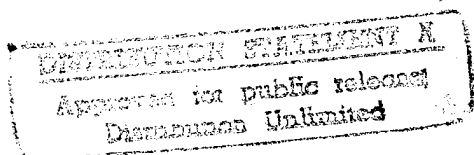


FIREBALL CALCULATIONS
SHOT WRANGELL
OPERATION HARDTACK, PHASE II
PROJECT 15.1



Report No. B-2064
4 March 1960

19960702 074

Prepared by J. E. Campbell
J. E. Campbell

Approved by D. F. Seacord, Jr.
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EDGERTON, GERMESHAUSEN & GRIER, INC.
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Defense Nuclear Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398



ISST

29 May 1996

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OCD/MR. BILL BUSH

SUBJECT: Documents for DTIC System

There is no record of your office receiving the following reports:

EGG-B-2064 (4 March 1960)
Fireball Calculations Shot
Wrangell Operation Hardtack
Phase II, Project 15.1

EGG-B-2063 (4 March 1960)
Fireball Calculations Shot Humboldt
Operation Hardtack Phase II
Project 15.1

Both documents are now approved for public release.

Therefore, we are transmitting copies for inclusion into the DTIC system, if not found there.

Enclosure:
A/S

Arldith Jarrett
ARDITH JARRETT
Chief, Technical Support

DTIC QUALITY INSPECTED 4

FIREBALL CALCULATIONS - SHOT WRANGELL

1.0 INTRODUCTION

Shot Wrangell was a 1500-foot balloon shot sponsored by LRL and detonated on 22 October 1958 in Area B-Fa of the Nevada Test Site at 0850 PST.

The fireball yield was $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

2.0 CAMERA INSTRUMENTATION AND OPERATION

Photographic coverage of fireball growth was provided by four high-speed Eastman cameras, two each at Station F-362 (6 x 6 No. 2) and Station F-369 (6 x 6 No. 3). In addition, two Rapatronic cameras were located at each of these stations to record early fireball growth.

Three Eastman cameras and three Rapatronics provided good records. The remaining Eastman and Rapatronic, because of malfunctions, did not provide records suitable for analysis.

The station locations, together with the burst location, are shown in Figure 1. Figure 2 contains the Survey Data.

3.0 RESULTS

Application of phi-comparison (EG&G Report No. B-1869) for Shot Wrangell indicates a yield of $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

An air density of 1.057 grams per liter was used in the yield calculations, based on a pressure of 863 millibars, a temperature of 11.1°C , and a relative humidity of 13 percent at the height of the device at shot time.

The following table shows the Wrangell yield as obtained by a phi-comparison to various other low-yield devices:

Comparison Shot	Wrangell Yield Tons
<u>Air Drop</u>	
Wasp	66.74
Buster Baker	62.41
Wasp'	66.38
Ranger E	63.56
Ranger A	66.73
Osage	71.64
<u>Tower</u>	
Hornet	64.97
Chaves	72.97
Rio Arriba	73.19
Quay	64.44
Humboldt	64.58
<u>Balloon</u>	
Hidalgo	66.46
Lea	71.03

$$\bar{W} = 67.3 \text{ tons}$$

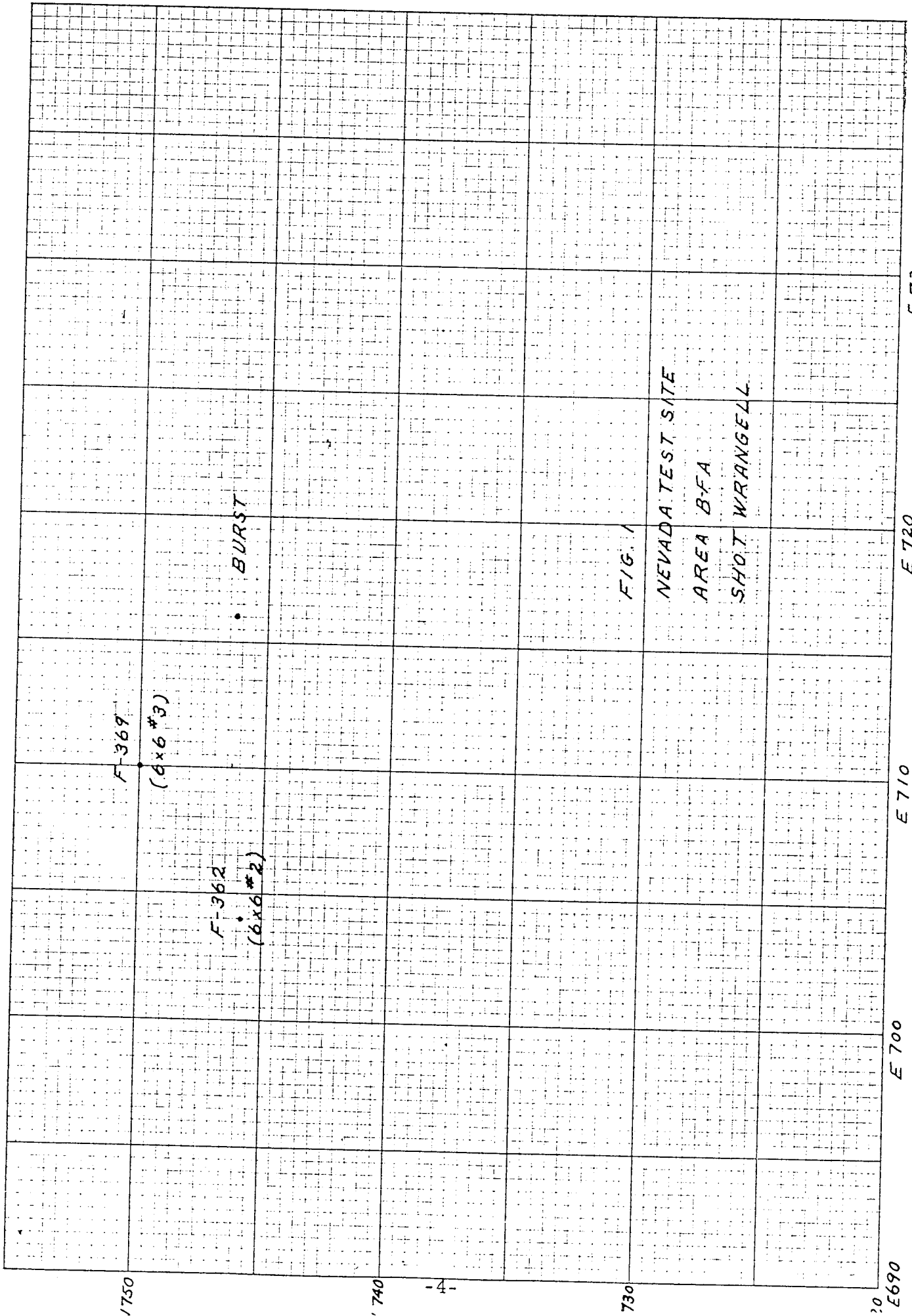
Diameter-time and phi-time plots are shown in Figures 3 and 4.

The following data sheets are included for each film:

- (a) Photo Plan and Photo Loading Chart
- (b) Camera Data and Calculation Sheet
- (c) Diameter Measurement Sheet
- (d) E-102 Print-Out Sheet of D , t , and \emptyset

Appendix A contains photographic examples of early fireball growth.

The zero-frame times of the Eastman records were determined by comparison with the Rapatronic diameter-time data.



1750

740

-4-

730

690

E 700

E 710

E 720

E 730

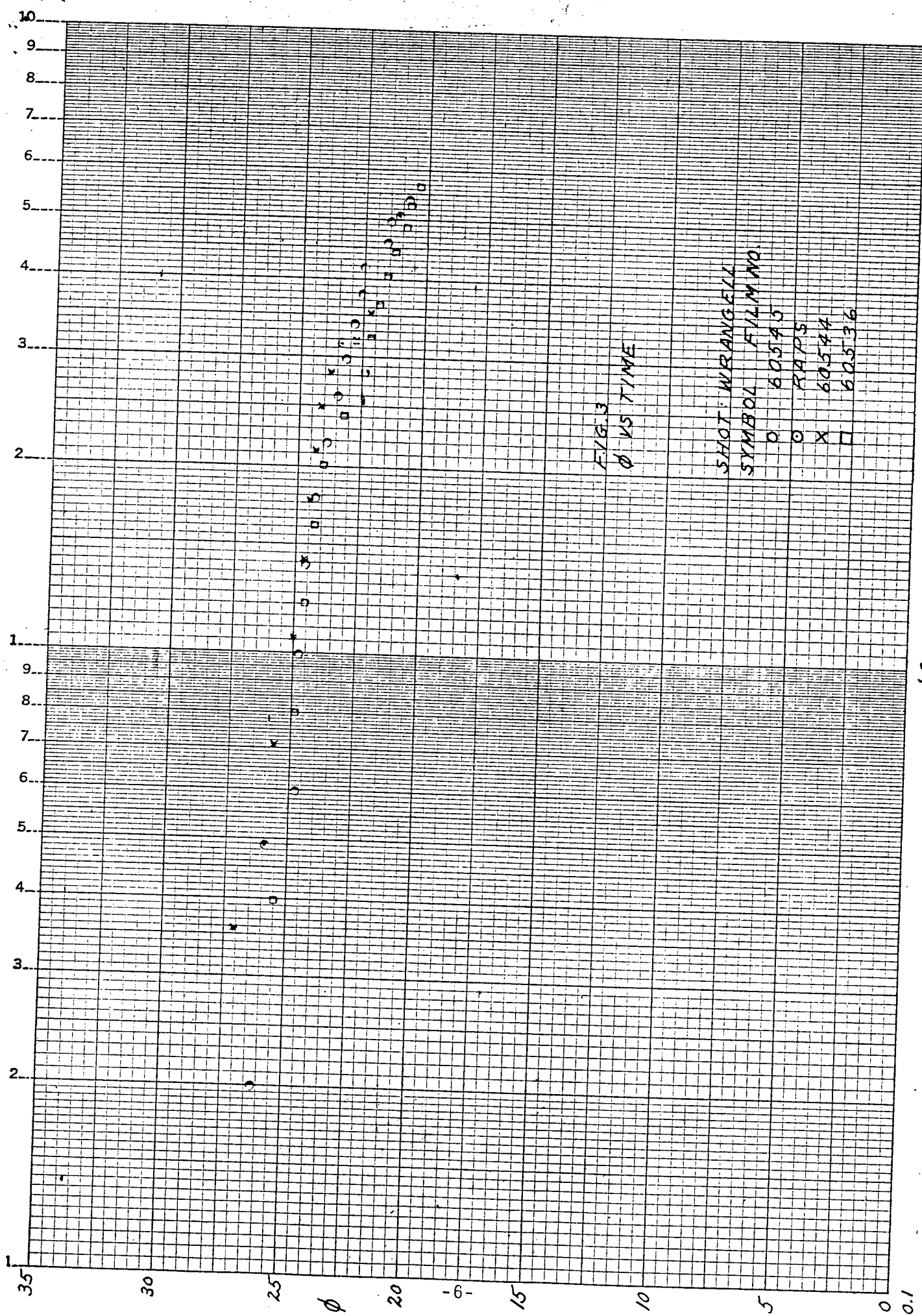


FIG. 3
 ϕ VS TIME

SHOT: WRANGELL
 SYMBOL FILM NO.
 O 60543
 X RAPS
 60544
 □ 60536

1.0
 TIME (msec)

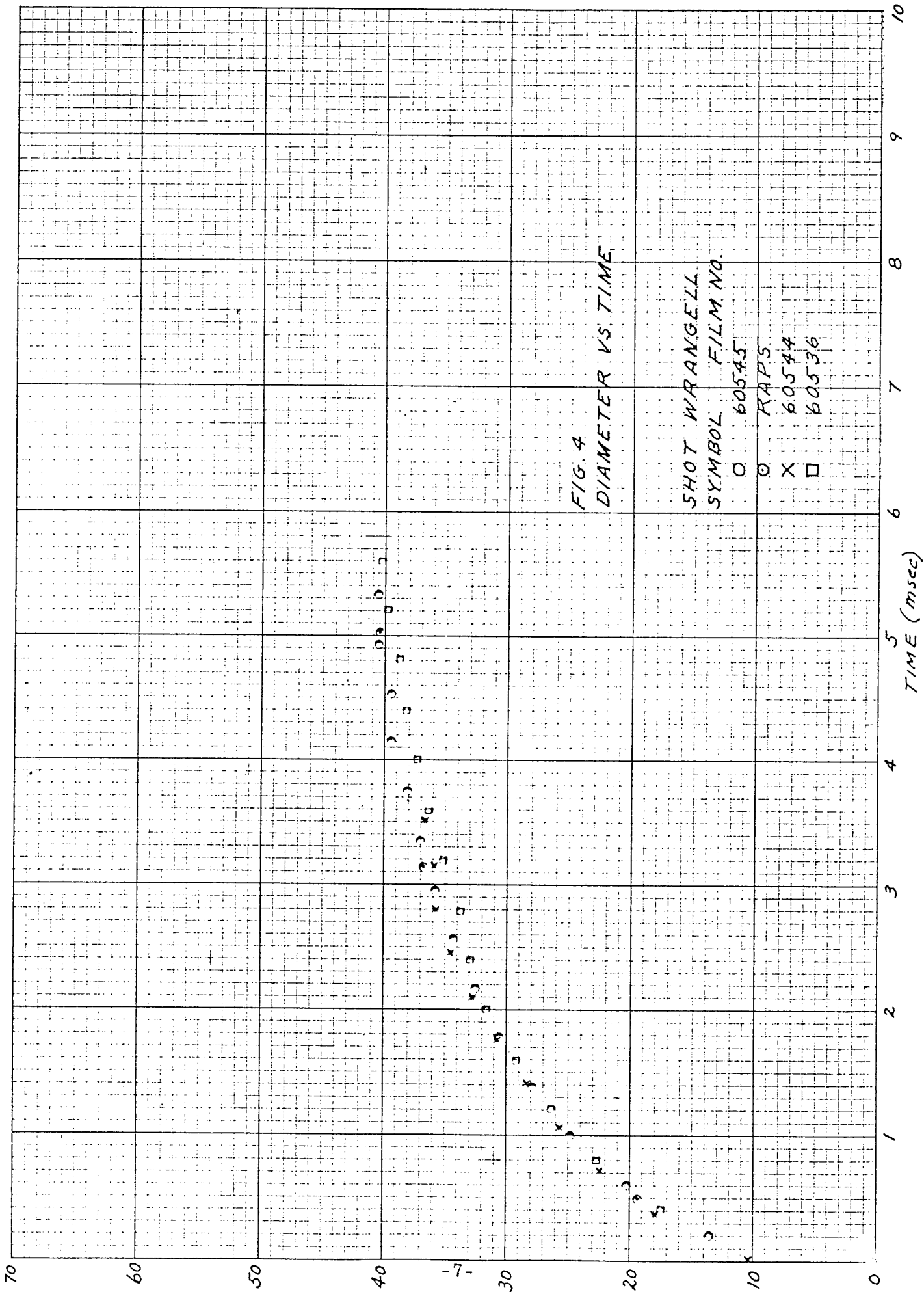


FIG. 4
DIAMETER VS. TIME

SHOT WRANGELL
SYMBOL FILM NO.
O 60545
X 60544
□ 60536

Table I
Hardtack Phase II, Wrangell.
Average Diameter vs. Time

Time (msec)	Diameter (Meters)
0.5	19.5
1.0	25.0
1.5	29.0
2.0	32.0
2.5	34.0
3.0	36.0
3.5	37.5
4.0	38.5
4.5	39.0
5.0	40.0
5.5	40.5

Table II

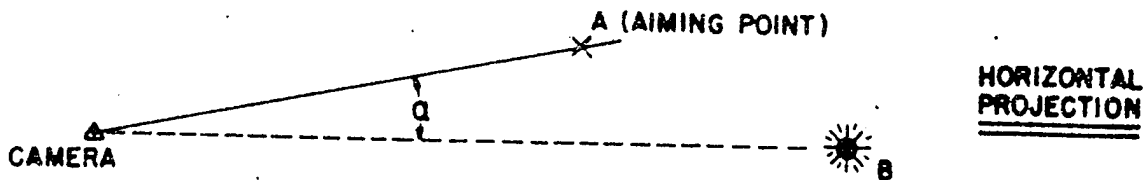
Hardtack Phase II - Wrangell

Rapatronic Summary

Station	Film No.	Camera No.	Range (m)	F. L. (mm)	Diameter (m)	Time (ms)
F-362 (6 x 6 No. 2)	60540	R-34	3704.1	479.03	36.88	3.17
	60539	R-30	3704.1	479.30	19.41	0.49
F-369 (6 x 6 No. 3)	60548	R-4	2196.3	477.82	40.32	5.07
	60547	XR-7	2196.3	481.92	Malfunction	

CAMERA DATA & CALCULATIONS

FILM NO. 60539	STATION NO. <i>F-362</i> <i>6x6 No. 2</i>	TEST <i>WRANGELL</i>	CALCULATED BY: <i>JEC</i>
CAMERA NO. <i>R-30</i>	EQ. AP.		DATE: <i>12/2/58</i>



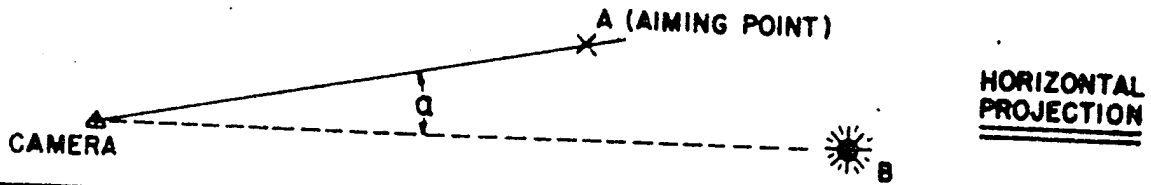
A. $R^{\circ}A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$		
$\alpha = 0^{\circ}00'$	$\beta = 7^{\circ}02'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.99248$	$H_C = 3090 \text{ ft}$
$CB_h = 3676.2 \text{ m}$	$\sin \beta = 0.12245$	$\Delta H = 1487 \text{ ft} = 453.2 \text{ m}$
$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$	$\Delta H \sin \beta = 55.5 \text{ m}$	$R^{\circ}A = \boxed{3704.1 \text{ m}}$
B. FOCAL LENGTH <i>479.30 mm</i>		

C. MAGNIFICATION FACTOR (meters/in.) <i>196.29</i>
--

D. ZERO TIME CORRECTION <i>0.49 msec delay</i>
--

CAMERA DATA & CALCULATIONS

FILM NO. 60540	STATION NO. <i>F-362</i> <i>6x6 No. 2</i>	TEST <i>WRANGELL</i>	CALCULATED BY: <i>JEC</i>
CAMERA NO. <i>R-34</i>	EQ. AP.		DATE: <i>12/2/58</i>



A. $R^0/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$	$\beta = 7^\circ 02'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.99248$	$H_C = 3090 \text{ ft}$
$CB_h = 3676.2 \text{ m}$	$\sin \beta = 0.12245$	$\Delta H = 1487 \text{ ft} = 453.2 \text{ m}$
$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$	$\Delta H \sin \beta = 55.5 \text{ m}$	$R^0/A = \boxed{3704.1 \text{ m}}$

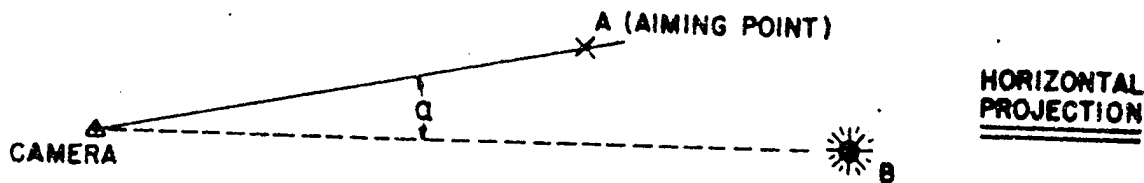
B. FOCAL LENGTH *479.03 mm*

C. MAGNIFICATION FACTOR (meters/in.) *196.41*

D. ZERO TIME CORRECTION *3.17 msec delay*

CAMERA DATA & CALCULATIONS

FILM NO. 60548	STATION NO. <i>F-369</i> <i>6x6 #3</i>	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. R-4	EQ. AP.		DATE: 12/2/58



A. $R^{\circ}/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^{\circ} 00'$	$\beta = 12^{\circ} 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^{\circ}/A = \boxed{2196.3 \text{ m}}$

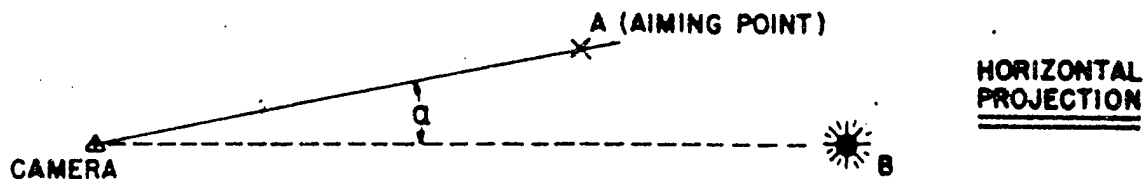
B. FOCAL LENGTH 477.82 mm

C. MAGNIFICATION FACTOR (meters/in.) 116.75

D. ZERO TIME CORRECTION 5.07 msec delay

CAMERA DATA & CALCULATIONS

FILM NO. 60545	STATION NO. ^{F-369} 6x6 No. 3	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-6	EQ. AP.		DATE: 12/2/58



A. $R^{\circ}/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^{\circ} 00'$	$\beta = 12^{\circ} 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^{\circ}/A = \boxed{2196.3 \text{ m}}$

B. FOCAL LENGTH 63.91 mm (ET1254)

C. MAGNIFICATION FACTOR (meters/in.) 872.9

D. ZERO TIME CORRECTION 0.20 msec $\frac{1}{2}$ frame

FIREBALL CALCULATIONS

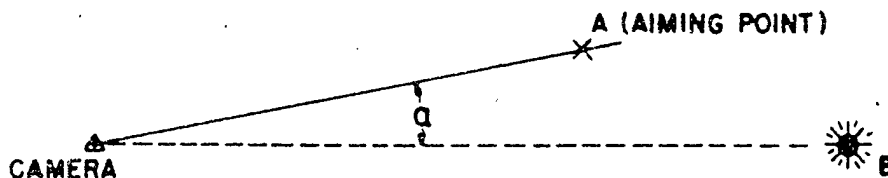
SHOT WRANGELL FILM NO. 60545

DATE _____

D	t	lnD	Int	t ^{2/5}	φ
13.70	.20	2.61742	1.60945 -	.525303	26080
2017	.50	3.00418	51020 -	215107	24743
2468	1.00	3.20592	07	1000031	24679
2784	1.39	3.32642	32933	1140806	24403
3040	1.79	3.41442	52226	1262262	24083
3236	2.19	3.47693	78385	1368260	23650
3416	2.59	3.53109	95158	1463210	23345
3567	2.98	3.57436	109189	1547680	23047
3702	3.38	3.61152	121790	1627692	22743
3808	3.78	3.63976	132979	1702194	22371
3943	4.18	3.67460	143038	1772080	22250
3943	4.57	3.67460	151956	1836433	21470
4048	4.97	3.70089	160343	1899084	21315
4064	5.37	3.70483	168079	1958774	20747

CAMERA DATA & CALCULATIONS

FILM NO. 60544	STATION NO. ^{F-369} 6x6 No.3	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-25	EQ. AP.		DATE: 12/2/58



A. $R^{\circ}/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^{\circ} 00'$	$\beta = 12^{\circ} 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^{\circ}/A = \boxed{2196.3 \text{ m}}$

B. FOCAL LENGTH 101.8 mm (RA 549)

C. MAGNIFICATION FACTOR (meters/in.) 547.9

D. ZERO TIME CORRECTION 0.01 msec 0.01 frame

FIREBALL CALCULATIONS

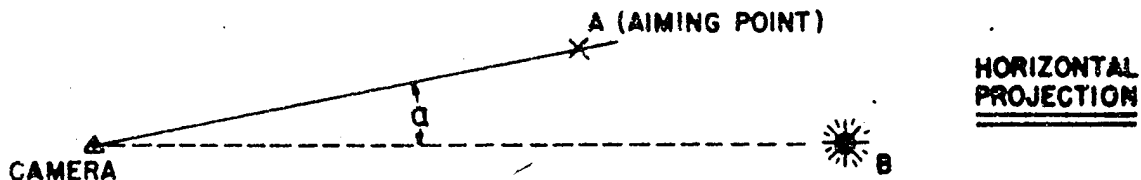
SHOT WRANGELL FILM NO. 60544

DATE _____

D	t	ln D	Int	$t^{2/5}$	ϕ
10.36	.01	2.33795	4.60509 -	.159064	651.30
17.87	.36	2.88317	1.02159 -	6.64553	268.90
22.30	.71	3.10453	3.4253 -	8.71956	255.74
25.49	1.06	3.23821	5.822	10.23565	249.03
28.17	1.42	3.33820	7.5070	11.50597	244.82
30.50	1.77	3.41771	5.7103	12.56604	242.71
32.60	2.12	3.48433	7.5137	13.50603	241.37
34.42	2.48	3.53868	9.0818	14.38027	239.35
35.73	2.83	3.57605	1.04022	15.16022	235.68
36.02	3.18	3.58413	1.15688	15.88441	226.76
36.70	3.54	3.60284	1.26417	16.58009	221.33

CAMERA DATA & CALCULATIONS

FILM NO. 60536	STATION NO. ^{F-362} _{6x6 No. 2}	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-34	EQ. AP.		DATE: 12/2/58



A. $R^0/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$	$\beta = 7^\circ 02'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.99248$	$H_C = 3090 \text{ ft}$
$CB_h = 3676.2 \text{ m}$	$\sin \beta = 0.12245$	$\Delta H = 1487 \text{ ft} = 453.24 \text{ m}$
$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$	$\Delta H \sin \beta = 55.5 \text{ m}$	$R^0/A = \boxed{3704.1 \text{ m}}$

B. FOCAL LENGTH 152.8 mm (RC 540)

C. MAGNIFICATION FACTOR (meters/in.) 615.7

D. ZERO TIME CORRECTION 0.40 msec (0.99 fr)

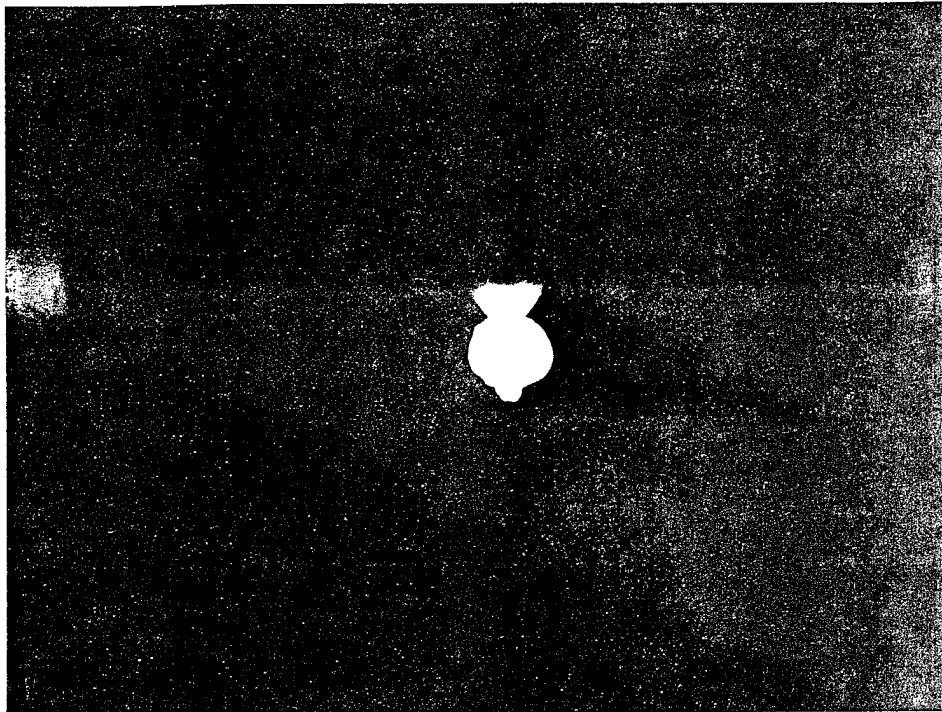
FIREBALL CALCULATIONS

SHOT WRANGELL FILM NO. 60536

DATE _____

D	t	ln D	ln t	t ^{2/3}	φ
17.59	.40	2.86739	.01621 -	.693164	25376
22.70	.80	3.12230	22311 -	914622	24818
26.28	1.21	3.26874	19056	1079205	24351
29.10	1.61	3.37070	47631	1209884	24051
31.53	2.02	3.45094	70308	1324763	23800
32.87	2.42	3.49258	88369	1424009	23082
33.77	2.82	3.51960	103668	1513876	22306
35.11	3.23	3.55853	117249	1598390	21965
36.39	3.63	3.59436	128929	1674839	21727
37.41	4.04	3.62201	139632	1748098	21400
38.31	4.44	3.64578	149071	1815364	21103
38.88	4.85	3.66056	157900	1880618	20674
39.78	5.25	3.68344	165820	1941155	20492
40.35	5.65	3.69767	173160	1998986	20185

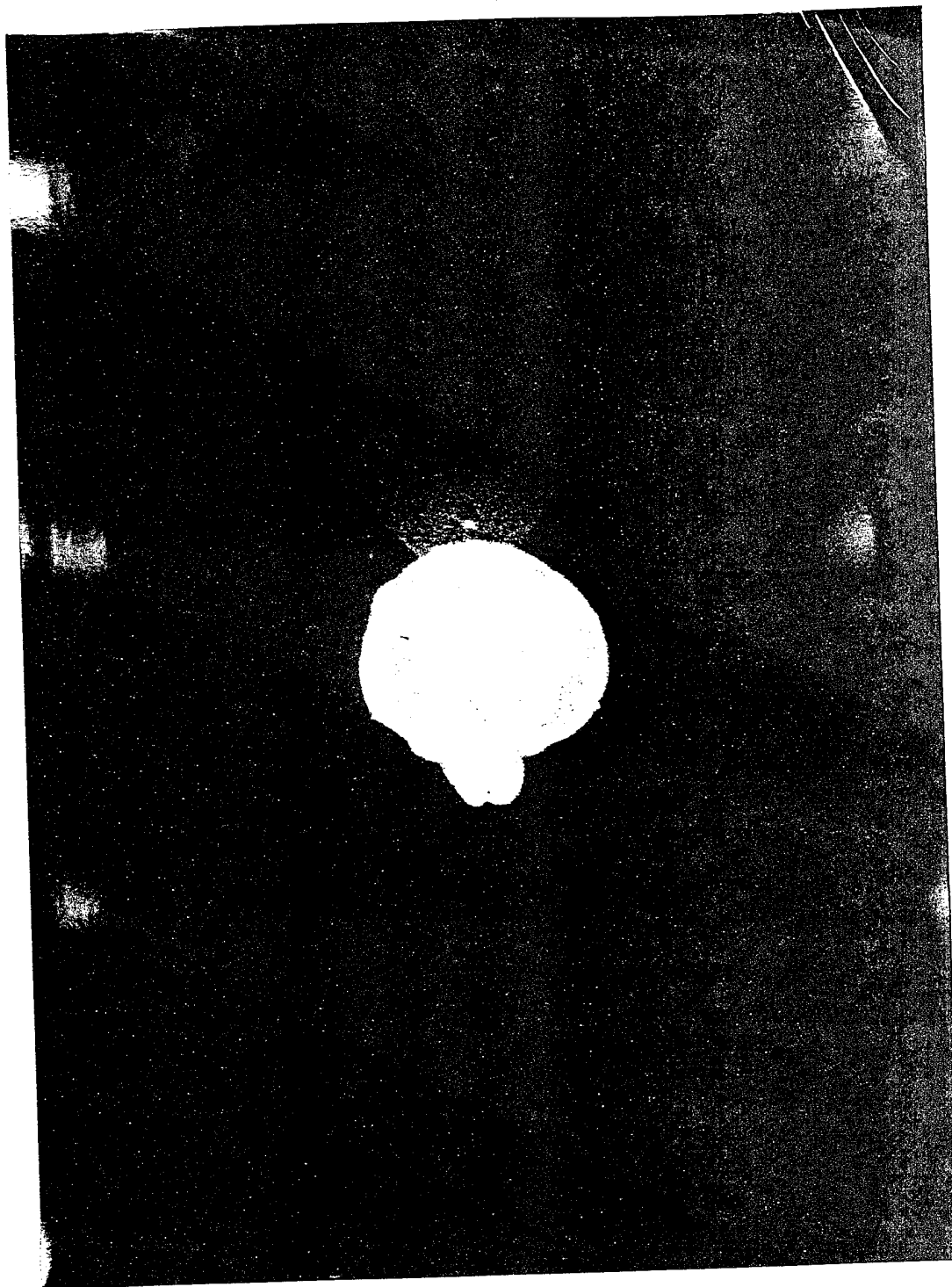
APPENDIX A
HARDTACK PHASE II, WRANGELL
PHOTOGRAPHIC EXAMPLES



Camera: E-34

Station: F-362 (6 x 6 No. 2)

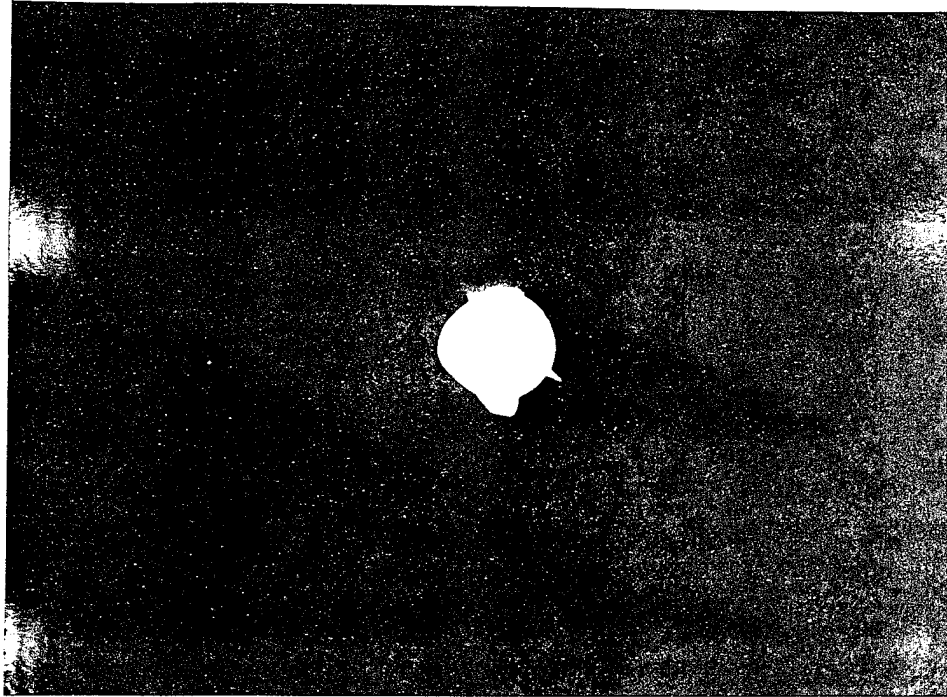
Time: 0.40 msec



Camera: R-30

Station: F-362 (6 x 6 No. 2)

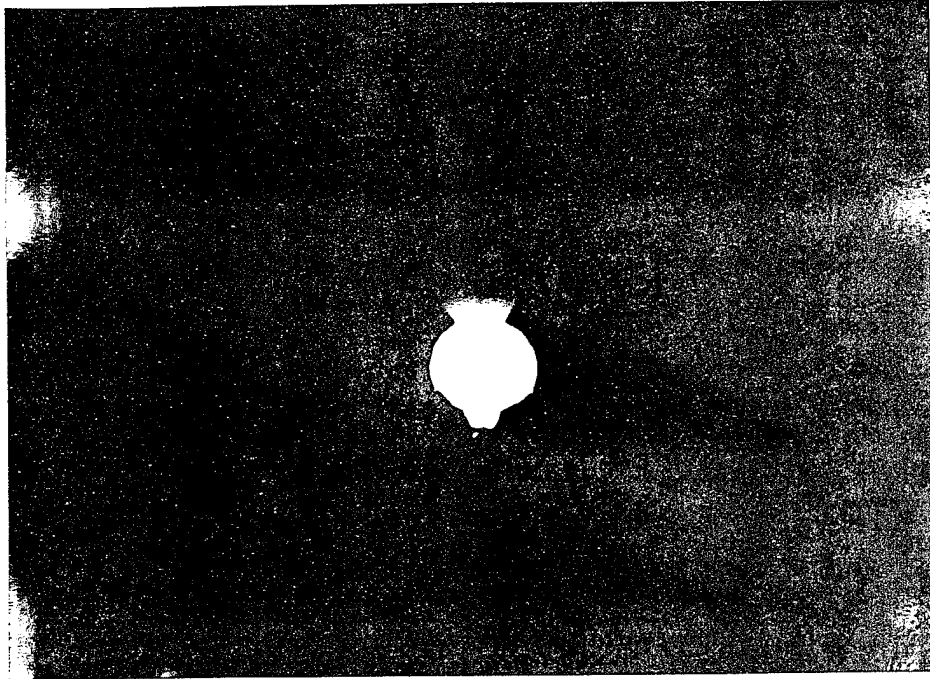
Time: 0.49 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

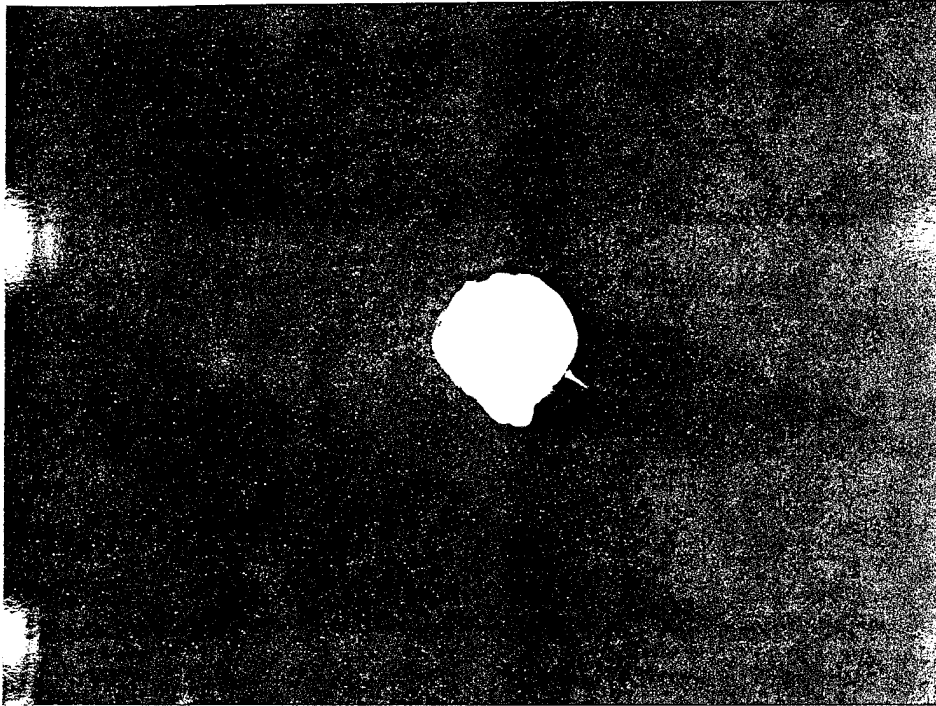
Time: 0.71 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

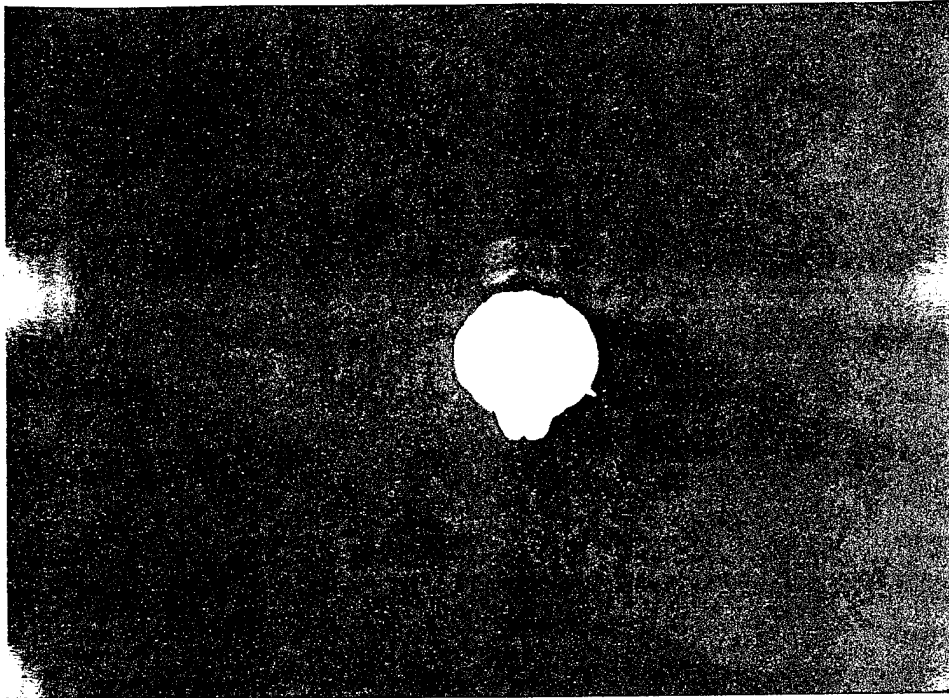
Time: 0.80 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

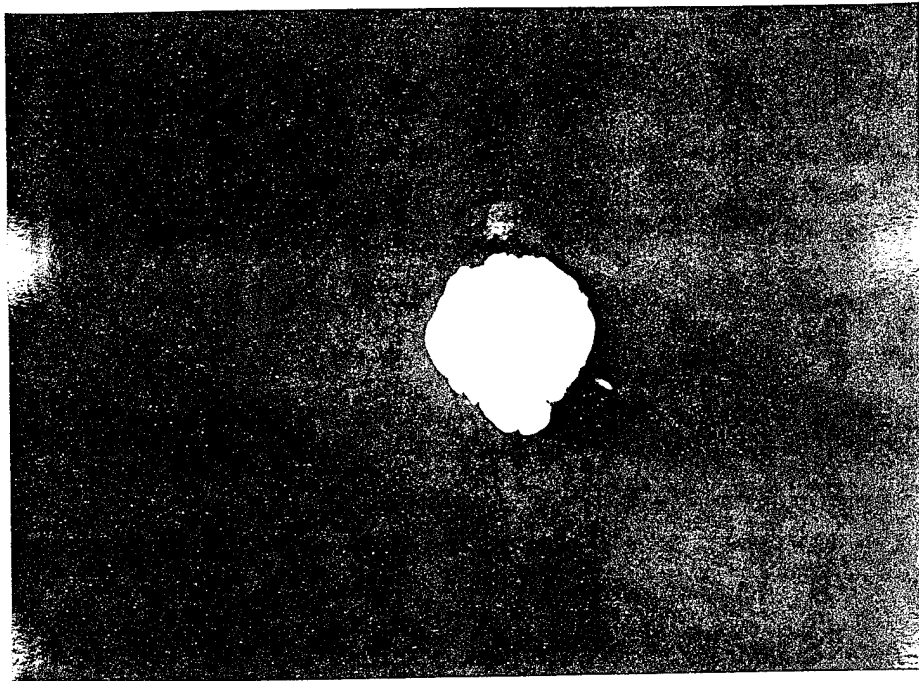
Time: 1.42 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

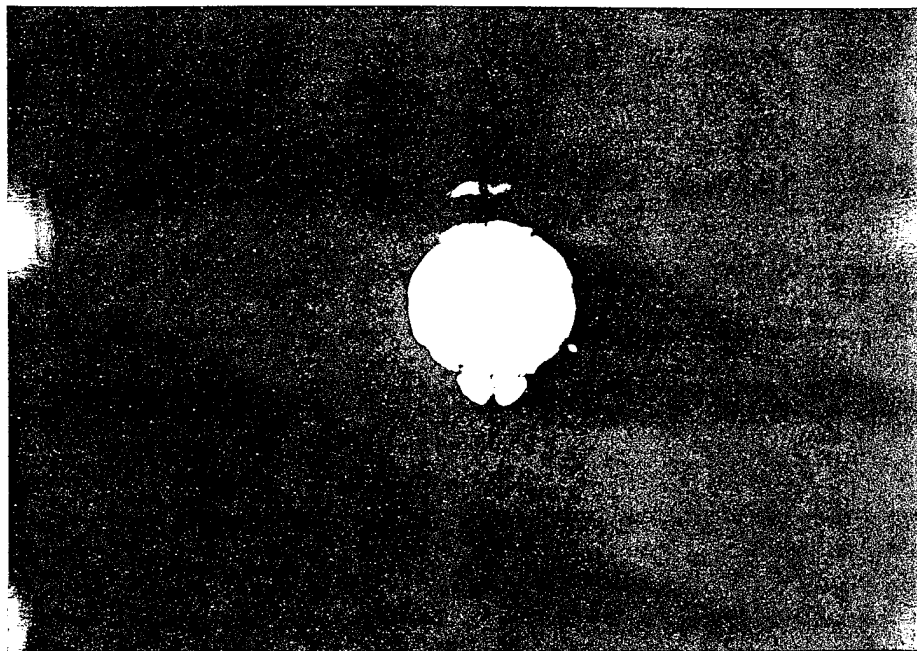
Time: 2.02 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

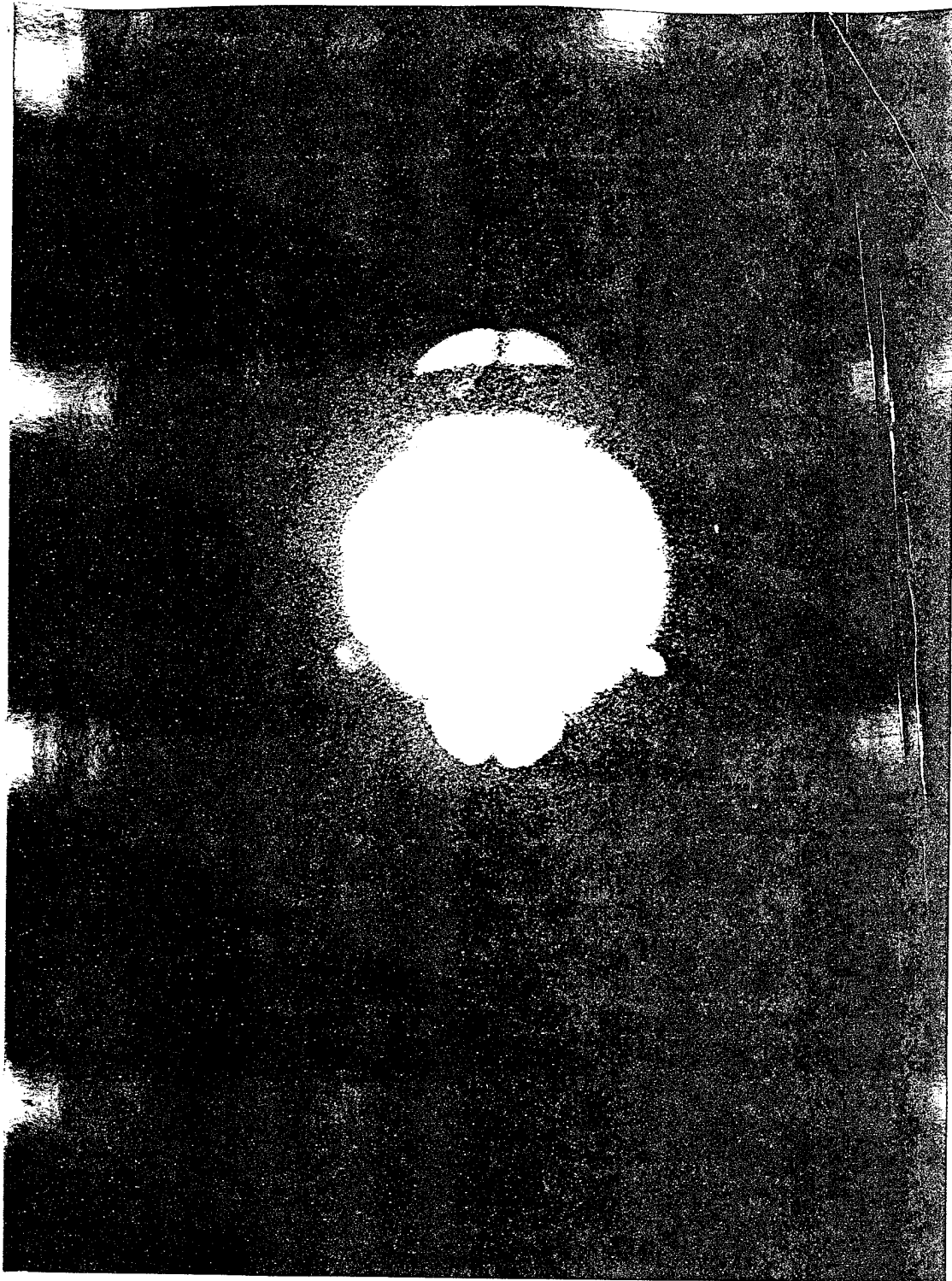
Time: 2.48 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

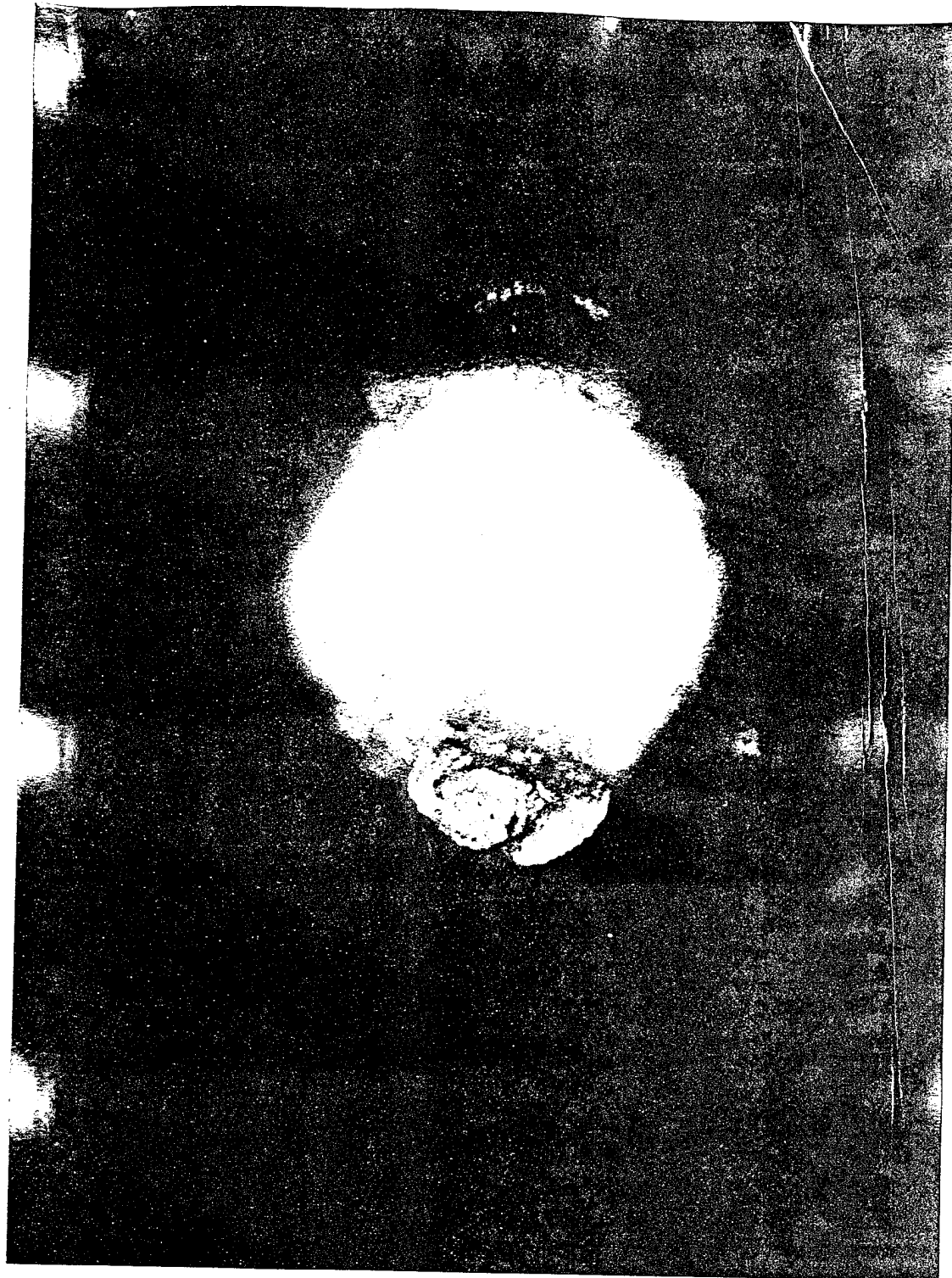
Time: 3.63 msec



Camera: R-34

Station: F-362 (6 x 6 No. 2)

Time: 3.17 msec



Camera: R-4

Station: F-369 (6 x 6 No. 3)

Time: 5.07 msec

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1	Dr. W. E. Ogle, LASL Test Group Director
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