

~~CONFIDENTIAL~~

MDH

①

MITRE CONTROL NO	DDP/NO. (S)	CLASS	BR/CTRL	DEC DATE	ACQUISIT
JSE 82-0254	1W	EU		April 1963	JASON
DOCUMENT TITLE					

Radiation Escape From a High Altitude Fireball (U)

MITRE

Derived From: DD254, W15P7T-04-C-A203, Dated
1 February 2004 and Multiple
Sources

~~Declassify On: OADR~~

13-m-4934

~~CONFIDENTIAL~~

~~SECRET~~
CONFIDENTIAL

218-1-163

~~4/16/63~~

INSTITUTE FOR DEFENSE ANALYSES
JASON DIVISION

MITRE CONTROL NO.	
JSE 82W00219	
Date	Copy
3/82	1W 2004

Internal Note ~~4/16/63~~

CONFIDENTIAL

RADIATION ESCAPE FROM A HIGH
ALTITUDE FIREBALL (u)

~~DECLASSIFY ON: OADR~~

by

Keith A. Brueckner

~~CONFIDENTIAL~~

DECLASSIFIED AT 18 YEAR INTER-
VAL. AUTOMATICALLY
DECLASSIFIED. 830 OADR 200410

~~ALL INFORMATION CONTAINED
HEREIN IS UNCLASSIFIED EXCEPT
WHERE SHOWN OTHERWISE BY THIS
DATE 2/15/76/2000~~

~~This document contains information affecting
the national defense of the United States within
the meaning of the Espionage Laws, Title 18,
U.S.C., Sections 793 and 794, the transmission
or the revelation of its contents in any manner
to an unauthorized person is prohibited by law.~~

~~NATIONAL SECURITY INFORMATION
Unauthorized Disclosure Subject to
Criminal Sanctions~~

~~THIS DOCUMENT REMAINS
CONFIDENTIAL
AUTHORITY 830 OADR APPROX 11~~

April 1963

BY ~~200~~ DATE ~~9-16-75~~

STANFORD RESEARCH INSTITUTE

REGISTER NO. SRI-78-0528 1 cy

PROJECT NO. 3000

SRI 2801 CONFIDENTIAL REGISTER

Copy 1 of 1 copy ~~4/16/63~~

Stanford Research Institute

S-41925

CONTROL NO. SRI 2801

SRI COPY NO. 1 PROJECT 3000

SRI 4228 82

CONFIDENTIAL

~~SECRET~~

IDA/HQ-63-1421

CONTROL NO. SRI-78-0528

PROJECT NO. 3000

SRI 2801

THIS DOCUMENT HAS BEEN MICROFILMED FROM THE BEST COPY AVAILABLE AT THE TIME OF FILMING. CERTAIN PORTIONS CONTAIN BROKEN COPY, PHOTO-REDUCTIONS, OR FINE PRINT WHICH MAY NOT BE LEGIBLE IN SUBSEQUENT BLOWBACK COPIES. THE DOCUMENT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

~~SECRET~~
~~CONFIDENTIAL~~

March 13, 1963

Radiation Escape from a High

Altitude Fireball

by

K. A. Brueckner

Using a previously established model¹ for the reradiation from a high altitude fireball, we found for the energy lost by radiation

$$\frac{Y_R}{Y} = \left(\frac{4}{3} \frac{\pi h_0^3 N_0}{Y} \right)^2 \left[\left(\frac{2}{3} + \frac{1}{3} \kappa \right) \kappa^{1/2} \gamma_0 \right]^2 \frac{1}{\gamma_0} \int_{y_0}^1 \left[\ln \left(\frac{2}{1-y} \right) \right]^4 (1-y) dy \quad (1)$$

with

$$y = e^{-R_+/h_0} \quad (2)$$

and y_0 the value corresponding to the maximum radius. The geometry of the radiating fireball was approximated by a sphere with diameter $D = R_+ + R_-$, with R_+ the distance of upward propagation of the radiation front, and R_- the distance of downward propagation.

The condition for 100% efficiency for radiation escape was previously assumed to be

$$\frac{Y_R}{Y} \geq 1 \text{ for } y_0 \rightarrow 0 \quad (3)$$

We now investigate another approximation to determine the efficiency for reradiation. We suppose that an energy E_D per atom is trapped in molecular dissociation and is not reradiated sufficiently rapidly to have an appreciable thermal effect. The total energy so trapped is

$$Y_D = \int dV (M(r) E_D) \quad (4)$$

1. See Appendix A of Intercept X Working Paper X-19.

~~CONFIDENTIAL~~

~~SECRET~~

~~SECRET~~
~~CONFIDENTIAL~~

We approximate this integral as before by

$$Y_0 = \frac{4\pi}{3} \left(\frac{R_+ + R_-}{2} \right)^3 N_0 E_0 \frac{R_+ - R_-}{R_+ + R_-} \frac{R_+ - R_-}{R_0} \quad (5)$$

Energy conservation now requires that the reradiation stops when

$$Y_D + Y_R = Y \quad (6)$$

For convenience in evaluating Eq. (6), we introduce the change in variable in Eq. (1)

$$R_+ - R_- = s \quad (7)$$

and write

$$\lambda = \frac{4\pi \lambda^3 E_0 N_0}{Y} \quad (8)$$

We also assume for constants in Eq. (1)

$$\alpha = 2$$

$$T_0 = 4 \text{ ev} \quad (9)$$

$$E_d = 2 \text{ ev}$$

Eq. (6) then becomes

$$1 = 0.754 \lambda^2 \int_0^a ds s^4 e^{-s} \frac{(1-e^{-s})}{(1+e^{-s})^3} + 0.250 \lambda^2 \frac{1-e^{-a}}{1+e^{-a}} \quad (10)$$

~~CONFIDENTIAL~~

~~SECRET~~

~~SECRET~~
~~CONFIDENTIAL~~

This equation takes on a simpler form in two limits:

$$1 = 0.784 \frac{(\lambda a)^2}{48} + 0.127 \lambda a^3, \quad a \ll 1 \quad (11a)$$

$$1 = 0.784 \lambda^2 \left[24 - (24 + 24a + 12a^2 + 4a^3 + a^4) e^{-a} \right] + 0.210 \lambda a^2, \quad a \gg 1 \quad (11b)$$

Eq. (11a) can be solved for λa^3 , giving

$$\left. \begin{aligned} \lambda a^3 &= 4.84 \\ Y_R/Y &= 40.90 \end{aligned} \right\} a \ll 1 \quad (12)$$

This result holds for a yield which is sufficiently small so that containment occurs,

i. e., such that

$$Y \ll 0.20 \frac{Y \rho_0^3 H_0^3}{\rho_0} \quad (13)$$

Eq. (11b) has been solved numerically for λ as a function of a , which also gives Y_R/Y as a function of λ . The results are given in Table I and in Fig. (1). The efficiency starts at 40% for low yield and starts to drop at $\lambda^{-1} = Y/\frac{4}{3} \rho_0^3 H_0^3 = 1$, falling to 33% at $\lambda^{-1} = 3$, to 15% at $\lambda^{-1} = 10$, and to 3% at $\lambda^{-1} = 25$. Translated to yields and altitudes, the predictions are given in Table II.

These results are indicative of a change in efficiency. Since, however, they are only a model of the process, the quantitative results should not be interpreted too literally!

~~CONFIDENTIAL~~
~~SECRET~~

~~CONFIDENTIAL~~

TABLE I

Variation of λ^{-1} and Y_R/Y with a

a	λ^{-1}	Y_R/T	$\lambda^{-1}Y_R/Y$
1.00	0.415	.395	.164
2.00	1.63	.382	.621
3.00	3.30	.320	1.056
4.00	5.29	.249	1.318
6.00	10.3	.128	1.312
10.00	25.7	.0277	0.712

TABLE II

Variation of Y_R/Y with Altitude

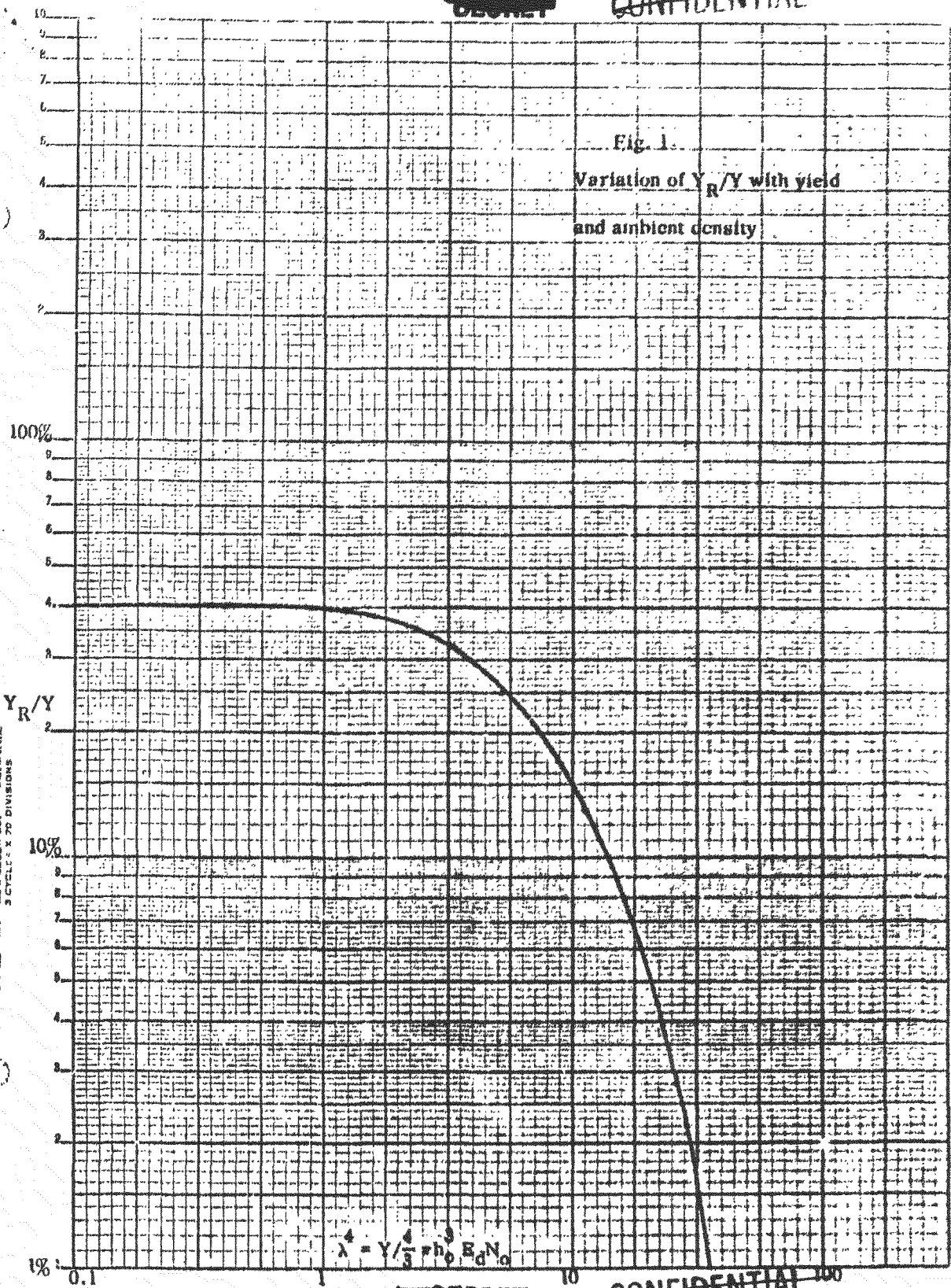
	Y_R/Y			
	40%	33%	15%	3%
100 MT	<34 km	42 km	51 km	57 km
4 MT	<57 km	65 km	73 km	80 km

~~CONFIDENTIAL~~

~~SECRET~~

~~SECRET~~

~~CONFIDENTIAL~~



K-E
 SEMILOGARITHMIC
 REPERTORY SHEET
 358-71
 3 CYCLES X 20 DIVISIONS

$$\lambda^4 = Y \frac{4}{3} \rho h_0^3 E_d N_0$$

~~SECRET~~

~~CONFIDENTIAL~~

Radiation escape from a
 High altitude
 Freeball
 of a Freeball

~~CONFIDENTIAL~~

See earlier note
 available to
 reference?
 App # of ...

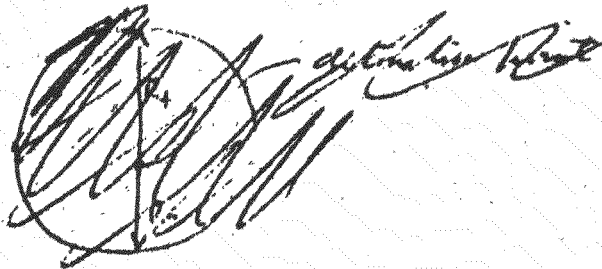
Using a previously established model for the
 reradiation from a high altitude freeball, we found
 for the thermal energy lost by radiation

$$\frac{Y_R}{Y} = \left(\frac{4}{3} \pi h_0^3 N_0 \right)^2 \left[\left(\frac{3}{2} + \frac{1}{3} \alpha \right) \alpha^{1/2} T_0^{3/2} \right]^2 \frac{1}{46} \int_{y_0}^1 (R_2 \frac{z-4}{z-1})^{4(1-y)} dy \quad (1)$$

with

$$y = \frac{R_2 + h_0}{e} \quad (2)$$

and y_0 the maximum value of y corresponding to
 the maximum radius. The geometry of the freeball was
 approximated by a sphere with diameter
 $D = R_2 + R_1$



with R_1 the distance of upward propagation
 front, and R_2 the distance of downward propagation.

We are using this model

if Y_R/Y were less than unity for $y_0 = 1$ we would have

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

The condition for 100% efficiency for ^{100%} photo radiation escape was previously assumed to be

$$\frac{Y_R}{Y} \approx 1 \quad \text{for } \gamma_0 \rightarrow 0 \quad (3)$$

We now investigate another approximation for escape to determine the efficiency for radiation. We suppose that an energy E_0 is trapped in molecular ^{in atom} vibration and is not radiated sufficiently to have an appreciable effect. ^{thermal} ~~that energy is~~ total energy so trapped is

$$Y_0 = \int dV N(r) E_0 \quad (4)$$

We approximate this integral as before by

$$Y_0 = \frac{V}{3} \pi \left(\frac{R_+ + R_-}{2} \right)^3 N_0 E_0 \frac{R_+ - R_-}{R_+ + R_-} \quad (5)$$

with $Y_0 = \frac{4}{3} \pi N_0 E_0 \left(\ln \frac{2 - \gamma_0}{\gamma_0} \right)^2 \frac{(1 - \gamma_0)}{\gamma_0}$
 $Y_0 = \frac{c}{-R_+ / h\nu}$ ~~delete~~

Energy conservation now requires that the radiation stops when

$$Y_0 + Y_R = Y \quad (6)$$

For convenience in evaluating Eq. (6), we introduce the class in variable in Eq. (1)

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~ -3-

$$\mu \frac{z-4}{4} = 5 \quad (7)$$

and write

$$\mu \frac{z-40}{40} = a \quad (8)$$
$$\lambda = \frac{4}{3} \pi h_0^3 N_0 f_0 / Y$$

We also assume for constants in Eq. (1)

$$\alpha = 2$$

$$\tau_0 = 4 \text{ ev} \quad (9)$$

$$E_0 = 2 \text{ ev}$$

Eq. (6) then becomes

$$1 = 0.754 \lambda^2 \int_0^a ds \frac{5^4 e^{-5s} (1-e^{-s})}{(1+e^{-s})^3}$$
$$+ 0.250 \lambda a^2 \frac{1-e^{-a}}{1+e^{-a}} \quad (10)$$

This equation takes on a simpler form in the limit:

$$1 = 0.754 \frac{(\lambda a^2)^2}{48} + 0.1125 \lambda a^3 \quad ; \quad a \ll 1 \quad (11a)$$

$$= 0.754 \lambda^2 [24 \cdot (24 + 24a + 12a^2 + 4a^3 + a^4) e^{-a}]$$
$$+ 0.250 \lambda a^2 \quad ; \quad a \approx 1 \quad (11b)$$

Eq. (11a) can be solved for λa^3 , giving

$$\lambda a^3 = 4.94 \quad a \ll 1 \quad (12)$$

$$Y_0/Y = 40\%$$

~~CONFIDENTIAL~~

This result holds for a field which is sufficiently small that

~~CONFIDENTIAL~~

-4-

total containment occurs, i.e. such that

$$Y \ll 0.20 \left(\frac{4}{3} \pi h_0^3 E_0 \right) \quad (15)$$

Eq. (11b) has been solved numerically for λ as a function of a , which also gives $Y(a)$ as a function of a .

No results are given in Table I and in Fig (1). The efficiency starts at 40% for low yield and starts to drop at $\lambda^{-1} = Y / \left(\frac{4}{3} \pi h_0^3 N_0 E_0 \right) = 1$, falling to 33% at $\lambda^{-1} = 3$, to 15% at $\lambda^{-1} = 10$, and to 3% at $\lambda^{-1} = 25$. Translated to yields and altitudes, the predictions are given in Table II.

These results are indicative of a drop in efficiency. Since, however, they are only a model of the process, the quantitative results should not be interpreted too literally!

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Table I } Variation of λ^{-1} and $Y_{R/Y}$ with a .

a	λ^{-1}	$Y_{R/Y}$	$\lambda^{-1} Y_{R/Y}$
1.00	0.415	.305	.164
2.00	1.63	.382	.621
3.00	3.30	.320	1.056
4.00	5.09	.249	1.318
6.00	10.3	.128	1.312
10.00	25.7	.0277	0.712

Table II

Variation of $Y_{R/Y}$ with altitude

	4070	3370	1570	370
100 AT	< 34 km	42 km	51 km	57 km
4 AT	< 57 km	65 km	79 km	80 km

~~CONFIDENTIAL~~