624	.68	32
24000	290	53.3	.002	-19.8	-30.8	413.30	37	.41	568.04	129	621	.48	32
25000	290	55.1	.003	-20.4	-40.2	396.72	15	.16	546.72	123	620	.18	32
26000	292	57.1	.004	-23.2	-42.3	380.69	15	.12	530.43	119	616	.14	32
27000	291	59.0	.003	-25.7	-43.7	365.15	17	.11	513.99	115	613	.12	33
28000	290	62.4	.006	-28.2	-44.8	350.10	18	.10	497.78	112	610	.11	33
29000	290	66.5	.007	-30.4	-41.2	335.54	34	.15	481.49	108	607	.16	33
30000	292	70.1	.007	-33.4	-40.6	321.43	48	.16	467.05	105	604	.17	33
31000	295	72.2	.006	-35.1	-47.2	307.78	29	.08	450.47	101	601	.09	33
32000	298	75.1	.008	-37.0	-53.6	294.63	16	.04	434.65	97	599	.04	33
33000	302	79.1	.011	-40.1	-56.7	281.90	15	.03	421.35	94	595	.03	33
34000	304	84.9	.011	-42.5	-58.7	269.59	15	.02	407.21	91	592	.02	33
35000	304	89.5	.008	-44.3	-60.1	257.70	15	.02	392.29	88	590	.02	33
36000	303	92.4	.005	-47.2	-62.2	246.24	16	.01	379.59	85	586	.01	33
37000	304	93.1	.001	-49.9	-64.2	235.14	16	.01	366.88	82	582	.01	33
38000	305	94.2	.004	-53.1	-66.7	224.41	17	.01	355.27	79	578	.01	33
39000	307	95.9	.006	-56.0	-69.0	214.03	18	.01	343.37	77	574	.01	33
40000	308	96.9	.004	-58.6	-71.2	204.01	18	.00	331.25	74	571	.00	33
41000	307	95.9	.003	-60.5	99.9	194.36	999	99.99	318.38	71	568	.00	999
42000	305	94.1	.007	-63.0	99.9	185.07	999	99.99	306.84	68	565	.00	999
43000	303	93.5	.006	-65.2	99.9	176.13	999	99.99	295.11	66	562	.00	999
44000	302	94.2	.003	-68.3	99.9	167.51	999	99.99	284.83	63	558	.00	999
45000	300	92.5	.006	-70.1	99.9	159.23	999	99.99	273.15	61	555	.00	999
46000	296	89.5	.011	-71.0	99.9	151.30	999	99.99	260.72	58	554	.00	999
47000	291	86.8	.014	-72.2	99.9	143.73	999	99.99	249.21	56	553	.00	999
48000	285	87.7	.015	-74.6	99.9	136.47	999	99.99	239.47	53	549	.00	999
49000	284	88.8	.003	-75.4	99.9	129.53	999	99.99	228.19	51	548	.00	999
50000	289	85.4	.014	-74.2	99.9	122.94	999	99.99	215.30	48	550	.00	999

51000	296	77.6	.022	-72.5	99.9	116.75	999	99.99	202.70	45	552	.00999
52000	302	66.4	.022	-72.6	99.9	110.88	999	99.99	192.58	43	552	.00999
53000	301	56.9	.016	-73.8	99.9	105.29	999	99.99	184.05	41	550	.00999
54000	293	48.7	.018	-74.7	99.9	99.96	999	99.99	175.51	39	549	.00999
55000	282	45.6	.016	-75.6	99.9	94.88	999	99.99	167.30	37	548	.00999
56000	275	46.0	.010	-74.7	99.9	90.05	999	99.99	158.07	35	549	.00999
57000	275	44.8	.002	-73.7	99.9	85.49	999	99.99	149.31	33	551	.00999
58000	284	40.7	.013	-68.4	99.9	81.22	999	99.99	138.21	31	558	.00999
59000	299	34.2	.020	-68.1	99.9	77.23	999	99.99	131.24	29	558	.00999
60000	310	26.9	.016	-69.5	99.9	73.42	999	99.99	125.62	28	556	.00999
61000	309	19.1	.013	-70.9	99.9	69.78	999	99.99	120.19	27	554	.00999
62000	294	13.7	.011	-71.3	99.9	66.30	999	99.99	114.41	25	554	.00999
63000	283	13.4	.004	-69.9	99.9	63.00	999	99.99	107.98	24	556	.00999
64000	287	13.7	.002	-68.7	99.9	59.89	999	99.99	102.03	23	557	.00999
65000	283	9.5	.007	-66.4	99.9	56.96	999	99.99	95.96	21	561	.00999
66000	261	5.5	.008	-65.5	99.9	54.19	999	99.99	90.90	20	562	.00999
67000	235	5.9	.004	-63.7	99.9	51.57	999	99.99	85.77	19	564	.00999
68000	235	6.4	.001	-62.2	99.9	49.10	999	99.99	81.09	18	566	.00999
69000	227	7.5	.003	-61.1	99.9	46.76	999	99.99	76.82	17	568	.00999
70000	237	7.0	.002	-60.8	99.9	44.54	999	99.99	73.07	16	568	.00999
71000	245	4.7	.004	-61.1	99.9	42.43	999	99.99	69.69	16	568	.00999
72000	249	2.0	.005	-60.8	99.9	40.41	999	99.99	66.29	15	568	.00999
73000	301	.5	.003	-58.8	99.9	38.51	999	99.99	62.59	14	571	.00999
74000	304	1.5	.002	-57.5	99.9	36.70	999	99.99	59.30	13	572	.00999
75000	313	1.9	.001	-57.1	99.9	34.99	999	99.99	56.42	13	573	.00999
76000	353	.8	.002	-57.2	99.9	33.36	999	99.99	53.80	12	573	.00999
77000	114	2.9	.006	-57.0	99.9	31.80	999	99.99	51.25	11	573	.00999
78000	131	6.6	.007	-55.8	99.9	30.32	999	99.99	48.61	11	575	.00999
79000	140	5.4	.003	-54.6	99.9	28.92	999	99.99	46.11	10	576	.00999
80000	105	.3	.009	-52.7	99.9	27.59	999	99.99	43.61	10	579	.00999
81000	358	3.0	.005	-52.1	99.9	26.33	999	99.99	41.50	9	580	.00999
82000	42	4.4	.005	-52.2	99.9	25.13	999	99.99	39.64	9	579	.00999
83000	59	5.9	.004	-51.6	99.9	23.99	999	99.99	37.72	8	580	.00999
84000	63	9.7	.007	-50.4	99.9	22.90	999	99.99	35.82	8	582	.00999
85000	66	15.1	.009	-49.3	99.9	21.87	999	99.99	34.03	8	583	.00999
86000	71	19.8	.008	-48.0	99.9	20.89	999	99.99	32.32	7	585	.00999
87000	73	24.3	.008	-46.5	99.9	19.96	999	99.99	30.67	7	587	.00999
88000	73	28.3	.007	-46.1	99.9	19.07	999	99.99	29.26	7	587	.00999
89000	71	30.6	.004	-45.8	99.9	18.22	999	99.99	27.93	6	588	.00999
90000	71	30.3	.000	-46.2	99.9	17.42	999	99.99	26.73	6	587	.00999
91000	78	28.8	.006	-46.8	99.9	16.64	999	99.99	25.61	6	586	.00999
92000	87	27.4	.008	-46.3	99.9	15.90	999	99.99	24.43	5	587	.00999
93000	95	25.9	.007	-46.8	99.9	15.20	999	99.99	23.39	5	586	.00999
94000	97	23.4	.004	-46.1	99.9	14.52	999	99.99	22.28	5	587	.00999
95000	94	21.5	.004	-45.4	99.9	13.88	999	99.99	21.23	5	588	.00999
96000	999	999.0	.999	-45.3	99.9	13.26	999	99.99	20.28	5	588	.00999
97000	999	999.0	.999	-44.9	99.9	12.68	999	99.99	19.35	4	589	.00999

TERMINATION 96472 GEOPFT 29405 GEOPM 12.6 MBS
TROPOPAUSE 48292 FEET 134.41 MB -75.0 C 99.9 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
631	73	7	21.6	16.3	1000.0	72
2083	84	6	17.1	14.5	950.0	85
3589	149	2	12.9	12.0	900.0	95
5161	303	10	11.7	-2.4	850.0	39
6819	290	20	9.7	-9.2	800.0	26
8569	283	24	7.0	3.5	750.0	78
10425	287	25	4.4	-1.4	700.0	66

12395	294	27	.8	-2.2	650.0	80
14498	305	35	-1.8	-6.5	600.0	70
16758	306	47	-5.5	-13.5	550.0	53
19193	295	48	-9.1	-17.9	500.0	49
21845	289	50	-14.5	-27.1	450.0	33
24734	290	55	-20.3	-38.5	400.0	18
27929	290	62	-28.2	-44.8	350.0	18
31494	296	74	-36.1	-51.9	300.0	18
35556	303	92	-46.2	-61.5	250.0	16
40275	308	97	-59.5	99.9	200.0	999
42978	302	94	-65.6	99.9	175.0	999
46000	295	89	-71.1	99.9	150.0	999
49492	287	87	-75.0	99.9	125.0	999
53776	293	49	-74.7	99.9	100.0	999
58055	288	39	-68.1	99.9	80.0	999
60673	309	20	-70.8	99.9	70.0	999
63677	287	14	-68.7	99.9	60.0	999
67315	236	6	-62.5	99.9	50.0	999
71860	252	1	-60.2	99.9	40.0	999
77823	133	6	-55.5	99.9	30.0	999
81675	46	5	-52.3	99.9	25.0	999
86466	73	24	-46.6	99.9	20.0	999
92737	97	25	-46.6	99.9	15.0	999

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	20	3	17.3	15.0	1021.8	348	86
212	69	7	22.8	18.7	1014.8	358	78
603	73	7	21.7	16.4	1001.0	343	72
2261	87	5	16.5	14.5	944.1	326	88
2832	106	4	15.0	14.3	925.0	322	96
3219	131	3	13.7	12.9	912.3	314	95
3786	166	2	12.5	11.6	893.8	305	94
4362	290	2	11.2	10.5	875.3	298	95
4907	304	7	11.4	2.1	858.2	267	53
5437	303	12	12.0	-7.0	841.8	246	26
6564	293	19	10.0	-7.2	807.9	238	29
7195	287	21	9.4	-11.8	789.4	228	21
7779	284	23	7.7	.6	772.6	244	61
8420	283	24	7.1	3.8	754.6	247	79
10239	287	25	4.7	-.4	705.4	226	69
10850	288	25	3.8	-3.4	689.5	216	59
12122	292	27	1.3	-1.7	657.4	213	80
13309	299	30	-.4	-3.6	628.5	202	79
15163	307	39	-2.8	-7.5	585.6	186	70
15775	308	42	-2.9	-14.5	572.1	174	40
16980	305	48	-5.9	-13.1	546.1	170	56
17577	303	48	-7.7	-13.2	533.6	168	64
18827	297	48	-8.3	-15.9	508.1	158	54
19419	294	48	-9.4	-18.8	496.5	154	46
20052	291	48	-9.9	-25.9	484.3	147	26
22524	290	51	-16.1	-26.8	438.8	136	39
23149	291	52	-17.8	-26.8	427.9	134	45
23838	290	53	-19.7	-29.1	416.1	131	43
25000	290	55	-20.4	-40.2	396.7	123	15
28194	290	63	-28.6	-45.0	347.2	111	19
29530	291	68	-32.0	-40.6	328.0	107	42
30150	293	71	-33.9	-40.6	319.4	105	50
31469	296	73	-35.8	-51.4	301.6	99	18
32212	298	76	-37.5	-54.4	291.9	96	15

33451	303	82	-41.2	-57.7	276.3	93	15
39694	308	97	-57.9	-70.6	207.0	75	18
44086	301	94	-68.5	99.9	166.8	63	999
47611	287	87	-74.1	99.9	139.3	54	999
48292	284	88	-75.0	99.9	134.4	53	999
51395	299	74	-72.4	99.9	114.4	44	999
54101	292	48	-74.8	99.9	99.4	39	999
54944	282	46	-75.6	99.9	95.2	37	999
57254	276	44	-73.7	99.9	84.4	33	999
57933	283	41	-68.5	99.9	81.5	31	999
61194	307	17	-71.2	99.9	69.1	27	999
67784	237	6	-62.3	99.9	49.6	18	999
76743	102	2	-57.3	99.9	32.2	12	999
87133	73	25	-46.2	99.9	19.8	7	999
97059	999	999	-44.9	99.9	12.6	4	999

TERMINATION
020 020
NNNN

K-15 Rawinsonde file (K15_2103.raw)

TEST NBR SITE: 900 OP NO: W3999 ASC NO: 208
900
BLDG 900, VANDENBERG AFB, CALIF.
RAWINSONDE MSS/WIN 9.0 15.2 23
2103Z 5 DEC 1995 991.14 3 305
ASCENT NBR 208

ALT	DIR	SPD	TEMP	DEWPT	PRESS	RH	ABH	DENSITY	IR	SOS	S	I
368.0	0.0	8.0	17.8	11.2	1002.90	65.0	0.0	1200.82	0.0	0.0	1	9
422.0	13.0	10.0	16.9	11.0	1000.97	68.0	0.0	1199.56	0.0	0.0	1	0
493.0	7.1	9.2	15.8	10.8	998.45	72.0	0.0	1197.90	0.0	0.0	1	9
572.0	358.0	10.0	15.6	11.2	995.63	74.8	0.0	1195.23	0.0	0.0	1	0
668.0	341.0	13.0	15.3	11.6	992.21	78.3	0.0	1191.99	0.0	0.0	1	0
716.0	346.0	16.1	15.2	11.8	990.50	80.0	0.0	1190.37	0.0	0.0	2	9
821.0	346.0	20.9	17.9	13.4	986.77	75.0	0.0	1174.16	0.0	0.0	2	9
1024.0	353.0	19.2	18.2	12.8	979.71	71.1	0.0	1164.67	0.0	0.0	2	0
1188.0	0.0	16.3	18.5	12.4	974.03	67.9	0.0	1157.06	0.0	0.0	2	0
1393.0	16.7	16.6	18.8	11.8	966.99	63.9	0.0	1147.62	0.0	0.0	2	9
1516.0	25.0	19.8	18.7	11.7	962.78	63.6	0.0	1142.92	0.0	0.0	2	0
1680.0	17.0	14.2	18.6	11.5	957.20	63.1	0.0	1136.67	0.0	0.0	2	0
1844.0	41.0	16.3	18.6	11.3	951.65	62.6	0.0	1130.46	0.0	0.0	2	0
2008.0	11.0	11.1	18.5	11.1	946.13	62.2	0.0	1124.29	0.0	0.0	2	0
2518.0	25.7	17.3	18.2	10.5	929.18	60.7	0.0	1105.31	0.0	0.0	2	9
3629.0	360.0	15.5	16.7	7.1	893.14	53.2	0.0	1068.88	0.0	0.0	4	9
4768.0	355.5	14.9	14.0	5.4	857.38	55.9	0.0	1036.09	0.0	0.0	4	9
5884.0	346.3	14.3	13.6	1.8	823.55	44.6	0.0	997.35	0.0	0.0	4	9
6470.0	331.5	14.6	12.1	2.6	806.24	52.0	0.0	981.27	0.0	0.0	4	9
6927.0	318.5	14.4	11.7	-2.5	792.98	37.0	0.0	967.48	0.0	0.0	4	9
7889.0	306.9	12.5	9.9	-4.6	765.60	35.6	0.0	940.28	0.0	0.0	4	9
8921.0	289.7	10.3	8.6	-5.6	737.13	35.9	0.0	909.58	0.0	0.0	4	9
10041.0	279.7	9.4	5.8	-5.7	707.24	43.4	0.0	881.37	0.0	0.0	4	9

TERMINATION AT 10200

RS011152310
TEST NBR A1756 RS9B 0630
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
2310Z 24 APR 96

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	360	3.0	.000	20.5	17.0	1018.80	81	14.33	1199.95	353	670	19.42	0
1000	14	13.7	.018	17.5	16.4	983.99	94	13.94	1171.05	345	667	18.69	4
2000	11	11.4	.004	16.4	15.4	949.62	94	13.11	1134.73	333	666	17.52	8
3000	333	8.0	.012	15.4	14.4	916.30	94	12.36	1098.68	320	664	16.45	12
4000	286	10.2	.013	14.6	13.1	884.08	91	11.33	1063.61	306	663	15.04	16
5000	278	13.1	.006	12.7	11.1	852.83	90	10.02	1033.27	292	661	13.22	19
6000	279	15.8	.005	10.9	9.3	822.47	90	8.94	1003.38	279	659	11.71	22
7000	278	18.4	.004	9.3	7.2	793.02	87	7.79	973.45	265	657	10.16	24
8000	279	20.7	.004	7.5	5.4	764.43	86	6.95	944.61	254	655	9.00	27
9000	278	21.6	.002	5.3	2.2	736.68	80	5.58	918.27	240	652	7.17	28
10000	277	19.3	.004	3.3	-2.4	709.70	68	4.14	891.91	225	649	5.27	30
11000	999	999.0	.999	4.8	-16.0	683.65	20	1.36	856.17	199	650	1.75	31

TERMINATION 11574 GEOPFT 3528 GEOPM 668.6 MBS
TROPOPAUSE 0 FEET .00 MB .0 C .0 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
544	11	14	18.8	16.5	1000.0	87
1986	11	11	16.4	15.4	950.0	94
3496	301	9	15.3	13.8	900.0	91
5083	278	13	12.5	11.0	850.0	91
6748	279	18	9.8	7.6	800.0	86
8501	279	21	6.5	3.5	750.0	81
10348	278	18	3.8	-10.0	700.0	39

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	360	3	20.5	17.0	1018.8	353	81
198	2	13	20.0	16.7	1012.3	350	81
1134	15	14	17.1	16.4	979.3	344	96
3238	314	8	15.6	14.3	908.5	317	92
7721	279	20	8.0	6.6	772.3	259	91
8845	278	22	5.7	2.5	740.9	241	80
9396	277	21	4.3	1.4	725.9	236	81
9939	277	20	3.2	-1.1	711.3	227	73
10482	279	18	3.9	-12.4	697.0	207	29
11023	999	999	4.8	-16.2	683.1	199	20
11597	999	999	3.5	-16.1	668.6	196	22

TERMINATION
100 100
NNNN
TERMINATION 11574 GEOPFT 3528 GEOPM 668.6 MBS
TROP

K-16 Rawinsonde file (K16_2310.raw)

RS011152310
TEST NBR A1756 RS9B 0630
RAWINSONDE MSS/MSS
CAPE CANAVERAL AFS, FLORIDA
2310Z 24 APR 96

ALT GEOMFT	DIR DEG	SPD KTS	SHR /SEC	TEMP DEG C	DPT DEG C	PRESS MBS	RH PCT	ABHUM G/M3	DENSITY G/M3	I/R N	V/S KTS	VPS MBS	PW MM
16	360	3.0	.000	20.5	17.0	1018.80	81	14.33	1199.95	353	670	19.42	0
1000	14	13.7	.018	17.5	16.4	983.99	94	13.94	1171.05	345	667	18.69	4
2000	11	11.4	.004	16.4	15.4	949.62	94	13.11	1134.73	333	666	17.52	8
3000	333	8.0	.012	15.4	14.4	916.30	94	12.36	1098.68	320	664	16.45	12
4000	286	10.2	.013	14.6	13.1	884.08	91	11.33	1063.61	306	663	15.04	16
5000	278	13.1	.006	12.7	11.1	852.83	90	10.02	1033.27	292	661	13.22	19
6000	279	15.8	.005	10.9	9.3	822.47	90	8.94	1003.38	279	659	11.71	22
7000	278	18.4	.004	9.3	7.2	793.02	87	7.79	973.45	265	657	10.16	24
8000	279	20.7	.004	7.5	5.4	764.43	86	6.95	944.61	254	655	9.00	27
9000	278	21.6	.002	5.3	2.2	736.68	80	5.58	918.27	240	652	7.17	28
10000	277	19.3	.004	3.3	-2.4	709.70	68	4.14	891.91	225	649	5.27	30
11000	999	999.0	.999	4.8	-16.0	683.65	20	1.36	856.17	199	650	1.75	31

TERMINATION 11574 GEOPFT 3528 GEOPM 668.6 MBS
TROPOPAUSE 0 FEET .00 MB .0 C .0 C

MANDATORY LEVELS

GEOPFT	DIR	KTS	TEMP	DPT	PRESS	RH
544	11	14	18.8	16.5	1000.0	87
1986	11	11	16.4	15.4	950.0	94
3496	301	9	15.3	13.8	900.0	91
5083	278	13	12.5	11.0	850.0	91
6748	279	18	9.8	7.6	800.0	86
8501	279	21	6.5	3.5	750.0	81
10348	278	18	3.8	-10.0	700.0	39

SIGNIFICANT LEVELS

GEOMFT	DIR	KTS	TEMP	DPT	PRESS	IR	RH
16	360	3	20.5	17.0	1018.8	353	81
198	2	13	20.0	16.7	1012.3	350	81
1134	15	14	17.1	16.4	979.3	344	96
3238	314	8	15.6	14.3	908.5	317	92
7721	279	20	8.0	6.6	772.3	259	91
8845	278	22	5.7	2.5	740.9	241	80
9396	277	21	4.3	1.4	725.9	236	81
9939	277	20	3.2	-1.1	711.3	227	73
10482	279	18	3.9	-12.4	697.0	207	29
11023	999	999	4.8	-16.2	683.1	199	20
11597	999	999	3.5	-16.1	668.6	196	22

TERMINATION
100 100
NNNN
TERMINATION 11574 GEOPFT 3528 GEOPM 668.6 MBS
TROP

K-22 Rawinsonde file (K22_2117.raw)

TEST NBR SITE: 1764   OP NO: W7788   ASC NO: 125
1764
BLDG 1764, VANDENBERG AFB, CALIF.
RAWINSONDE MSS/WIN
2117Z 12 MAY 1996
ASCENT NBR 125

ALT	DIR	SPD	TEMP	DEWPT	PRESS	RH	ABSHUM	DEN	IR	SOS
329.	290.	5.	19.4	10.7	1001.80	57.	.0952	1192.94	322.	667.
400.	305.	7.	18.1	9.6	999.27	58.	.0895	1193.44	319.	666.
600.	310.	9.	16.6	9.9	992.17	65.	.0913	1187.51	320.	665.
800.	299.	7.	15.2	9.5	985.09	69.	.0892	1184.60	318.	663.
1000.	289.	6.	15.5	9.7	978.05	69.	.0906	1175.05	317.	664.
1200.	293.	6.	18.8	9.2	971.11	54.	.0867	1153.65	309.	668.
1400.	312.	9.	23.5	11.0	964.29	45.	.0959	1126.66	308.	673.
1600.	324.	12.	24.5	9.4	957.61	39.	.0860	1115.57	299.	674.
1800.	326.	12.	25.4	8.1	950.99	34.	.0791	1105.01	293.	675.
2000.	328.	13.	26.2	6.9	944.42	29.	.0722	1094.55	286.	676.
2200.	330.	13.	26.3	6.1	937.90	27.	.0681	1086.84	282.	676.
2400.	331.	13.	26.1	5.4	931.44	27.	.0652	1080.28	279.	676.
2600.	333.	13.	25.9	4.8	925.01	26.	.0624	1073.77	276.	675.
2800.	334.	13.	25.6	4.1	918.62	25.	.0597	1067.44	273.	675.
3000.	335.	13.	25.3	3.5	912.25	24.	.0573	1061.32	270.	675.
3200.	336.	12.	25.0	2.9	905.93	24.	.0549	1055.23	268.	674.
3400.	337.	12.	24.7	2.2	899.65	23.	.0526	1049.17	265.	674.
3600.	338.	11.	24.4	1.6	893.42	22.	.0502	1043.15	262.	673.
3800.	340.	11.	24.0	.9	887.23	22.	.0478	1037.16	259.	673.
4000.	341.	10.	23.6	.5	881.05	22.	.0462	1031.50	257.	672.
4200.	344.	9.	23.1	.2	874.89	22.	.0453	1026.08	256.	672.
4400.	347.	9.	22.6	-.1	868.77	22.	.0444	1020.70	254.	671.
4600.	350.	8.	22.1	-.4	862.70	22.	.0435	1015.34	252.	671.
4800.	355.	7.	21.6	-.7	856.67	22.	.0426	1010.00	250.	670.
5000.	360.	6.	21.1	-1.1	850.68	23.	.0417	1004.70	249.	669.
5200.	4.	6.	20.6	-1.2	844.70	23.	.0412	999.27	247.	669.
5400.	7.	5.	20.1	-1.4	838.74	23.	.0408	993.78	246.	668.
5600.	11.	5.	19.7	-1.5	832.82	24.	.0405	988.33	245.	668.
5800.	16.	4.	19.2	-1.6	826.94	24.	.0402	982.90	243.	667.
6000.	22.	4.	18.8	-1.8	821.10	25.	.0399	977.50	242.	667.
6200.	30.	3.	18.3	-1.9	815.31	25.	.0396	972.14	240.	666.
6400.	33.	3.	18.0	-2.5	809.53	25.	.0381	966.30	238.	666.
6600.	29.	2.	17.9	-3.5	803.78	23.	.0357	960.09	235.	666.
6800.	24.	2.	17.7	-4.5	798.06	22.	.0333	953.93	233.	665.
7000.	14.	1.	17.5	-5.5	792.39	21.	.0309	947.81	230.	665.
7200.	354.	1.	17.4	-6.6	786.76	19.	.0285	941.72	227.	665.
7400.	315.	1.	17.2	-7.6	781.17	18.	.0261	935.67	224.	665.
7600.	280.	1.	17.0	-8.3	775.61	17.	.0243	929.77	222.	665.
7800.	266.	2.	16.7	-8.6	770.07	17.	.0238	924.15	220.	664.
8000.	260.	2.	16.4	-8.9	764.56	17.	.0234	918.56	219.	664.
8200.	256.	3.	16.1	-9.2	759.10	17.	.0229	913.00	217.	663.
8400.	254.	3.	15.8	-9.5	753.68	17.	.0224	907.48	216.	663.
8600.	252.	4.	15.4	-9.7	748.29	17.	.0219	901.99	214.	663.
8800.	251.	4.	15.1	-10.0	742.94	17.	.0215	896.46	213.	662.
9000.	250.	5.	14.9	-10.1	737.60	17.	.0213	890.73	211.	662.
9200.	249.	5.	14.7	-10.3	732.30	17.	.0210	885.04	210.	662.
9400.	248.	5.	14.5	-10.4	727.03	17.	.0208	879.39	209.	662.
9600.	247.	5.	14.2	-10.6	721.81	17.	.0206	873.77	207.	661.
9800.	246.	5.	14.0	-10.7	716.62	17.	.0203	868.19	206.	661.
10000.	246.	5.	13.8	-10.9	711.47	17.	.0201	862.64	204.	661.
10200.	245.	6.	13.3	-11.1	706.32	17.	.0198	857.79	203.	660.
10400.	245.	6.	12.7	-11.3	701.20	18.	.0195	853.27	202.	660.

10600.	245.	6.	12.2	-11.5	696.12	18.	.0192	848.77	201.	659.
10800.	245.	6.	11.6	-11.7	691.07	18.	.0189	844.30	200.	658.
11000.	245.	6.	11.1	-12.0	686.06	19.	.0187	839.85	199.	658.
11200.	245.	6.	10.5	-12.2	681.09	19.	.0184	835.42	197.	657.
11400.	246.	6.	10.0	-12.4	676.13	19.	.0181	830.89	196.	656.
11600.	246.	6.	9.5	-12.7	671.17	19.	.0177	826.12	195.	656.
11800.	247.	6.	9.1	-12.9	666.25	20.	.0174	821.37	194.	655.
12000.	247.	7.	8.6	-13.2	661.37	20.	.0170	816.64	193.	655.
12200.	248.	7.	8.2	-13.5	656.52	20.	.0167	811.95	191.	654.
12400.	248.	7.	7.7	-13.7	651.70	20.	.0163	807.28	190.	654.
12600.	249.	7.	7.3	-14.0	646.92	20.	.0160	802.64	189.	653.
12800.	248.	7.	6.8	-14.3	642.13	20.	.0156	798.17	188.	653.
13000.	248.	7.	6.3	-14.7	637.37	21.	.0152	793.74	186.	652.
13200.	248.	7.	5.8	-15.0	632.64	21.	.0149	789.32	185.	651.
13400.	248.	7.	5.2	-15.3	627.95	21.	.0145	784.93	184.	651.
13600.	248.	7.	4.7	-15.6	623.30	21.	.0141	780.57	183.	650.
13800.	248.	7.	4.2	-15.9	618.68	21.	.0138	776.23	182.	650.
14000.	248.	7.	3.7	-16.3	614.06	22.	.0134	771.97	180.	649.
14200.	247.	7.	3.1	-16.7	609.45	22.	.0130	767.78	179.	648.
14400.	246.	6.	2.5	-17.0	604.87	22.	.0127	763.61	178.	648.
14600.	245.	6.	2.0	-17.4	600.33	22.	.0123	759.46	177.	647.
14800.	244.	6.	1.4	-17.8	595.82	22.	.0120	755.34	176.	646.
15000.	243.	6.	.8	-18.1	591.35	23.	.0116	751.24	175.	646.
15200.	242.	6.	.3	-18.5	586.91	23.	.0112	747.16	174.	645.
15400.	242.	6.	-.3	-18.6	582.45	24.	.0112	742.98	173.	644.
15600.	241.	6.	-.8	-18.7	578.02	24.	.0111	738.82	172.	644.
15800.	241.	6.	-1.4	-18.8	573.62	25.	.0111	734.68	171.	643.
16000.	240.	6.	-1.9	-18.8	569.26	26.	.0110	730.56	170.	642.
16200.	240.	6.	-2.5	-18.9	564.92	27.	.0110	726.46	169.	642.
16400.	240.	6.	-3.0	-19.0	560.62	28.	.0109	722.39	168.	641.
16600.	240.	6.	-3.6	-19.1	556.34	29.	.0108	718.36	167.	640.
16800.	242.	6.	-4.2	-19.3	552.05	30.	.0107	714.40	166.	640.
17000.	243.	6.	-4.8	-19.5	547.79	31.	.0105	710.47	165.	639.
17200.	245.	5.	-5.4	-19.7	543.57	31.	.0104	706.55	164.	638.
17400.	248.	5.	-6.0	-19.9	539.37	32.	.0102	702.66	163.	637.
17600.	250.	5.	-6.5	-20.1	535.22	33.	.0101	698.78	162.	637.
17800.	253.	5.	-7.1	-20.3	531.08	34.	.0099	694.92	161.	636.
18000.	256.	5.	-7.7	-20.4	526.93	35.	.0098	690.95	160.	635.
18200.	259.	4.	-8.3	-20.6	522.81	36.	.0097	687.00	159.	635.
18400.	263.	4.	-8.8	-20.7	518.72	38.	.0096	683.08	159.	634.
18600.	266.	4.	-9.4	-20.9	514.66	39.	.0095	679.17	158.	633.
18800.	270.	4.	-9.9	-21.0	510.64	40.	.0094	675.29	157.	633.
19000.	274.	4.	-10.5	-21.1	506.64	41.	.0093	671.43	156.	632.
19200.	278.	4.	-11.0	-21.3	502.67	42.	.0092	667.57	155.	631.
19400.	279.	4.	-11.5	-22.1	498.69	41.	.0087	663.47	154.	631.
19600.	280.	4.	-12.0	-22.9	494.74	40.	.0081	659.39	152.	630.
19800.	282.	5.	-12.4	-23.7	490.81	38.	.0076	655.34	151.	630.
20000.	283.	5.	-12.9	-24.5	486.92	37.	.0071	651.32	150.	629.
20200.	284.	5.	-13.3	-25.4	483.06	36.	.0066	647.32	149.	629.
20400.	284.	5.	-13.8	-26.2	479.23	34.	.0061	643.34	147.	628.
20600.	284.	5.	-14.2	-26.9	475.42	33.	.0056	639.29	146.	627.
20800.	282.	5.	-14.6	-27.7	471.61	32.	.0053	635.05	145.	627.
21000.	280.	5.	-14.9	-28.4	467.84	31.	.0050	630.84	144.	627.
21200.	278.	6.	-15.3	-29.2	464.09	29.	.0047	626.66	143.	626.
21400.	276.	6.	-15.6	-29.9	460.37	28.	.0044	622.50	142.	626.
21600.	275.	6.	-16.0	-30.7	456.68	27.	.0040	618.38	141.	625.
21800.	273.	6.	-16.3	-31.4	453.02	26.	.0037	614.28	139.	625.
22000.	270.	6.	-16.7	-32.1	449.37	25.	.0035	610.25	138.	624.
22200.	266.	7.	-17.1	-32.8	445.74	24.	.0033	606.30	137.	624.
22400.	262.	7.	-17.5	-33.5	442.13	23.	.0031	602.37	136.	623.

22600.	259.	7.	-17.9	-34.1	438.55	23.	.0029	598.47	135.	623.
22800.	256.	8.	-18.3	-34.8	435.00	22.	.0027	594.59	134.	622.
23000.	253.	8.	-18.8	-35.5	431.48	21.	.0025	590.74	133.	622.
23200.	250.	8.	-19.2	-36.2	427.99	20.	.0023	586.91	132.	621.
23400.	248.	9.	-19.6	-36.6	424.50	20.	.0022	583.09	131.	621.
23600.	245.	9.	-20.0	-37.1	421.02	20.	.0021	579.28	131.	620.
23800.	243.	9.	-20.4	-37.6	417.58	20.	.0021	575.50	130.	620.
24000.	241.	10.	-20.8	-38.1	414.16	19.	.0020	571.75	129.	619.
24200.	239.	10.	-21.3	-38.5	410.77	19.	.0019	568.02	128.	619.
24400.	238.	11.	-21.7	-39.0	407.41	19.	.0018	564.31	127.	618.
24600.	236.	11.	-22.1	-39.5	404.08	19.	.0017	560.63	126.	618.
24800.	234.	11.	-22.5	-39.8	400.74	19.	.0016	556.96	125.	617.
25000.	232.	12.	-23.0	-40.1	397.42	19.	.0016	553.32	124.	617.
25200.	231.	12.	-23.4	-40.5	394.13	19.	.0015	549.70	124.	616.
25400.	229.	12.	-23.8	-40.8	390.87	19.	.0015	546.10	123.	616.
25600.	227.	12.	-24.3	-41.2	387.64	19.	.0014	542.53	122.	615.
25800.	226.	13.	-24.7	-41.5	384.43	19.	.0014	538.98	121.	614.
26000.	224.	13.	-25.1	-41.8	381.24	19.	.0013	535.45	120.	614.
26200.	223.	13.	-25.6	-42.1	378.04	20.	.0013	531.92	119.	613.
26400.	221.	14.	-26.0	-42.3	374.88	20.	.0013	528.42	119.	613.
26600.	220.	14.	-26.5	-42.6	371.74	20.	.0012	524.94	118.	612.
26800.	219.	14.	-26.9	-42.8	368.62	20.	.0012	521.48	117.	612.
27000.	217.	15.	-27.4	-43.1	365.54	21.	.0012	518.05	116.	611.
27200.	216.	15.	-27.8	-43.4	362.48	21.	.0011	514.64	115.	611.
27400.	215.	15.	-28.3	-43.7	359.43	21.	.0011	511.33	115.	610.
27600.	215.	16.	-28.9	-44.0	356.37	21.	.0011	508.18	114.	609.
27800.	216.	16.	-29.4	-44.4	353.35	22.	.0010	505.06	113.	609.
28000.	216.	17.	-30.0	-44.7	350.35	22.	.0010	501.95	113.	608.
28200.	216.	17.	-30.6	-45.1	347.37	23.	.0010	498.87	112.	607.
28400.	216.	18.	-31.2	-45.4	344.42	23.	.0009	495.80	111.	606.
28600.	216.	18.	-31.7	-45.8	341.50	23.	.0009	492.75	110.	606.
28800.	216.	19.	-32.3	-46.2	338.57	23.	.0009	489.67	110.	605.
29000.	217.	20.	-32.9	-46.6	335.64	24.	.0008	486.59	109.	604.
29200.	218.	20.	-33.4	-47.0	332.75	24.	.0008	483.53	108.	604.
29400.	218.	21.	-34.0	-47.5	329.88	24.	.0007	480.48	108.	603.
29600.	219.	22.	-34.5	-47.9	327.03	24.	.0007	477.46	107.	602.
29800.	219.	23.	-35.1	-48.3	324.21	24.	.0007	474.45	106.	601.
30000.	220.	23.	-35.7	-48.8	321.41	24.	.0006	471.47	105.	601.
30200.	220.	24.	-36.2	-49.2	318.61	24.	.0006	468.41	105.	600.
30400.	220.	25.	-36.7	-49.6	315.82	25.	.0006	465.30	104.	599.
30600.	220.	25.	-37.2	-50.0	313.05	25.	.0006	462.22	103.	599.
30800.	220.	26.	-37.7	-50.4	310.31	25.	.0005	459.16	103.	598.
31000.	220.	27.	-38.2	-50.8	307.59	25.	.0005	456.12	102.	597.
31200.	219.	27.	-38.7	-51.2	304.90	25.	.0005	453.10	101.	597.
31400.	219.	28.	-39.2	-51.6	302.22	25.	.0005	450.10	101.	596.
31600.	220.	28.	-39.7	-52.0	299.55	25.	.0004	446.90	100.	596.
31800.	220.	28.	-40.1	-52.4	296.89	25.	.0004	443.70	99.	595.
32000.	220.	29.	-40.5	-52.7	294.25	25.	.0004	440.52	98.	595.
32200.	221.	29.	-40.9	-53.1	291.64	25.	.0004	437.37	98.	594.
32400.	221.	29.	-41.3	-53.5	289.05	25.	.0004	434.24	97.	594.
32600.	221.	29.	-41.7	-53.8	286.49	25.	.0004	431.13	96.	593.
32800.	221.	29.	-42.1	-54.2	283.94	25.	.0003	428.07	96.	593.
33000.	222.	29.	-42.5	-54.6	281.39	25.	.0003	425.09	95.	592.
33200.	223.	29.	-43.0	-55.0	278.86	25.	.0003	422.13	94.	591.
33400.	223.	30.	-43.5	-55.4	276.36	25.	.0003	419.18	94.	591.
33600.	224.	30.	-43.9	-55.8	273.87	25.	.0003	416.26	93.	590.
33800.	224.	30.	-44.4	-56.2	271.41	25.	.0003	413.36	92.	590.
34000.	225.	30.	-44.9	-56.6	268.97	25.	.0003	410.50	92.	589.
34200.	225.	30.	-45.4	-57.1	266.52	25.	.0002	407.76	91.	588.
34400.	225.	31.	-46.0	-57.6	264.10	25.	.0002	405.03	90.	588.

34600.	225.	31.	-46.5	-58.0	261.69	25.	.0002	402.32	90.	587.
34800.	225.	32.	-47.1	-58.5	259.31	25.	.0002	399.63	89.	586.
35000.	225.	32.	-47.6	-58.9	256.95	25.	.0002	396.96	89.	585.
35200.	224.	33.	-48.2	-59.4	254.61	26.	.0002	394.30	88.	585.
35400.	224.	33.	-48.7	-59.8	252.27	26.	.0002	391.50	87.	584.
35600.	224.	33.	-49.1	-60.2	249.94	26.	.0002	388.62	87.	583.
35800.	224.	33.	-49.5	-60.5	247.63	26.	.0002	385.77	86.	583.
36000.	224.	34.	-49.9	-60.9	245.34	26.	.0002	382.94	85.	582.
36200.	224.	34.	-50.4	-61.2	243.08	26.	.0001	380.12	85.	582.
36400.	224.	34.	-50.8	-61.6	240.83	26.	.0001	377.33	84.	581.
36600.	224.	34.	-51.2	-62.0	238.61	26.	.0001	374.56	84.	581.
36800.	224.	35.	-51.7	-62.3	236.38	26.	.0001	371.81	83.	580.
37000.	224.	35.	-52.1	-62.7	234.17	26.	.0001	369.08	82.	580.
37200.	225.	35.	-52.6	-63.1	231.98	26.	.0001	366.37	82.	579.
37400.	225.	35.	-53.0	-63.5	229.81	26.	.0001	363.68	81.	578.
37600.	226.	35.	-53.5	-63.9	227.66	26.	.0001	361.01	81.	578.
37800.	226.	35.	-53.9	-64.3	225.53	26.	.0001	358.36	80.	577.
38000.	226.	35.	-54.4	-64.7	223.40	26.	.0001	355.73	79.	577.
38200.	226.	35.	-54.8	-65.1	221.28	26.	.0001	353.12	79.	576.
38400.	227.	36.	-55.3	-65.5	219.19	26.	.0001	350.52	78.	575.
38600.	227.	36.	-55.8	-65.9	217.12	26.	.0001	347.95	78.	575.
38800.	227.	36.	-56.2	-66.3	215.06	26.	.0001	345.40	77.	574.
39000.	227.	36.	-56.7	-66.7	213.02	26.	.0001	342.83	76.	574.
39200.	227.	36.	-57.1	-67.0	210.98	26.	.0001	340.19	76.	573.
39400.	227.	36.	-57.5	-67.4	208.96	27.	.0001	337.57	75.	572.
39600.	226.	37.	-57.9	-67.7	206.96	27.	.0001	334.97	75.	572.
39800.	226.	37.	-58.3	-68.1	204.98	27.	.0001	332.39	74.	571.
40000.	226.	37.	-58.7	-68.4	203.02	27.	.0001	329.83	74.	571.
40200.	226.	37.	-59.1	-68.8	201.07	27.	.0001	327.28	73.	570.
40400.	226.	37.	-59.3	-69.0	199.13	27.	.0001	324.46	72.	570.
40600.	227.	37.	-59.6	-69.2	197.21	27.	.0001	321.67	72.	570.
40800.	227.	37.	-59.8	-69.3	195.30	27.	.0000	318.90	71.	569.
41000.	227.	38.	-60.0	-69.5	193.41	27.	.0000	316.15	70.	569.
41200.	228.	38.	-60.2	-69.7	191.55	27.	.0000	313.43	70.	569.
41400.	229.	38.	-60.4	-69.9	189.69	27.	.0000	310.69	69.	569.
41600.	230.	37.	-60.6	-70.0	187.85	27.	.0000	307.87	69.	568.
41800.	231.	37.	-60.7	-70.2	186.03	27.	.0000	305.07	68.	568.
42000.	233.	37.	-60.8	-70.3	184.23	27.	.0000	302.30	67.	568.
42200.	234.	37.	-61.0	-70.4	182.44	27.	.0000	299.55	67.	568.
42400.	236.	37.	-61.1	-70.5	180.67	27.	.0000	296.84	66.	568.
42600.	236.	36.	-61.4	-70.8	178.90	27.	.0000	294.30	66.	567.
42800.	237.	36.	-61.6	-71.0	177.16	27.	.0000	291.77	65.	567.
43000.	238.	35.	-61.9	-71.2	175.43	27.	.0000	289.27	64.	567.
43200.	239.	35.	-62.1	-71.4	173.72	27.	.0000	286.79	64.	566.
43400.	240.	34.	-62.4	-71.6	172.03	27.	.0000	284.33	63.	566.
43600.	240.	34.	-62.6	-71.8	170.35	27.	.0000	281.85	63.	566.
43800.	240.	34.	-62.5	-71.7	168.68	27.	.0000	278.93	62.	566.
44000.	239.	34.	-62.3	-71.6	167.04	27.	.0000	276.05	62.	566.
44200.	239.	33.	-62.2	-71.5	165.40	27.	.0000	273.20	61.	566.
44400.	238.	33.	-62.1	-71.4	163.79	27.	.0000	270.37	60.	566.
44600.	238.	33.	-62.0	-71.3	162.19	27.	.0000	267.57	60.	566.
44800.	237.	33.	-61.9	-71.2	160.61	27.	.0000	264.86	59.	567.
45000.	236.	33.	-61.9	-71.2	159.04	27.	.0000	262.27	58.	567.
45200.	236.	33.	-61.9	-71.2	157.49	27.	.0000	259.72	58.	567.
45400.	235.	34.	-61.9	-71.2	155.95	27.	.0000	257.18	57.	567.
45600.	235.	34.	-61.9	-71.2	154.43	27.	.0000	254.68	57.	567.
45800.	234.	34.	-61.9	-71.2	152.92	27.	.0000	252.19	56.	567.
46000.	234.	34.	-62.0	-71.3	151.43	27.	.0000	249.81	56.	566.
46200.	234.	34.	-62.1	-71.4	149.95	27.	.0000	247.47	55.	566.
46400.	235.	35.	-62.1	-71.5	148.49	27.	.0000	245.16	55.	566.

46600.	235.	35.	-62.2	-71.6	147.04	27.	.0000	242.87	54.	566.
46800.	235.	35.	-62.3	-71.7	145.60	27.	.0000	240.60	54.	566.
47000.	236.	35.	-62.4	-71.7	144.18	27.	.0000	238.32	53.	566.
47200.	236.	35.	-62.3	-71.6	142.78	27.	.0000	235.89	53.	566.
47400.	236.	34.	-62.2	-71.6	141.38	27.	.0000	233.47	52.	566.
47600.	236.	34.	-62.1	-71.5	140.00	27.	.0000	231.09	52.	566.
47800.	237.	34.	-62.0	-71.4	138.64	26.	.0000	228.72	51.	566.
48000.	237.	33.	-61.9	-71.3	137.28	26.	.0000	226.39	50.	567.
48200.	237.	33.	-61.8	-71.3	135.94	26.	.0000	224.08	50.	567.
48400.	236.	33.	-61.8	-71.3	134.62	26.	.0000	221.94	49.	567.
48600.	236.	33.	-61.9	-71.3	133.31	26.	.0000	219.81	49.	567.
48800.	235.	33.	-61.9	-71.4	132.01	26.	.0000	217.70	49.	567.
49000.	234.	33.	-61.9	-71.4	130.72	26.	.0000	215.62	48.	566.
49200.	233.	33.	-62.0	-71.4	129.44	26.	.0000	213.55	48.	566.
49400.	232.	33.	-62.0	-71.5	128.18	26.	.0000	211.52	47.	566.
49600.	232.	33.	-62.1	-71.6	126.93	26.	.0000	209.54	47.	566.
49800.	231.	34.	-62.2	-71.6	125.69	26.	.0000	207.58	46.	566.
50000.	231.	34.	-62.3	-71.7	124.46	26.	.0000	205.64	46.	566.
50200.	230.	35.	-62.4	-71.8	123.25	26.	.0000	203.71	45.	566.
50400.	230.	35.	-62.5	-71.9	122.04	26.	.0000	201.81	45.	566.
50600.	230.	35.	-62.3	-71.7	120.86	26.	.0000	199.70	45.	566.
50800.	230.	35.	-62.0	-71.5	119.68	26.	.0000	197.47	44.	566.
51000.	230.	36.	-61.7	-71.2	118.51	26.	.0000	195.26	44.	567.
51200.	230.	36.	-61.4	-71.0	117.36	26.	.0000	193.08	43.	567.
51400.	231.	36.	-61.1	-70.7	116.22	26.	.0000	190.92	43.	568.
51600.	231.	36.	-60.8	-70.4	115.09	26.	.0000	188.79	42.	568.
51800.	231.	36.	-60.7	-70.4	113.97	26.	.0000	186.87	42.	568.
52000.	231.	35.	-60.9	-70.6	112.86	26.	.0000	185.23	41.	568.
52200.	232.	34.	-61.1	-70.7	111.77	26.	.0000	183.61	41.	568.
52400.	232.	33.	-61.3	-70.9	110.68	26.	.0000	182.00	41.	567.
52600.	232.	33.	-61.5	-71.1	109.61	26.	.0000	180.40	40.	567.
52800.	232.	32.	-61.7	-71.3	108.54	26.	.0000	178.82	40.	567.
53000.	232.	31.	-61.8	-71.4	107.48	26.	.0000	177.17	40.	567.
53200.	231.	30.	-61.9	-71.5	106.44	26.	.0000	175.53	39.	567.
53400.	230.	29.	-62.0	-71.6	105.40	26.	.0000	173.90	39.	566.
53600.	229.	28.	-62.1	-71.7	104.37	26.	.0000	172.29	38.	566.
53800.	228.	27.	-62.2	-71.8	103.35	26.	.0000	170.69	38.	566.
54000.	227.	26.	-62.3	-71.9	102.34	26.	.0000	169.13	38.	566.
54200.	226.	26.	-62.6	-72.1	101.34	26.	.0000	167.65	37.	566.
54400.	225.	25.	-62.8	-72.3	100.35	26.	.0000	166.19	37.	565.
54600.	224.	25.	-63.0	-72.5	99.37	26.	.0000	164.74	37.	565.
54800.	223.	24.	-63.3	-72.7	98.39	26.	.0000	163.31	36.	565.
55000.	221.	24.	-63.5	-72.9	97.43	26.	.0000	161.88	36.	564.
55200.	220.	23.	-63.7	-73.1	96.47	26.	.0000	160.47	36.	564.
55400.	220.	23.	-64.0	-73.3	95.52	26.	.0000	159.08	35.	564.
55600.	220.	22.	-64.2	-73.5	94.58	26.	.0000	157.70	35.	563.
55800.	219.	22.	-64.5	-73.7	93.65	26.	.0000	156.33	35.	563.
56000.	219.	21.	-64.7	-74.0	92.73	26.	.0000	154.97	35.	563.
56200.	219.	21.	-64.9	-74.2	91.81	26.	.0000	153.63	34.	562.
56400.	218.	20.	-65.2	-74.4	90.91	26.	.0000	152.29	34.	562.
56600.	218.	19.	-65.2	-74.4	90.01	26.	.0000	150.80	34.	562.
56800.	217.	19.	-65.2	-74.4	89.11	26.	.0000	149.32	33.	562.
57000.	217.	18.	-65.2	-74.5	88.23	26.	.0000	147.85	33.	562.
57200.	216.	17.	-65.3	-74.5	87.36	26.	.0000	146.40	33.	562.
57400.	216.	16.	-65.3	-74.5	86.49	26.	.0000	144.96	32.	562.
57600.	215.	15.	-65.3	-74.6	85.64	26.	.0000	143.54	32.	562.
57800.	213.	15.	-65.5	-74.7	84.79	26.	.0000	142.26	32.	562.
58000.	212.	14.	-65.7	-74.9	83.95	26.	.0000	141.00	31.	561.
58200.	210.	13.	-66.0	-75.1	83.11	26.	.0000	139.75	31.	561.
58400.	207.	13.	-66.2	-75.3	82.29	26.	.0000	138.50	31.	561.

58600.	205.	12.	-66.4	-75.5	81.47	26.	.0000	137.27	31.	561.
58800.	202.	11.	-66.5	-75.6	80.66	26.	.0000	135.99	30.	560.
59000.	199.	11.	-66.5	-75.6	79.86	26.	.0000	134.64	30.	560.
59200.	195.	10.	-66.5	-75.6	79.06	26.	.0000	133.31	30.	560.
59400.	190.	10.	-66.6	-75.6	78.28	26.	.0000	132.00	29.	560.
59600.	186.	9.	-66.6	-75.6	77.50	26.	.0000	130.70	29.	560.
59800.	180.	9.	-66.6	-75.6	76.72	26.	.0000	129.41	29.	560.
60000.	175.	9.	-66.8	-75.8	75.96	26.	.0000	128.24	29.	560.
60200.	170.	8.	-67.0	-76.0	75.20	26.	.0000	127.10	28.	560.
60400.	164.	8.	-67.3	-76.2	74.45	26.	.0000	125.96	28.	559.
60600.	158.	8.	-67.5	-76.4	73.70	26.	.0000	124.84	28.	559.
60800.	151.	8.	-67.7	-76.6	72.97	26.	.0000	123.73	28.	559.
61000.	145.	8.	-67.9	-76.9	72.24	26.	.0000	122.63	27.	558.
61200.	141.	8.	-68.0	-76.9	71.51	26.	.0000	121.42	27.	558.
61400.	137.	9.	-67.9	-76.9	70.80	26.	.0000	120.18	27.	558.
61600.	134.	9.	-67.9	-76.8	70.09	26.	.0000	118.94	27.	558.
61800.	131.	9.	-67.8	-76.8	69.39	26.	.0000	117.72	26.	559.
62000.	128.	10.	-67.8	-76.8	68.69	26.	.0000	116.51	26.	559.
62200.	126.	10.	-67.7	-76.7	68.00	26.	.0000	115.32	26.	559.
62400.	125.	10.	-67.7	-76.7	67.32	26.	.0000	114.17	25.	559.
62600.	125.	10.	-67.8	-76.8	66.65	26.	.0000	113.05	25.	559.
62800.	125.	11.	-67.8	-76.8	65.98	26.	.0000	111.93	25.	559.
63000.	125.	11.	-67.8	-76.8	65.32	26.	.0000	110.83	25.	559.
63200.	125.	11.	-67.9	-76.8	64.67	26.	.0000	109.74	24.	559.
63400.	125.	11.	-67.9	-76.9	64.02	26.	.0000	108.66	24.	558.
63600.	124.	11.	-67.9	-76.8	63.38	26.	.0000	107.56	24.	558.
63800.	124.	11.	-67.9	-76.8	62.74	26.	.0000	106.48	24.	558.
64000.	123.	11.	-67.8	-76.8	62.11	26.	.0000	105.40	24.	559.
64200.	122.	11.	-67.8	-76.8	61.49	26.	.0000	104.34	23.	559.
64400.	122.	11.	-67.8	-76.8	60.88	26.	.0000	103.28	23.	559.
64600.	121.	11.	-67.8	-76.8	60.27	26.	.0000	102.24	23.	559.
64800.	121.	12.	-67.8	-76.7	59.66	26.	.0000	101.20	23.	559.
65000.	121.	12.	-67.7	-76.7	59.07	26.	.0000	100.17	22.	559.
65200.	120.	13.	-67.7	-76.7	58.47	26.	.0000	99.15	22.	559.
65400.	120.	13.	-67.7	-76.7	57.89	26.	.0000	98.14	22.	559.
65600.	120.	14.	-67.6	-76.6	57.31	26.	.0000	97.14	22.	559.
65800.	120.	14.	-67.5	-76.5	56.74	26.	.0000	96.12	21.	559.
66000.	120.	14.	-67.3	-76.4	56.17	26.	.0000	95.08	21.	559.
66200.	120.	15.	-67.2	-76.3	55.61	26.	.0000	94.06	21.	559.
66400.	120.	15.	-67.0	-76.1	55.06	26.	.0000	93.05	21.	560.
66600.	120.	15.	-66.9	-76.0	54.51	26.	.0000	92.05	21.	560.
66800.	120.	16.	-66.7	-75.9	53.96	26.	.0000	91.06	20.	560.
67000.	119.	16.	-66.7	-75.9	53.42	26.	.0000	90.17	20.	560.
67200.	118.	16.	-66.8	-76.0	52.89	26.	.0000	89.30	20.	560.
67400.	117.	15.	-66.8	-76.0	52.37	26.	.0000	88.43	20.	560.
67600.	116.	15.	-66.9	-76.0	51.84	26.	.0000	87.56	20.	560.
67800.	114.	15.	-66.9	-76.1	51.33	26.	.0000	86.71	19.	560.
68000.	113.	15.	-67.0	-76.1	50.82	26.	.0000	85.87	19.	560.
68200.	111.	15.	-66.8	-76.0	50.31	25.	.0000	84.95	19.	560.
68400.	109.	15.	-66.6	-75.8	49.81	25.	.0000	84.00	19.	560.
68600.	107.	14.	-66.3	-75.5	49.32	25.	.0000	83.05	19.	561.
68800.	104.	14.	-66.0	-75.3	48.83	25.	.0000	82.12	18.	561.
69000.	101.	14.	-65.8	-75.1	48.34	25.	.0000	81.20	18.	561.
69200.	99.	14.	-65.5	-74.8	47.86	25.	.0000	80.29	18.	562.
69400.	96.	14.	-65.2	-74.6	47.39	25.	.0000	79.40	18.	562.
69600.	93.	14.	-65.0	-74.4	46.92	25.	.0000	78.54	18.	562.
69800.	89.	14.	-64.8	-74.2	46.46	25.	.0000	77.68	17.	563.
70000.	86.	14.	-64.6	-74.0	46.00	25.	.0000	76.84	17.	563.
70200.	83.	14.	-64.4	-73.9	45.55	25.	.0000	76.00	17.	563.
70400.	79.	14.	-64.2	-73.7	45.10	25.	.0000	75.17	17.	564.

70600.	78.	14.	-63.9	-73.5	44.65	25.	.0000	74.35	17.	564.
70800.	77.	14.	-63.6	-73.2	44.22	25.	.0000	73.53	16.	564.
71000.	76.	14.	-63.4	-73.0	43.78	25.	.0000	72.71	16.	565.
71200.	75.	14.	-63.1	-72.8	43.36	25.	.0000	71.91	16.	565.
71400.	74.	14.	-62.8	-72.6	42.93	25.	.0000	71.11	16.	565.
71600.	73.	14.	-62.6	-72.3	42.51	25.	.0000	70.33	16.	566.
71800.	73.	14.	-62.2	-72.1	42.10	25.	.0000	69.53	16.	566.
72000.	75.	14.	-61.8	-71.7	41.69	25.	.0000	68.72	15.	567.
72200.	77.	14.	-61.4	-71.3	41.28	25.	.0000	67.92	15.	567.
72400.	78.	14.	-61.0	-71.0	40.88	25.	.0000	67.12	15.	568.
72600.	80.	14.	-60.5	-70.6	40.49	25.	.0000	66.34	15.	568.
72800.	82.	14.	-60.1	-70.3	40.10	24.	.0000	65.56	15.	569.
73000.	84.	14.	-59.7	-69.9	39.71	24.	.0000	64.79	14.	570.
73200.	85.	14.	-59.3	-69.6	39.33	24.	.0000	64.08	14.	570.
73400.	87.	14.	-59.0	-69.4	38.95	24.	.0000	63.37	14.	570.
73600.	88.	14.	-58.7	-69.2	38.58	24.	.0001	62.68	14.	571.
73800.	90.	14.	-58.4	-68.9	38.21	24.	.0001	61.99	14.	571.
74000.	92.	13.	-58.1	-68.7	37.84	24.	.0001	61.31	14.	572.
74200.	94.	13.	-57.8	-68.4	37.48	24.	.0001	60.64	14.	572.
74400.	94.	13.	-57.7	-68.4	37.12	24.	.0001	60.03	13.	572.
74600.	94.	13.	-57.7	-68.3	36.77	24.	.0001	59.44	13.	572.
74800.	94.	13.	-57.6	-68.3	36.42	24.	.0001	58.85	13.	572.
75000.	94.	13.	-57.5	-68.2	36.07	24.	.0001	58.27	13.	572.
75200.	94.	13.	-57.4	-68.2	35.73	23.	.0001	57.69	13.	573.
75400.	93.	12.	-57.3	-68.2	35.39	23.	.0001	57.12	13.	573.
75600.	94.	12.	-57.3	-68.2	35.05	23.	.0001	56.58	13.	573.
75800.	95.	12.	-57.4	-68.3	34.71	23.	.0001	56.06	13.	573.
76000.	96.	11.	-57.5	-68.4	34.38	23.	.0001	55.55	12.	572.
76200.	97.	11.	-57.6	-68.5	34.06	23.	.0001	55.05	12.	572.
76400.	98.	11.	-57.8	-68.6	33.73	23.	.0001	54.55	12.	572.
76600.	99.	10.	-57.9	-68.7	33.41	23.	.0001	54.06	12.	572.
76800.	101.	10.	-58.0	-68.8	33.09	23.	.0001	53.57	12.	572.
77000.	102.	9.	-57.9	-68.7	32.78	23.	.0001	53.03	12.	572.
77200.	104.	9.	-57.6	-68.5	32.46	23.	.0001	52.47	12.	572.
77400.	106.	8.	-57.4	-68.3	32.16	23.	.0001	51.91	12.	573.
77600.	109.	8.	-57.1	-68.1	31.85	23.	.0001	51.36	11.	573.
77800.	112.	7.	-56.9	-67.9	31.55	23.	.0001	50.81	11.	573.
78000.	116.	6.	-56.6	-67.7	31.25	23.	.0001	50.27	11.	574.
78200.	118.	6.	-56.5	-67.5	30.95	23.	.0001	49.75	11.	574.
78400.	118.	6.	-56.3	-67.5	30.66	23.	.0001	49.26	11.	574.
78600.	118.	5.	-56.2	-67.4	30.37	23.	.0001	48.77	11.	574.
78800.	117.	5.	-56.1	-67.3	30.08	23.	.0001	48.28	11.	574.
79000.	117.	4.	-56.0	-67.3	29.79	22.	.0001	47.80	11.	574.
79200.	116.	4.	-55.9	-67.2	29.51	22.	.0001	47.33	11.	575.
79400.	116.	3.	-55.8	-67.1	29.23	22.	.0001	46.86	10.	575.
79600.	113.	3.	-55.7	-67.0	28.96	22.	.0001	46.38	10.	575.
79800.	108.	3.	-55.5	-66.9	28.68	22.	.0001	45.91	10.	575.
80000.	104.	3.	-55.3	-66.7	28.41	22.	.0001	45.44	10.	575.
80200.	99.	3.	-55.1	-66.6	28.15	22.	.0001	44.97	10.	576.
80400.	93.	3.	-55.0	-66.4	27.88	22.	.0001	44.51	10.	576.
80600.	88.	3.	-54.8	-66.3	27.62	22.	.0001	44.06	10.	576.
80800.	82.	3.	-54.6	-66.2	27.36	22.	.0001	43.61	10.	576.
81000.	77.	3.	-54.4	-66.0	27.10	22.	.0001	43.16	10.	577.
81200.	72.	3.	-54.2	-65.9	26.85	22.	.0001	42.72	10.	577.
81400.	68.	3.	-54.1	-65.7	26.60	22.	.0001	42.29	9.	577.
81600.	65.	4.	-53.9	-65.6	26.35	22.	.0001	41.85	9.	577.
81800.	62.	4.	-53.7	-65.5	26.10	22.	.0001	41.42	9.	578.
82000.	60.	5.	-53.5	-65.3	25.86	22.	.0001	41.00	9.	578.
82200.	58.	5.	-53.3	-65.2	25.61	21.	.0001	40.59	9.	578.
82400.	58.	5.	-53.2	-65.2	25.38	21.	.0001	40.19	9.	578.

82600.	57.	5.	-53.1	-65.1	25.14	21.	.0001	39.80	9.	578.
82800.	57.	6.	-53.0	-65.0	24.90	21.	.0001	39.41	9.	578.
83000.	57.	6.	-52.9	-65.0	24.67	21.	.0001	39.02	9.	579.
83200.	57.	6.	-52.8	-64.9	24.44	21.	.0001	38.64	9.	579.
83400.	56.	7.	-52.7	-64.8	24.21	21.	.0001	38.26	9.	579.
83600.	57.	7.	-52.6	-64.8	23.99	21.	.0001	37.89	9.	579.
83800.	58.	7.	-52.5	-64.7	23.77	21.	.0001	37.51	8.	579.
84000.	59.	7.	-52.3	-64.6	23.54	21.	.0001	37.14	8.	579.
84200.	60.	7.	-52.2	-64.5	23.33	21.	.0001	36.78	8.	579.
84400.	61.	6.	-52.1	-64.4	23.11	21.	.0001	36.41	8.	580.
84600.	62.	6.	-52.0	-64.4	22.89	21.	.0001	36.06	8.	580.
84800.	63.	6.	-51.9	-64.3	22.68	20.	.0001	35.70	8.	580.
85000.	65.	6.	-51.7	-64.2	22.47	20.	.0001	35.35	8.	580.
85200.	66.	6.	-51.5	-64.1	22.26	20.	.0001	34.99	8.	580.
85400.	68.	5.	-51.4	-64.0	22.06	20.	.0001	34.65	8.	581.
85600.	71.	5.	-51.2	-63.8	21.85	20.	.0001	34.30	8.	581.
85800.	73.	5.	-51.1	-63.7	21.65	20.	.0001	33.96	8.	581.
86000.	76.	4.	-50.9	-63.6	21.45	20.	.0001	33.62	8.	581.
86200.	79.	4.	-50.8	-63.5	21.25	20.	.0001	33.29	8.	581.
86400.	82.	4.	-50.8	-63.6	21.06	20.	.0001	32.99	7.	581.
86600.	85.	4.	-50.9	-63.6	20.86	20.	.0001	32.69	7.	581.
86800.	88.	4.	-50.9	-63.7	20.67	20.	.0001	32.39	7.	581.
87000.	91.	3.	-50.9	-63.7	20.48	20.	.0001	32.10	7.	581.
87200.	95.	3.	-51.0	-63.8	20.29	20.	.0001	31.80	7.	581.
87400.	99.	3.	-51.0	-63.8	20.10	20.	.0001	31.52	7.	581.
87600.	103.	3.	-51.0	-63.8	19.92	20.	.0001	31.22	7.	581.
87800.	107.	3.	-50.8	-63.7	19.73	20.	.0001	30.91	7.	581.
88000.	110.	3.	-50.7	-63.6	19.55	20.	.0001	30.61	7.	581.
88200.	113.	4.	-50.5	-63.5	19.37	19.	.0001	30.30	7.	582.
88400.	116.	4.	-50.3	-63.4	19.19	19.	.0001	30.00	7.	582.
88600.	118.	4.	-50.2	-63.2	19.02	19.	.0001	29.71	7.	582.
88800.	120.	4.	-50.0	-63.1	18.84	19.	.0001	29.41	7.	582.
89000.	123.	4.	-49.9	-63.0	18.67	19.	.0001	29.12	7.	582.
89200.	126.	5.	-49.9	-63.0	18.50	19.	.0001	28.86	7.	582.
89400.	128.	5.	-49.9	-63.0	18.33	19.	.0001	28.59	6.	582.
89600.	131.	5.	-49.9	-63.1	18.16	19.	.0001	28.33	6.	582.
89800.	133.	5.	-49.9	-63.1	17.99	19.	.0001	28.07	6.	582.
90000.	135.	6.	-49.9	-63.1	17.82	19.	.0001	27.81	6.	582.
90200.	137.	6.	-49.9	-63.1	17.66	19.	.0001	27.55	6.	582.
90400.	138.	6.	-49.9	-63.1	17.50	19.	.0001	27.30	6.	582.
90600.	140.	6.	-49.8	-63.0	17.34	19.	.0001	27.03	6.	583.
90800.	142.	6.	-49.7	-63.0	17.18	19.	.0001	26.77	6.	583.
91000.	144.	7.	-49.5	-62.9	17.02	19.	.0001	26.51	6.	583.
91200.	146.	7.	-49.4	-62.8	16.87	19.	.0001	26.26	6.	583.
91400.	148.	7.	-49.3	-62.7	16.71	19.	.0001	26.00	6.	583.
91600.	150.	7.	-49.2	-62.7	16.56	19.	.0001	25.75	6.	583.
91800.	152.	7.	-49.1	-62.6	16.41	19.	.0001	25.50	6.	584.
92000.	154.	7.	-48.9	-62.5	16.26	19.	.0001	25.25	6.	584.
92200.	155.	7.	-48.8	-62.3	16.11	19.	.0001	25.00	6.	584.
92400.	157.	8.	-48.6	-62.2	15.96	19.	.0001	24.76	6.	584.
92600.	159.	8.	-48.5	-62.1	15.81	19.	.0001	24.52	6.	584.
92800.	161.	8.	-48.3	-62.0	15.67	19.	.0001	24.28	6.	585.
93000.	162.	8.	-48.2	-61.9	15.53	19.	.0001	24.04	5.	585.
93200.	164.	8.	-48.0	-61.7	15.39	18.	.0001	23.80	5.	585.
93400.	166.	8.	-47.9	-61.6	15.25	18.	.0001	23.57	5.	585.
93600.	168.	8.	-47.7	-61.5	15.11	18.	.0001	23.33	5.	585.
93800.	170.	9.	-47.5	-61.3	14.97	18.	.0001	23.10	5.	586.
94000.	172.	9.	-47.3	-61.2	14.83	18.	.0001	22.87	5.	586.
94200.	174.	9.	-47.1	-61.0	14.70	18.	.0001	22.65	5.	586.
94400.	176.	9.	-47.0	-60.9	14.57	18.	.0002	22.42	5.	586.

94600.	999.	999.	-46.7	-60.7	14.43	18.	.0002	22.20	5.	587.
94800.	999.	999.	-46.4	-60.5	14.30	18.	.0002	21.97	5.	587.
95000.	999.	999.	-46.2	-60.3	14.17	18.	.0002	21.75	5.	587.
95200.	999.	999.	-45.9	-60.1	14.05	18.	.0002	21.52	5.	588.
95400.	999.	999.	-45.6	-59.8	13.92	18.	.0002	21.30	5.	588.
95600.	999.	999.	-45.4	-59.6	13.79	18.	.0002	21.09	5.	588.
95800.	999.	999.	-45.1	-59.4	13.67	18.	.0002	20.87	5.	589.

EOF

APPENDIX C

REEDM Output Files
for
K-23 using
γ = .64, .57, and .50

----- PROGRAM OPTIONS -----

MODEL		CONCENTRATION
RUN TYPE		RESEARCH
WIND-FIELD TERRAIN EFFECTS MODEL		NONE
LAUNCH VEHICLE		TITAN IV
LAUNCH TYPE		NORMAL
LAUNCH COMPLEX NUMBER		40
TURBULENCE PARAMETERS ARE DETERMINED FROM		CLIMATOLOGICAL DATA
SURFACE CHEMISTRY MODEL		absorption coefficient
SPECIES SURFACE FACTOR	HCL	0.000
CLOUD SHAPE		ELLIPTICAL
CALCULATION HEIGHT		SURFACE
PROPELLANT TEMPERATURE (DEG. C)		25.74
CONCENTRATION AVERAGING TIME (SEC.)		1800.00
mixing layer reflection coefficient (RNG- 0 TO 1,no reflection=0)		1.0000
DIFFUSION COEFFICIENTS	LATERAL	1.0000
	VERTICAL	1.0000
VEHICLE AIR ENTRAINMENT PARAMETER	GAMMAE	0.6400
DOWNWIND EXPANSION DISTANCE (METERS)	LATERAL	100.00
	VERTICAL	100.00

----- DATA FILES -----

INPUT FILES

RAWINSONDE FILE	k23_1327.raw
DATA BASE FILE	rdmbase.ksc

OUTPUT FILES

PRINT FILE	k23amg64.out

----- METEOROLOGICAL RAWINSONDE DATA -----

RAWINSONDE MSS/MSS
TIME- 1327 Z DATE- 14 MAY 95
ASCENT NUMBER 0

----- T -0.3 HR SOUNDING -----

MET. LEV. NO.	MSL (FT)	ALTITUDE GND (FT)	GND (M)	WIND DIR (DEG)	WIND SPEED (M/S)	(KTS)	TEMP	AIR PTEMP (DEG C)	DPTEMP	AIR PRESS (MB)	AIR RH (%)	H M	INT-ERP
1	16	0.0	0.0	270	3.1	6.0	29.5	31.4	23.9	1016.7	72.0		

2	67	51.3	15.6	275	3.5	6.7	28.8	30.7	23.5	1014.9	73.1	**
3	119	102.5	31.2	280	3.9	7.5	28.0	30.1	23.0	1013.1	74.3	**
4	170	153.8	46.9	284	4.2	8.2	27.3	29.4	22.5	1011.4	75.5	**
5	221	205.0	62.5	289	4.6	9.0	26.5	28.7	22.1	1009.6	77.0	
6	314	297.7	90.7	284	4.6	9.0	26.3	28.9	22.4	1006.4	79.2	**
7	406	390.3	119.0	279	4.6	9.0	26.2	29.1	22.8	1003.2	81.6	**
8	499	483.0	147.2	274	4.6	9.0	26.0	29.2	23.1	1000.0	84.0	
9	603	587.0	178.9	269	4.6	9.0	25.9	29.5	23.5	996.4	86.9	**
10	707	691.0	210.6	263	4.6	9.0	25.7	29.8	23.9	992.9	90.0	*
11	854	837.5	255.3	260	4.6	8.9	25.9	30.3	23.2	987.9	85.1	**
12	1000	984.0	299.9	256	4.5	8.8	26.1	30.8	22.5	983.0	81.0	
13	1253	1237.0	377.0	251	4.6	9.0	26.4	31.6	21.2	974.4	73.0	
14	1524	1508.0	459.6	246	4.6	9.0	26.0	32.1	20.9	965.4	73.2	**
15	1795	1779.0	542.2	241	4.6	9.0	25.7	32.5	20.5	956.4	73.0	
16	2000	1984.0	604.7	239	4.9	9.5	25.2	32.5	20.1	949.7	73.0	
17	2349	2333.0	711.1	234	5.1	10.0	24.4	32.7	19.4	938.3	74.0	
18	3000	2984.0	909.5	231	4.8	9.3	22.8	32.9	18.2	917.4	75.0	
19	3542	3526.0	1074.7	234	4.6	9.0	21.3	33.0	17.6	900.0	80.0	
20	3921	3905.0	1190.2	236	4.1	8.0	20.4	33.2	17.3	888.3	83.0	
21	4000	3984.0	1214.3	237	4.0	7.8	20.2	33.2	17.2	885.8	83.0	
22	4462	4446.0	1355.1	243	3.6	7.0	19.2	33.5	16.7	871.6	85.0	
23	5000	4984.0	1519.1	253	2.7	5.2	18.3	34.0	14.8	855.2	80.0	
24	5163	5147.0	1568.8	256	2.6	5.0	18.2	34.4	14.2	850.0	78.0	
25	5582	5565.5	1696.4	266	2.0	3.9	17.6	35.0	13.0	837.6	74.6	**
26	6000	5984.0	1823.9	276	1.4	2.8	17.1	35.6	11.8	825.4	71.0	
27	6863	6847.0	2087.0	284	1.0	2.0	15.7	36.2	4.9	800.0	50.0	
28	7000	6984.0	2128.7	283	1.0	2.0	15.5	36.2	3.2	796.4	45.0	
29	7259	7243.0	2207.7	281	1.0	2.0	15.0	36.2	-0.5	789.1	35.0	
30	7839	7823.0	2384.5	267	1.5	3.0	13.4	36.8	5.1	772.8	57.0	
31	8000	7984.0	2433.5	266	1.4	2.7	13.2	37.0	4.2	768.3	54.0	
32	8650	8634.0	2631.6	269	1.5	3.0	12.1	37.9	2.3	750.0	51.0	
33	9272	9255.5	2821.1	294	1.4	2.8	11.0	38.7	2.7	733.6	57.5	**
34	9772	9755.5	2973.5	323	1.7	3.2	10.4	39.4	-1.0	720.4	46.5	**

* - INDICATES THE CALCULATED TOP OF THE SURFACE MIXING LAYER

** - INDICATES THAT DATA IS LINEARLY INTERPOLATED FROM INPUT METEOROLOGY

1***

launch time: 0945 EDT 14 MAY 1995

RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- METEOROLOGICAL RAWINSONDE DATA -----

SURFACE AIR DENSITY (GM/M**3)	1157.37
DEFAULT CALCULATED MIXING LAYER HEIGHT (M)	210.62
CLOUD COVER IN TENTHS OF CELESTIAL DOME	0.0
CLOUD CEILING (M)	9999.0

----- PLUME RISE DATA -----

EXHAUST RATE OF MATERIAL INTO GRN CLD-	(GRAMS/SEC)		4.23912E+06
TOTAL GROUND CLD MATERIAL-	(GRAMS)		3.98995E+07
HEAT OUTPUT PER GRAM-	(CALORIES)		1555.6
VEHICLE RISE HEIGHT DEFINING GROUND CLD-	(M)		199.9
VEHICLE RISE TIME PARAMETERS-	(TK=(A*Z**B)+C)	A=	0.8677
		B=	0.4500
		C=	0.0000

EXHAUST RATE OF MATERIAL INTO CONTRAIL- (GRAMS/SEC) 4.23912E+06
CONTRAIL HEAT OUTPUT PER GRAM- (CALORIES) 1555.6

1***

VERSION 7.07 AT CCAS
1643 EST 12 NOV 1996
launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- EXHAUST CLOUD -----

MET. LAYER NO.	TOP OF LAYER (METERS)	CLOUD RISE TIME (SECONDS)	CLOUD RISE RANGE (METERS)	CLOUD RISE BEARING (DEGREES)	STABILIZED CLOUD RANGE (METERS)	STABILIZED CLOUD BEARING (DEGREES)
1	15.6	2.0	3.2	91.3	0.0	0.0
2	31.2	3.2	8.7	93.4	0.0	0.0
3	46.9	4.3	13.1	95.5	0.0	0.0
4	62.5	5.5	18.0	97.9	0.0	0.0
5	90.7	7.8	25.8	100.9	0.0	0.0
6	119.0	10.3	37.0	101.8	0.0	0.0
7	147.2	13.1	49.3	101.1	0.0	0.0
8	178.9	16.7	64.0	99.4	0.0	0.0
9	210.6	20.6	80.9	97.1	0.0	0.0
10	255.3	26.8	103.7	94.0	0.0	0.0
11	299.9	33.6	132.8	90.7	0.0	0.0
12	377.0	47.3	178.2	86.8	1385.8	75.2
13	459.6	64.4	247.1	82.3	1387.4	70.9
14	542.2	84.6	330.9	78.0	1375.4	67.0
15	604.7	102.4	416.4	74.6	1404.1	64.3
16	711.1	139.2	546.4	70.6	1402.5	62.0
17	909.5	268.1	955.1	63.3	1169.7	61.3
18	1074.7	311.9 *	1471.5	59.1	1471.5	59.1
19	1190.2	311.9 *	1471.5	59.1	1471.5	59.1
20	1214.3	311.9 *	1471.5	59.1	1471.5	59.1
21	1355.1	311.9 *	1471.5	59.1	1471.5	59.1
22	1519.1	311.9 *	1471.5	59.1	1471.5	59.1
23	1568.8	311.9 *	1471.5	59.1	1471.5	59.1
24	1696.4	311.9 *	1471.5	59.1	1471.5	59.1
25	1823.9	311.9 *	1471.5	59.1	1471.5	59.1
26	2087.0	311.9 *	1471.5	59.1	1471.5	59.1
27	2128.7	311.9 *	1471.5	59.1	1471.5	59.1
28	2207.7	311.9 *	1471.5	59.1	1471.5	59.1
29	2384.5	311.9 *	1471.5	59.1	1471.5	59.1
30	2433.5	311.9 *	1471.5	59.1	1471.5	59.1
31	2631.6	311.9 *	1471.5	59.1	1471.5	59.1
32	2821.1	311.9 *	1471.5	59.1	1471.5	59.1
33	2973.5	311.9 *	1471.5	59.1	1471.5	59.1

* - INDICATES CLOUD STABILIZATION TIME WAS USED

1***

VERSION 7.07 AT CCAS
1643 EST 12 NOV 1996
launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- EXHAUST CLOUD -----

CHEMICAL SPECIES = HCL

MET. LAYER NO.	TOP OF LAYER (METERS)		LAYER SOURCE STRENGTH (GRAMS)	CLOUD UPDRAFT VELOCITY (M/S)	CLOUD RADIUS (METERS)	STD. DEVIATION ALONGWIND (METERS)	MATERIAL DIST. CROSSWIND (METERS)
1	15.6		0.00000E+00	12.2	0.0	0.0	0.0
2	31.2		0.00000E+00	13.7	0.0	0.0	0.0
3	46.9		0.00000E+00	13.6	0.0	0.0	0.0
4	62.5		0.00000E+00	13.1	0.0	0.0	0.0
5	90.7		0.00000E+00	11.8	0.0	0.0	0.0
6	119.0		0.00000E+00	10.5	0.0	0.0	0.0
7	147.2		0.00000E+00	9.5	0.0	0.0	0.0
8	178.9		0.00000E+00	8.5	0.0	0.0	0.0
9	210.6		0.00000E+00	7.7	0.0	0.0	0.0
10	255.3		0.00000E+00	6.8	0.0	0.0	0.0
11	299.9		0.00000E+00	6.1	0.0	0.0	0.0
12	377.0		6.44412E+04	5.2	91.3	42.5	42.5
13	459.6		4.40660E+05	4.4	343.2	159.9	159.9
14	542.2		8.03232E+05	3.8	462.7	215.6	215.6
15	604.7		8.09013E+05	3.3	533.4	248.6	248.6
16	711.1		1.68998E+06	2.5	591.5	275.6	275.6
17	909.5		3.78042E+06	0.6	649.8	302.8	302.8
18	1074.7	*	4.34621E+06	0.0	657.4	306.3	306.3
19	1190.2	*	2.79845E+06	0.0	618.7	288.3	288.3
20	1214.3	*	5.32233E+05	0.0	582.9	271.6	271.6
21	1355.1	*	2.63934E+06	0.0	522.7	243.6	243.6
22	1519.1	*	1.75050E+06	0.0	324.2	151.1	151.1
23	1568.8	*	2.86673E+05	0.0	199.9	93.2	93.2
24	1696.4	*	7.13905E+05	0.0	199.9	93.2	93.2
25	1823.9	*	6.84945E+05	0.0	199.9	93.2	93.2
26	2087.0	*	1.33363E+06	0.0	199.9	93.2	93.2
27	2128.7	*	2.03022E+05	0.0	199.9	93.2	93.2
28	2207.7	*	3.77915E+05	0.0	199.9	93.2	93.2
29	2384.5	*	8.20172E+05	0.0	199.9	93.2	93.2
30	2433.5	*	2.21691E+05	0.0	199.9	93.2	93.2
31	2631.6	*	8.70909E+05	0.0	199.9	93.2	93.2
32	2821.1	*	7.99591E+05	0.0	199.9	93.2	93.2
33	2973.5	*	6.22072E+05	0.0	199.9	93.2	93.2

* - INDICATES CLOUD STABILIZATION TIME WAS USED

----- CLOUD STABILIZATION -----

CALCULATION HEIGHT	(METERS)	0.00
STABILIZATION HEIGHT	(METERS)	922.80
STABILIZATION TIME	(SECS)	311.93

FIRST MIXING LAYER HEIGHT-	(METERS)	TOP =	210.62
		BASE=	0.00
SECOND SELECTED LAYER HEIGHT-	(METERS)	TOP =	2973.48
		BASE=	210.62
SIGMAR(AZ) AT THE SURFACE	(DEGREES)		13.5054
SIGMER(EL) AT THE SURFACE	(DEGREES)		2.9738

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
1	3.36	0.39	272.38	4.75	11.5683	4.0633
2	3.67	0.39	277.13	4.75	9.2377	5.5360
3	4.05	0.39	281.88	4.75	8.6290	6.1691
4	4.44	0.39	286.63	4.75	8.2676	6.6091
5	4.63	0.00	286.50	-5.00	7.9393	7.0625
6	4.63	0.00	281.50	-5.00	7.7111	7.3978
7	4.63	0.00	276.50	-5.00	7.5268	7.3381
8	4.63	0.00	271.25	-5.50	5.4115	5.3204
9	4.63	0.00	265.75	-5.50	2.2172	2.2172
10	4.60	-0.05	261.25	-3.50	1.0000	1.0000
11	4.55	-0.05	257.75	-3.50	1.0000	1.0000
12	4.58	0.10	253.50	-5.00	1.0000	1.0000
13	4.63	0.00	248.50	-5.00	1.0000	1.0000
14	4.63	0.00	243.50	-5.00	1.0000	1.0000
15	4.76	0.26	240.00	-2.00	1.0000	1.0000
16	5.02	0.26	236.50	-5.00	1.0000	1.0000
17	4.96	-0.36	232.50	-3.00	1.0000	1.0000
18	4.71	-0.15	232.50	3.00	1.0000	1.0000
19	4.37	-0.51	235.00	2.00	1.0000	1.0000
20	4.06	-0.10	236.50	1.00	1.0000	1.0000
21	3.81	-0.41	240.00	6.00	1.0000	1.0000
22	3.14	-0.93	248.00	10.00	1.0000	1.0000
23	2.62	-0.10	254.50	3.00	1.0000	1.0000
24	2.29	-0.57	261.00	10.00	1.0000	1.0000
25	1.72	-0.57	271.00	10.00	1.0000	1.0000
26	1.23	-0.41	280.00	8.00	1.0000	1.0000
27	1.03	0.00	283.50	-1.00	1.0000	1.0000
28	1.03	0.00	282.00	-2.00	1.0000	1.0000
29	1.29	0.51	274.00	-14.00	1.0000	1.0000
30	1.47	-0.15	266.50	-1.00	1.0000	1.0000

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----- CALCULATED METEOROLOGICAL LAYER PARAMETERS -----

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
31	1.47	0.15	267.50	3.00	1.0000	1.0000
32	1.49	-0.10	281.25	24.50	1.0000	1.0000

33	1.56	0.23	308.00	29.00	1.0000	1.0000

ALTITUDE RANGE USED IN COMPUTING TRANSITION LAYER AVERAGES IS 0.0 TO 1519.1 METERS.

TRANSITION LAYER NUMBER- 1

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	210.62	302.90	4.63		263.00		1.0000	1.0000
LAYER-			4.38	0.27	277.03	5.81	7.0311	5.7253
BOTTOM-	0.00	304.58	3.09		270.00		13.5054	2.9738

TRANSITION LAYER NUMBER- 2

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	2973.48	312.54	1.67		322.50		1.0000	1.0000
LAYER-			4.37	0.46	240.58	6.26	1.0000	1.0000
BOTTOM-	210.62	302.90	4.63		263.00		1.0000	1.0000

*** REEDM HAS TERMINATED

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1*****************************************************************************
            ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM        PAGE    2
                        VERSION AM7.07 AT CCAS
                          1733 EST 12 NOV 1996
                   launch time:  0945 EDT 14 MAY 1995
     RAWINSONDE ASCENT NUMBER       0, 1327    Z 14 MAY    95   T   -0.3 HR
*****************************************************************************

                         ----- PROGRAM OPTIONS -----

 MODEL                                                        CONCENTRATION
 RUN TYPE                                                          RESEARCH
 WIND-FIELD TERRAIN EFFECTS MODEL                                      NONE
 LAUNCH VEHICLE                                                    TITAN IV
 LAUNCH TYPE                                                         NORMAL
 LAUNCH COMPLEX NUMBER                                                   40
 TURBULENCE PARAMETERS ARE DETERMINED FROM               CLIMATOLOGICAL DATA
 SURFACE CHEMISTRY MODEL                              absorption coefficient
 SPECIES      SURFACE FACTOR                                HCL       0.000
 CLOUD SHAPE                                                     ELLIPTICAL
 CALCULATION HEIGHT                                                 SURFACE
 PROPELLANT TEMPERATURE (DEG. C)                                      25.74
 CONCENTRATION AVERAGING TIME (SEC.)                                1800.00
 mixing layer reflection coefficient (RNG- 0 TO 1,no reflection=0)   1.0000
 DIFFUSION COEFFICIENTS                                 LATERAL      1.0000
                                                        VERTICAL     1.0000
 VEHICLE AIR ENTRAINMENT PARAMETER                      GAMMAE       0.5700
 DOWNWIND EXPANSION DISTANCE (METERS)                   LATERAL      100.00
                                                        VERTICAL     100.00

                           ----- DATA FILES -----

                                INPUT FILES
 RAWINSONDE FILE                                               k23_1327.raw
 DATA BASE FILE                                                rdmbase.ksc

                                OUTPUT FILES
 PRINT FILE                                                    k23amg57.out
1*****************************************************************************
            ROCKET EXHAUST EFFLUENT DIFFUSION MODEL REEDM        PAGE    3
                         VERSION 7.07 AT CCAS
                          1733 EST 12 NOV 1996
                   launch time:  0945 EDT 14 MAY 1995
     RAWINSONDE ASCENT NUMBER       0, 1327    Z 14 MAY    95   T   -0.3 HR
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                 ----- METEOROLOGICAL RAWINSONDE DATA -----


     RAWINSONDE MSS/MSS
     TIME- 1327    Z     DATE- 14 MAY    95
     ASCENT NUMBER         0

                       -----  T   -0.3 HR SOUNDING -----

MET.      ALTITUDE        WIND    WIND            AIR           AIR    AIR
LEV.  MSL   GND    GND    DIR    SPEED     TEMP  PTEMP DPTEMP  PRESS    RH  H INT-
NO.  (FT)  (FT)    (M)  (DEG)(M/S) (KTS)        (DEG C)         (MB)    (%) M ERP
---------------------------------------------------------------------------------
 1    16    0.0    0.0 270    3.1    6.0  29.5   31.4   23.9 1016.7   72.0
```

2	67	51.3	15.6	275	3.5	6.7	28.8	30.7	23.5	1014.9	73.1	**
3	119	102.5	31.2	280	3.9	7.5	28.0	30.1	23.0	1013.1	74.3	**
4	170	153.8	46.9	284	4.2	8.2	27.3	29.4	22.5	1011.4	75.5	**
5	221	205.0	62.5	289	4.6	9.0	26.5	28.7	22.1	1009.6	77.0	
6	314	297.7	90.7	284	4.6	9.0	26.3	28.9	22.4	1006.4	79.2	**
7	406	390.3	119.0	279	4.6	9.0	26.2	29.1	22.8	1003.2	81.6	**
8	499	483.0	147.2	274	4.6	9.0	26.0	29.2	23.1	1000.0	84.0	
9	603	587.0	178.9	269	4.6	9.0	25.9	29.5	23.5	996.4	86.9	**
10	707	691.0	210.6	263	4.6	9.0	25.7	29.8	23.9	992.9	90.0	*
11	854	837.5	255.3	260	4.6	8.9	25.9	30.3	23.2	987.9	85.1	**
12	1000	984.0	299.9	256	4.5	8.8	26.1	30.8	22.5	983.0	81.0	
13	1253	1237.0	377.0	251	4.6	9.0	26.4	31.6	21.2	974.4	73.0	
14	1524	1508.0	459.6	246	4.6	9.0	26.0	32.1	20.9	965.4	73.2	**
15	1795	1779.0	542.2	241	4.6	9.0	25.7	32.5	20.5	956.4	73.0	
16	2000	1984.0	604.7	239	4.9	9.5	25.2	32.5	20.1	949.7	73.0	
17	2349	2333.0	711.1	234	5.1	10.0	24.4	32.7	19.4	938.3	74.0	
18	3000	2984.0	909.5	231	4.8	9.3	22.8	32.9	18.2	917.4	75.0	
19	3542	3526.0	1074.7	234	4.6	9.0	21.3	33.0	17.6	900.0	80.0	
20	3921	3905.0	1190.2	236	4.1	8.0	20.4	33.2	17.3	888.3	83.0	
21	4000	3984.0	1214.3	237	4.0	7.8	20.2	33.2	17.2	885.8	83.0	
22	4462	4446.0	1355.1	243	3.6	7.0	19.2	33.5	16.7	871.6	85.0	
23	5000	4984.0	1519.1	253	2.7	5.2	18.3	34.0	14.8	855.2	80.0	
24	5163	5147.0	1568.8	256	2.6	5.0	18.2	34.4	14.2	850.0	78.0	
25	5582	5565.5	1696.4	266	2.0	3.9	17.6	35.0	13.0	837.6	74.6	**
26	6000	5984.0	1823.9	276	1.4	2.8	17.1	35.6	11.8	825.4	71.0	
27	6863	6847.0	2087.0	284	1.0	2.0	15.7	36.2	4.9	800.0	50.0	
28	7000	6984.0	2128.7	283	1.0	2.0	15.5	36.2	3.2	796.4	45.0	
29	7259	7243.0	2207.7	281	1.0	2.0	15.0	36.2	-0.5	789.1	35.0	
30	7839	7823.0	2384.5	267	1.5	3.0	13.4	36.8	5.1	772.8	57.0	
31	8000	7984.0	2433.5	266	1.4	2.7	13.2	37.0	4.2	768.3	54.0	
32	8650	8634.0	2631.6	269	1.5	3.0	12.1	37.9	2.3	750.0	51.0	
33	9272	9255.5	2821.1	294	1.4	2.8	11.0	38.7	2.7	733.6	57.5	**
34	9772	9755.5	2973.5	323	1.7	3.2	10.4	39.4	-1.0	720.4	46.5	**

* - INDICATES THE CALCULATED TOP OF THE SURFACE MIXING LAYER
** - INDICATES THAT DATA IS LINEARLY INTERPOLATED FROM INPUT METEOROLOGY

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launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- METEOROLOGICAL RAWINSONDE DATA -----

SURFACE AIR DENSITY (GM/M**3)	1157.37
DEFAULT CALCULATED MIXING LAYER HEIGHT (M)	210.62
CLOUD COVER IN TENTHS OF CELESTIAL DOME	0.0
CLOUD CEILING (M)	9999.0

----- PLUME RISE DATA -----

EXHAUST RATE OF MATERIAL INTO GRN CLD-	(GRAMS/SEC)		4.23912E+06
TOTAL GROUND CLD MATERIAL-	(GRAMS)		3.98995E+07
HEAT OUTPUT PER GRAM-	(CALORIES)		1555.6
VEHICLE RISE HEIGHT DEFINING GROUND CLD-	(M)		199.9
VEHICLE RISE TIME PARAMETERS-	(TK=(A*Z**B)+C)	A=	0.8677
		B=	0.4500
		C=	0.0000

EXHAUST RATE OF MATERIAL INTO CONTRAIL- (GRAMS/SEC) 4.23912E+06
CONTRAIL HEAT OUTPUT PER GRAM- (CALORIES) 1555.6

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launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- EXHAUST CLOUD -----

MET. LAYER NO.	TOP OF LAYER (METERS)	CLOUD RISE TIME (SECONDS)	CLOUD RISE RANGE (METERS)	CLOUD RISE BEARING (DEGREES)	STABILIZED CLOUD RANGE (METERS)	STABILIZED CLOUD BEARING (DEGREES)
1	15.6	2.0	3.2	91.3	0.0	0.0
2	31.2	3.1	8.5	93.4	0.0	0.0
3	46.9	4.2	12.8	95.4	0.0	0.0
4	62.5	5.3	17.3	97.8	0.0	0.0
5	90.7	7.4	24.5	100.7	0.0	0.0
6	119.0	9.7	34.6	101.7	0.0	0.0
7	147.2	12.2	45.8	101.0	0.0	0.0
8	178.9	15.3	58.8	99.4	0.0	0.0
9	210.6	18.8	73.8	97.2	0.0	0.0
10	255.3	24.2	93.7	94.1	0.0	0.0
11	299.9	30.2	119.1	90.9	0.0	0.0
12	377.0	41.9	158.4	87.0	0.0	0.0
13	459.6	56.6	217.7	82.5	1496.2	70.5
14	542.2	73.8	289.1	78.4	1485.9	66.4
15	604.7	88.7	361.1	74.9	1519.1	63.5
16	711.1	118.5	467.1	71.1	1537.6	60.9
17	909.5	197.7	735.1	64.7	1403.6	58.8
18	1074.7	334.0 *	1562.7	58.0	1562.7	58.0
19	1190.2	334.0 *	1562.7	58.0	1562.7	58.0
20	1214.3	334.0 *	1562.7	58.0	1562.7	58.0
21	1355.1	334.0 *	1562.7	58.0	1562.7	58.0
22	1519.1	334.0 *	1562.7	58.0	1562.7	58.0
23	1568.8	334.0 *	1562.7	58.0	1562.7	58.0
24	1696.4	334.0 *	1562.7	58.0	1562.7	58.0
25	1823.9	334.0 *	1562.7	58.0	1562.7	58.0
26	2087.0	334.0 *	1562.7	58.0	1562.7	58.0
27	2128.7	334.0 *	1562.7	58.0	1562.7	58.0
28	2207.7	334.0 *	1562.7	58.0	1562.7	58.0
29	2384.5	334.0 *	1562.7	58.0	1562.7	58.0
30	2433.5	334.0 *	1562.7	58.0	1562.7	58.0
31	2631.6	334.0 *	1562.7	58.0	1562.7	58.0
32	2821.1	334.0 *	1562.7	58.0	1562.7	58.0
33	2973.5	334.0 *	1562.7	58.0	1562.7	58.0

* - INDICATES CLOUD STABILIZATION TIME WAS USED

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launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- EXHAUST CLOUD -----

CHEMICAL SPECIES = HCL

MET. LAYER NO.	TOP OF LAYER (METERS)		LAYER SOURCE STRENGTH (GRAMS)	CLOUD UPDRAFT VELOCITY (M/S)	CLOUD RADIUS (METERS)	STD. DEVIATION ALONGWIND (METERS)	MATERIAL DIST. CROSSWIND (METERS)
1	15.6		0.00000E+00	12.6	0.0	0.0	0.0
2	31.2		0.00000E+00	14.4	0.0	0.0	0.0
3	46.9		0.00000E+00	14.6	0.0	0.0	0.0
4	62.5		0.00000E+00	14.1	0.0	0.0	0.0
5	90.7		0.00000E+00	13.0	0.0	0.0	0.0
6	119.0		0.00000E+00	11.7	0.0	0.0	0.0
7	147.2		0.00000E+00	10.7	0.0	0.0	0.0
8	178.9		0.00000E+00	9.6	0.0	0.0	0.0
9	210.6		0.00000E+00	8.8	0.0	0.0	0.0
10	255.3		0.00000E+00	7.8	0.0	0.0	0.0
11	299.9		0.00000E+00	7.1	0.0	0.0	0.0
12	377.0		0.00000E+00	6.1	0.0	0.0	0.0
13	459.6		7.52229E+03	5.2	201.4	93.8	93.8
14	542.2		3.11617E+05	4.5	280.9	130.9	130.9
15	604.7		5.10198E+05	4.0	411.9	191.9	191.9
16	711.1		1.32093E+06	3.2	508.5	236.9	236.9
17	909.5		3.53704E+06	1.8	611.2	284.8	284.8
18	1074.7	*	3.73044E+06	0.0	659.0	307.1	307.1
19	1190.2	*	3.14714E+06	0.0	651.3	303.5	303.5
20	1214.3	*	6.24867E+05	0.0	633.0	295.0	295.0
21	1355.1	*	3.31151E+06	0.0	597.6	278.5	278.5
22	1519.1	*	2.79396E+06	0.0	481.1	224.2	224.2
23	1568.8	*	5.46291E+05	0.0	329.5	153.5	153.5
24	1696.4	*	8.13543E+05	0.0	275.4	128.3	128.3
25	1823.9	*	6.84945E+05	0.0	199.9	93.2	93.2
26	2087.0	*	1.33363E+06	0.0	199.9	93.2	93.2
27	2128.7	*	2.03022E+05	0.0	199.9	93.2	93.2
28	2207.7	*	3.77915E+05	0.0	199.9	93.2	93.2
29	2384.5	*	8.20172E+05	0.0	199.9	93.2	93.2
30	2433.5	*	2.21691E+05	0.0	199.9	93.2	93.2
31	2631.6	*	8.70909E+05	0.0	199.9	93.2	93.2
32	2821.1	*	7.99591E+05	0.0	199.9	93.2	93.2
33	2973.5	*	6.22072E+05	0.0	199.9	93.2	93.2

* - INDICATES CLOUD STABILIZATION TIME WAS USED

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launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- CLOUD STABILIZATION -----

CALCULATION HEIGHT	(METERS)	0.00
STABILIZATION HEIGHT	(METERS)	1033.74
STABILIZATION TIME	(SECS)	333.97

FIRST MIXING LAYER HEIGHT-	(METERS)	TOP =	210.62
		BASE=	0.00
SECOND SELECTED LAYER HEIGHT-	(METERS)	TOP =	2973.48
		BASE=	210.62
SIGMAR(AZ) AT THE SURFACE	(DEGREES)		13.6911
SIGMER(EL) AT THE SURFACE	(DEGREES)		2.9738

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
1	3.36	0.39	272.38	4.75	11.7274	4.0633
2	3.67	0.39	277.13	4.75	9.3647	5.5360
3	4.05	0.39	281.88	4.75	8.7476	6.1691
4	4.44	0.39	286.63	4.75	8.3813	6.6091
5	4.63	0.00	286.50	-5.00	8.0484	7.0625
6	4.63	0.00	281.50	-5.00	7.8171	7.3978
7	4.63	0.00	276.50	-5.00	7.6303	7.3381
8	4.63	0.00	271.25	-5.50	5.4844	5.3204
9	4.63	0.00	265.75	-5.50	2.2392	2.2172
10	4.60	-0.05	261.25	-3.50	1.0000	1.0000
11	4.55	-0.05	257.75	-3.50	1.0000	1.0000
12	4.58	0.10	253.50	-5.00	1.0000	1.0000
13	4.63	0.00	248.50	-5.00	1.0000	1.0000
14	4.63	0.00	243.50	-5.00	1.0000	1.0000
15	4.76	0.26	240.00	-2.00	1.0000	1.0000
16	5.02	0.26	236.50	-5.00	1.0000	1.0000
17	4.96	-0.36	232.50	-3.00	1.0000	1.0000
18	4.71	-0.15	232.50	3.00	1.0000	1.0000
19	4.37	-0.51	235.00	2.00	1.0000	1.0000
20	4.06	-0.10	236.50	1.00	1.0000	1.0000
21	3.81	-0.41	240.00	6.00	1.0000	1.0000
22	3.14	-0.93	248.00	10.00	1.0000	1.0000
23	2.62	-0.10	254.50	3.00	1.0000	1.0000
24	2.29	-0.57	261.00	10.00	1.0000	1.0000
25	1.72	-0.57	271.00	10.00	1.0000	1.0000
26	1.23	-0.41	280.00	8.00	1.0000	1.0000
27	1.03	0.00	283.50	-1.00	1.0000	1.0000
28	1.03	0.00	282.00	-2.00	1.0000	1.0000
29	1.29	0.51	274.00	-14.00	1.0000	1.0000
30	1.47	-0.15	266.50	-1.00	1.0000	1.0000

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VERSION 7.07 AT CCAS

1733 EST 12 NOV 1996

launch time: 0945 EDT 14 MAY 1995

RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- CALCULATED METEOROLOGICAL LAYER PARAMETERS -----

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
31	1.47	0.15	267.50	3.00	1.0000	1.0000
32	1.49	-0.10	281.25	24.50	1.0000	1.0000

33	1.56	0.23	308.00	29.00	1.0000	1.0000

ALTITUDE RANGE USED IN COMPUTING TRANSITION LAYER AVERAGES
IS 0.0 TO 1696.4 METERS.

TRANSITION LAYER NUMBER- 1

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	210.62	302.90	4.63		263.00		1.0000	1.0000
LAYER-			4.38	0.27	277.03	5.81	7.1263	5.7253
BOTTOM-	0.00	304.58	3.09		270.00		13.6911	2.9738

TRANSITION LAYER NUMBER- 2

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	2973.48	312.54	1.67		322.50		1.0000	1.0000
LAYER-			4.12	0.68	241.83	6.73	1.0000	1.0000
BOTTOM-	210.62	302.90	4.63		263.00		1.0000	1.0000

DIAGNOSTICS FOR MODEL CALCULATIONS

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 210.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)

** NO HCL FOUND **

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----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 210.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	30.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)
		** NO HCL	FOUND **	

*** REEDM HAS TERMINATED

----- PROGRAM OPTIONS -----

MODEL		CONCENTRATION
RUN TYPE		RESEARCH
WIND-FIELD TERRAIN EFFECTS MODEL		NONE
LAUNCH VEHICLE		TITAN IV
LAUNCH TYPE		NORMAL
LAUNCH COMPLEX NUMBER		40
TURBULENCE PARAMETERS ARE DETERMINED FROM		CLIMATOLOGICAL DATA
SURFACE CHEMISTRY MODEL		absorption coefficient
SPECIES SURFACE FACTOR	HCL	0.000
CLOUD SHAPE		ELLIPTICAL
CALCULATION HEIGHT		SURFACE
PROPELLANT TEMPERATURE (DEG. C)		25.74
CONCENTRATION AVERAGING TIME (SEC.)		1800.00
mixing layer reflection coefficient (RNG- 0 TO 1,no reflection=0)		1.0000
DIFFUSION COEFFICIENTS	LATERAL	1.0000
	VERTICAL	1.0000
VEHICLE AIR ENTRAINMENT PARAMETER	GAMMAE	0.5000
DOWNWIND EXPANSION DISTANCE (METERS)	LATERAL	100.00
	VERTICAL	100.00

----- DATA FILES -----

INPUT FILES

RAWINSONDE FILE	k23_1327.raw
DATA BASE FILE	rdmbase.ksc

OUTPUT FILES

PRINT FILE	k23amg50.out

----- METEOROLOGICAL RAWINSONDE DATA -----

RAWINSONDE MSS/MSS
TIME- 1327 Z DATE- 14 MAY 95
ASCENT NUMBER 0

----- T -0.3 HR SOUNDING -----

MET. LEV. NO.	ALTITUDE MSL (FT)	GND (FT)	GND (M)	WIND DIR (DEG)	WIND SPEED (M/S)	(KTS)	TEMP	AIR PTEMP (DEG C)	DPTEMP	AIR PRESS (MB)	AIR RH (%)	H M	INT-ERP
1	16	0.0	0.0	270	3.1	6.0	29.5	31.4	23.9	1016.7	72.0		

2	67	51.3	15.6	275	3.5	6.7	28.8	30.7	23.5	1014.9	73.1	**
3	119	102.5	31.2	280	3.9	7.5	28.0	30.1	23.0	1013.1	74.3	**
4	170	153.8	46.9	284	4.2	8.2	27.3	29.4	22.5	1011.4	75.5	**
5	221	205.0	62.5	289	4.6	9.0	26.5	28.7	22.1	1009.6	77.0	
6	314	297.7	90.7	284	4.6	9.0	26.3	28.9	22.4	1006.4	79.2	**
7	406	390.3	119.0	279	4.6	9.0	26.2	29.1	22.8	1003.2	81.6	**
8	499	483.0	147.2	274	4.6	9.0	26.0	29.2	23.1	1000.0	84.0	
9	603	587.0	178.9	269	4.6	9.0	25.9	29.5	23.5	996.4	86.9	**
10	707	691.0	210.6	263	4.6	9.0	25.7	29.8	23.9	992.9	90.0	*
11	854	837.5	255.3	260	4.6	8.9	25.9	30.3	23.2	987.9	85.1	**
12	1000	984.0	299.9	256	4.5	8.8	26.1	30.8	22.5	983.0	81.0	
13	1253	1237.0	377.0	251	4.6	9.0	26.4	31.6	21.2	974.4	73.0	
14	1524	1508.0	459.6	246	4.6	9.0	26.0	32.1	20.9	965.4	73.2	**
15	1795	1779.0	542.2	241	4.6	9.0	25.7	32.5	20.5	956.4	73.0	
16	2000	1984.0	604.7	239	4.9	9.5	25.2	32.5	20.1	949.7	73.0	
17	2349	2333.0	711.1	234	5.1	10.0	24.4	32.7	19.4	938.3	74.0	
18	3000	2984.0	909.5	231	4.8	9.3	22.8	32.9	18.2	917.4	75.0	
19	3542	3526.0	1074.7	234	4.6	9.0	21.3	33.0	17.6	900.0	80.0	
20	3921	3905.0	1190.2	236	4.1	8.0	20.4	33.2	17.3	888.3	83.0	
21	4000	3984.0	1214.3	237	4.0	7.8	20.2	33.2	17.2	885.8	83.0	
22	4462	4446.0	1355.1	243	3.6	7.0	19.2	33.5	16.7	871.6	85.0	
23	5000	4984.0	1519.1	253	2.7	5.2	18.3	34.0	14.8	855.2	80.0	
24	5163	5147.0	1568.8	256	2.6	5.0	18.2	34.4	14.2	850.0	78.0	
25	5582	5565.5	1696.4	266	2.0	3.9	17.6	35.0	13.0	837.6	74.6	**
26	6000	5984.0	1823.9	276	1.4	2.8	17.1	35.6	11.8	825.4	71.0	
27	6863	6847.0	2087.0	284	1.0	2.0	15.7	36.2	4.9	800.0	50.0	
28	7000	6984.0	2128.7	283	1.0	2.0	15.5	36.2	3.2	796.4	45.0	
29	7259	7243.0	2207.7	281	1.0	2.0	15.0	36.2	-0.5	789.1	35.0	
30	7839	7823.0	2384.5	267	1.5	3.0	13.4	36.8	5.1	772.8	57.0	
31	8000	7984.0	2433.5	266	1.4	2.7	13.2	37.0	4.2	768.3	54.0	
32	8650	8634.0	2631.6	269	1.5	3.0	12.1	37.9	2.3	750.0	51.0	
33	9272	9255.5	2821.1	294	1.4	2.8	11.0	38.7	2.7	733.6	57.5	**
34	9772	9755.5	2973.5	323	1.7	3.2	10.4	39.4	-1.0	720.4	46.5	**

* - INDICATES THE CALCULATED TOP OF THE SURFACE MIXING LAYER
** - INDICATES THAT DATA IS LINEARLY INTERPOLATED FROM INPUT METEOROLOGY

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VERSION 7.07 AT CCAS
1752 EST 12 NOV 1996
launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- METEOROLOGICAL RAWINSONDE DATA -----

SURFACE AIR DENSITY (GM/M**3)	1157.37
DEFAULT CALCULATED MIXING LAYER HEIGHT (M)	210.62
CLOUD COVER IN TENTHS OF CELESTIAL DOME	0.0
CLOUD CEILING (M)	9999.0

----- PLUME RISE DATA -----

EXHAUST RATE OF MATERIAL INTO GRN CLD-	(GRAMS/SEC)		4.23912E+06
TOTAL GROUND CLD MATERIAL-	(GRAMS)		3.98995E+07
HEAT OUTPUT PER GRAM-	(CALORIES)		1555.6
VEHICLE RISE HEIGHT DEFINING GROUND CLD-	(M)		199.9
VEHICLE RISE TIME PARAMETERS-	(TK=(A*Z**B)+C)	A=	0.8677
		B=	0.4500
		C=	0.0000

EXHAUST RATE OF MATERIAL INTO CONTRAIL- (GRAMS/SEC) 4.23912E+06
CONTRAIL HEAT OUTPUT PER GRAM- (CALORIES) 1555.6

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----- EXHAUST CLOUD -----

MET. LAYER NO.	TOP OF LAYER (METERS)	CLOUD RISE TIME (SECONDS)	CLOUD RISE RANGE (METERS)	CLOUD RISE BEARING (DEGREES)	STABILIZED CLOUD RANGE (METERS)	STABILIZED CLOUD BEARING (DEGREES)
1	15.6	2.0	3.1	91.3	0.0	0.0
2	31.2	3.1	8.4	93.3	0.0	0.0
3	46.9	4.1	12.4	95.4	0.0	0.0
4	62.5	5.1	16.7	97.7	0.0	0.0
5	90.7	7.0	23.3	100.6	0.0	0.0
6	119.0	9.0	32.4	101.5	0.0	0.0
7	147.2	11.3	42.3	100.9	0.0	0.0
8	178.9	14.0	53.8	99.4	0.0	0.0
9	210.6	17.0	66.9	97.2	0.0	0.0
10	255.3	21.7	84.1	94.3	0.0	0.0
11	299.9	26.8	106.0	91.2	0.0	0.0
12	377.0	36.9	139.5	87.3	0.0	0.0
13	459.6	49.3	189.7	82.9	0.0	0.0
14	542.2	63.6	249.5	78.7	0.0	0.0
15	604.7	75.8	309.0	75.3	1690.8	62.8
16	711.1	99.6	394.4	71.6	1730.3	59.9
17	909.5	156.9	593.2	65.5	1631.7	57.2
18	1074.7	227.5	894.3	60.8	1552.1	57.3
19	1190.2	325.8	1278.2	58.8	1462.8	58.3
20	1214.3	368.1 *	1659.4	58.1	1659.4	58.1
21	1355.1	368.1 *	1659.4	58.1	1659.4	58.1
22	1519.1	368.1 *	1659.4	58.1	1659.4	58.1
23	1568.8	368.1 *	1659.4	58.1	1659.4	58.1
24	1696.4	368.1 *	1659.4	58.1	1659.4	58.1
25	1823.9	368.1 *	1659.4	58.1	1659.4	58.1
26	2087.0	368.1 *	1659.4	58.1	1659.4	58.1
27	2128.7	368.1 *	1659.4	58.1	1659.4	58.1
28	2207.7	368.1 *	1659.4	58.1	1659.4	58.1
29	2384.5	368.1 *	1659.4	58.1	1659.4	58.1
30	2433.5	368.1 *	1659.4	58.1	1659.4	58.1
31	2631.6	368.1 *	1659.4	58.1	1659.4	58.1
32	2821.1	368.1 *	1659.4	58.1	1659.4	58.1
33	2973.5	368.1 *	1659.4	58.1	1659.4	58.1

* - INDICATES CLOUD STABILIZATION TIME WAS USED

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VERSION 7.07 AT CCAS
1752 EST 12 NOV 1996
launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- EXHAUST CLOUD -----

CHEMICAL SPECIES = HCL

MET. LAYER NO.	TOP OF LAYER (METERS)		LAYER SOURCE STRENGTH (GRAMS)	CLOUD UPDRAFT VELOCITY (M/S)	CLOUD RADIUS (METERS)	STD. DEVIATION MATERIAL DIST. ALONGWIND (METERS)	CROSSWIND (METERS)
1	15.6		0.00000E+00	12.9	0.0	0.0	0.0
2	31.2		0.00000E+00	15.2	0.0	0.0	0.0
3	46.9		0.00000E+00	15.6	0.0	0.0	0.0
4	62.5		0.00000E+00	15.4	0.0	0.0	0.0
5	90.7		0.00000E+00	14.3	0.0	0.0	0.0
6	119.0		0.00000E+00	13.2	0.0	0.0	0.0
7	147.2		0.00000E+00	12.1	0.0	0.0	0.0
8	178.9		0.00000E+00	11.0	0.0	0.0	0.0
9	210.6		0.00000E+00	10.1	0.0	0.0	0.0
10	255.3		0.00000E+00	9.1	0.0	0.0	0.0
11	299.9		0.00000E+00	8.3	0.0	0.0	0.0
12	377.0		0.00000E+00	7.2	0.0	0.0	0.0
13	459.6		0.00000E+00	6.2	0.0	0.0	0.0
14	542.2		0.00000E+00	5.4	0.0	0.0	0.0
15	604.7		4.29166E+02	4.9	207.1	96.5	96.5
16	711.1		4.16238E+05	4.1	285.0	132.8	132.8
17	909.5		2.48169E+06	2.9	509.8	237.6	237.6
18	1074.7		3.18286E+06	1.8	630.0	293.6	293.6
19	1190.2		2.51089E+06	0.5	667.8	311.2	311.2
20	1214.3	*	6.15950E+05	0.0	672.3	313.3	313.3
21	1355.1	*	3.93703E+06	0.0	665.8	310.3	310.3
22	1519.1	*	4.02790E+06	0.0	618.4	288.2	288.2
23	1568.8	*	1.02682E+06	0.0	552.3	257.3	257.3
24	1696.4	*	2.06918E+06	0.0	468.0	218.1	218.1
25	1823.9	*	1.07102E+06	0.0	246.4	114.8	114.8
26	2087.0	*	1.33363E+06	0.0	199.9	93.2	93.2
27	2128.7	*	2.03022E+05	0.0	199.9	93.2	93.2
28	2207.7	*	3.77915E+05	0.0	199.9	93.2	93.2
29	2384.5	*	8.20172E+05	0.0	199.9	93.2	93.2
30	2433.5	*	2.21691E+05	0.0	199.9	93.2	93.2
31	2631.6	*	8.70909E+05	0.0	199.9	93.2	93.2
32	2821.1	*	7.99591E+05	0.0	199.9	93.2	93.2
33	2973.5	*	6.22072E+05	0.0	199.9	93.2	93.2

* - INDICATES CLOUD STABILIZATION TIME WAS USED

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launch time: 0945 EDT 14 MAY 1995
RAWINSONDE ASCENT NUMBER 0, 1327 Z 14 MAY 95 T -0.3 HR

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----- CLOUD STABILIZATION -----

CALCULATION HEIGHT	(METERS)	0.00
STABILIZATION HEIGHT	(METERS)	1201.61
STABILIZATION TIME	(SECS)	368.08

FIRST MIXING LAYER HEIGHT- (METERS) TOP = 210.62
BASE= 0.00

SECOND SELECTED LAYER HEIGHT- (METERS) TOP = 2973.48
BASE= 210.62

SIGMAR(AZ) AT THE SURFACE (DEGREES) 13.9599
SIGMER(EL) AT THE SURFACE (DEGREES) 2.9738

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
1	3.36	0.39	272.38	4.75	11.9576	4.0633
2	3.67	0.39	277.13	4.75	9.5486	5.5360
3	4.05	0.39	281.88	4.75	8.9194	6.1691
4	4.44	0.39	286.63	4.75	8.5458	6.6091
5	4.63	0.00	286.50	-5.00	8.2065	7.0625
6	4.63	0.00	281.50	-5.00	7.9706	7.3978
7	4.63	0.00	276.50	-5.00	7.7801	7.3381
8	4.63	0.00	271.25	-5.50	5.5921	5.3204
9	4.63	0.00	265.75	-5.50	2.2734	2.2172
10	4.60	-0.05	261.25	-3.50	1.0000	1.0000
11	4.55	-0.05	257.75	-3.50	1.0000	1.0000
12	4.58	0.10	253.50	-5.00	1.0000	1.0000
13	4.63	0.00	248.50	-5.00	1.0000	1.0000
14	4.63	0.00	243.50	-5.00	1.0000	1.0000
15	4.76	0.26	240.00	-2.00	1.0000	1.0000
16	5.02	0.26	236.50	-5.00	1.0000	1.0000
17	4.96	-0.36	232.50	-3.00	1.0000	1.0000
18	4.71	-0.15	232.50	3.00	1.0000	1.0000
19	4.37	-0.51	235.00	2.00	1.0000	1.0000
20	4.06	-0.10	236.50	1.00	1.0000	1.0000
21	3.81	-0.41	240.00	6.00	1.0000	1.0000
22	3.14	-0.93	248.00	10.00	1.0000	1.0000
23	2.62	-0.10	254.50	3.00	1.0000	1.0000
24	2.29	-0.57	261.00	10.00	1.0000	1.0000
25	1.72	-0.57	271.00	10.00	1.0000	1.0000
26	1.23	-0.41	280.00	8.00	1.0000	1.0000
27	1.03	0.00	283.50	-1.00	1.0000	1.0000
28	1.03	0.00	282.00	-2.00	1.0000	1.0000
29	1.29	0.51	274.00	-14.00	1.0000	1.0000
30	1.47	-0.15	266.50	-1.00	1.0000	1.0000

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----- CALCULATED METEOROLOGICAL LAYER PARAMETERS -----

MET. LAYER NO.	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIRECTION (DEG)	WIND DIRECTION SHEAR (DEG)	SIGMA OF AZI ANG (DEG)	SIGMA OF ELE ANG (DEG)
31	1.47	0.15	267.50	3.00	1.0000	1.0000
32	1.49	-0.10	281.25	24.50	1.0000	1.0000

33	1.56	0.23	308.00	29.00	1.0000	1.0000

ALTITUDE RANGE USED IN COMPUTING TRANSITION LAYER AVERAGES
IS 0.0 TO 2087.0 METERS.

TRANSITION LAYER NUMBER- 1

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	210.62	302.90	4.63		263.00		1.0000	1.0000
LAYER-			4.38	0.27	277.03	5.81	7.2647	5.7253
BOTTOM-	0.00	304.58	3.09		270.00		13.9599	2.9738

TRANSITION LAYER NUMBER- 2

VALUE AT	HEIGHT (METERS)	TEMP. (DEG K)	WIND SPEED (M/SEC)	WIND SPEED SHEAR (M/SEC)	WIND DIR. (DEG)	WIND DIR. SHEAR (DEG)	SIGMA AZI. (DEG)	SIGMA ELE. (DEG)
TOP-	2973.48	312.54	1.67		322.50		1.0000	1.0000
LAYER-			3.50	1.01	244.51	8.38	1.0000	1.0000
BOTTOM-	210.62	302.90	4.63		263.00		1.0000	1.0000

DIAGNOSTICS FOR MODEL CALCULATIONS

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 210.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	PEAK CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)

** NO HCL FOUND **

----- MAXIMUM CENTERLINE CALCULATIONS -----

** DECAY COEFFICIENT (1/SEC) = 0.00000E+00 **

CONCENTRATION OF HCL AT A HEIGHT OF 0.0 METERS
DOWNWIND FROM A TITAN IV NORMAL LAUNCH
CALCULATIONS APPLY TO THE LAYER BETWEEN 0.0 AND 210.6 METERS

RANGE FROM PAD (METERS)	BEARING FROM PAD (DEGREES)	30.0 MIN. MEAN CONCEN-TRATION (PPM)	CLOUD ARRIVAL TIME (MIN)	CLOUD DEPARTURE TIME (MIN)

** NO HCL FOUND **

*** REEDM HAS TERMINATED

APPENDIX D

Complete Results

K-23:14 May 95	CCAS				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers707	AM707	MOD 2	Observed	Vers707	AM707	MOD 2	Vers707	AM707	MOD 2	Vers707	AM707	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	787.86	922.80	1031.52	1640.00	852.14	717.20	608.48							134.94	243.66	0.17	0.31
Gamma=.57	879.36	1033.74	1155.27	1640.00	760.64	606.26	484.73	91.50	110.94	123.75	0.12	0.12	0.12	154.38	275.91	0.18	0.31
Gamma=.5	1021.20	1201.61	1329.29	1640.00	618.80	438.39	310.71	141.84	167.87	174.02	0.16	0.16	0.15	180.41	308.09	0.18	0.30
K-19: 10 July 95	CCAS				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers7.07	AM7.07	MOD 2	Observed	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	851.30	997.60	1108.14	1774.00	922.70	776.40	665.86							146.30	256.84	0.17	0.30
Gamma=.57	973.72	1117.15	1219.60	1774.00	800.28	656.85	554.40	122.42	119.55	111.46	0.14	0.12	0.10	143.43	245.88	0.15	0.25
Gamma=.5	1096.78	1243.06	1337.57	1774.00	677.22	530.94	436.43	123.06	125.91	117.97	0.13	0.11	0.10	146.28	240.79	0.13	0.22
K-15: 5 Dec 95	VAFB				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers7.07	AM7.07	MOD 2	Observed	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	514.76	629.40	761.20	899.00	384.24	269.60	137.80							114.64	246.44	0.22	0.48
Gamma=.57	581.66	739.05	895.58	899.00	317.34	159.95	3.42	66.90	109.65	134.38	0.13	0.17	0.18	157.39	313.92	0.27	0.54
Gamma=.5	695.90	874.65	1023.91	899.00	203.10	24.35	-124.91	114.24	135.60	128.33	0.20	0.18	0.14	178.75	328.01	0.26	0.47
K-22:12 May 96	VAFB				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers7.07	AM7.07	MOD 2	Observed	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	438.26	528.10	633.30	827.00	47.01	36.14	23.42							89.84	195.04	0.20	0.45
Gamma=.57	470.67	564.69	671.77	827.00	43.09	31.72	18.77	32.41	36.59	38.47	0.07	0.07	0.06	94.02	201.10	0.20	0.43
Gamma=.5	509.37	611.83	727.82	827.00	38.41	26.02	11.99	38.70	47.14	56.05	0.08	0.08	0.08	102.46	218.45	0.20	0.43
K-21: 6 Nov 95	CCAS				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers7.07	AM7.07	MOD 2	Observed	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	1131.99	1210.51	1259.82	1375.00	243.01	164.49	115.18							78.52	127.83	0.07	0.11
Gamma=.57	1214.16	1295.91	1340.60	1375.00	160.84	79.09	34.40	82.17	85.40	80.78	0.07	0.07	0.06	81.75	126.44	0.07	0.10
Gamma=.5	1302.87	1386.28	1429.79	1375.00	72.13	-11.28	-54.79	88.71	90.37	89.19	0.07	0.07	0.07	83.41	126.92	0.06	0.10
K-16:24 Mar 96	CCAS				Difference from Observed			Differences wrt gammas			% Increase			Diff from V7.07		% Change	
REEDM Version	Vers7.07	AM7.07	MOD 2	Observed	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	Vers7.07	AM7.07	MOD 2	AM7.07	MOD 2	AM7.07	MOD 2
Gamma=.64	756.80	854.19	936.55	1023.00	266.20	168.81	86.45							97.39	179.75	0.13	0.24
Gamma=.57	810.94	917.76	999.50	1023.00	212.06	105.24	23.50	54.14	63.57	62.95	0.07	0.07	0.07	106.82	188.56	0.13	0.23
Gamma=.5	881.25	995.39	1080.65	1023.00	141.75	27.61	-57.65	70.31	77.63	81.15	0.09	0.08	0.08	114.14	199.40	0.13	0.23
									Average %:		0.11	0.11	0.10			0.15	0.31

Table D: Complete Table of Cloud Stabilization Height Data

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	81.36	8.89	1.7311E+06	2.77
3	31.24	15.63	31.25	91.36	9.98	1.7339E+06	4.40
4	46.86	15.63	46.87	101.40	9.91	1.7365E+06	5.96
5	62.48	15.63	62.49	111.40	9.50	1.7387E+06	7.57
6	90.73	28.25	90.73	129.40	8.56	1.7404E+06	10.70
7	119.00	28.25	118.98	147.50	7.67	1.7375E+06	14.19
8	147.20	28.25	147.25	165.60	6.91	1.7278E+06	18.07
9	178.90	31.71	178.91	185.90	6.18	1.7060E+06	22.93
10	210.60	31.71	210.61	206.20	5.60	1.7144E+06	28.33
11	255.30	44.66	255.26	234.80	4.99	1.8075E+06	36.78
12	299.90	44.66	299.96	263.40	4.52	1.8524E+06	46.18
13	377.00	77.12	377.02	312.70	3.88	1.8169E+06	64.57
14	459.60	82.61	459.61	365.60	3.26	1.4671E+06	87.71
15	542.20	82.61	542.21	418.40	2.67	9.1036E+05	115.60
16	604.70	62.49	604.69	458.40	2.22	3.3701E+05	141.20
17	711.10	106.40	711.10	526.50	1.38	-9.7940E+05	200.60
18	909.52		787.87	575.66		3.1282E+02	312.80

K-23 Vers 707
Gamma = .64
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	81.36	12.23	3.2785E+06	2.01
3	31.24	15.63	31.25	91.36	13.73	3.2812E+06	3.19
4	46.86	15.63	46.87	101.40	13.64	3.2838E+06	4.33
5	62.48	15.63	62.49	111.40	13.06	3.2861E+06	5.50
6	90.73	28.25	90.73	129.40	11.77	3.2878E+06	7.78
7	119.00	28.25	118.98	147.50	10.55	3.2850E+06	10.31
8	147.20	28.25	147.25	165.60	9.50	3.2755E+06	13.14
9	178.90	31.70	178.90	185.90	8.51	3.2541E+06	16.67
10	210.60	31.71	210.61	206.20	7.70	3.2631E+06	20.59
11	255.30	44.66	255.26	234.80	6.83	3.3575E+06	26.75
12	299.90	44.66	299.96	263.40	6.15	3.4043E+06	33.65
13	377.00	77.12	377.02	312.70	5.23	3.3735E+06	47.25
14	459.60	82.61	459.61	365.60	4.44	3.0324E+06	64.38
15	542.20	82.61	542.21	418.50	3.76	2.4877E+06	84.59
16	604.70	62.49	604.69	458.40	3.28	1.9263E+06	102.40
17	711.10	106.40	711.10	526.50	2.52	6.3848E+05	139.20
18	909.50	198.40	909.50	653.50	0.61	-3.6121E+06	268.10
19	1074.72		922.80	662.01			311.93

K-23 AM707
Gamma = .64
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	72.20	15.92	3.2784E+06	1.83
3	31.24	15.63	31.25	73.38	21.98	3.2805E+06	2.65
4	46.86	15.63	46.87	75.59	25.14	3.2822E+06	3.31
5	62.48	15.63	62.49	78.82	26.24	3.2836E+06	3.92
6	90.73	28.25	90.73	86.52	25.38	3.2851E+06	5.01
7	119.00	28.25	118.98	97.57	21.94	3.2853E+06	6.21
8	147.20	28.25	147.25	112.00	17.88	3.2831E+06	7.65
9	178.90	31.71	178.91	131.90	13.85	3.2760E+06	9.68
10	210.60	31.71	210.61	152.20	11.40	3.3049E+06	12.22
11	255.30	44.66	255.26	180.80	9.35	3.4377E+06	16.57
12	299.90	44.66	299.96	209.30	8.02	3.5369E+06	21.74
13	377.00	77.12	377.02	258.70	6.54	3.6266E+06	32.43
14	459.60	82.61	459.61	311.60	5.44	3.5127E+06	46.31
15	542.20	82.61	542.21	364.40	4.59	3.2354E+06	62.86
16	604.70	62.49	604.69	404.40	4.05	2.9033E+06	77.36
17	711.10	106.40	711.10	472.50	3.26	2.0601E+06	106.60
18	909.50	198.40	909.50	599.50	1.87	-1.0395E+06	184.80
19	1074.72		1031.52	677.60			317.32

K-23 MOD2
Gamma = .64
Initial heat (Q0) = 0.620663E+11 cal

Table D-1. Results for K-23 Launch

K-23 Vers 707
Gamma = .57
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	80.33	9.14	1.7311E+06	2.74
3	31.24	15.63	31.25	89.24	10.48	1.7338E+06	4.31
4	46.86	15.63	46.87	98.15	10.59	1.7363E+06	5.78
5	62.48	15.63	62.49	107.10	10.28	1.7385E+06	7.28
6	90.73	28.25	90.73	123.20	9.42	1.7405E+06	10.14
7	119.00	28.25	118.98	139.30	8.54	1.7388E+06	13.29
8	147.20	28.25	147.25	155.40	7.76	1.7315E+06	16.77
9	178.90	31.71	178.91	173.40	7.00	1.7148E+06	21.07
10	210.60	31.71	210.61	191.50	6.38	1.7295E+06	25.82
11	255.30	44.66	255.26	217.00	5.73	1.8340E+06	33.21
12	299.90	44.66	299.96	242.40	5.22	1.8861E+06	41.37
13	377.00	77.12	377.02	286.40	4.51	1.8354E+06	57.23
14	459.60	82.61	459.61	333.50	3.84	1.6068E+06	77.04
15	542.20	82.61	542.21	380.60	3.23	1.2216E+06	100.40
16	604.70	62.49	604.69	416.20	2.79	8.2159E+05	121.20
17	711.10	106.40	711.10	476.80	2.05	-7.9707E+04	165.30
18	909.52		879.36	572.72			331.05

K-23 AM707
Gamma = .57
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	80.33	12.57	3.2785E+06	1.99
3	31.24	15.63	31.25	89.24	14.43	3.2812E+06	3.13
4	46.86	15.63	46.87	98.15	14.57	3.2837E+06	4.20
5	62.48	15.63	62.49	107.10	14.14	3.2859E+06	5.29
6	90.73	28.25	90.73	123.20	12.95	3.2879E+06	7.37
7	119.00	28.25	118.98	139.30	11.75	3.2862E+06	9.66
8	147.20	28.25	147.25	155.40	10.67	3.2791E+06	12.19
9	178.90	31.71	178.91	173.40	9.63	3.2627E+06	15.32
10	210.60	31.70	210.60	191.50	8.77	3.2779E+06	18.77
11	255.30	44.66	255.26	217.00	7.83	3.3835E+06	24.16
12	299.90	44.66	299.96	242.40	7.08	3.4372E+06	30.16
13	377.00	77.12	377.02	286.40	6.07	3.3908E+06	41.93
14	459.60	82.61	459.61	333.50	5.19	3.1690E+06	56.64
15	542.20	82.61	542.21	380.60	4.46	2.7934E+06	73.80
16	604.70	62.49	604.69	416.20	3.96	2.4026E+06	88.67
17	711.10	106.40	711.10	476.80	3.21	1.5225E+06	118.50
18	909.50	198.40	909.50	589.90	1.85	-1.1455E+06	197.70
19	1074.72		1033.74	660.73			333.97

K23 MOD2
Gamma = .57
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	72.20	15.93	3.2784E+06	1.83
3	31.24	15.63	31.25	73.26	22.08	3.2805E+06	2.65
4	46.86	15.63	46.87	75.24	25.43	3.2822E+06	3.30
5	62.48	15.63	62.49	78.13	26.82	3.2836E+06	3.90
6	90.73	28.25	90.74	85.00	26.48	3.2851E+06	4.96
7	118.97	28.24	118.97	94.85	23.44	3.2854E+06	6.10
8	147.22	28.25	147.22	107.69	19.51	3.2836E+06	7.42
9	178.92	31.71	178.93	125.43	15.41	3.2778E+06	9.27
10	210.62	31.71	210.63	143.50	12.83	3.3086E+06	11.53
11	255.27	44.66	255.28	168.96	10.62	3.4453E+06	15.38
12	299.92	44.66	299.93	194.41	9.17	3.5464E+06	19.92
13	377.04	77.12	377.04	238.37	7.53	3.6245E+06	29.23
14	459.64	82.61	459.65	285.46	6.30	3.5777E+06	41.24
15	542.24	82.61	542.25	332.55	5.38	3.4047E+06	55.44
16	604.72	62.49	604.73	368.17	4.79	3.1844E+06	67.75
17	711.10	106.38	711.10	428.81	3.97	2.6237E+06	92.12
18	909.52	198.43	909.53	541.91	2.69	7.0265E+05	152.30
19	1074.70	165.21	1074.73	636.08	1.46	-2.2221E+06	232.40
20	1190.20		1155.30	681.99			343.90

Table D-1. Results for K-23 Launch

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	79.31	9.40	1.7311E+06	2.710
3	31.24	15.63	31.25	87.12	11.03	1.7337E+06	4.216
4	46.86	15.63	46.87	94.94	11.34	1.7361E+06	5.606
5	62.48	15.63	62.49	102.80	11.17	1.7383E+06	6.991
6	90.73	28.25	90.73	116.90	10.43	1.7404E+06	9.603
7	119.00	28.25	118.98	131.00	9.59	1.7396E+06	12.43
8	147.20	28.25	147.25	145.10	8.80	1.7344E+06	15.50
9	178.90	31.70	178.90	161.00	8.02	1.7219E+06	19.28
10	210.60	31.71	210.61	176.80	7.36	1.7411E+06	23.41
11	255.30	44.66	255.26	199.20	6.67	1.8530E+06	29.79
12	299.90	44.66	299.96	221.50	6.11	1.9040E+06	36.78
13	377.00	77.12	377.02	260.10	5.32	1.8941E+06	50.28
14	459.60	82.61	459.61	301.40	4.61	1.7694E+06	66.93
15	542.20	82.61	542.21	342.70	3.98	1.5308E+06	86.20
16	604.70	62.49	604.69	373.90	3.53	1.2789E+06	102.9
17	711.10	106.40	711.10	427.10	2.86	7.3305E+05	136.2
18	909.50	198.40	909.50	526.30	1.61	-8.5324E+05	225.4
19	1074.72		1021.20	582.15			365.069

K -23 Vers707
Gamma = .50
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	79.31	12.93	3.2785E+06	1.97
3	31.24	15.63	31.25	87.12	15.18	3.2811E+06	3.06
4	46.86	15.63	46.87	94.94	15.61	3.2835E+06	4.07
5	62.48	15.63	62.49	102.75	15.36	3.2856E+06	5.08
6	90.73	28.25	90.73	116.87	14.35	3.2878E+06	6.98
7	118.97	28.25	118.98	131.00	13.19	3.2870E+06	9.03
8	147.22	28.25	147.22	145.13	12.11	3.2820E+06	11.27
9	178.92	31.71	178.93	160.98	11.03	3.2697E+06	14.02
10	210.62	31.71	210.63	176.83	10.11	3.2893E+06	17.02
11	255.27	44.66	255.28	199.16	9.10	3.4021E+06	21.68
12	299.92	44.66	299.93	221.49	8.28	3.4545E+06	26.83
13	377.04	77.12	377.04	260.05	7.15	3.4481E+06	36.85
14	459.64	82.61	459.65	301.36	6.19	3.3288E+06	49.28
15	542.24	82.61	542.25	342.66	5.39	3.0975E+06	63.58
16	604.72	62.49	604.73	373.91	4.86	2.8524E+06	75.79
17	711.10	106.38	711.10	427.10	4.09	2.3213E+06	99.63
18	909.52	198.43	909.53	526.32	2.89	7.8539E+05	156.90
19	1074.70	165.21	1074.73	608.92	1.82	-1.3609E+06	227.50
20	1190.20	115.51	1190.21	666.68	0.54	-3.6105E+06	325.80
21	1214.32		1201.61	672.36			368.08

K23 AM707
Gamma = .50
Initial heat (Q0) = 0.620663E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	72.00	0.00	0.0000E+00	0.00
2	15.62	14.63	15.63	72.19	15.93	3.2784E+06	1.83
3	31.24	15.63	31.25	73.14	22.17	3.2805E+06	2.65
4	46.86	15.63	46.87	74.89	25.73	3.2822E+06	3.30
5	62.48	15.63	62.49	77.44	27.42	3.2836E+06	3.88
6	90.73	28.25	90.73	83.49	27.65	3.2851E+06	4.91
7	119.00	28.25	118.98	92.15	25.08	3.2856E+06	5.98
8	147.20	28.25	147.25	103.40	21.38	3.2842E+06	7.21
9	178.90	31.70	178.90	119.00	17.28	3.2795E+06	8.87
10	210.60	31.71	210.61	134.80	14.59	3.3116E+06	10.87
11	255.30	44.66	255.26	157.20	12.21	3.4505E+06	14.23
12	299.90	44.66	299.96	179.50	10.63	3.5493E+06	18.16
13	377.00	77.12	377.02	218.00	8.80	3.6460E+06	26.17
14	459.60	82.61	459.61	259.30	7.44	3.6574E+06	36.40
15	542.20	82.61	542.21	300.70	6.41	3.5742E+06	48.37
16	604.70	62.49	604.69	331.90	5.78	3.4502E+06	58.64
17	711.10	106.40	711.10	385.10	4.90	3.1331E+06	78.65
18	909.50	198.40	909.50	484.30	3.63	2.0582E+06	125.60
19	1075.00	165.20	1074.70	566.90	2.67	4.1253E+05	178.30
20	1190.00	115.50	1190.50	624.70	1.92	-1.3863E+06	228.70
21	1214.00	24.09	1214.09	636.70	1.73	-1.8164E+06	242.00
22	1355.14		1329.29	694.20			376.39

K-23 MOD2
Gamma = .50
Initial heat (Q0) = 0.620663E+11 cal

Table D-1. Results for K-23 Launch

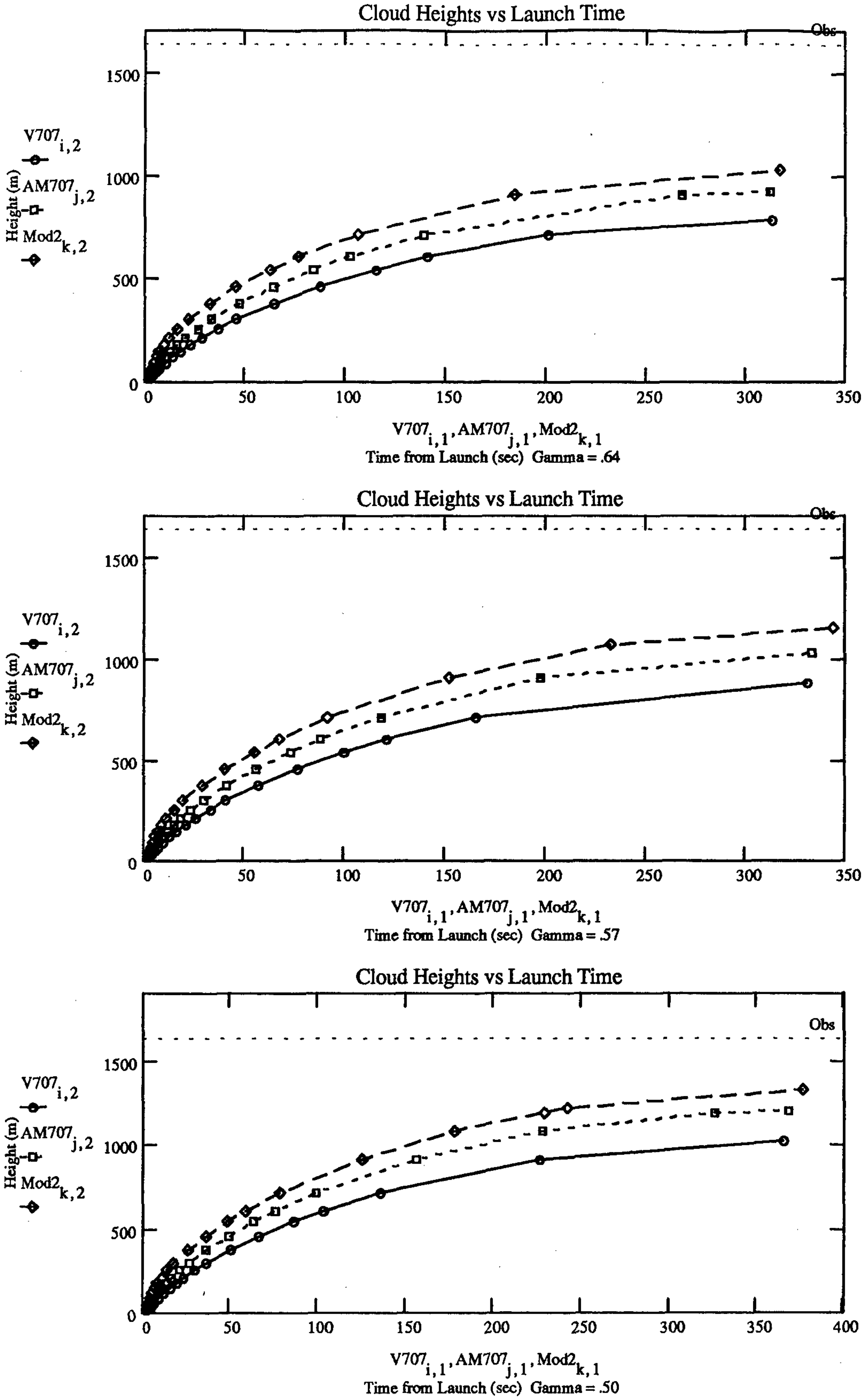


Figure D-1. K-23 Cloud Height Profiles

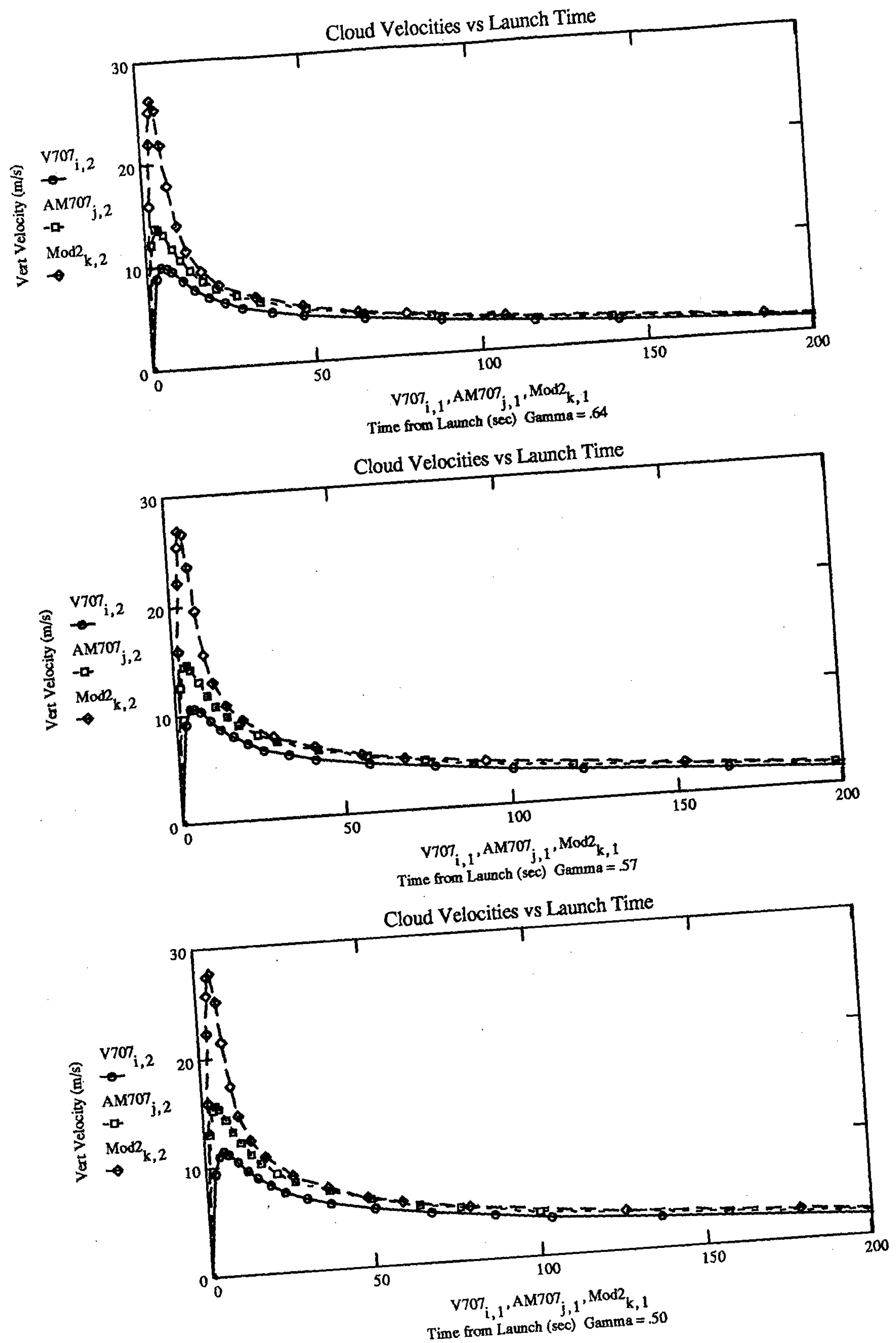


Figure D-2. K-23 Cloud Velocity Profiles

K-19 Vers 707
Gamma = .64
Initial heat (Q0) = 0.623588E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.37	11.38	12.38	79.28	8.31	1.7367E+06	2.38
3	24.75	12.38	24.75	87.20	9.77	1.7340E+06	3.73
4	37.12	12.38	37.13	95.13	10.03	1.7304E+06	4.98
5	49.50	12.38	49.50	103.10	9.85	1.7257E+06	6.22
6	61.87	12.38	61.88	111.00	9.50	1.7199E+06	7.50
7	84.53	22.66	84.53	125.50	8.73	1.7069E+06	9.98
8	107.20	22.66	107.19	140.00	7.97	1.6911E+06	12.70
9	129.80	22.66	129.86	154.50	7.29	1.6718E+06	15.68
10	157.60	27.74	157.54	172.20	6.56	1.6431E+06	19.69
11	185.30	27.74	185.34	190.00	5.94	1.6078E+06	24.14
12	242.60	57.31	242.61	226.70	5.05	1.6727E+06	34.61
13	299.90	57.31	299.91	263.40	4.42	1.7268E+06	46.75
14	394.00	94.09	393.99	323.60	3.65	1.6556E+06	70.11
15	488.10	94.09	488.09	383.80	3.03	1.4338E+06	98.34
16	582.20	94.09	582.19	444.00	2.47	9.4391E+05	132.60
17	604.70	22.56	604.76	458.50	2.33	7.9231E+05	142.00
18	757.10	152.40	757.10	556.00	1.38	-8.3707E+05	224.20
19	909.52		851.30	616.26			362.21

K-19 AM 707
Gamma = .64
Initial heat (Q0) = 0.623588E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.38	11.38	12.38	79.28	11.48	3.3107E+06	1.73
3	24.75	12.38	24.76	87.20	13.49	3.3080E+06	2.70
4	37.13	12.38	37.13	95.13	13.85	3.3044E+06	3.60
5	49.50	12.38	49.51	103.05	13.61	3.2998E+06	4.50
6	61.87	12.38	61.88	110.97	13.13	3.2940E+06	5.43
7	84.53	22.67	84.54	125.48	12.08	3.2811E+06	7.23
8	107.19	22.67	107.20	139.98	11.04	3.2654E+06	9.19
9	129.84	22.67	129.86	154.49	10.11	3.2463E+06	11.34
10	157.58	27.75	157.59	172.25	9.12	3.2179E+06	14.23
11	185.32	27.74	185.32	190.00	8.29	3.1829E+06	17.42
12	242.62	57.31	242.63	226.68	7.01	3.2486E+06	24.95
13	299.92	57.31	299.93	263.36	6.09	3.3042E+06	33.73
14	394.00	94.09	394.01	323.58	5.01	3.2373E+06	50.77
15	488.09	94.09	488.09	383.79	4.19	3.0229E+06	71.33
16	582.17	94.09	582.18	444.01	3.52	2.5475E+06	95.82
17	604.72	22.56	604.73	458.45	3.37	2.4005E+06	102.40
18	757.12	152.41	757.13	555.99	2.44	8.2438E+05	155.10
19	909.52	152.41	909.53	653.53	1.42	-1.7162E+06	234.60
20	1053.40		997.60	709.90	0.00		359.41

K -19 MOD2
Gamma = .64
Initial heat (Q0) = 0.623588E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.37	11.38	12.38	72.16	14.14	3.3109E+06	1.60
3	24.75	12.38	24.75	72.92	19.89	3.3091E+06	2.33
4	37.12	12.38	37.13	74.33	23.38	3.3072E+06	2.90
5	49.50	12.38	49.50	76.39	25.31	3.3052E+06	3.41
6	61.87	12.38	61.88	79.09	26.02	3.3030E+06	3.89
7	84.53	22.66	84.53	85.20	25.50	3.2982E+06	4.77
8	107.20	22.67	107.20	93.48	23.08	3.2928E+06	5.70
9	129.80	22.66	129.86	103.90	19.92	3.2866E+06	6.76
10	157.60	27.74	157.54	119.30	16.16	3.2773E+06	8.32
11	185.30	27.74	185.34	137.10	13.10	3.2648E+06	10.24
12	242.60	57.31	242.61	173.70	9.77	3.3854E+06	15.37
13	299.90	57.31	299.91	210.40	7.98	3.5120E+06	21.90
14	394.00	94.09	393.99	270.60	6.25	3.5996E+06	35.28
15	488.10	94.09	488.09	330.90	5.13	3.5621E+06	51.93
16	582.20	94.09	582.19	391.10	4.30	3.3215E+06	71.98
17	604.70	22.56	604.76	405.50	4.12	3.2365E+06	77.34
18	757.10	152.40	757.10	503.10	3.13	2.1919E+06	119.70
19	909.50	152.40	909.50	600.60	2.22	3.2954E+05	177.00
20	1053.00	143.90	1053.40	692.70	1.13	-2.8774E+06	263.10
21	1214.32		1108.14	727.71			360.29

Table D-2. Results for K-19 Launch

K-19 Vers 707
Gamma = .57
Initial heat (Q0) = 0.623588E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.37	11.38	12.38	78.48	8.50	1.7368E+06	2.36
3	24.75	12.38	24.75	85.54	10.18	1.7341E+06	3.67
4	37.12	12.38	37.13	92.60	10.61	1.7308E+06	4.85
5	49.50	12.38	49.50	99.66	10.55	1.7265E+06	6.02
6	61.87	12.38	61.88	106.70	10.28	1.7213E+06	7.21
7	84.53	22.66	84.53	119.60	9.58	1.7096E+06	9.49
8	107.20	22.66	107.19	132.60	8.84	1.6957E+06	11.95
9	129.80	22.66	129.86	145.50	8.15	1.6790E+06	14.62
10	157.60	27.74	157.54	161.30	7.40	1.6547E+06	18.19
11	185.30	27.74	185.34	177.10	6.75	1.6251E+06	22.12
12	242.60	57.31	242.61	209.80	5.80	1.7059E+06	31.29
13	299.90	57.31	299.91	242.40	5.12	1.7874E+06	41.80
14	394.00	94.09	393.99	296.10	4.32	1.8268E+06	61.78
15	488.10	94.09	488.09	349.70	3.68	1.7412E+06	85.36
16	582.20	94.09	582.19	403.30	3.13	1.4924E+06	113.00
17	604.70	22.56	604.76	416.20	3.00	1.4174E+06	120.40
18	757.10	152.40	757.10	503.10	2.22	4.5841E+05	178.80
19	909.50	152.40	909.50	589.90	1.19	-1.5342E+06	268.00
20	1053.39		973.72	626.52			375.51

K-19 AM707 K19
Gamma = .57
Initial heat (Q0) = 0.623588E+11 ca

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.38	11.38	12.38	78.48	11.73	3.3107E+06	1.71
3	24.75	12.38	24.76	85.54	14.06	3.3081E+06	2.66
4	37.13	12.38	37.13	92.60	14.66	3.3048E+06	3.52
5	49.50	12.38	49.51	99.65	14.58	3.3006E+06	4.36
6	61.87	12.38	61.88	106.71	14.21	3.2954E+06	5.22
7	84.53	22.67	84.54	119.63	13.25	3.2838E+06	6.87
8	107.19	22.67	107.20	132.55	12.25	3.2700E+06	8.65
9	129.84	22.67	129.86	145.47	11.31	3.2535E+06	10.58
10	157.58	27.75	157.59	161.28	10.29	3.2293E+06	13.15
11	185.32	27.75	185.33	177.10	9.40	3.2001E+06	15.97
12	242.62	57.31	242.63	209.77	8.04	3.2816E+06	22.58
13	299.92	57.31	299.93	242.43	7.04	3.3642E+06	30.21
14	394.00	94.09	394.01	296.06	5.86	3.4067E+06	44.87
15	488.09	94.09	488.09	349.69	4.98	3.3265E+06	62.29
16	582.17	94.09	582.18	403.32	4.28	3.0876E+06	82.66
17	604.72	22.56	604.73	416.18	4.13	3.0158E+06	88.03
18	757.12	152.41	757.13	503.06	3.23	2.0943E+06	129.60
19	909.52	152.41	909.53	589.93	2.36	1.7748E+05	184.30
20	1053.40	143.87	1053.39	671.93	1.28	-2.7504E+06	263.80
21	1214.30		1117.10	708.28			363.99

K-19 MOD2
Gamma = .57
Initial heat (Q0) = 0.623588E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	12.38	11.38	12.38	72.15	14.14	3.3109E+06	1.60
3	24.75	12.38	24.76	72.85	19.95	3.3091E+06	2.33
4	37.13	12.38	37.13	74.11	23.56	3.3072E+06	2.90
5	49.50	12.38	49.51	75.95	25.67	3.3053E+06	3.40
6	61.87	12.38	61.88	78.37	26.62	3.3031E+06	3.87
7	84.53	22.66	84.54	83.83	26.52	3.2985E+06	4.72
8	107.19	22.67	107.20	91.21	24.46	3.2933E+06	5.61
9	129.84	22.67	129.86	100.50	21.49	3.2876E+06	6.60
10	157.58	27.74	157.58	114.23	17.78	3.2790E+06	8.03
11	185.32	27.74	185.32	130.04	14.63	3.2680E+06	9.76
12	242.62	57.31	242.63	162.71	11.08	3.3937E+06	14.32
13	299.92	57.31	299.93	195.38	9.13	3.5318E+06	20.04
14	394.00	94.09	394.01	249.01	7.24	3.6773E+06	31.67
15	488.09	94.09	488.09	302.64	6.01	3.7198E+06	45.98
16	582.17	94.09	582.18	356.27	5.11	3.6333E+06	62.98
17	604.72	22.56	604.73	369.13	4.92	3.5992E+06	67.48
18	757.12	152.41	757.13	456.00	3.89	3.0201E+06	102.30
19	909.52	152.41	909.53	542.87	3.00	1.6244E+06	146.70
20	1053.40	143.87	1053.39	624.88	2.12	-6.4448E+05	203.10
21	1214.30	160.93	1214.33	716.61	0.37	-4.7037E+06	333.30
22	1519.10		1219.60	719.62			361.66

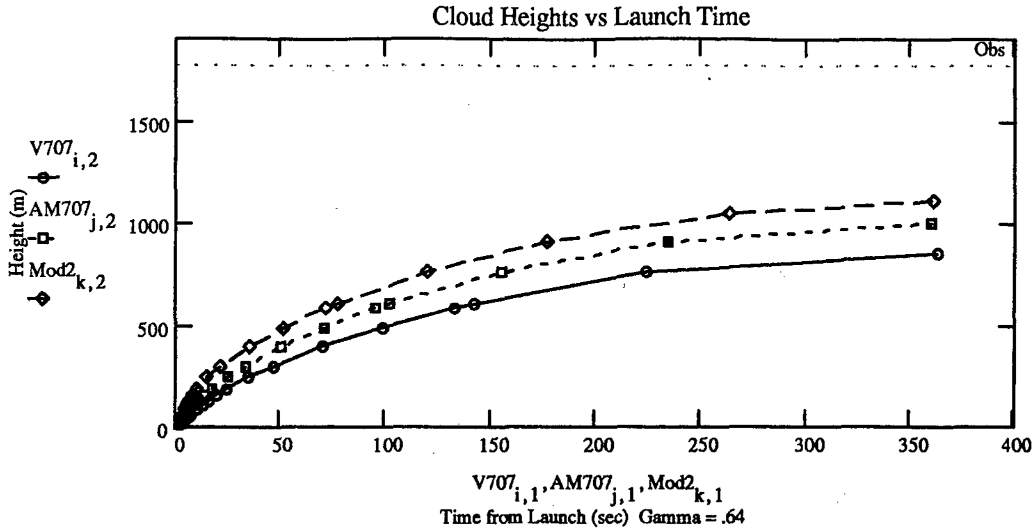
Table D-2. Results for K-19 Launch

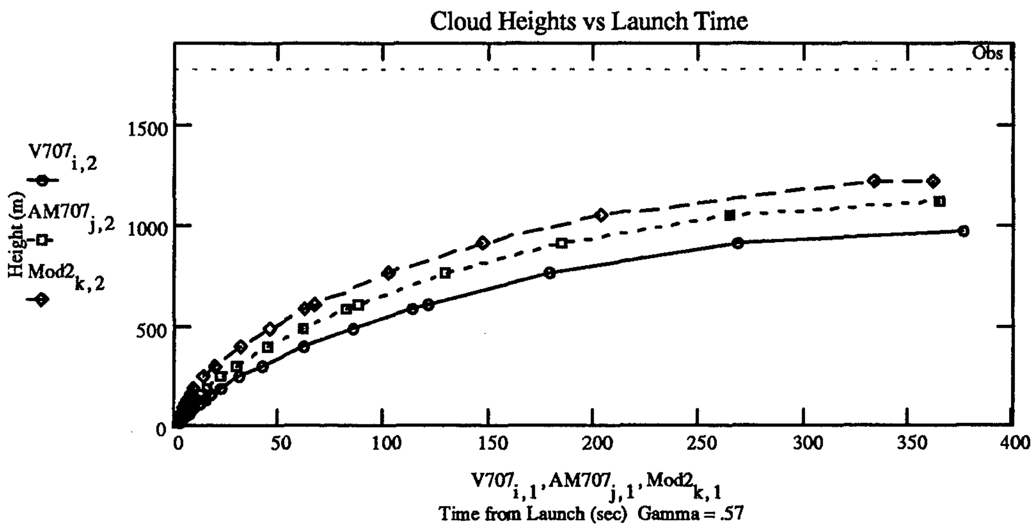
Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-19 Vers707	
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = .50	
2	12.37	11.38	12.38	77.68	8.69	1.7368E+06	2.34	Initial heat (Q0) =	0.623588E+11 cal
3	24.75	12.38	24.75	83.87	10.62	1.7343E+06	3.61		
4	37.12	12.38	37.13	90.06	11.25	1.7311E+06	4.73		
5	49.50	12.38	49.50	96.26	11.34	1.7273E+06	5.83		
6	61.87	12.38	61.88	102.40	11.17	1.7226E+06	6.93		
7	84.53	22.66	84.53	113.80	10.58	1.7122E+06	9.01		
8	107.20	22.66	107.19	125.10	9.89	1.7000E+06	11.22		
9	129.80	22.66	129.86	136.40	9.21	1.6857E+06	13.60		
10	157.60	27.74	157.54	150.30	8.44	1.6653E+06	16.75		
11	185.30	27.74	185.34	164.20	7.76	1.6405E+06	20.18		
12	242.60	57.31	242.61	192.80	6.74	1.7353E+06	28.11		
13	299.90	57.31	299.91	221.50	6.01	1.8454E+06	37.10		
14	394.00	94.09	393.99	268.50	5.16	1.9607E+06	53.96		
15	488.10	94.09	488.09	315.60	4.49	1.9848E+06	73.49		
16	582.20	94.09	582.19	362.60	3.93	1.9231E+06	95.88		
17	604.70	22.56	604.76	373.90	3.80	1.8879E+06	101.70		
18	757.10	152.40	757.10	450.10	3.04	1.2720E+06	146.20		
19	909.50	152.40	909.50	526.30	2.20	-8.9618E+04	204.30		
20	1053.00	143.90	1053.40	598.20	1.06	-2.2000E+06	292.50		
21	1214.32		1096.78	619.95			374.50		

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-19 AM 707	
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = .50	
2	12.38	11.38	12.38	77.69	12.00	3.3107E+06	1.70	Initial heat (Q0) =	0.623588E+11 cal
3	24.75	12.38	24.76	83.88	14.67	3.3082E+06	2.61		
4	37.13	12.38	37.13	90.07	15.54	3.3051E+06	3.43		
5	49.50	12.38	49.51	96.26	15.66	3.3013E+06	4.22		
6	61.87	12.38	61.88	102.45	15.43	3.2967E+06	5.02		
7	84.53	22.66	84.54	113.78	14.63	3.2864E+06	6.52		
8	107.19	22.66	107.19	125.11	13.69	3.2743E+06	8.12		
9	129.84	22.66	129.85	136.44	12.76	3.2601E+06	9.84		
10	157.58	27.74	157.58	150.31	11.72	3.2399E+06	12.11		
11	185.32	27.75	185.33	164.19	10.79	3.2153E+06	14.58		
12	242.62	57.31	242.63	192.84	9.33	3.3107E+06	20.30		
13	299.92	57.31	299.93	221.50	8.24	3.4217E+06	26.84		
14	394.00	94.09	394.01	268.54	6.95	3.5391E+06	39.28		
15	488.09	94.09	488.09	315.58	5.99	3.5669E+06	53.87		
16	582.17	94.09	582.18	362.63	5.24	3.5117E+06	70.66		
17	604.72	22.56	604.73	373.91	5.07	3.4786E+06	75.04		
18	757.12	152.41	757.13	450.11	4.14	2.8895E+06	108.20		
19	909.52	152.41	909.53	526.32	3.27	1.5823E+06	149.50		
20	1053.40	143.88	1053.40	598.26	2.40	-4.4373E+05	200.40		
21	1214.30	160.93	1214.33	678.72	0.92	-4.1038E+06	297.50		
22	1519.10		1243.10	693.09			359.81		

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-19 MOD2	
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = .50	
2	12.37	11.38	12.38	72.14	14.15	3.3109E+06	1.60	Initial heat (Q0) =	0.623588E+11 cal
3	24.75	12.38	24.75	72.77	20.00	3.3091E+06	2.33		
4	37.12	12.38	37.13	73.89	23.73	3.3073E+06	2.89		
5	49.50	12.38	49.50	75.52	26.05	3.3053E+06	3.39		
6	61.87	12.38	61.88	77.65	27.24	3.3032E+06	3.85		
7	84.53	22.66	84.53	82.45	27.60	3.2987E+06	4.68		
8	107.20	22.66	107.19	88.94	25.96	3.2938E+06	5.52		
9	129.80	22.67	129.87	97.10	23.27	3.2884E+06	6.45		
10	157.60	27.74	157.54	109.10	19.67	3.2807E+06	7.75		
11	185.30	27.74	185.34	123.00	16.47	3.2708E+06	9.30		
12	242.60	57.31	242.61	151.70	12.71	3.4011E+06	13.30		
13	299.90	57.31	299.91	180.30	10.58	3.5519E+06	18.26		
14	394.00	94.09	393.99	227.40	8.49	3.7375E+06	28.23		
15	488.10	94.09	488.09	274.40	7.13	3.8452E+06	40.35		
16	582.20	94.09	582.19	321.50	6.14	3.8796E+06	54.59		
17	604.70	22.56	604.76	332.70	5.93	3.8718E+06	58.33		
18	757.10	152.40	757.10	408.90	4.82	3.5263E+06	86.84		
19	909.50	152.40	909.50	485.20	3.88	2.5914E+06	122.00		
20	1053.00	143.90	1053.40	557.10	3.04	1.0300E+06	163.70		
21	1214.00	160.90	1213.90	637.60	1.95	-1.9197E+06	228.50		
22	1519.12		1337.57	699.18			355.71		

Table D-2. Results for K-19 Launch





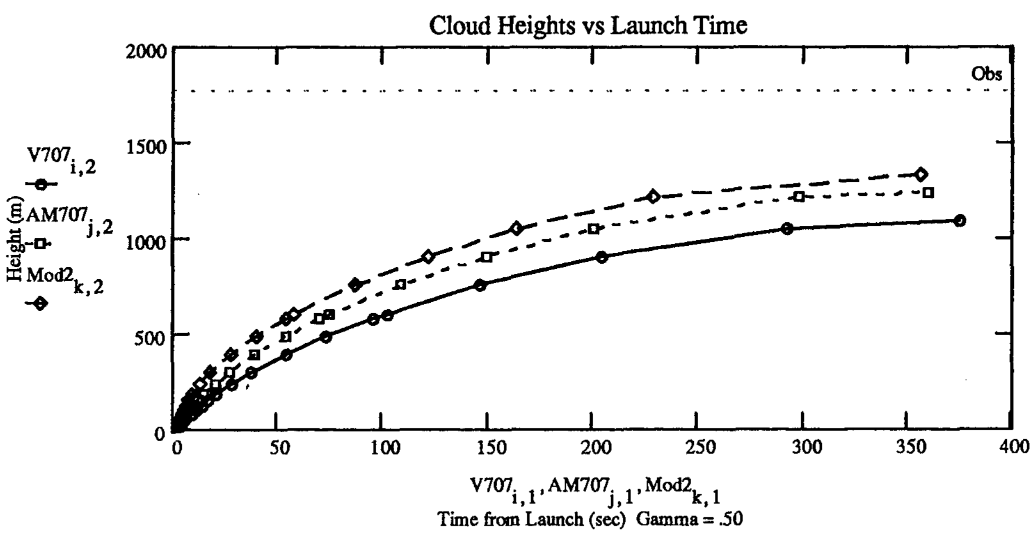


Figure D-3: K-19 Cloud Height Profiles

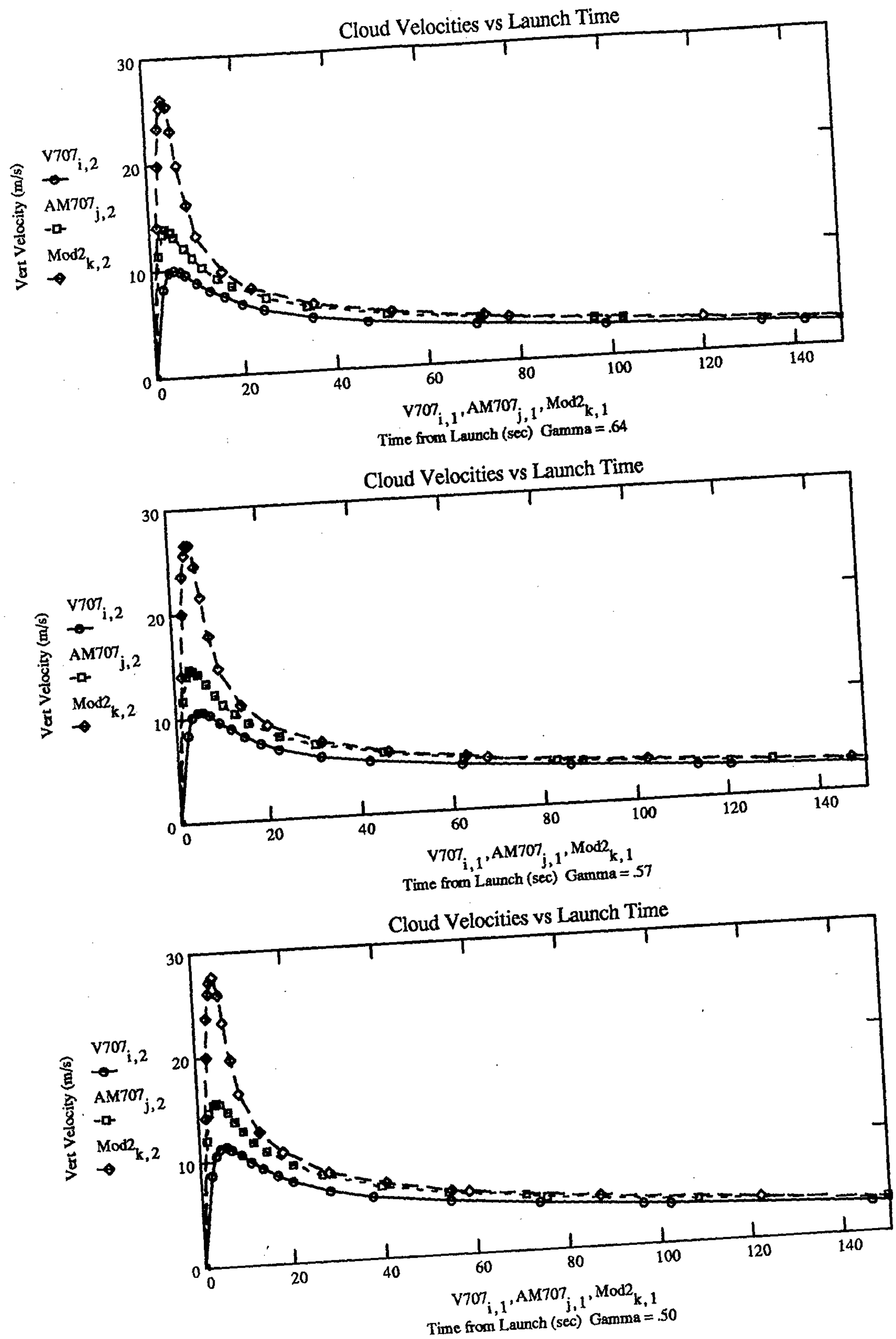


Figure D-4. K-19 Cloud Velocity Profiles

K-21 Vers 707
Gamma = .64
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	14.94	13.94	14.94	80.92	8.70	1.6972E+06	2.71
3	29.87	14.94	29.88	90.48	9.85	1.6907E+06	4.30
4	44.81	14.94	44.81	100.00	9.83	1.6833E+06	5.81
5	59.74	14.94	59.75	109.60	9.45	1.6750E+06	7.35
6	91.67	31.93	91.67	130.00	8.37	1.6550E+06	10.94
7	123.60	31.93	123.60	150.50	7.37	1.6290E+06	15.01
8	155.50	31.93	155.53	170.90	6.52	1.5965E+06	19.62
9	187.50	31.93	187.43	191.40	5.81	1.5573E+06	24.82
10	243.70	56.24	243.74	227.30	4.96	1.6354E+06	35.29
11	299.90	56.24	299.94	263.30	4.37	1.7157E+06	47.37
12	401.50	101.60	401.50	328.40	3.64	1.8391E+06	72.82
13	503.10	101.60	503.10	393.40	3.18	2.2208E+06	102.80
14	604.70	101.60	604.70	458.40	2.88	2.5711E+06	136.30
15	630.00	25.31	630.01	474.60	2.82	2.6555E+06	145.20
16	684.30	54.26	684.26	509.40	2.70	2.8437E+06	164.90
17	858.30	174.00	858.30	620.70	2.26	2.0364E+06	234.50
18	909.50	51.22	909.52	653.50	2.08	1.3341E+06	258.10
19	976.30	66.76	976.26	696.20	1.80	-6.3434E+04	292.40
20	1089.00	112.80	1089.10	768.40	0.98	-3.9107E+06	372.70
21	1149.10		1131.99	795.91			459.04

K-21 AM707
Gamma = .64
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	14.94	13.94	14.94	80.92	11.91	3.1795E+06	1.98
3	29.87	14.94	29.88	90.48	13.48	3.1729E+06	3.14
4	44.81	14.94	44.81	100.04	13.47	3.1655E+06	4.24
5	59.74	14.94	59.75	109.61	12.95	3.1573E+06	5.37
6	91.67	31.94	91.68	130.05	11.50	3.1373E+06	7.99
7	123.60	31.94	123.60	150.49	10.14	3.1114E+06	10.95
8	155.52	31.94	155.54	170.92	8.99	3.0789E+06	14.30
9	187.45	31.94	187.46	191.36	8.05	3.0397E+06	18.06
10	243.69	56.24	243.69	227.36	6.84	3.1178E+06	25.65
11	299.92	56.24	299.93	263.35	5.97	3.1982E+06	34.46
12	401.52	101.61	401.53	328.38	4.90	3.3213E+06	53.28
13	503.12	101.61	503.13	393.41	4.19	3.7018E+06	75.78
14	604.72	101.61	604.73	458.44	3.72	4.0510E+06	101.60
15	630.02	25.31	630.03	474.63	3.61	4.1354E+06	108.50
16	684.28	54.26	684.28	509.36	3.42	4.3236E+06	123.90
17	858.32	174.05	858.33	620.75	2.85	3.5714E+06	179.30
18	909.52	51.21	909.53	653.53	2.66	2.9066E+06	197.80
19	976.27	66.76	976.28	696.25	2.38	1.5818E+06	224.20
20	1089.10	112.78	1089.05	768.43	1.76	-2.0668E+06	278.50
21	1149.10	60.05	1149.15	806.87	1.26	-4.7055E+06	318.20
22	1170.80	21.75	1170.85	820.79	1.02	-5.7989E+06	337.30
23	1192.60	21.75	1192.55	834.71	0.69	-6.9749E+06	362.80
24	1214.30		1210.50	846.18			414.98

K-21 MOD2
Gamma = 0.64
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
2	14.94	13.94	14.94	72.19	15.33	3.1798E+06	1.81
3	29.87	14.94	29.88	73.28	21.23	3.1750E+06	2.63
4	44.81	14.94	44.81	75.30	24.41	3.1708E+06	3.28
5	59.74	14.94	59.75	78.26	25.68	3.1669E+06	3.87
6	91.67	31.94	91.68	86.60	25.07	3.1593E+06	5.13
7	123.60	31.94	123.61	99.21	21.17	3.1508E+06	6.52
8	155.50	31.93	155.53	116.10	16.65	3.1404E+06	8.24
9	187.50	31.93	187.43	136.50	12.94	3.1271E+06	10.43
10	243.70	56.24	243.74	172.50	9.66	3.2546E+06	15.53
11	299.90	56.24	299.94	208.50	7.91	3.3911E+06	21.99
12	401.50	101.60	401.50	273.60	6.12	3.5925E+06	36.69
13	503.10	101.60	503.10	338.60	5.06	3.9259E+06	55.02
14	604.70	101.60	604.70	403.60	4.37	4.2364E+06	76.66
15	630.00	25.30	630.00	419.80	4.23	4.3118E+06	82.55
16	684.30	54.26	684.26	454.50	3.96	4.4783E+06	95.82
17	858.30	174.00	858.30	565.90	3.24	4.0130E+06	144.30
18	909.50	51.21	909.51	598.70	3.03	3.5278E+06	160.60
19	976.30	66.76	976.26	641.40	2.73	2.5272E+06	183.80
20	1089.00	112.80	1089.10	713.60	2.14	-3.2268E+05	230.00
21	1149.00	60.05	1149.05	752.10	1.73	-2.4285E+06	261.00
22	1171.00	21.75	1170.75	766.00	1.55	-3.3086E+06	274.20
23	1193.00	21.75	1192.75	779.90	1.35	-4.2595E+06	289.20
24	1214.00	21.75	1214.75	793.80	1.12	-5.2843E+06	306.80
25	1242.00	27.59	1241.59	811.50	0.70	-6.7131E+06	337.10
26	1297.08		1259.82	822.93			387.93

Table D-3: Results for K-21 Launch

K-21 Vers 707
Gamma = 0.57
Initial heat (Q0) = 0.612841E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
2	14.94	13.94	14.94	79.94	8.90	1.6845E+06	2.69
3	29.87	14.94	29.88	88.46	10.29	1.6781E+06	4.23
4	44.81	14.94	44.81	96.97	10.44	1.6712E+06	5.66
5	59.74	14.94	59.75	105.50	10.17	1.6635E+06	7.11
6	91.67	31.93	91.67	123.70	9.19	1.6456E+06	10.40
7	123.60	31.93	123.60	141.90	8.19	1.6228E+06	14.08
8	155.50	31.93	155.53	160.10	7.32	1.5948E+06	18.21
9	187.50	31.93	187.43	178.30	6.58	1.5615E+06	22.81
10	243.70	56.25	243.75	210.40	5.68	1.6517E+06	32.02
11	299.90	56.24	299.94	242.40	5.04	1.7666E+06	42.53
12	401.50	101.60	401.50	300.30	4.32	2.1111E+06	64.29
13	503.10	101.60	503.10	358.20	3.84	2.4222E+06	89.19
14	604.70	101.60	604.70	416.20	3.49	2.7564E+06	116.90
15	630.00	25.31	630.01	430.60	3.41	2.8331E+06	124.20
16	684.30	54.26	684.26	461.50	3.26	3.0019E+06	140.50
17	858.30	174.10	858.40	560.70	2.80	2.6669E+06	197.70
18	909.50	51.21	909.51	589.90	2.64	2.3269E+06	216.50
19	976.30	66.76	976.26	628.00	2.39	1.3914E+06	243.00
20	1089.00	112.80	1089.10	692.30	1.81	-1.3624E+06	296.40
21	1149.00	60.05	1149.05	726.50	1.33	-3.4304E+06	334.70
22	1171.00	21.75	1170.75	738.90	1.09	-4.2925E+06	352.70
23	1193.00	21.75	1192.75	751.30	0.77	-5.2217E+06	376.10
24	1214.32		1214.16	763.58			431.80

K-21 AM707
Gamma =.57
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
2	14.94	13.943	14.94	79.94	12.23	3.1795E+06	1.96
3	29.87	14.944	29.88	88.46	14.14	3.1731E+06	3.08
4	44.81	14.944	44.81	96.98	14.36	3.1662E+06	4.12
5	59.74	14.945	59.75	105.50	13.99	3.1586E+06	5.17
6	91.67	31.936	91.68	123.70	12.66	3.1406E+06	7.57
7	123.60	31.936	123.61	141.90	11.31	3.1179E+06	10.24
8	155.52	31.936	155.54	160.11	10.13	3.0899E+06	13.22
9	187.45	31.936	187.46	178.31	9.14	3.0566E+06	16.55
10	243.69	56.243	243.69	210.37	7.84	3.1481E+06	23.20
11	299.92	56.244	299.93	242.43	6.90	3.2644E+06	30.86
12	401.52	101.61	401.53	300.34	5.76	3.6104E+06	47.01
13	503.12	101.61	503.13	358.26	5.00	3.9231E+06	65.96
14	604.72	101.61	604.73	416.18	4.45	4.2575E+06	87.52
15	630.02	25.303	630.02	430.60	4.33	4.3347E+06	93.29
16	684.28	54.263	684.28	461.53	4.10	4.5044E+06	106.20
17	858.32	174.05	858.33	560.74	3.47	4.2049E+06	152.20
18	909.52	51.212	909.53	589.93	3.28	3.8863E+06	167.30
19	976.27	66.758	976.28	627.98	3.02	3.0016E+06	188.50
20	1089.10	112.78	1089.05	692.27	2.48	3.9126E+05	229.30
21	1149.10	60.054	1149.15	726.50	2.11	-1.5707E+06	255.50
22	1170.80	21.752	1170.85	738.89	1.95	-2.3887E+06	266.20
23	1192.60	21.75	1192.55	751.29	1.78	-3.2702E+06	277.90
24	1214.30	21.748	1214.35	763.69	1.59	-4.2179E+06	290.80
25	1241.90	27.59	1241.89	779.41	1.30	-5.5207E+06	309.90
26	1297.10		1295.90	810.20			392.62

K-21 MOD2
Gamma = 0.57
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
2	14.94	13.94	14.94	72.19	15.33	3.1798E+06	1.81
3	29.87	14.95	29.88	73.17	21.31	3.1750E+06	2.62
4	44.81	14.94	44.81	74.98	24.68	3.1709E+06	3.27
5	59.74	14.94	59.75	77.63	26.21	3.1670E+06	3.86
6	91.67	31.94	91.68	85.08	26.15	3.1595E+06	5.07
7	123.60	31.94	123.61	96.32	22.67	3.1515E+06	6.39
8	155.52	31.93	155.53	111.38	18.26	3.1419E+06	7.97
9	187.45	31.93	187.45	129.58	14.45	3.1298E+06	9.95
10	243.69	56.25	243.70	161.64	10.96	3.2614E+06	14.47
11	299.92	56.24	299.93	193.70	9.05	3.4138E+06	20.15
12	401.52	101.61	401.53	251.61	7.11	3.7371E+06	32.90
13	503.12	101.61	503.13	309.53	5.94	4.0294E+06	48.59
14	604.72	101.61	604.73	367.45	5.14	4.3307E+06	67.00
15	630.02	25.30	630.02	381.87	4.98	4.4013E+06	72.00
16	684.28	54.26	684.28	412.80	4.67	4.5551E+06	83.26
17	858.32	174.05	858.33	512.01	3.87	4.4212E+06	124.20
18	909.52	51.21	909.53	541.20	3.65	4.1990E+06	137.80
19	976.27	66.76	976.28	579.25	3.36	3.5367E+06	156.80
20	1089.10	112.78	1089.05	643.54	2.81	1.5019E+06	193.30
21	1149.10	60.05	1149.15	677.77	2.47	-6.3574E+04	216.00
22	1170.80	21.75	1170.85	690.16	2.33	-7.2221E+05	225.10
23	1192.60	21.75	1192.55	702.56	2.17	-1.4352E+06	234.80

Table D-3: Results for K-21 Launch

K-21 Vers 707
Gamma = .64
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	14.94	13.94	14.94	78.96	9.18	1.6973E+06	2.657
3	29.87	14.94	29.88	86.44	10.85	1.6912E+06	4.126
4	44.81	14.94	44.81	93.91	11.21	1.6846E+06	5.473
5	59.74	14.94	59.75	101.40	11.07	1.6776E+06	6.812
6	91.67	31.93	91.67	117.30	10.23	1.6615E+06	9.804
7	123.60	31.93	123.60	133.30	9.26	1.6417E+06	13.08
8	155.50	31.93	155.53	149.30	8.38	1.6179E+06	16.71
9	187.50	31.93	187.43	165.20	7.60	1.5898E+06	20.72
10	243.70	56.24	243.74	193.40	6.63	1.6963E+06	28.64
11	299.90	56.24	299.94	221.50	5.96	1.8668E+06	37.59
12	401.50	101.60	401.50	272.30	5.19	2.2187E+06	55.85
13	503.10	101.60	503.10	323.10	4.64	2.5176E+06	76.55
14	604.70	101.60	604.70	373.90	4.22	2.8397E+06	99.51
15	630.00	25.31	630.01	386.60	4.12	2.9183E+06	105.6
16	684.30	54.26	684.26	413.70	3.94	3.0729E+06	119.0
17	858.30	174.00	858.30	500.70	3.45	3.0968E+06	166.0
18	909.50	51.21	909.51	526.30	3.29	2.9387E+06	181.2
19	976.30	66.76	976.26	559.70	3.06	2.4018E+06	202.2
20	1089.00	112.80	1089.10	616.10	2.57	5.4398E+05	242.1
21	1149.00	60.05	1149.05	646.10	2.21	-9.1987E+05	267.2
22	1171.00	21.75	1170.75	657.00	2.06	-1.5422E+06	277.4
23	1193.00	21.75	1192.75	667.90	1.89	-2.2146E+06	288.4
24	1214.00	21.75	1214.75	678.70	1.71	-2.9393E+06	300.5
25	1242.00	27.59	1241.59	692.50	1.42	-3.9375E+06	318.1
26	1297.00	55.16	1297.16	720.10	0.45	-6.2134E+06	376.9
27	1490.78		1302.87	723.01			402.849

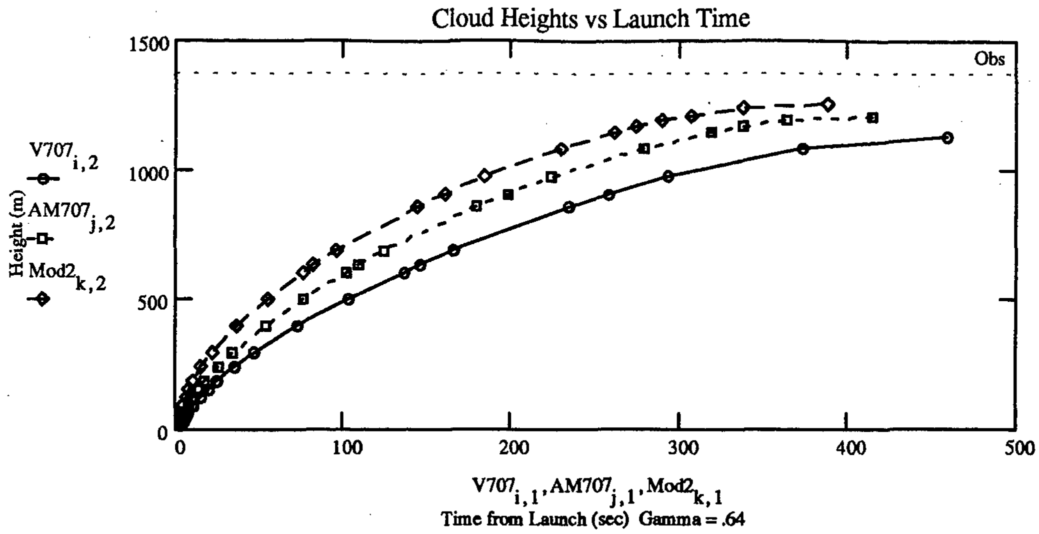
K-21 AM707
Gamma = .50
Initial heat (Q0) = 0.617472E+11 cal

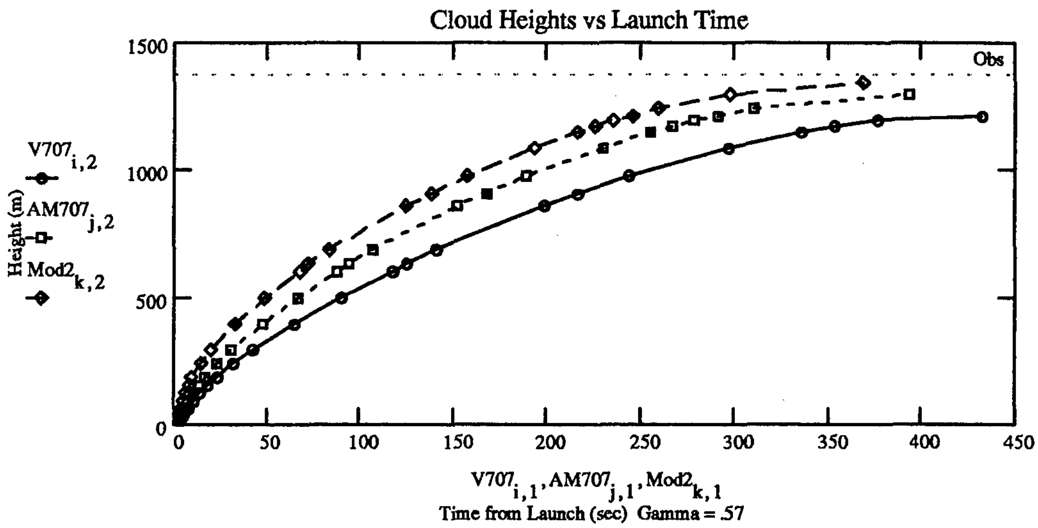
Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	14.94	13.94	14.94	78.97	12.56	3.1795E+06	1.94
3	29.87	14.95	29.88	86.44	14.86	3.1734E+06	3.02
4	44.81	14.94	44.81	93.91	15.35	3.1668E+06	4.00
5	59.74	14.94	59.75	101.38	15.17	3.1598E+06	4.98
6	91.67	31.94	91.68	117.35	14.04	3.1437E+06	7.16
7	123.60	31.94	123.61	133.32	12.73	3.1240E+06	9.55
8	155.52	31.94	155.54	149.28	11.54	3.1002E+06	12.18
9	187.45	31.94	187.46	165.25	10.49	3.0722E+06	15.09
10	243.69	56.24	243.69	193.38	9.10	3.1787E+06	20.85
11	299.92	56.25	299.94	221.50	8.09	3.3492E+06	27.42
12	401.52	101.61	401.53	272.30	6.84	3.7004E+06	41.10
13	503.12	101.61	503.13	323.11	5.97	3.9990E+06	57.02
14	604.72	101.61	604.73	373.91	5.33	4.3193E+06	75.05
15	630.02	25.30	630.02	386.56	5.19	4.3975E+06	79.86
16	684.28	54.26	684.28	413.69	4.92	4.5521E+06	90.61
17	858.32	174.05	858.33	500.71	4.22	4.5930E+06	128.80
18	909.52	51.22	909.54	526.32	4.02	4.4469E+06	141.20
19	976.27	66.76	976.28	559.70	3.76	3.9402E+06	158.30
20	1089.10	112.79	1089.06	616.09	3.26	2.1790E+06	190.40
21	1149.10	60.05	1149.15	646.12	2.93	7.8903E+05	209.80
22	1170.80	21.75	1170.85	657.00	2.80	1.9783E+05	217.40
23	1192.60	21.75	1192.55	667.87	2.67	-4.4089E+05	225.30
24	1214.30	21.75	1214.35	678.75	2.52	-1.1292E+06	233.70
25	1241.90	27.59	1241.89	692.54	2.32	-2.0771E+06	245.10
26	1297.10	55.18	1297.08	720.13	1.84	-4.2377E+06	271.70
27	1490.80		1386.30	764.73			367.37

K-21 MOD2
Gamma = 0.50
Initial heat (Q0) = 0.617472E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	14.94	13.94	14.94	78.97	12.56	3.1795E+06	1.94
3	29.87	14.94	29.88	86.44	14.86	3.1734E+06	3.02
4	44.81	14.94	44.81	93.91	15.35	3.1668E+06	4.00
5	59.74	14.94	59.75	101.38	15.17	3.1598E+06	4.98
6	91.67	31.93	91.67	117.35	14.04	3.1437E+06	7.16
7	123.60	31.94	123.61	133.32	12.73	3.1240E+06	9.55
8	155.52	31.94	155.54	149.28	11.54	3.1002E+06	12.18

Table D-3: Results for K-21 Launch





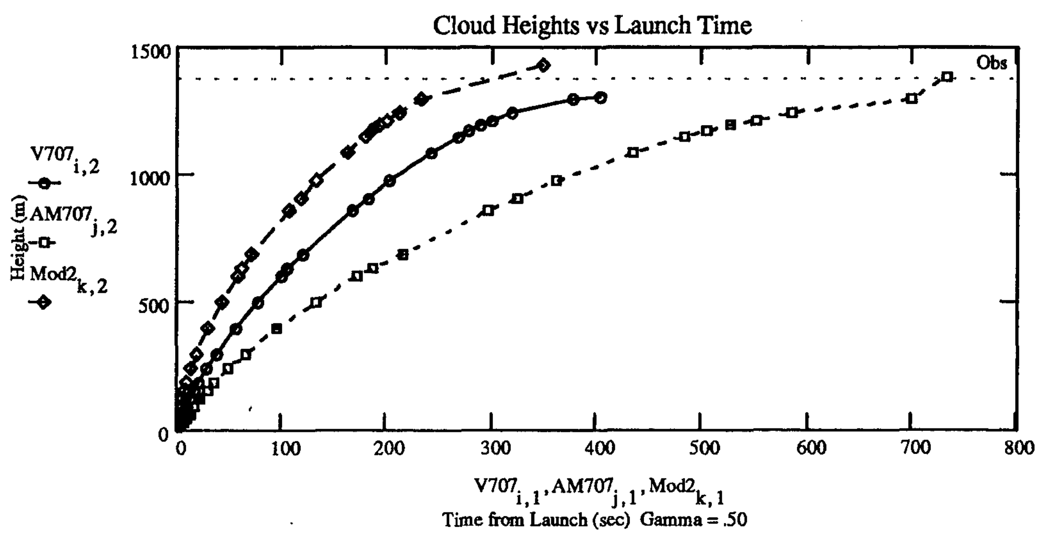


Figure D-5: K-21 Cloud Height Profiles

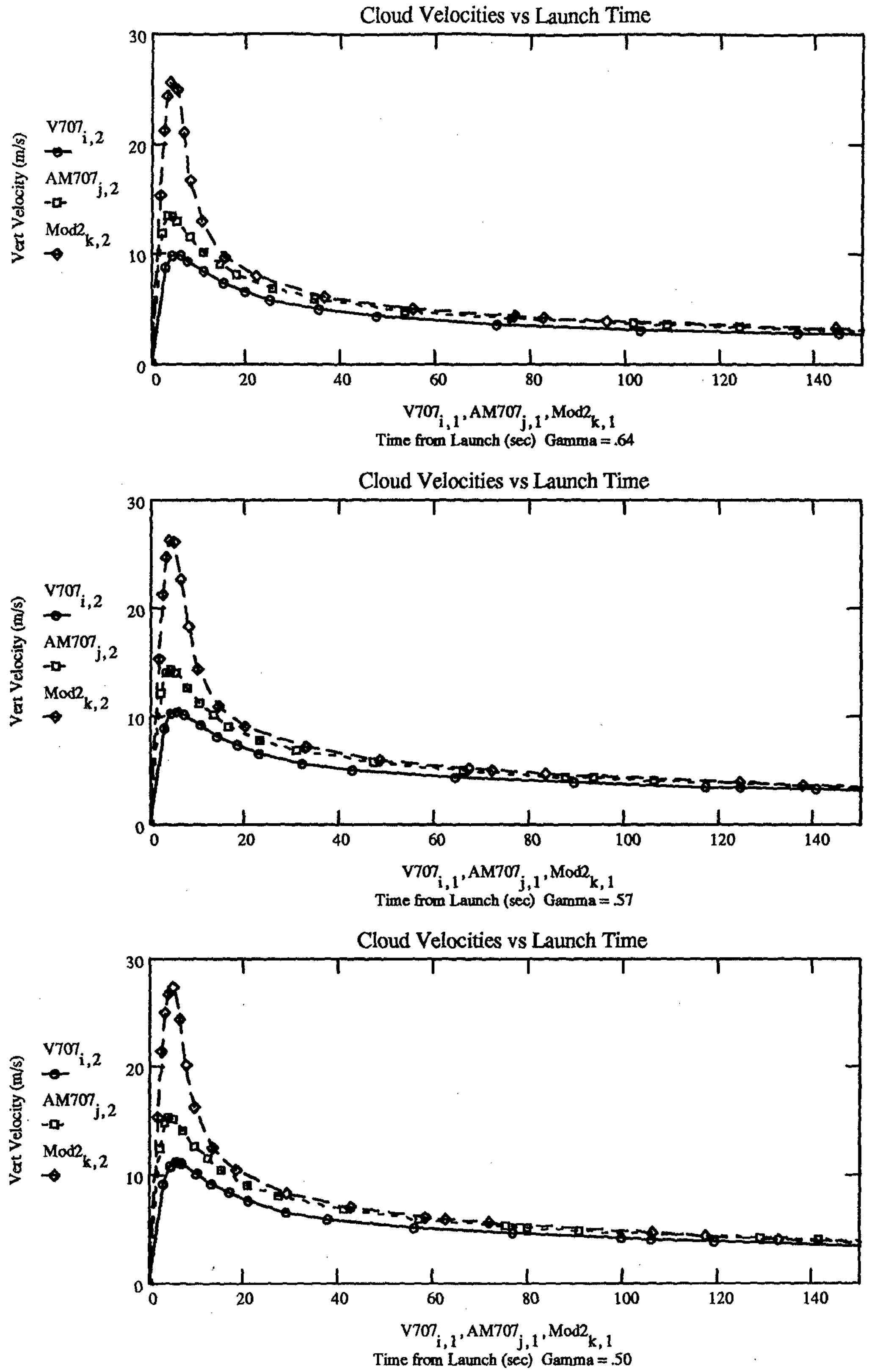


Figure D-6: K-21 Cloud Velocity Profiles

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-15 Vers 707	
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma =.64	
2	16.46	15.46	16.46	81.89	8.91	1.6939E+06	2.89	Initial heat (Q0) =	0.606548E+11 cal
3	27.28	10.83	27.29	88.82	9.76	1.6920E+06	4.04		
4	38.10	10.83	38.11	95.75	9.90	1.6861E+06	5.14		
5	50.14	12.05	50.15	103.50	9.71	1.6773E+06	6.36		
6	62.18	12.04	62.18	111.20	9.37	1.6668E+06	7.62		
7	76.81	14.64	76.82	120.50	8.87	1.6513E+06	9.23		
8	91.44	14.64	91.45	129.90	8.36	1.6324E+06	10.93		
9	106.10	14.64	106.08	139.30	7.87	1.6093E+06	12.74		
10	138.10	32.01	138.11	159.80	6.90	1.5434E+06	17.09		
11	169.00	30.94	169.04	179.60	6.10	1.4574E+06	21.86		
12	199.90	30.95	199.95	199.40	5.41	1.3460E+06	27.26		
13	249.90	50.00	249.90	231.40	4.60	1.2832E+06	37.27		
14	312.40	62.49	312.39	271.40	3.80	1.0222E+06	52.18		
15	349.90	37.50	349.90	295.40	3.33	7.2805E+05	62.71		
16	399.90	49.99	399.89	327.40	2.70	1.9361E+05	79.32		
17	424.90	25.00	424.90	343.40	2.35	-1.5308E+05	89.22		
18	449.90	25.00	449.90	359.40	1.97	-5.5218E+05	100.80		
19	474.90	25.00	474.90	375.40	1.53	-1.0074E+06	115.10		
20	499.90	25.00	499.90	391.40	0.92	-1.5207E+06	135.60		
21	655.32		514.76	400.89			168.22		

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-15 AM707	
2	16.46	15.46	16.46	81.89	12.16	3.1529E+06	2.12	Gamma = .64	
3	27.28	10.83	27.29	88.82	13.32	3.1510E+06	2.96	Initial heat (Q0) =	0.606548E+11 cal
4	38.10	10.83	38.11	95.75	13.52	3.1451E+06	3.76		
5	50.14	12.05	50.15	103.46	13.26	3.1365E+06	4.66		
6	62.18	12.05	62.19	111.17	12.80	3.1260E+06	5.59		
7	76.81	14.64	76.82	120.53	12.13	3.1107E+06	6.76		
8	91.44	14.64	91.45	129.90	11.45	3.0919E+06	8.00		
9	106.07	14.64	106.08	139.27	10.79	3.0691E+06	9.32		
10	138.07	32.01	138.08	159.76	9.51	3.0038E+06	12.48		
11	169.01	30.95	169.02	179.56	8.46	2.9187E+06	15.94		
12	199.95	30.95	199.96	199.37	7.58	2.8084E+06	19.81		
13	249.94	49.99	249.94	231.36	6.51	2.7485E+06	26.93		
14	312.42	62.49	312.43	271.36	5.47	2.4931E+06	37.41		
15	349.91	37.50	349.92	295.36	4.92	2.2042E+06	44.64		
16	399.90	49.99	399.90	327.36	4.24	1.6788E+06	55.58		
17	424.89	25.00	424.90	343.36	3.91	1.3378E+06	61.72		
18	449.88	25.00	449.89	359.36	3.58	9.4520E+05	68.40		
19	474.88	25.00	474.88	375.36	3.25	4.9739E+05	75.73		
20	499.87	25.00	499.88	391.36	2.90	-7.3323E+03	83.87		
21	655.32		629.40	474.26			176.30		

Lyr	AltHgt	Rise Hgt	Cld Hgt	CldRad	CldVel	Bouyancy	RisTim		
2	16.46	15.46	16.46	72.21	16.06	3.1530E+06	1.92	K-15 MOD2	
3	27.28	10.83	27.29	73.07	20.30	3.1532E+06	2.51	Gamma = 0.64	
4	38.10	10.83	38.11	74.42	23.03	3.1522E+06	3.01	Initial heat (Q0) =	0.606548E+11 cal
5	50.14	12.05	50.15	76.47	24.78	3.1490E+06	3.51		
6	62.18	12.05	62.19	79.12	25.41	3.1448E+06	3.99		
7	76.81	14.64	76.82	83.09	25.11	3.1393E+06	4.57		
8	91.44	14.64	91.45	87.96	23.92	3.1331E+06	5.17		
9	106.10	14.64	106.08	93.73	22.19	3.1259E+06	5.81		
10	138.10	32.01	138.11	108.30	18.30	3.1053E+06	7.40		
11	169.00	30.94	169.04	126.60	14.40	3.0766E+06	9.33		
12	199.90	30.94	199.94	146.40	11.65	3.0353E+06	11.73		
13	249.90	50.00	249.90	178.40	9.16	3.1138E+06	16.61		
14	312.40	62.49	312.39	218.40	7.35	3.0910E+06	24.26		
15	349.90	37.50	349.90	242.40	6.56	2.9876E+06	29.66		
16	399.90	49.99	399.89	274.40	5.69	2.7472E+06	37.85		
17	424.90	25.00	424.90	290.40	5.30	2.5706E+06	42.41		
18	449.90	25.00	449.90	306.40	4.94	2.3555E+06	47.30		
19	474.90	25.00	474.90	322.40	4.59	2.0985E+06	52.55		
20	499.90	25.00	499.90	338.40	4.26	1.7976E+06	58.20		
21	655.30	155.50	655.40	437.80	2.36	-8.4061E+05	105.90		
22	824.64		761.20	505.61			200.84		

Table D-4: Results for K-15 Launch

K-15 Vers 707
Gamma = 0.57
Initial heat (Q0) = 0.606548E+11 cal

Lyr	AltHgt	Ris Hgt	Cld Hgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	0.00	0.00	0.0000E+00	0.00
2	16.46	15.46	16.46	80.81	9.18	1.6939E+06	2.86
3	27.28	10.83	27.29	86.98	10.21	1.6924E+06	3.97
4	38.10	10.83	38.11	93.15	10.49	1.6874E+06	5.01
5	50.14	12.05	50.15	100.00	10.41	1.6793E+06	6.16
6	62.18	12.05	62.19	106.90	10.14	1.6698E+06	7.33
7	76.81	14.64	76.82	115.20	9.69	1.6561E+06	8.81
8	91.44	14.64	91.45	123.60	9.21	1.6396E+06	10.35
9	106.10	14.64	106.08	131.90	8.73	1.6197E+06	11.99
10	138.10	32.01	138.11	150.20	7.75	1.5640E+06	15.88
11	169.00	30.94	169.04	167.80	6.92	1.4918E+06	20.11
12	199.90	30.94	199.94	185.40	6.20	1.3999E+06	24.83
13	249.90	50.00	249.90	213.90	5.35	1.3772E+06	33.50
14	312.40	62.49	312.39	249.50	4.51	1.1877E+06	46.19
15	349.90	37.50	349.90	270.90	4.03	9.6952E+05	54.97
16	399.90	50.00	399.90	299.40	3.41	5.5948E+05	68.43
17	424.90	25.00	424.90	313.70	3.08	2.8947E+05	76.14
18	449.90	25.00	449.90	327.90	2.74	-2.1524E+03	84.75
19	474.90	25.00	474.90	342.20	2.38	-2.8753E+05	94.53
20	499.90	25.00	499.90	356.40	2.01	-5.6077E+05	105.90
21	655.32		581.66	403.04			109.20

K-15 AM707
Gamma = .57
Initial heat (Q0) = 0.606548E+11 ca

Lyr	AltHgt	Ris Hgt	Cld Hgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	0.00	0.00	0.0000E+00	0.00
2	16.46	15.47	16.47	80.81	12.52	3.1529E+06	2.10
3	27.28	10.83	27.29	86.98	13.93	3.1515E+06	2.91
4	38.10	10.83	38.11	93.16	14.31	3.1464E+06	3.67
5	50.14	12.05	50.15	100.02	14.21	3.1384E+06	4.51
6	62.18	12.05	62.19	106.89	13.85	3.1290E+06	5.37
7	76.81	14.64	76.82	115.23	13.25	3.1154E+06	6.45
8	91.44	14.64	91.45	123.58	12.61	3.0990E+06	7.58
9	106.07	14.64	106.08	131.92	11.97	3.0794E+06	8.78
10	138.07	32.01	138.08	150.17	10.67	3.0242E+06	11.61
11	169.01	30.94	169.01	167.80	9.58	2.9527E+06	14.67
12	199.95	30.95	199.96	185.44	8.65	2.8617E+06	18.07
13	249.94	49.99	249.94	213.94	7.50	2.8413E+06	24.28
14	312.42	62.49	312.43	249.56	6.39	2.6564E+06	33.31
15	349.91	37.50	349.92	270.93	5.80	2.4424E+06	39.47
16	399.90	50.00	399.91	299.43	5.09	2.0396E+06	48.66
17	424.89	25.00	424.90	313.68	4.75	1.7741E+06	53.74
18	449.88	25.00	449.89	327.93	4.41	1.4875E+06	59.20
19	474.88	25.00	474.88	342.18	4.09	1.2075E+06	65.09
20	499.87	25.00	499.88	356.43	3.77	9.3992E+05	71.45
21	655.32	155.46	655.33	445.04	1.99	-1.1337E+06	126.40
22	824.64		739.05	492.77			213.09

K-15 MOD2
Gamma = 0.57
Initial heat (Q0) = 0.606548E+11 cal

Lyr	AltHgt	Ris Hgt	Cld Hgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	0.00	0.00	0.0000E+00	0.00
2	16.46	15.47	16.47	72.21	16.06	3.1530E+06	1.92
3	27.28	10.83	27.29	72.98	20.37	3.1532E+06	2.51
4	38.10	10.83	38.11	74.19	23.22	3.1522E+06	3.01
5	50.14	12.05	50.15	76.03	25.14	3.1492E+06	3.51
6	62.18	12.05	62.19	78.40	26.00	3.1451E+06	3.98
7	76.81	14.64	76.82	81.94	25.98	3.1397E+06	4.54
8	91.44	14.64	91.45	86.29	25.05	3.1338E+06	5.11
9	106.07	14.64	106.08	91.43	23.53	3.1271E+06	5.72
10	138.07	32.01	138.08	104.43	19.86	3.1082E+06	7.20
11	169.01	30.95	169.02	120.69	15.95	3.0824E+06	8.95
12	199.95	30.94	199.95	138.33	13.09	3.0465E+06	11.11
13	249.94	49.99	249.94	166.82	10.42	3.1385E+06	15.42
14	312.42	62.49	312.43	202.44	8.45	3.1450E+06	22.11
15	349.91	37.50	349.92	223.82	7.58	3.0779E+06	26.79
16	399.90	49.99	399.90	252.31	6.64	2.9020E+06	33.85
17	424.89	25.00	424.90	266.56	6.22	2.7675E+06	37.74
18	449.88	25.00	449.89	280.81	5.83	2.6142E+06	41.89
19	474.88	25.00	474.88	295.06	5.47	2.4595E+06	46.32

Table D-4: Results for K-15 Launch

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	16.46	15.47	16.47	79.73	9.45	1.6939E+06	2.83
3	27.28	10.83	27.29	85.14	10.69	1.6928E+06	3.90
4	38.10	10.83	38.11	90.56	11.13	1.6886E+06	4.88
5	50.14	12.05	50.15	96.58	11.19	1.6812E+06	5.96
6	62.18	12.05	62.19	102.60	11.02	1.6726E+06	7.04
7	76.81	14.64	76.82	109.90	10.65	1.6605E+06	8.39
8	91.44	14.64	91.45	117.20	10.22	1.6462E+06	9.80
9	106.10	14.64	106.08	124.60	9.76	1.6293E+06	11.26
10	138.10	32.01	138.11	140.60	8.79	1.5826E+06	14.72
11	169.00	30.95	169.05	156.00	7.94	1.5227E+06	18.42
12	199.90	30.94	199.94	171.50	7.19	1.4453E+06	22.52
13	249.90	49.99	249.89	196.50	6.29	1.4564E+06	29.95
14	312.40	62.49	312.39	227.80	5.41	1.3412E+06	40.64
15	349.90	37.50	349.90	246.50	4.91	1.1881E+06	47.91
16	399.90	49.99	399.89	271.50	4.28	8.8828E+05	58.80
17	424.90	25.00	424.90	284.00	3.97	7.5378E+05	64.87
18	449.90	25.00	449.90	296.50	3.67	6.2824E+05	71.42
19	474.90	25.00	474.90	309.00	3.38	4.8361E+05	78.52
20	499.90	25.00	499.90	321.50	3.10	3.1927E+05	86.23
21	655.30	155.40	655.30	399.20	1.34	-1.1314E+06	156.40
22	824.64		695.90	419.51			218.10

K-15 Vers 707
Gamma = .50
Initial heat (Q0) = 0.606548E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	16.46	28.11	29.11	79.72	29.48	3.1529E+06	5.96
3	27.28	18.27	34.73	85.13	31.86	3.1519E+06	8.31
4	38.10	15.61	42.89	90.54	32.09	3.1476E+06	10.25
5	50.14	16.24	54.34	96.56	31.44	3.1403E+06	12.29
6	62.18	16.16	66.30	102.60	30.39	3.1318E+06	14.38
7	76.81	18.63	80.81	109.90	28.97	3.1199E+06	16.89
8	91.44	18.50	95.31	117.20	27.51	3.1057E+06	19.51
9	106.10	18.36	109.80	124.50	26.09	3.0889E+06	22.25
10	138.10	35.36	141.46	140.50	23.46	3.0427E+06	27.96
11	169.00	34.03	172.13	156.00	21.20	2.9835E+06	34.06
12	199.90	33.76	202.76	171.50	19.22	2.9070E+06	40.74
13	249.90	52.30	252.20	196.50	16.70	2.9201E+06	52.37
14	312.40	64.23	314.13	227.70	14.09	2.8089E+06	68.99
15	349.90	39.16	351.56	246.40	12.83	2.6592E+06	80.59
16	399.90	51.25	401.15	271.40	11.16	2.3655E+06	97.57
17	424.90	26.65	426.55	283.90	10.52	2.2342E+06	107.40
18	449.90	26.71	451.61	296.40	9.92	2.1121E+06	117.80
19	474.90	26.60	476.50	308.90	9.34	1.9713E+06	128.80
20	499.90	26.49	501.39	321.40	8.79	1.8112E+06	140.50
21	655.30	154.70	654.60	399.20	1.29	3.9838E+05	254.20
22	824.64		790.42	466.70			413.62

K-15 AM707
Gamma = .50
Initial heat (Q0) = 0.606548E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	16.46	15.47	16.47	72.20	16.06	3.1530E+06	1.92
3	27.28	10.83	27.29	72.89	20.43	3.1532E+06	2.51
4	38.10	10.83	38.11	73.96	23.40	3.1523E+06	3.00
5	50.14	12.05	50.15	75.58	25.52	3.1494E+06	3.50
6	62.18	12.04	62.18	77.68	26.61	3.1454E+06	3.96
7	76.81	14.64	76.82	80.80	26.90	3.1402E+06	4.50
8	91.44	14.64	91.45	84.62	26.27	3.1345E+06	5.05
9	106.10	14.64	106.08	89.13	25.00	3.1282E+06	5.63
10	138.10	32.01	138.11	100.50	21.65	3.1109E+06	7.01
11	169.00	30.95	169.05	114.80	17.79	3.0878E+06	8.59
12	199.90	30.94	199.94	130.30	14.83	3.0556E+06	10.50
13	249.90	49.99	249.89	155.30	11.99	3.1590E+06	14.28
14	312.40	62.49	312.39	186.50	9.84	3.1974E+06	20.05
15	349.90	37.50	349.90	205.30	8.89	3.1618E+06	24.07
16	399.90	49.99	399.89	230.30	7.85	3.0437E+06	30.06
17	424.90	25.00	424.90	242.80	7.40	2.9881E+06	33.34
18	449.90	25.00	449.90	255.30	6.99	2.9348E+06	36.81
19	474.90	25.00	474.90	267.80	6.62	2.8664E+06	40.49
20	499.90	25.00	499.90	280.30	6.28	2.7823E+06	44.37
21	655.30	155.50	655.40	358.00	4.62	1.9036E+06	73.18
22	824.60	169.30	824.60	442.70	3.11	2.9467E+05	117.50
23	994.00	169.30	993.90	527.30	1.16	-2.8474E+06	197.30

K-15 MOD2
Gamma = 0.5
Initial heat (Q0) = 0.606548E+11 cal

Table D-4: Results for K-15 Launch

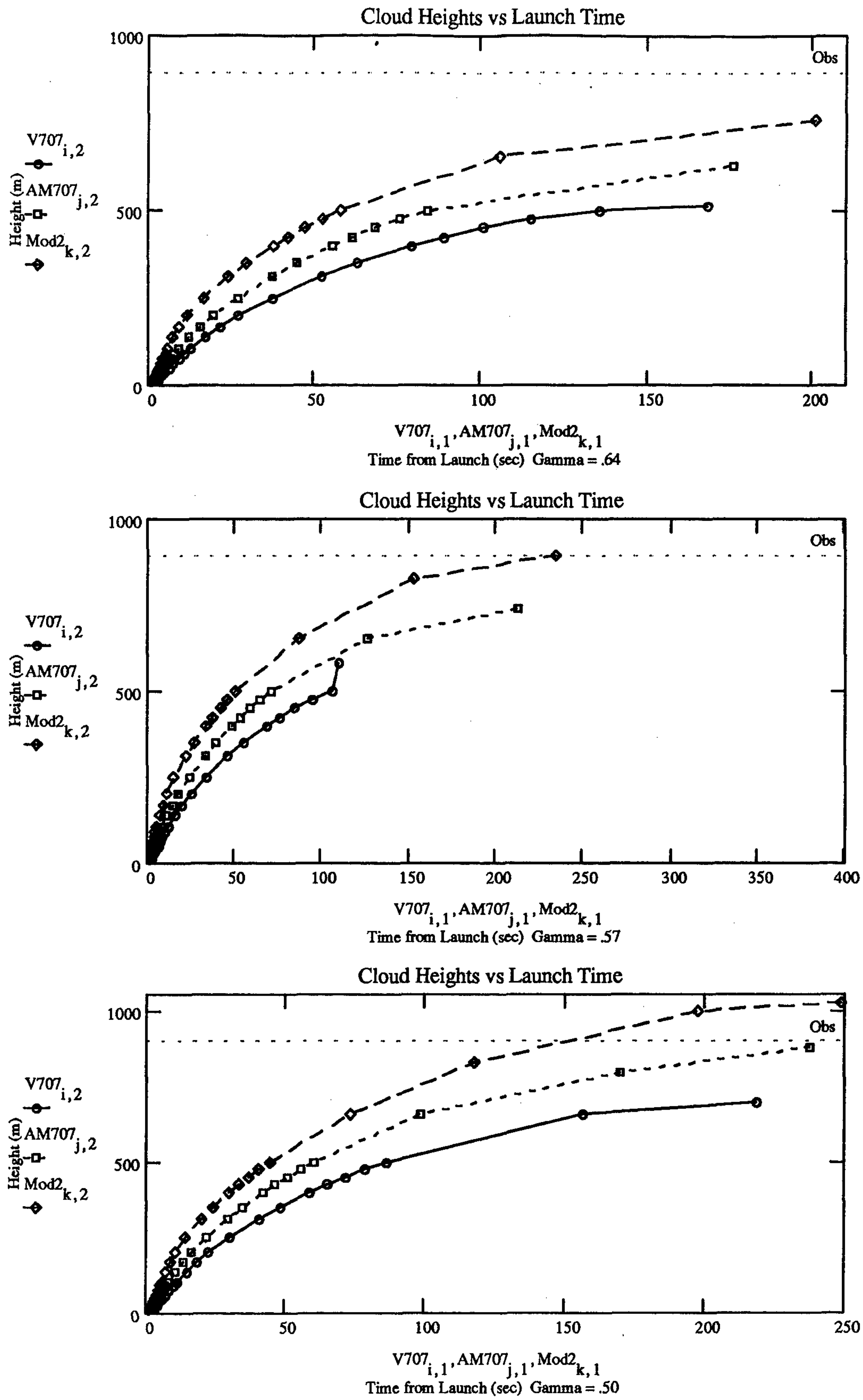


Figure D-7: K-15 Cloud Height Profiles

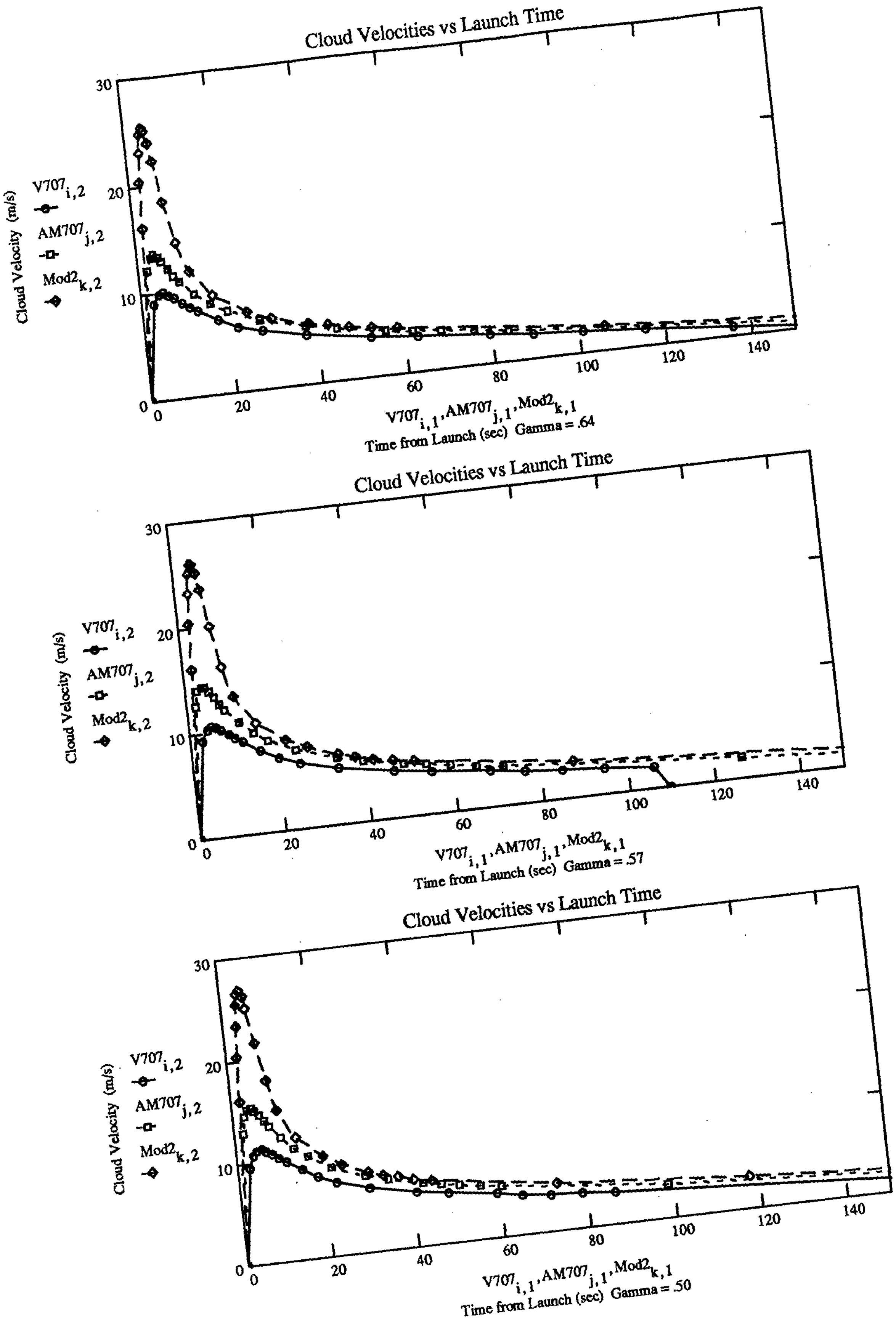


Figure D-8: K-15 Cloud Velocity Profiles

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	78.46	7.93	1.7037E+06	2.25
3	21.92	10.83	21.93	85.39	9.50	1.7061E+06	3.47
4	37.16	15.25	37.17	95.15	9.95	1.7109E+06	5.03
5	52.40	15.25	52.41	104.90	9.72	1.7160E+06	6.57
6	67.64	15.25	67.65	114.70	9.27	1.7205E+06	8.18
7	82.88	15.25	82.89	124.40	8.77	1.7233E+06	9.87
8	113.40	30.49	113.37	143.90	7.78	1.6984E+06	13.56
9	143.80	30.49	143.89	163.40	6.90	1.6148E+06	17.72
10	174.30	30.49	174.29	183.00	6.11	1.4754E+06	22.43
11	204.80	30.49	204.79	202.50	5.40	1.3045E+06	27.74
12	265.80	60.97	265.77	241.50	4.31	9.5823E+05	40.34
13	326.70	60.97	326.77	280.50	3.29	2.9757E+05	56.43
14	387.70	60.97	387.67	319.50	2.13	-7.3076E+05	79.00
15	448.64		438.26	351.90			126.73

K-22 Vers 707
Gamma = .64
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	78.46	10.84	3.1837E+06	1.65
3	21.92	10.83	21.93	85.39	12.99	3.1861E+06	2.54
4	37.16	15.25	37.17	95.15	13.60	3.1908E+06	3.68
5	52.40	15.25	52.41	104.90	13.27	3.1960E+06	4.81
6	67.64	15.25	67.65	114.66	12.66	3.2004E+06	5.98
7	82.88	15.25	82.89	124.42	11.97	3.2031E+06	7.22
8	113.36	30.49	113.37	143.93	10.63	3.1786E+06	9.93
9	143.84	30.49	143.85	163.45	9.45	3.0962E+06	12.97
10	174.32	30.49	174.33	182.96	8.43	2.9587E+06	16.39
11	204.80	30.49	204.81	202.47	7.55	2.7905E+06	20.22
12	265.76	60.97	265.77	241.49	6.19	2.4526E+06	29.14
13	326.72	60.97	326.73	280.51	5.05	1.8048E+06	40.03
14	387.68	60.97	387.69	319.53	4.00	7.9498E+05	53.54
15	448.64	60.97	448.65	358.55	2.89	-6.6859E+05	71.30
16	509.60	60.96	509.60	397.56	1.36	-2.6536E+06	100.20
17	570.56		528.10	409.40			127.61

K-22 AM707
Gamma = .64
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	72.14	13.07	3.1834E+06	1.54
3	21.92	10.83	21.93	72.75	18.42	3.1851E+06	2.23
4	37.16	15.24	37.16	74.31	22.98	3.1876E+06	2.96
5	52.40	15.25	52.41	76.84	25.22	3.1903E+06	3.59
6	67.64	15.25	67.65	80.35	25.74	3.1929E+06	4.19
7	82.88	15.25	82.89	84.83	25.01	3.1950E+06	4.79
8	113.36	30.49	113.37	95.75	22.12	3.1933E+06	6.09
9	143.84	30.49	143.85	110.57	17.99	3.1742E+06	7.63
10	174.32	30.49	174.33	129.29	14.07	3.1284E+06	9.56
11	204.80	30.49	204.81	148.80	11.51	3.0767E+06	11.97
12	265.76	60.97	265.77	187.82	8.68	3.0511E+06	18.13
13	326.72	60.97	326.73	226.84	6.98	2.8215E+06	25.99
14	387.68	60.97	387.69	265.86	5.71	2.3395E+06	35.65
15	448.64	60.97	448.65	304.88	4.64	1.5308E+06	47.48
16	509.60	60.97	509.61	343.90	3.60	3.3093E+05	62.33
17	570.56	60.97	570.57	382.92	2.45	-1.3339E+06	82.55
18	692.48		633.30	423.07			134.84

K-22 MOD2
Gamma = 0.64
Initial heat (Q0) = 0.606060E+11 cal

Table D-5: Results for K-22 Launch

K-22 Vers 707
Gamma = 0.57
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	77.76	8.09	1.7037E+06	2.24
3	21.92	10.83	21.93	83.93	9.86	1.7060E+06	3.42
4	37.16	15.25	37.17	92.62	10.52	1.7104E+06	4.91
5	52.40	15.25	52.41	101.30	10.43	1.7154E+06	6.36
6	67.64	15.25	67.65	110.00	10.07	1.7198E+06	7.84
7	82.88	15.25	82.89	118.70	9.61	1.7232E+06	9.39
8	113.40	30.49	113.37	136.10	8.65	1.7056E+06	12.73
9	143.80	30.49	143.89	153.50	7.76	1.6430E+06	16.46
10	174.30	30.49	174.29	170.80	6.95	1.5283E+06	20.61
11	204.80	30.49	204.79	188.20	6.22	1.3923E+06	25.25
12	265.80	60.97	265.77	223.00	5.10	1.1444E+06	36.05
13	326.70	60.97	326.77	257.70	4.07	6.2134E+05	49.37
14	387.70	60.97	387.67	292.50	2.99	-2.3328E+05	66.67
15	448.60	60.97	448.67	327.20	1.51	-1.4618E+06	93.86
16	509.60		470.67	339.77	0.00		123.21

K-22 AM707
Gamma = .57
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	77.75	11.06	3.1836E+06	1.63
3	21.92	10.83	21.93	83.93	13.48	3.1860E+06	2.50
4	37.16	15.25	37.17	92.62	14.38	3.1904E+06	3.59
5	52.40	15.25	52.41	101.31	14.25	3.1953E+06	4.65
6	67.64	15.25	67.65	110.00	13.75	3.1997E+06	5.74
7	82.88	15.25	82.89	118.69	13.12	3.2030E+06	6.87
8	113.36	30.49	113.37	136.07	11.81	3.1857E+06	9.32
9	143.84	30.49	143.85	153.44	10.62	3.1240E+06	12.05
10	174.32	30.49	174.33	170.82	9.56	3.0109E+06	15.07
11	204.80	30.49	204.81	188.20	8.64	2.8771E+06	18.43
12	265.76	60.97	265.77	222.95	7.20	2.6359E+06	26.16
13	326.72	60.97	326.73	257.70	6.01	2.1236E+06	35.42
14	387.68	60.97	387.69	292.46	4.92	1.2843E+06	46.60
15	448.64	60.97	448.65	327.21	3.82	7.6649E+04	60.59
16	509.60	60.97	509.61	361.96	2.55	-1.5660E+06	79.80
17	570.56		564.69	393.36			123.55

K-22 MOD2
Gamma = 0.57
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	72.13	13.07	3.1834E+06	1.54
3	21.92	10.83	21.93	72.69	18.46	3.1851E+06	2.23
4	37.16	15.25	37.17	74.09	23.15	3.1876E+06	2.96
5	52.40	15.25	52.41	76.36	25.62	3.1903E+06	3.58
6	67.64	15.25	67.65	79.49	26.42	3.1929E+06	4.17
7	82.88	15.25	82.89	83.50	25.99	3.1949E+06	4.75
8	113.36	30.48	113.36	93.23	23.53	3.1942E+06	5.98
9	143.84	30.49	143.85	106.44	19.59	3.1789E+06	7.41
10	174.32	30.49	174.33	123.12	15.63	3.1387E+06	9.16
11	204.80	30.49	204.81	140.49	12.95	3.0969E+06	11.32
12	265.76	60.97	265.77	175.25	9.92	3.1061E+06	16.75
13	326.72	60.97	326.73	210.00	8.07	2.9351E+06	23.58
14	387.68	60.97	387.69	244.75	6.70	2.5365E+06	31.88
15	448.64	60.97	448.65	279.50	5.55	1.8682E+06	41.86
16	509.60	60.97	509.61	314.25	4.48	8.7126E+05	54.05
17	570.56	60.97	570.57	349.00	3.36	-5.0925E+05	69.65
18	692.48		671.77	406.70	0.00		131.76

Table D-5: Results for K-22 Launch

K-22 Vers 7.07
Gamma =.5
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.10	11.10	77.05	8.26	1.7036E+06	2.22
3	21.92	10.83	21.93	82.46	10.25	1.7059E+06	3.37
4	37.16	15.25	37.17	90.08	11.16	1.7100E+06	4.79
5	52.40	15.25	52.41	97.71	11.23	1.7148E+06	6.14
6	67.64	15.25	67.65	105.30	10.98	1.7190E+06	7.51
7	82.88	15.25	82.89	113.00	10.59	1.7223E+06	8.93
8	113.40	30.49	113.37	128.20	9.69	1.7108E+06	11.93
9	143.80	30.49	143.89	143.40	8.81	1.6654E+06	15.23
10	174.30	30.49	174.29	158.70	7.98	1.5725E+06	18.87
11	204.80	30.49	204.79	173.90	7.23	1.4632E+06	22.88
12	265.80	60.97	265.77	204.40	6.07	1.3010E+06	32.07
13	326.70	60.97	326.77	234.90	5.02	8.9500E+05	43.07
14	387.70	60.97	387.67	265.40	3.96	2.1853E+05	56.66
15	448.60	60.97	448.67	295.90	2.72	-7.6775E+05	74.94
16	509.60		509.37	326.23			119.82

K-22 AM 7.07
Gamma =.50
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	77.05	11.29	3.1836E+06	1.62
3	21.92	10.83	21.93	82.46	14.01	3.1859E+06	2.47
4	37.16	15.25	37.17	90.08	15.25	3.1899E+06	3.50
5	52.40	15.25	52.41	97.71	15.35	3.1947E+06	4.49
6	67.64	15.25	67.65	105.33	15.00	3.1989E+06	5.50
7	82.88	15.25	82.89	112.96	14.46	3.2022E+06	6.53
8	113.36	30.49	113.37	128.20	13.23	3.1908E+06	8.73
9	143.84	30.49	143.85	143.44	12.04	3.1461E+06	11.15
10	174.32	30.49	174.33	158.69	10.96	3.0544E+06	13.81
11	204.80	30.49	204.81	173.93	9.99	2.9469E+06	16.72
12	265.76	60.97	265.77	204.41	8.47	2.7902E+06	23.35
13	326.72	60.97	326.73	234.90	7.21	2.3929E+06	31.15
14	387.68	60.97	387.69	265.38	6.06	1.7288E+06	40.36
15	448.64	60.97	448.65	295.86	4.95	7.5935E+05	51.45
16	509.60	60.97	509.61	326.35	3.76	-5.4159E+05	65.48
17	570.56	60.97	523.37	356.83	2.30	-2.1551E+06	85.68
18	692.48		611.83	377.47			122.27

K-22 MOD2
Gamma = 0.50
Initial heat (Q0) = 0.606060E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	11.10	10.11	11.11	72.13	13.08	3.1834E+06	1.54
3	21.92	10.83	21.93	72.63	18.50	3.1851E+06	2.23
4	37.16	15.25	37.17	73.87	23.32	3.1875E+06	2.95
5	52.40	15.25	52.41	75.88	26.03	3.1902E+06	3.57
6	67.64	15.25	67.65	78.64	27.14	3.1928E+06	4.14
7	82.88	15.25	82.89	82.16	27.03	3.1949E+06	4.71
8	113.36	30.49	113.37	90.72	25.09	3.1951E+06	5.88
9	143.84	30.49	143.85	102.31	21.42	3.1832E+06	7.20
10	174.32	30.49	174.33	116.94	17.48	3.1479E+06	8.78
11	204.80	30.49	204.81	132.19	14.70	3.1135E+06	10.69
12	265.76	60.97	265.77	162.67	11.46	3.1535E+06	15.42
13	326.72	60.97	326.73	193.15	9.45	3.0323E+06	21.30
14	387.68	60.97	387.69	223.64	7.96	2.7216E+06	28.33
15	448.64	60.97	448.65	254.12	6.72	2.1849E+06	36.66
16	509.60	60.97	509.61	284.60	5.59	1.3930E+06	46.59
17	570.56	60.97	570.57	315.09	4.49	3.4714E+05	58.72
18	692.48	121.91	692.47	376.04	1.96	-2.3645E+06	97.15
19	814.40		727.82	393.71			134.15

Table D-5: Results for K-22 Launch

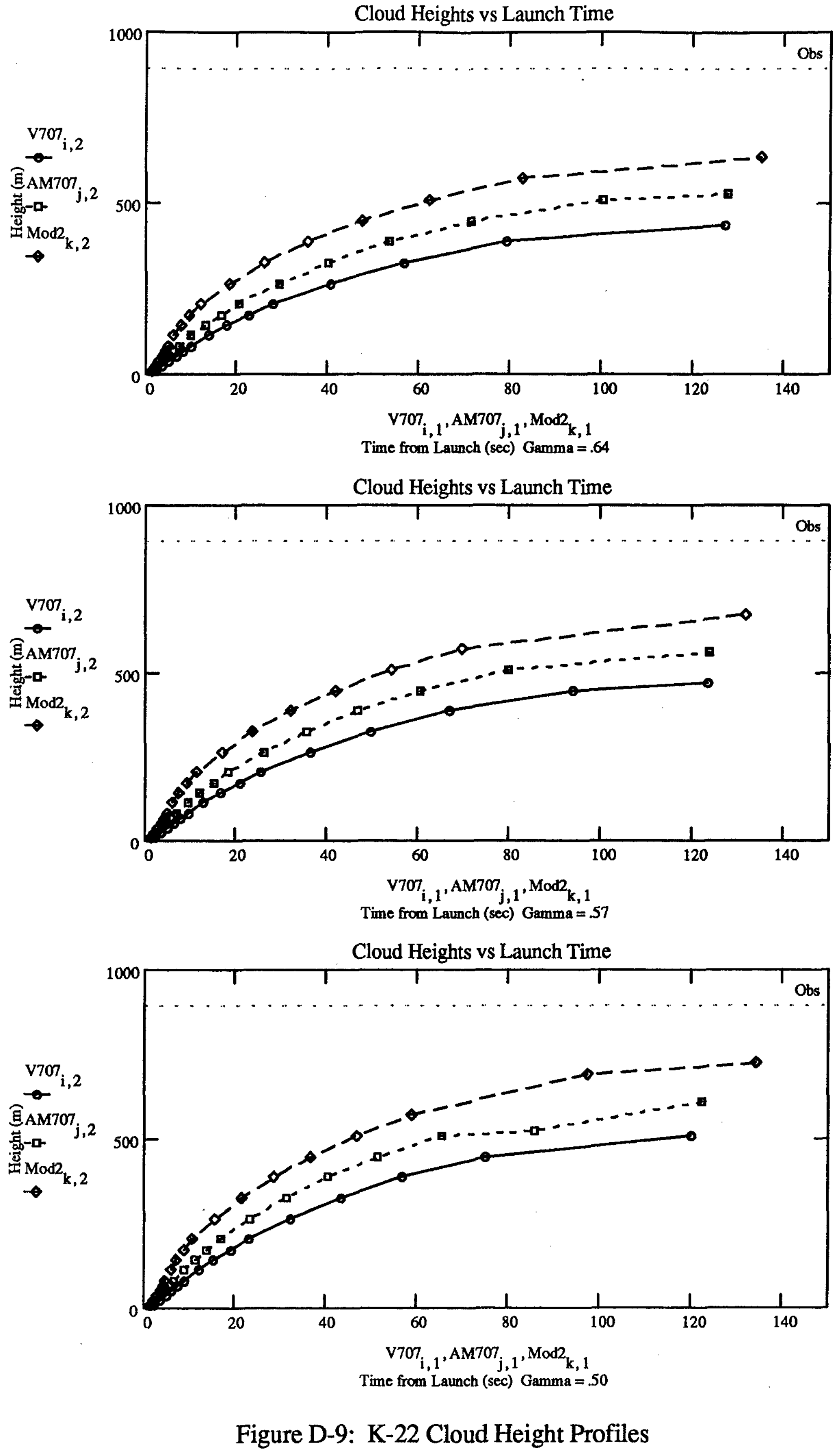


Figure D-9: K-22 Cloud Height Profiles

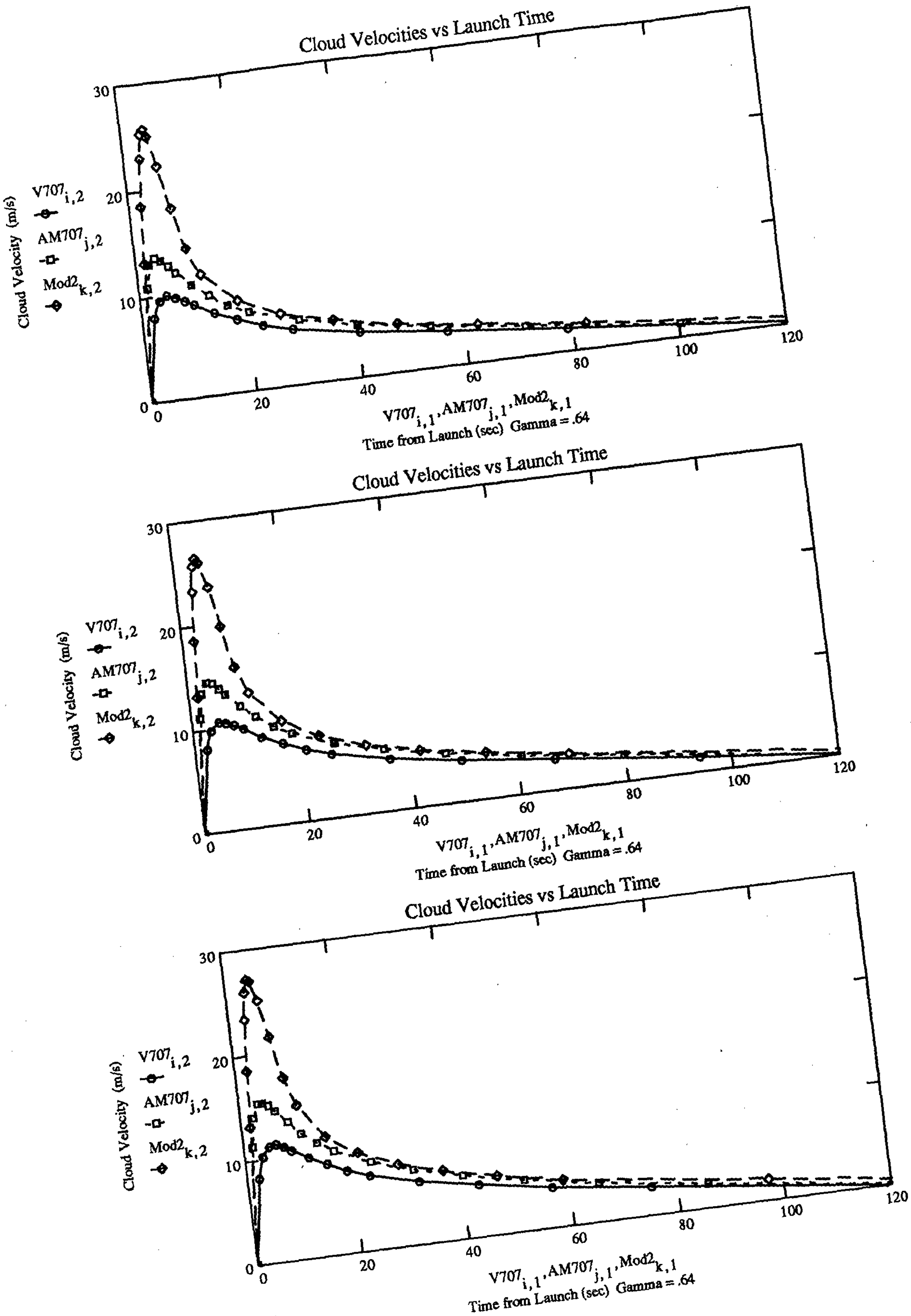


Figure D-10: K-22 Cloud Velocity Profiles

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-16 Vers7.07
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = .64
2	13.87	12.86	13.86	80.23	11.71	3.2144E+06	1.88	Initial heat (Q0) = 0.618104E+11 cal
3	27.74	13.88	27.74	89.11	13.47	3.2148E+06	2.97	
4	41.61	13.87	41.60	97.98	13.62	3.2153E+06	3.98	
5	55.47	13.88	55.48	106.86	13.22	3.2160E+06	5.02	
6	81.84	26.37	81.84	123.74	12.05	3.2173E+06	7.10	
7	108.20	26.37	108.21	140.62	10.88	3.2187E+06	9.41	
8	134.57	26.38	134.58	157.50	9.84	3.2200E+06	11.96	
9	160.93	26.37	160.94	174.38	8.96	3.2216E+06	14.77	
10	207.26	46.34	207.27	204.03	7.73	3.2406E+06	20.35	
11	253.59	46.34	253.60	233.69	6.84	3.3791E+06	26.73	
12	299.92	46.34	299.93	263.34	6.15	3.4702E+06	33.88	
13	340.77	40.85	340.77	289.49	5.65	3.5049E+06	40.81	
14	472.74	131.99	472.76	373.96	4.42	3.1965E+06	67.22	
15	604.72	131.98	604.72	458.43	3.35	1.7948E+06	101.30	
16	757.12	152.41	756.80	555.97	1.99	-1.4709E+06	158.70	
17	909.52		854.19	618.09			257.26	

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-16 AM707
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = .64
2	13.87	12.86	13.86	80.23	18.57	3.2144E+06	3.03	Initial heat (Q0) = 0.618104E+11 cal
3	27.74	13.88	27.74	89.11	21.22	3.2148E+06	4.79	
4	41.61	13.87	41.60	97.98	21.35	3.2153E+06	6.45	
5	55.47	13.88	55.48	106.90	20.66	3.2160E+06	8.13	
6	81.84	26.37	81.84	123.70	18.79	3.2173E+06	11.48	
7	108.20	26.37	108.21	140.60	16.93	3.2187E+06	15.20	
8	134.57	26.38	134.58	157.50	15.30	3.2200E+06	19.33	
9	160.93	26.37	160.94	174.40	13.91	3.2216E+06	23.89	
10	207.26	46.34	207.27	204.00	12.01	3.2406E+06	32.76	
11	253.59	46.34	253.60	233.70	10.63	3.3791E+06	42.86	
12	299.92	46.34	299.93	263.30	9.55	3.4703E+06	54.16	
13	340.77	40.85	340.77	289.40	8.75	3.5050E+06	65.13	
14	472.74	131.99	472.76	373.90	6.57	3.1969E+06	107.30	
15	604.72	131.98	604.72	458.40	4.46	1.7959E+06	165.00	
16	757.12	152.41	757.13	555.90	1.46	-1.4684E+06	268.70	
17	909.52		854.19	598.67			359.04	

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim	K-16 MOD2
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00	Gamma = 0.64
2	13.87	12.87	13.87	72.18	14.81	3.2144E+06	1.73	Initial heat (Q0) = 0.618104E+11 cal
3	27.74	13.88	27.75	73.12	20.65	3.2146E+06	2.51	
4	41.61	13.87	41.61	74.88	23.98	3.2149E+06	3.13	
5	55.47	13.88	55.49	77.44	25.55	3.2151E+06	3.69	
6	81.84	26.37	81.84	83.85	25.72	3.2157E+06	4.72	
7	108.20	26.37	108.21	93.18	23.05	3.2162E+06	5.80	
8	134.60	26.37	134.57	105.40	19.36	3.2167E+06	7.06	
9	160.90	26.36	160.96	120.60	15.73	3.2172E+06	8.58	
10	207.30	46.34	207.24	150.20	11.48	3.2421E+06	12.08	
11	253.60	46.34	253.64	179.90	9.32	3.3974E+06	16.59	
12	299.90	46.33	299.93	209.60	7.97	3.5204E+06	21.98	
13	340.80	40.85	340.75	235.70	7.11	3.5981E+06	27.41	
14	472.70	132.00	472.80	320.20	5.32	3.5609E+06	48.97	
15	604.70	132.00	604.70	404.60	4.07	2.7370E+06	77.33	
16	757.10	152.40	757.10	502.20	2.78	4.8920E+05	122.20	
17	909.50	152.40	909.50	599.70	1.04	-3.6369E+06	203.00	
18	982.07		936.55	617.01			255.25	

Table D-6: Results for K-16 Launch

K-16 Vers 707
Gamma = 0.57
Initial heat (Q0) = 0.618104E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.87	13.87	79.33	8.76	1.7114E+06	2.56
3	27.74	13.88	27.75	87.24	10.29	1.7117E+06	3.99
4	41.61	13.87	41.61	95.15	10.56	1.7122E+06	5.32
5	55.47	13.88	55.49	103.10	10.38	1.7128E+06	6.64
6	81.84	26.37	81.84	118.10	9.64	1.7140E+06	9.27
7	108.20	26.37	108.21	133.10	8.81	1.7153E+06	12.13
8	134.60	26.37	134.57	148.20	8.04	1.7165E+06	15.27
9	160.90	26.37	160.97	163.20	7.37	1.7179E+06	18.69
10	207.30	46.34	207.24	189.60	6.43	1.7404E+06	25.44
11	253.60	46.34	253.64	216.00	5.78	1.8864E+06	33.04
12	299.90	46.34	299.94	242.40	5.28	1.9917E+06	41.43
13	340.80	40.85	340.75	265.70	4.90	2.0454E+06	49.47
14	472.70	132.00	472.80	340.90	3.94	1.8684E+06	79.29
15	604.70	132.00	604.70	416.20	2.97	7.9889E+05	117.40
16	757.10	152.40	757.10	503.00	1.49	-1.7932E+06	185.70
17	909.52		810.94	533.72			258.30

K-16 AM707
Gamma=.57
Initial heat (Q0) = 0.618104E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.86	13.86	79.33	12.01	3.2144E+06	1.87
3	27.74	13.87	27.74	87.23	14.10	3.2148E+06	2.91
4	41.61	13.88	41.61	95.14	14.47	3.2153E+06	3.88
5	55.47	13.87	55.48	103.05	14.23	3.2158E+06	4.84
6	81.84	26.37	81.85	118.08	13.21	3.2170E+06	6.76
7	108.20	26.38	108.21	133.11	12.07	3.2183E+06	8.85
8	134.57	26.37	134.57	148.14	11.02	3.2196E+06	11.14
9	160.93	26.37	160.94	163.17	10.10	3.2209E+06	13.64
10	207.26	46.34	207.27	189.58	8.79	3.2435E+06	18.57
11	253.59	46.34	253.60	215.99	7.83	3.3899E+06	24.16
12	299.92	46.34	299.93	242.41	7.08	3.4960E+06	30.39
13	340.77	40.85	340.77	265.69	6.53	3.5511E+06	36.40
14	472.74	131.99	472.76	340.93	5.19	3.3851E+06	59.07
15	604.72	131.99	604.73	416.16	4.07	2.3488E+06	87.69
16	757.12	152.41	757.13	503.03	2.76	-1.6592E+05	132.50
17	909.52	152.39	848.32	589.90	0.61	-4.4267E+06	224.00
18	982.07		917.76	594.59			251.05

K-16 MOD2
Gamma = 0.57
Initial heat (Q0) = 0.618104E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.87	13.87	72.17	14.82	3.2144E+06	1.73
3	27.74	13.88	27.74	73.03	20.73	3.2146E+06	2.51
4	41.61	13.88	41.61	74.60	24.21	3.2149E+06	3.13
5	55.47	13.88	55.48	76.90	26.01	3.2151E+06	3.68
6	81.84	26.37	81.85	82.62	26.65	3.2157E+06	4.68
7	108.20	26.37	108.21	90.95	24.41	3.2162E+06	5.71
8	134.57	26.37	134.57	101.86	20.94	3.2167E+06	6.88
9	160.93	26.37	160.94	115.37	17.32	3.2172E+06	8.27
10	207.26	46.34	207.27	141.79	12.91	3.2432E+06	11.41
11	253.59	46.34	253.60	168.20	10.59	3.4016E+06	15.40
12	299.92	46.34	299.93	194.61	9.11	3.5311E+06	20.13
13	340.77	40.85	340.77	217.89	8.16	3.6186E+06	24.88
14	472.74	131.98	472.75	293.12	6.19	3.6608E+06	43.52
15	604.72	131.98	604.72	368.35	4.83	3.0701E+06	67.64
16	757.12	152.41	757.13	455.23	3.50	1.3465E+06	104.40
17	909.52	152.41	909.53	542.10	2.04	-1.8260E+06	159.80
18	982.07	72.54	982.06	583.44	0.89	-4.0753E+06	209.50
19	1060.70		999.50	593.38			248.90

Table D-6: Results for K-16 Launch

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.87	13.87	78.43	8.98	1.7114E+06	2.53
3	27.74	13.88	27.75	85.37	10.77	1.7117E+06	3.92
4	41.61	13.88	41.62	92.31	11.25	1.7121E+06	5.17
5	55.47	13.87	55.48	99.24	11.21	1.7127E+06	6.40
6	81.84	26.37	81.84	112.40	10.62	1.7138E+06	8.81
7	108.20	26.37	108.21	125.60	9.84	1.7149E+06	11.39
8	134.60	26.37	134.57	138.80	9.08	1.7161E+06	14.18
9	160.90	26.37	160.97	152.00	8.40	1.7172E+06	17.20
10	207.30	46.34	207.24	175.20	7.40	1.7424E+06	23.09
11	253.60	46.34	253.64	198.30	6.70	1.8950E+06	29.67
12	299.90	46.34	299.94	221.50	6.16	2.0127E+06	36.88
13	340.80	40.85	340.75	241.90	5.75	2.0820E+06	43.74
14	472.70	132.00	472.80	307.90	4.73	2.0312E+06	68.90
15	604.70	132.00	604.70	373.90	3.74	1.2920E+06	100.00
16	757.10	152.40	757.10	450.10	2.43	-6.1697E+05	149.40
17	909.52		881.25	512.17			252.15

K-16 Vers707
Gamma = .50
Initial heat (Q0) = 0.618104E+11 cal

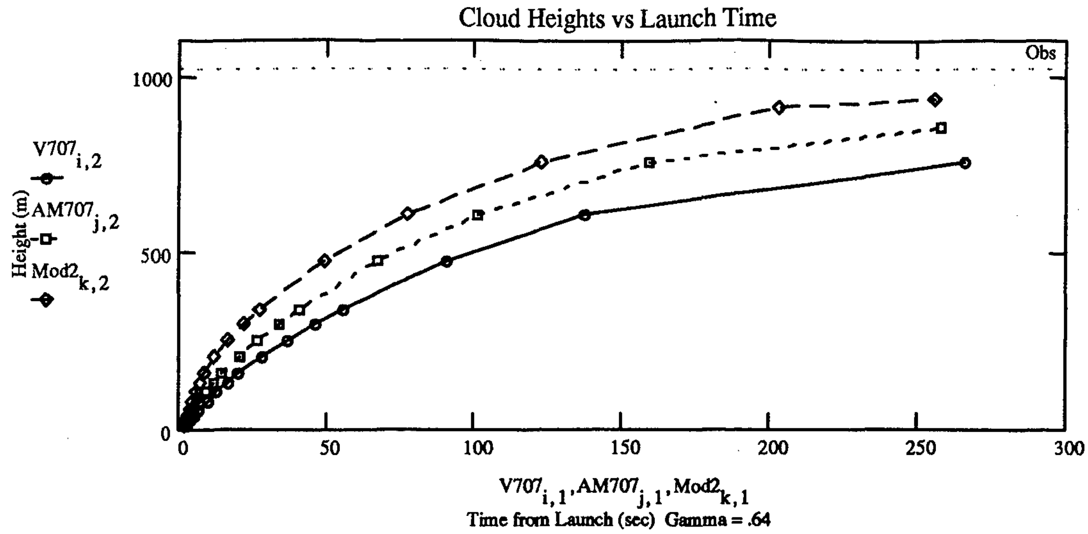
Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.86	13.86	78.42	12.31	3.2144E+06	1.85
3	27.74	13.88	27.74	85.36	14.76	3.2148E+06	2.86
4	41.61	13.87	41.61	92.30	15.42	3.2152E+06	3.77
5	55.47	13.88	55.48	99.24	15.37	3.2157E+06	4.67.
6	81.84	26.37	81.84	112.42	14.55	3.2168E+06	6.43
7	108.20	26.37	108.21	125.61	13.49	3.2180E+06	8.31
8	134.57	26.37	134.57	138.79	12.45	3.2191E+06	10.35
9	160.93	26.37	160.94	151.98	11.50	3.2202E+06	12.55
10	207.26	46.34	207.27	175.15	10.12	3.2455E+06	16.85
11	253.59	46.34	253.60	198.32	9.08	3.3983E+06	21.69
12	299.92	46.34	299.93	221.49	8.26	3.5167E+06	27.05
13	340.77	40.85	340.77	241.91	7.65	3.5870E+06	32.19
14	472.74	131.98	472.75	307.90	6.18	3.5442E+06	51.36
15	604.72	131.98	604.72	373.90	4.98	2.8295E+06	75.09
16	757.12	152.41	757.13	450.10	3.67	9.7870E+05	110.40
17	909.52	152.41	909.53	526.30	2.12	-2.1877E+06	163.30
18	982.07	72.53	924.89	562.57	0.83	-4.2772E+06	212.60
19	1060.70		995.39	569.23			244.96

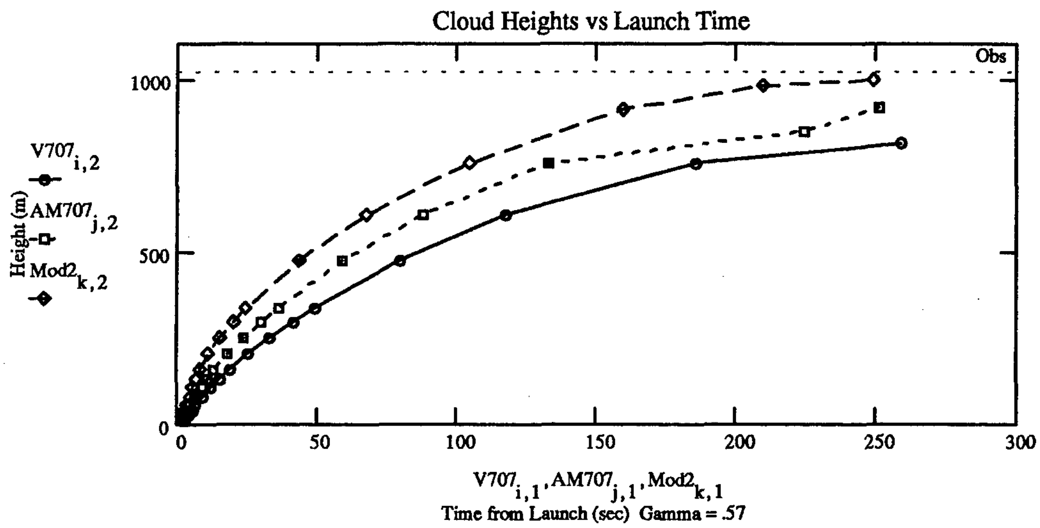
K-16 AM707
Gamma = .50
Initial heat (Q0) = 0.618104E+11 cal

Lyr	AltHgt	Rise Hgt	CldHgt	CldRad	CldVel	Bouyancy	RisTim
1	1.00	0.00	0.00	71.99	0.00	0.0000E+00	0.00
2	13.87	12.87	13.87	72.16	14.81	3.2144E+06	1.73
3	27.74	13.88	27.75	72.93	20.79	3.2146E+06	2.51
4	41.61	13.88	41.62	74.33	24.43	3.2149E+06	3.12
5	55.47	13.87	55.48	76.35	26.47	3.2151E+06	3.67
6	81.84	26.37	81.84	81.39	27.64	3.2157E+06	4.64
7	108.20	26.37	108.21	88.71	25.89	3.2162E+06	5.62
8	134.60	26.37	134.57	98.29	22.72	3.2166E+06	6.71
9	160.90	26.37	160.97	110.10	19.20	3.2171E+06	7.98
10	207.30	46.34	207.24	133.30	14.66	3.2441E+06	10.77
11	253.60	46.34	253.64	156.50	12.17	3.4050E+06	14.26
12	299.90	46.34	299.94	179.70	10.55	3.5400E+06	18.36
13	340.80	40.85	340.75	200.10	9.50	3.6348E+06	22.45
14	472.70	132.00	472.80	266.10	7.31	3.7467E+06	38.34
15	604.70	132.00	604.70	332.10	5.83	3.3628E+06	58.57
16	757.10	152.40	757.10	408.30	4.43	2.1050E+06	88.48
17	909.50	152.40	909.50	484.50	3.05	-2.4998E+05	129.50
18	982.10	72.55	982.05	520.70	2.26	-1.8666E+06	156.90
19	1061.00	78.63	1060.73	560.10	1.00	-3.9863E+06	205.40
20	1214.32		1080.65	570.03			245.53

K-16 MOD2
Gamma = 0.50
Initial heat (Q0) = 0.618104E+11 cal

Table D-6: Results for K-16 Launch





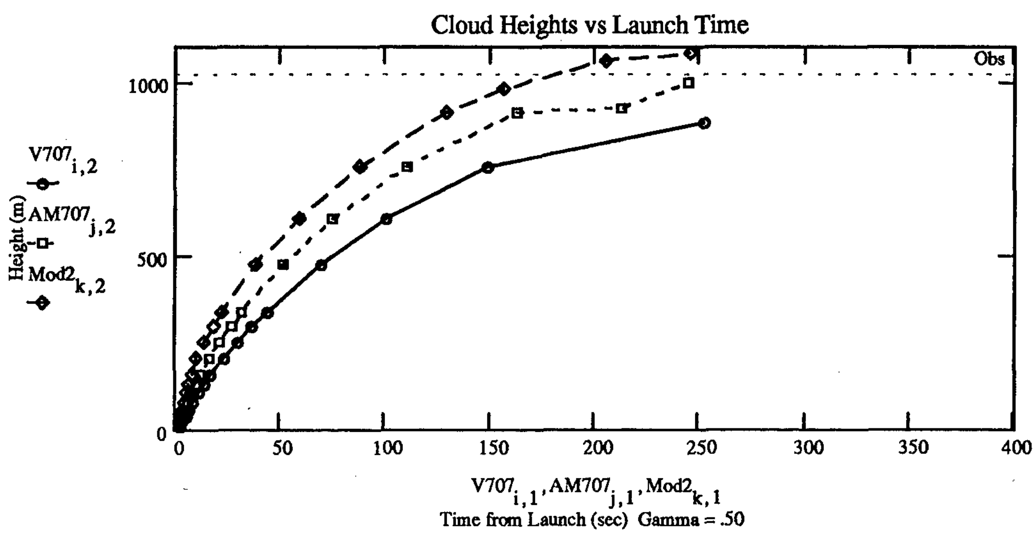


Figure D-11: K-16 Cloud Height Profiles

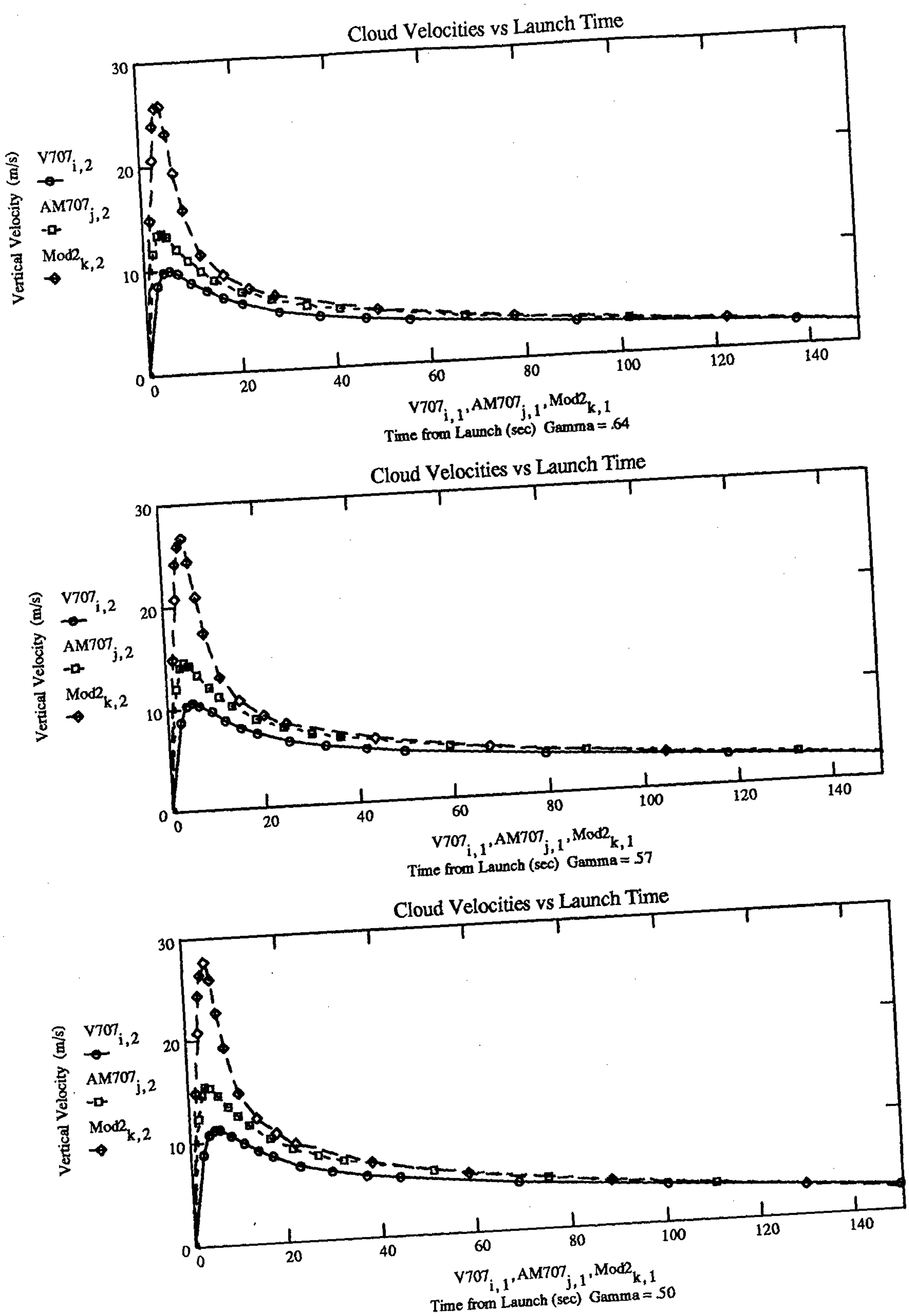


Figure D-12: K-16 Cloud Velocity Profiles

APPENDIX E

Resources Needed for Research

Resources not readily available were needed for this thesis effort. They are listed in Table E.

NEEDED RESOURCE	SOURCE
REEDM Version 7.07 Source Files	ACTA Inc.
Rawinsonde Meteorological Files	ACTA Inc. and Aerospace Corp.
Lahey FORTRAN Compiler Software	Wright Labs/Avionics Directorate
Launch Observation Reports	Aerospace Inc.

Table E: Needed Resources

APPENDIX F

ALTERNATE DERIVATION OF EQUATION 2-26

Change of mass during time Δt is $\Delta M = \Delta t \frac{dM}{dt}$ or

$$\Delta M = \Delta t \frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho_c\right). \tag{F-1}$$

But this is mass entrained which is

$$4\pi r^2 \left(\frac{dr}{dt}\Delta t\right)\rho = 4\pi r^2 \rho \gamma w \Delta t$$

Thus

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho_c\right) = 4\pi r^2 \rho \gamma w \tag{F-2}$$

But $$4\pi r^2 \gamma w = \frac{d}{dt}\left(\frac{4}{3}\pi r^3\right)$$

So, (F-2) becomes

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho_c\right) = \rho \frac{d}{dt}\left(\frac{4}{3}\pi r^3\right) \tag{F-3}$$

But from the chain rule, $\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho\right) = \rho \frac{d}{dt}\left(\frac{4}{3}\pi r^3\right) + \frac{4}{3}\pi r^3 \frac{d\rho}{dt}$

Thus, (F-3) becomes

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho_c\right) = \frac{d}{dt}\left(\frac{4}{3}\pi r^3 \rho\right) - \frac{4}{3}\pi r^3 \frac{d\rho}{dt}$$

or

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 (\rho_c - \rho)\right) = -\frac{4}{3}\pi r^3 \frac{d\rho}{dz}\frac{dz}{dt}$$

or

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 (\rho_c - \rho)\right) = -\frac{4}{3}\pi r^3 w \frac{d\rho}{dz}$$

Thus

$$\frac{d}{dt}\left(\frac{4}{3}\pi r^3 \left(\frac{-\rho_c + \rho}{\rho_c}\right)\rho_c\right) = \frac{4}{3}\pi r^3 w \frac{d\rho}{dz} \tag{F-4}$$

Using the product rule, (F-4) becomes:

$$\rho_c \frac{d}{dt}\left[\frac{4}{3}\pi r^3\left(\frac{\rho-\rho_c}{\rho_c}\right)\right]+\frac{4}{3}\pi r^3\left(\frac{\rho-\rho_c}{\rho_c}\right)\frac{d\rho_c}{dt}=\frac{4}{3}\pi r^3 w\frac{d\rho}{dz}$$

Assuming the term containing $\frac{d\rho_c}{dt}$ is negligible (consistent with Morton, Taylor, and Turner), and dividing by ρ_c, this becomes

$$\frac{d}{dt}\left[\frac{4}{3}\pi r^3\left(\frac{\rho-\rho_c}{\rho_c}\right)\right]=\frac{4}{3}\pi r^3\frac{w}{\rho_c}\frac{d\rho}{dz}$$

Multiplying by the gravitational acceleration constant, yields:

$$\frac{d}{dt}\left[\frac{4}{3}\pi r^3 g\left(\frac{\rho-\rho_c}{\rho_c}\right)\right]=\frac{4}{3}\pi r^3\frac{g}{\rho_c}\frac{d\rho}{dz}w$$

Dividing by $\frac{4}{3}\pi$, and substituting in the definition of $b=g\left(\frac{\rho-\rho_c}{\rho_c}\right)$ yields equation (2-26):

$$\frac{d}{dt}[r^3 b]=r^3 w(-s), \quad \text{where } s=-\frac{g}{\rho_c}\frac{d\rho}{dz}.$$

The fact that s as defined here equals the value of s defined in Chapter II follows from the following argument:

$$\rho=\frac{\theta_c}{\theta}\rho_c=\theta_c\rho_c\theta^{-1} \qquad (22: 70)$$

$$\frac{d\rho}{dz}=\theta_c\rho_c(-1)\theta^{-2}\frac{d\theta}{dz}$$

$$s=-\frac{g}{\rho_c}\frac{d\rho}{dz}=-\frac{g}{\rho_c}\left(\frac{-\theta_c\rho_c}{\theta^2}\frac{d\theta}{dz}\right)$$

$$=\frac{g\theta_c}{\theta^2}\frac{d\theta}{dz}\cong\frac{g}{\theta}\frac{d\theta}{dz}$$

Here, the assumption is made that $\frac{\theta_c}{\theta^2}\approx\frac{1}{\theta}$. The validity of this assumption is not known in the current application of rocket exhaust. This deserves attention in future research.

VITA

Captain Paul F. Sand [redacted] He graduated from St. Xavier High School in 1985. He became an Eagle Scout of Boy Scout Troop 871 that same year. He attended and graduated from the University of Cincinnati, earning a BS degree in Engineering Mechanics in 1990. He was commissioned a 2nd Lieutenant in the United States Air Force through the Air Force Reserve Officer Training Corps (ROTC).

He entered active duty in February of 1991, reporting to the 28th Civil Engineering Squadron at Ellsworth AFB in South Dakota. His duties included energy, design and maintenance engineering as well as readiness functions. While there, he had the opportunity to lead a Prime Base Engineering Emergency Force (BEEF) team on an exercise deployment to Egypt for eight weeks. In 1994 he volunteered for a remote assignment to Osan AB in South Korea, working as a member of the 51st Civil Engineering Squadron. In October of 1994, he was promoted to the rank of Captain.

In May of 1994, he reported to the Air Force Institute of Technology at Wright-Patterson AFB to earn a MS degree in Engineering and Environmental Management. His area of study was air quality management with a supporting program of environmental sciences. Upon completion of his thesis he graduated in December 1996.

His assignment following the Master's degree program is to Arnold Air Force Station in Tennessee, where he will be working in the Environmental Service Directorate.

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13. ABSTRACT *(Maximum 200 words)*

Rocket launches at Vandenburg Air Force Base and Cape Canaveral Air Station produce exhaust clouds containing several toxic by-products, including HCl and Al_2O_3. These clouds rise to atmospheric stabilization heights, and then start dispersing and diffusing through the air. Upon reaching the ground, concentration levels of the toxins may present a human health risk. To predict these risks and concentration levels, range officials use a computer program titled the Rocket Effluent Exhaust Diffusion Model (REEDM). The version currently in use has been shown to underpredict the stabilization height of the exhaust cloud. This thesis examines the theory and algorithms used in REEDM that govern buoyant cloud rise. Further, modifications that improved the physics of the algorithms and changed an entrainment assumption were implemented and tested in REEDM.

Stabilization heights predicted by REEDM using these modifications increased and in some cases closely agreed with observed heights. However, in some circumstances, predicted heights exceeded those observed.

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