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Height of IVY Mike Cloud

Memo by W. D. Urry, AFOAT-1
with enclosures

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SECRET
AUTH CS USAF
DHF 1?

V/O

AFOAT-1

4 MAY 1953

24 April 1953

MEMORANDUM FOR RECORD

SUBJECT: (Confidential) Height of IVY (Restricted) Mike Cloud

1. At the time of the IVY Mike Operation two aircraft designated "Saltshaker" flew race-track courses, one due south of ground zero at approximately 70 nautical miles, the other due east of ground zero at approximately 80 nautical miles. The planned mission of these flights was to secure a photograph of the IVY Mike cloud each minute for one hour following the explosion. This mission was requested by Headquarters USAF, AFOAT-1 for after-the-fact cloud height calculations but the pictures have not yet been received, and may not be of much value for the intended purpose because of poorly defined or absent horizons.

2. Unscheduled bubble sextant readings were made by Dr. [redacted] in the aircraft to the south and Colonel [redacted] of Headquarters USAF, AFOAT-1 in the aircraft to the east. Aircraft loran positions were provided by the navigator of the aircraft who also checked some of the angle observations. Attached hereto is Table I giving the observations and calculations of cloud height and heights of various outstanding features of the cloud. The observations of angle, distance to ground zero, and aircraft altitude are believed to be such that the calculated heights are not in error one way or the other by more than a few thousand feet. Consideration of some points would lead one to believe that no large errors were introduced by "edge" sighting and thereby obtaining erroneously high angles. First of all, there can be little of this kind of error in sighting on the rather sharp-pointed plume which yielded an altitude of 135,500 feet. The difference between this altitude and the top of the cloud at around 120,000 feet was in the correct proportion to the thickness of the cloud (120,000 - 67,000 = 43,000 feet) as judged at the time. Secondly, a sighting on the far right edge of the cloud (obs: at 11.75 minutes in Table I) gave 104,000 feet and this can hardly be in error by 40,000 feet due to erroneous sighting arising from edge and thickness effects, as it would be if the cloud did not rise above the tropopause. Thirdly, the main shear layer measured at 15.25 minutes in Table I gave an altitude corresponding exactly to that of the prognosticated principle shear altitude for the event and was again judged to be at the correct proportional altitude for a top at around 120,000 feet. Fourthly, the altitudes of 110,000 and 112,000 feet at 2.66 and 3.42 minutes are not explainable on false base line because of lateral movement of the cloud; air movements are not that rapid compared with a plane to ground zero base line of 68 nautical miles.

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Inclosure 1 [1]

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3. The constancy of the measured height of the top of the cloud over a period of one hour in Table I is consistent with the slow movement of the cloud. Measurements by Colonel [redacted] in the aircraft to the east of ground zero are not so consistent and calculated heights appear to decrease with time, probably due to an increase in true base line owing to a westward movement of the cloud. Colonel Fee's data place the top of the cloud variously between 127,000 and 99,000 feet.

4. The rate of rise of the cloud can be obtained from Figure I. It is to be noted that a marked vertical deceleration occurred at two minutes, at which time the conspicuous lateral spreading occurred. This is in agreement with the observations of [redacted] except that actual measurement indicates the "splashing" occurred against a barrier between 100,000 and 110,000 feet, which may be of significance in connection with the usual increase in temperature at around 100,000 feet. Some observations given to Dr. [redacted] by Col. [redacted] in the B/36 sampling control aircraft are plotted also in Figure I. Col. [redacted] observation at 40 seconds as the cloud went by his altitude is in fair agreement with Dr. [redacted] curve as also is his observation some time after 20 minutes. At five minutes, Col. [redacted] observation is considerably lower than Dr. [redacted] but the top is well within the stratosphere.

5. Some observations by [redacted] of Headquarters USAF, APOAT-1 under similar conditions, but at 30 to 40 nautical miles from ground zero at the time of IVY King test are shown on Figure I for comparison.

6. The hypothesis put forward by Professor C. E. Palmer in his second letter of 2 February 1953 for the secondary formation of the main large cloud appears to the author to be plausible but it also appears equally certain that the bulk of this main cloud ended up in the stratosphere between 60 and 120 thousand feet. The maintenance of its shape and form are believed to be due to its internal turbulence and unequal heat distribution. Any estimate of the degree of mixing of the secondarily formed large main cloud with a primary column of nuclear debris, if indeed this did not intimately occur during rise, is purely hazardous guesswork. As far as is known, no observations were made for guidance on this aspect of the problem. It seems apparent that sampling was conducted some thousands of feet below the bottom of the main cloud, as statements by some of the pilots of the F-84 sampling aircraft, appears to confirm.

7. There is attached hereto as an integral part of this problem a memorandum from Mr. [redacted] to Dr. [redacted] dated 11 December 1952, discussing a well-defined relation between early rate of rise of the cloud and the energy of a nuclear explosion.

[redacted]
Assistant for Nuclear Physics
Office of the Technical Director, APOAT-1

3 Incls
Table 1
Figure I
Memo dtd 11 Dec 52 fm Mr. [redacted] to Dr. [redacted]

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CLOUD HEIGHT DATA FOR MIK[illegible] SHOT, [illegible]ATION IVY, Taken by Dr. [redacted]

Incl. 1

Time Local 1 Nov 52	Decimal Time H + Min	Aircraft Position Latitude Longitude	Aircraft Altitude Feet	Distance from Mike Ground Zero Naut. Mi.	Distance from Mike Ground Zero Feet	Elevation Angle Deg Min	Calculated Height Above Aircraft	Correction for Earth Curvature	Total Height	Coordinates of Ground Zero Approx. 11-40.2 N 162-11.7 E
0715	0	10-36 N 161-47 E	12300	68.6	416000	- -	-	-	-	
0716.5	1.5	10-35 N 161-50 E	12300	68.5	415000	05-47	42200	4000	58200	Absolute Top, Ma[illegible] Cloud
0717.7	2.66	10-35 N 161-52 E	12300	67.9	412000	12-30	94000	4000	110000	" " "
0718.4	3.42	10-34.5N 161-53.5E	12300	67.9	412000	13-04	95800	4000	111800	" " "
0719.4	4.42	10-34.5N 161-55.5E	12300	67.6	411000	13-33	99000	4000	115000	" " "
0720.8	5.75	10-34.25N 161-57 E	12300	67.5	410000	14-10	103500	4000	119500	Top of main cloud, plume above top of m[illegible]
072[illegible]	8.9	10-37 N 161-50 E	12300	66.9	405500	16-28	119500	4000	135500	Point A, Picture A Top of plume
0725.5	10.5	10-39.5N 161-45.25E	12300	65.9	400000	07-18	51200	4000	67200	Point B, Picture A Base of mushroom
0726.8	11.75	10-40.5N 161-44 E	12300	65.5	397500	12-30	88000	4000	104000	Point C, Picture B Right side of top
0728.4	13.4	10-41.5N 161-41.75E	12300	65.8	399000	14-38	104000	4000	120000	Absolute top, Main Clo[illegible]
0730.3	15.25	10-42.5N 161-39.5E	12300	65.9	400000	01-35	11100	4000	27100	Point D, Picture C Lower shear layer
0811	56	10-38.5N 161-35 E	12300	71.1	432000	14-00	108000	4000	124000	Top of orange cloud
0812	57	10-38.5N 161-23 E	12300	72.5	440000	13-55	109000	4000	125000	Top of orange cloud
0815	60	10-38 N 161-24 E	12300	78.0	474000	13-17	112000	4000	128000	Top of orange clouds
0818	63	10-34 N 161-29.5E	12300	77.8	472000	16-35	140000	4000	156000	Hgt of [illegible] sun + cloud [illegible]
0820	65	10-32.5N 161-31.8E	12300	78.1	475000	12-10	102000	4000	118000	Top of orange [illegible]

Table I

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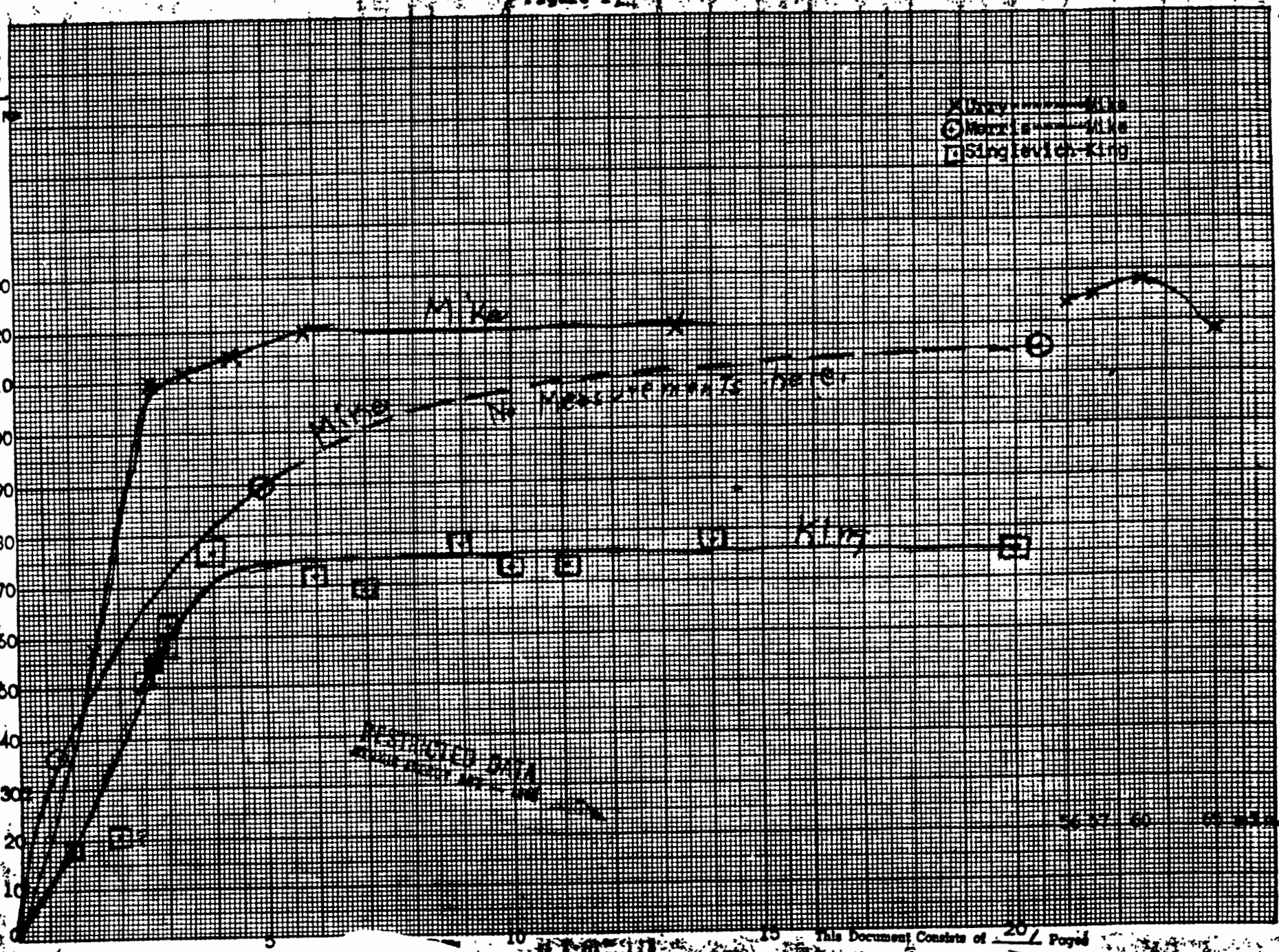
Figure 11.



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AUTH CS USAF
Mr.Allen/mhk/62189

SUBJ: The Relationship Between Energy and Rate of Cloud Rise

TO: Dr. [redacted] FROM: [redacted] DATE: 11 Dec 52 CMT. 1

1. As you suggested last week, I have gone over all available data on the rates of rise of clouds from U.S. atomic tests and have plotted values for the rates of rise against energy in KT, as shown in the accompanying graph, together with the empirical equation of relationship.

2. The rate of rise changes with time, increasing to a maximum during the first minute and decreasing thereafter to essentially zero after about 10 minutes. The data available to us are not good enough to show the maximum rate due to poor timing and infrequent measurements, but may be used to obtain the average rate of rise over a period of minutes. The average over the initial 3 minutes is used on this graph. In all cases except IVY Mike the clouds were still rising rapidly and were still in the troposphere after the third minute. The Mike cloud was treated in a special manner as indicated below.

It is reasonable to believe there to be some dependency of rise rate on the lapse of ambient air temperature with altitude. The effect of inversions and stable layers will, however, be a minimum in the earliest seconds of rise, increasing in importance as the temperature difference decreases between cloud and surrounding atmosphere. When the cloud reaches ambient air temperature, further vertical motion is damped out. It is therefore preferable to measure the rate of rise at the earliest possible time, and the maximum rate of rise should be more indicative of energy than the mean 3-minute rate used here.

Since the mean lapse rate of temperature is markedly different in the stratosphere than in the troposphere, it is preferable to make all measurements in the troposphere until adequate corrections can be made for this.

3. Rate of rise data are available from the following sources:

a. Operation SANDSTONE. Mr. Paul Humphreys, USNR, documented the rise and dispersion of the SANDSTONE clouds in an AFSWP publication, "Classified Scientific Meteorological Information, Operation SANDSTONE." His data were obtained by theodolite and are reasonably accurate over at least the first few minutes of rise.

b. Operation GREENHOUSE. The rise of the GREENHOUSE clouds were obtained from an unpublished report on "Cloud Physics", Proj. 4.6, by Dr. W.W.Kellogg, Rand Corp. Motion picture photography were analyzed for cloud rise and cloud dimensions, and the ra tes of rise over the first 4 or 5 minutes are probably good, although weather clouds obscured parts of the atomic clouds. The maximum altitudes of the Dog and George clouds are still in doubt since the tops of these clouds were not visible from the camera positions.

c. Operations BUSTER-JANGLE. Two sources of cloud rise data are available for these operations, one being that taken by myself (with your help in a

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couple of cases) by hand clinometer, and [illegible] taken by Air Weather Service personnel by theodolite. These two sets [illegible] very well in all cases except Charlie cloud. On the graph, the average of the two is indicated by the circled dot, with the outriggers showing the values themselves.

d. Operation IVY. Three surface vessels and three aircraft were engaged in making cloud rise and height measurements of Mike cloud. Of these, one vessel failed to make any height measurements until H + 8½ min., and one airplane made only one measurement, at approximately H + 40 sec, before H + 5 min. It is not believed that timing was very accurate on this measurement so it was discarded. The other measurements showed the cloud to have approached maximum altitude at 3 minutes so in addition to the 3 minute average an average was obtained using earlier measurements. Since there is reason to believe the rate to decrease in the stratosphere (above 58000 ft on Mike day) the second average was taken of observations below that height. The two averages are shown as horizontal lines on the graph.

(1) Three minute heights:

U.S.S Curtiss	100,500 ft.	
U.S.S. Rendova	117,000 ft.	
Aircraft No. 1 (Dr. [redacted])	111,000 ft.	
Aircraft No. 2 (Col. [redacted])	127,000 ft.	
Average	114,000 ft. in 3 min.	

(2) Extrapolation of troposphere rates:

U.S.S. Curtiss	46,600 ft. at 1 min.	139,800 ft/3 mi
U.S.S. Rendova	No early measurements	
Aircraft No. 1	58,200 ft. at 1½ min.	116,400 ft/3 mi
Aircraft No. 2	No early measurements	
Average		128,100 ft/3 mi

Three surface vessels and two aircraft made measurements of the King cloud, and all data are on hand except that from one surface vessel. The three minute heights are as follows:

U.S.S. Oak Hill	58,300
U.S.S. Rendova	56,100
Aircraft No. 1 (Mr. [redacted])	58,300
Aircraft No. 2 (Col. [redacted])	53,000 (Doubtful)
Average	56,400

The average is plotted on the graph.

4. Considerable improvement in this relationship might well result from more accurate determination of the rate of rise and in particular of the maximum rate, and from development of a correction factor for variations in the ambient air lapse rate of temperature.

[redacted]

(6)

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Chart

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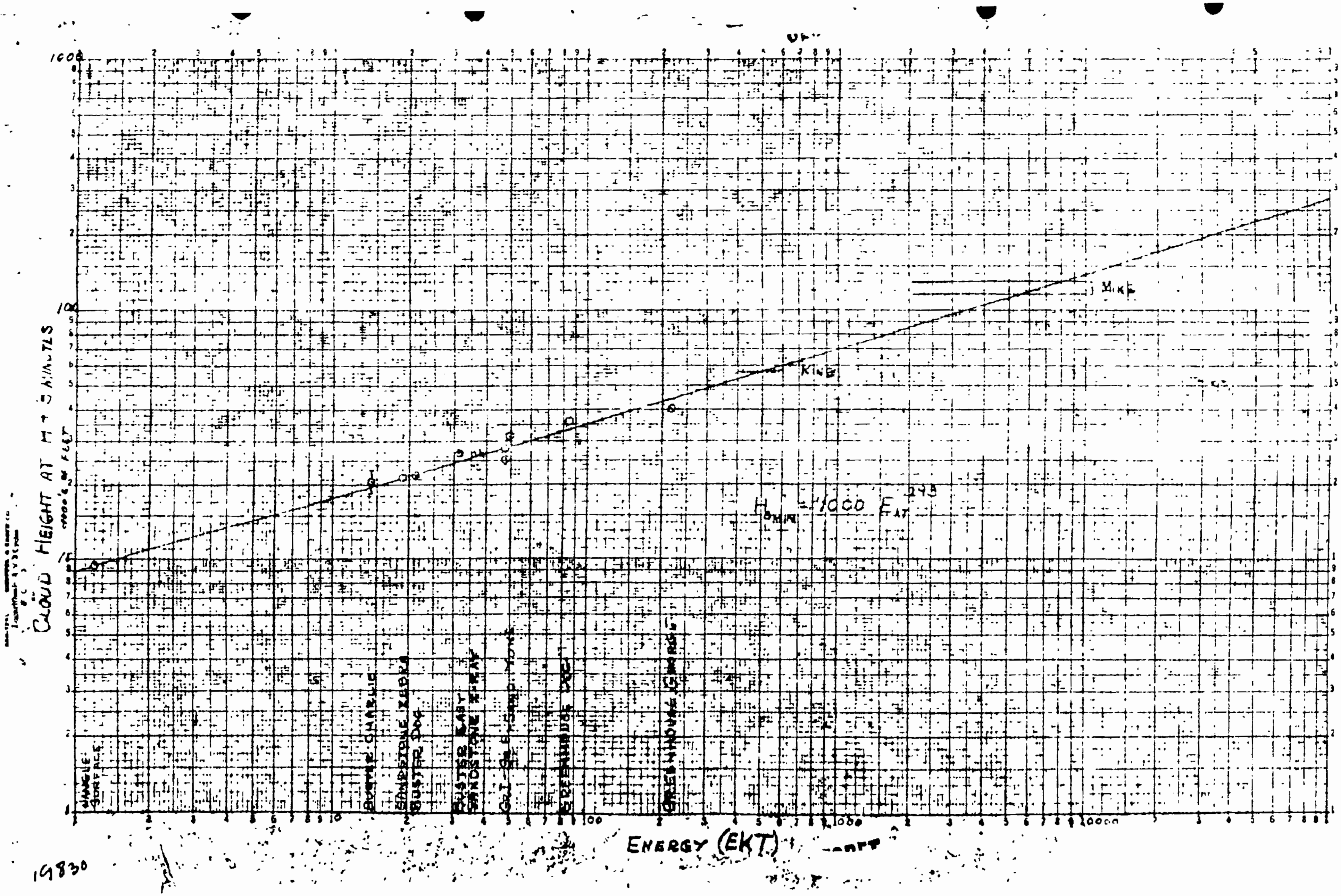

CLOUD HEIGHT AT M + 5 MINUTES
1000's of FEET
ENERGY (EKT)
MIKE
KING
$H_{5MIN} = 11000\ E_{KT}^{.245}$
JANGLE SURFACE
BUSTER CHARLIE
SANDSTONE ZEBRA
BUSTER DOG
BUSTER EASY
SANDSTONE X-RAY
GREENHOUSE DOG
GREENHOUSE GEORGE

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