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Operation

JANGLE

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 1(9)-3

SOME HE TESTS AND OBSERVATIONS ON CRATERS AND BASE SURGES

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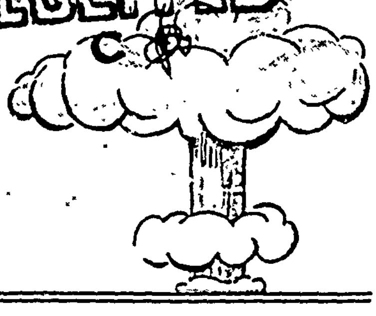

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ATOMIC ENERGY ACT 1946

ARMED FORCES SPECIAL WEAPONS PROJECT
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(10) DONALD C. CAMPBELL

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PROJECT 1(9)-3

CONTENTS

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RESTRICTED DATA
ATOMIC ENERGY ACT 1946

ILLUSTRATIONS

PROJECT 1(9)-3

TABLES

PROJECT 1(9)-3

ABSTRACT

A series of HE Tests was planned at the Nevada Test Site preparatory to the nuclear explosions in Operation JANGLE. These HE shots were designed to obtain, under similar conditions, data to be used as a basis for making predictions concerning the phenomena to be studied during the nuclear explosions.

The HE program, as originally conceived, was expanded to permit further study of the base surge and crater phenomena.

Ten HE shots (a total of thirteen explosions) were conducted in the upper Yucca Flat and Frenchman Flat areas.

Practically all of the instrumentation by the various participating agencies was done on the first series (HE-1 through HE-4). With a few minor exceptions, all instrumentation performed in a satisfactory manner.

Shot HE-2 consisting of 40,000 pounds of TNT was fired with the c. g. 4.63 feet below the surface. There was a high order of detonation and the shot was completely successful. The following indications were noted as a result of this shot:

a. The ground acceleration phenomenon falls at a different attenuation factor than anticipated in the predictions from Lampson's work. This factor more nearly fits a square function than a fourth power law.

b. There is good agreement between the HE-1 and HE-2 results and it should be possible to extrapolate from HE to the nuclear.

c. Air blast has scaled from 1 pound of TNT to the large HE shots and should continue to the nuclear range. Air pressure measurements showed a true blast wave. Considerable underground shock can be anticipated from the air blast.

d. The various methods of measurement between different agencies were in excellent agreement. There should be no question concerning the measurement technique on the nuclear tests.

Meteorological data was carefully recorded for each shot in order to study the base surge and fall-out phenomena. Pie pan dust collectors were used on some of the shots for a simplified study of fall-out.

PROJECT 1(9)-3

The base surge formation in HE-7 was so slight that it was not considered necessary to fire additional shots to confirm the curve in Figure 1.1.

It was tentatively concluded that there is little difference in the above ground activity produced by TNT and Pentolite.

It is certain that some minimum density of soil is required in the plume in order to produce the downward sweep of dust which, at ground level, moves outward as a base surge. The density is produced by blowing a large volume of earth a relatively short distance up into the air. The closer the charge to the surface (smaller values of λ_c), the smaller the crater and greater the height of plume, hence, lower density and less base surge contribution.

Inasmuch as the phenomenology is so complex and only limited HE tests were conducted, it is very difficult to come to any clear-cut set of conclusions to use as a basis for predicting what will occur in the way of craters and base surges for the nuclear shots. However, on the basis of these limited tests, the following guesses are made:

a. For the surface nuclear shot, a base surge appears very unlikely. The crater radius should be 80-90 feet while the crater depth should be 25-30 feet. The maximum cloud height should be 12,000 feet.

b. For the underground nuclear shot, there will be a considerable amount of throw-out at the base of the plume which may be mistaken for a base surge. The probability of a base surge appears small. The crater radius should be 140-150 feet; its depth should be 50-60 feet. Maximum cloud height should be 6,000 feet.

Since it is an observed fact that the crater diameter is a readily scaled parameter for underground TNT explosions, the immediate observation (photographic or otherwise) of the underground crater diameter may be a simple and reliable method for determining equivalent TNT mechanical yield of the nuclear weapon.

Of course, if predictions were always right there would be no need for experimental programs and field tests.

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SECTION 1

INTRODUCTION

1.1 GENERAL

A series of large scale TNT explosions fired by the Army Corps of Engineers at the Dugway Proving Ground has indicated that a base surge formation was most probable at λ_c=0.5 (λ_c = depth to c.g. divided by $W^{1/3}$ where W is the equivalent TNT weight in pounds) and, with decreasing values of λ_c, the possibility of a base surge decreased so that there is a good chance of no base surge occurring at λ_c=0.17. This is shown diagrammatically in Figure 1.1.

The series of HE tests at the Nevada Test Site was designed primarily to obtain, under similar conditions, data to be used as a basis for making predictions concerning the phenomena to be studied during the nuclear tests of Operation JANGLE.

Originally a series of four HE explosions was planned. However, before this series was completed, it was decided to continue the tests with a second series with particular attention to the study of craters and base surges since plans called for the underground shot to be fired at λ_c= 0.135 and TNT charges HE-1 and HE-2 in the first series, with λ_c = 0.15, had not produced base surges. The course of action for the second series of shots outlined in Table 1.1 was developed in consultation with Dr. Herbert Scoville Jr., AFSWP, Dr. Pete Swift, NOL, and CAPT Frank I. Winant, USN, SWC.

1.2 LAYOUT OF TESTS

The original series of high explosive tests (HE-1 through HE-4) was conducted in the JANGLE area of upper Yucca Flat at a location midway between points S and U. The second series of tests was conducted in Frenchman Flat about one mile west of the northern half of the dry lake. Soil conditions appeared to be similar in the two regions and primarily consisted of a powdery sand mixed with some gravel. The Frenchman Flat site had a greater number of rocks and boulders.

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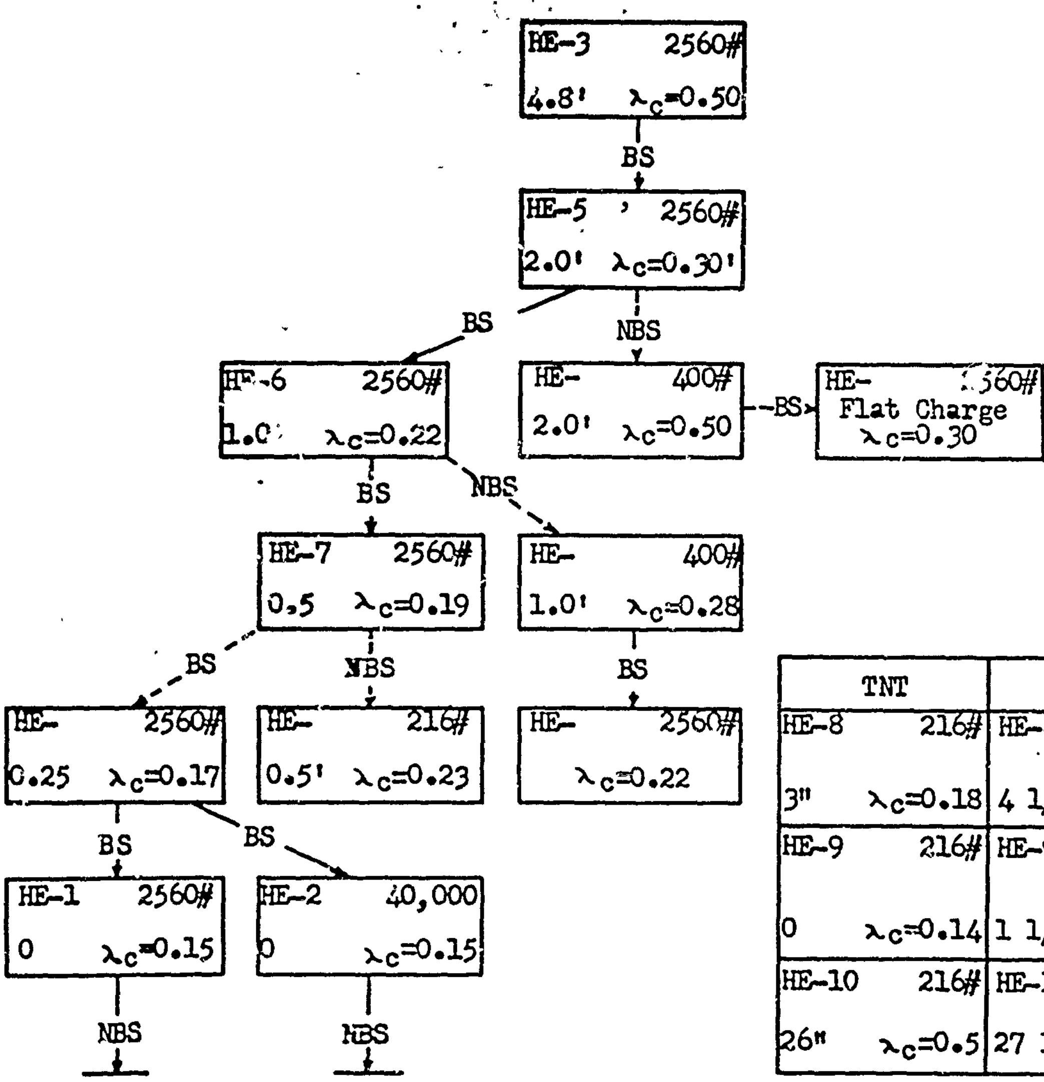
PROJECT 1(9)-3

TABLE 1.1

Base Surge Studies



TNT		PENTOLITE	
HE-8	216#	HE-8	177#
3"	λ_c=0.18	4 1/8"	λ_c=0.18
HE-9	216#	HE-9	177#
0	λ_c=0.14	1 1/8"	λ_c=0.14
HE-10	216#	HE-10	177#
26"	λ_c=0.5	27 1/8"	λ_c=0.5

The HE-number indicates the number assigned to actually conducted shots. Number in upper right hand corner is the charge weight. Lower left hand corner is the dirt cover from the top of the charge to the surface. Values for λ_c are given in the lower right.

W = 40,000 lb — $W^{1/3}$ = 34.2 W = 400 lb — $W^{1/3}$ = 7.4
W = 2560 lb — $W^{1/3}$ = 13.68 W = 216 lb — $W^{1/3}$ = 6.0

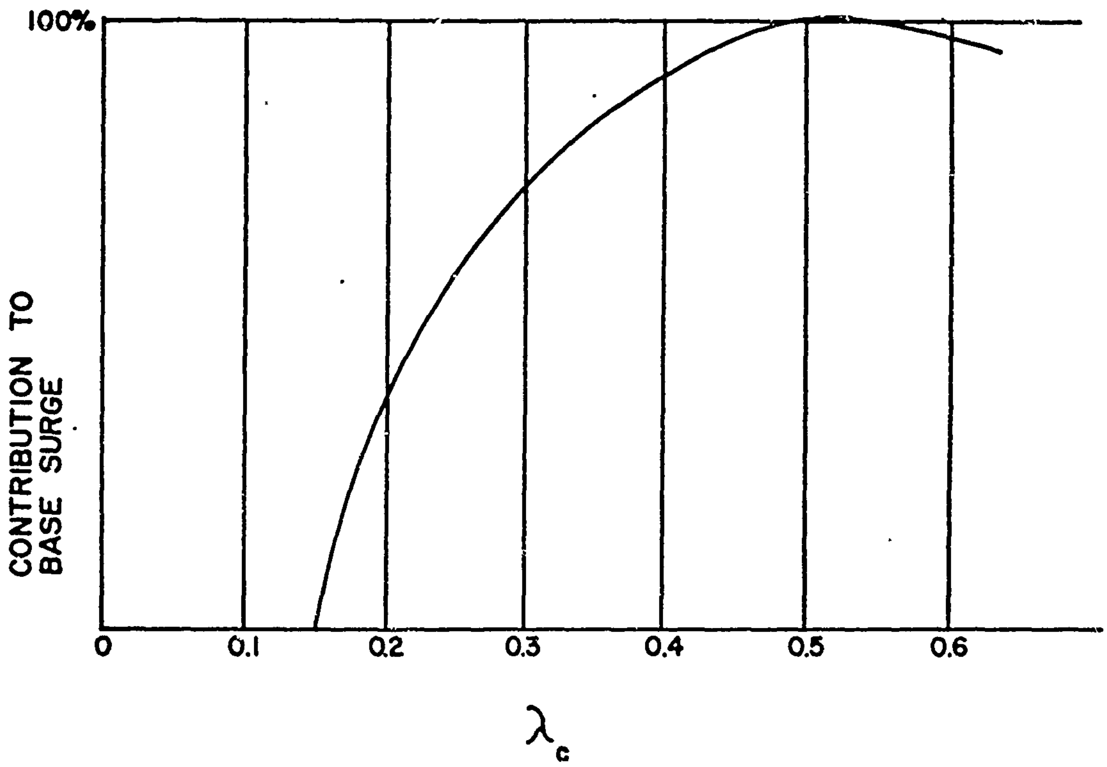


Fig. 1.1 Base Surge Formation as a Function of λ_c

SECTION 2

THE HE SHOTS

2.1 SHOT HE-1 ($\lambda_c = 0.15$)

This shot consisted of 2560 pounds of TNT with the center of gravity at a depth of 2.01 feet below the ground surface. It was fired on 25 August at 0915 PST. The detonation was of high order and completely successful.

During the period immediately following the explosion the surface wind averaged approximately 8 mph from N 60° E. The surface temperature was 86.5° F. The relative humidity at the Air Force Weather Station, 18 miles from the site, was 12 per cent. Immediately following the detonation there was observed a throw-out of streamers which appeared to travel several hundred feet radially outward. A considerable fall-out of dirt occurred in the immediate vicinity of the crater. A cloud of dust rose to a height of approximately 1500 feet and drifted in a southwest direction. This cloud dissipated within 45 minutes.

With a few minor exceptions, all instrumentation apparently performed in a satisfactory manner. Ground acceleration measurements appeared to run from 2 to 20 times the values predicted from theory. The factor increased with increasing distance. This was of considerable interest in setting gage ranges for subsequent HE and nuclear shots. This information was also of interest in the layout of Program Three structures.

2.2 SHOT HE-2 ($\lambda_c = 0.15$)

This charge of 40,000 pounds of TNT, with the center of gravity 4.63 feet below the ground surface and the upper edge tangent to the earth surface, was fired at 0900 PST on 3 September 1951. The detonation was of a high order and completely successful. A considerable throw-out was observed. A number of streamers appeared to travel out on trajectories having elevations between 30° and 45°. The majority of the throw-out fell within 500 feet of ground zero. A large cloud of dust, starting with a 500-foot diameter rose to an estimated height of 2,000 to 3,000 feet. This cloud moved slowly north and was observed over the underground site one hour and fifteen minutes after firing. A considerable fall-out occurred in the immediate vicinity of ground zero and continued along the path of the cloud movement. A definite darkening of the ground was observed out to 2,500 feet in a

PROJECT 1(9)-3

TABLE 2.1

Permanent Displacements, Shot HE-1

Radial Distance	S 50° E		N 80° E		S 85° W		N 5° W	
	ΔR	ΔT	ΔR	ΔT	ΔR	ΔT	ΔR	ΔT
28.00	.34	0.03	0.21	-0.12	0.53	0.15	0.43	0
32.00	.19	0.06	0.09	-0.12	0.42	0.13	0.29	0.04
36.00	.18	0.04	0.02	-0.13	0.18	0.15	0.13	0.09
40.00	.15	0.03	0.01	-0.13	0.12	0.17	0.05	0.10
44.00	.15	0	0.01	-0.08	0.09	0.19	0.02	0.05
48.00	D	D	0.01	-0.02	0.09	0.19	0.04	0.08
52.00	.20	0	-0.01	-0.08	0.04	0.19	-0.07	0.09
56.00	.12	0	-0.01	-0.06	0	0.24	-0.11	0.10
60.00	.10	-0.01	-0.02	-0.05	-0.02	0.25	-0.06	0.07
64.00	.10	0	-0.03	-0.05	D	D	-0.06	0.08
68.00	.11	0	-0.03	-0.04	-0.01	0.22	-0.11	0.12
72.00	.11	0	-0.02	-0.04	-0.03	0.22	-0.07	0.07
76.00	.11	0.02	0	-0.04	0	0.22	-0.08	0.08
80.00	.10	0.02	0	-0.03	-0.02	0.24	-0.11	0.09
84.00	.10	0	0	-0.05	-0.02	0.26	.10	0.09

ΔR = Radial Displacements - Positive in direction away from ground zero in feet. ΔT = Tangential Displacements - Positive is left of radial line in feet. D = Damaged Stake.

TABLE 2.2

Crater Data, Shot HE-1

R	S 40° E		N 40° W		S 50° W		N 50° E	
	Ea	Er	Ea	Er	Ea	Er	Ea	Er
0	-6.8	-7.6	-6.8	-7.6	-6.8	-7.6	-6.8	-7.6
3	-5.4	-6.5	-6.7	-7.5	-3.8	-5.6	-5.0	-6.0
5	-4.5	-6.1	-6.1	-7.0	-2.8	-4.8	-4.4	-5.7
8	-3.1	-5.3	-5.5	-6.0	-1.5	-3.7	-2.2	-5.0
10	-3.0	-4.5	-3.5	-5.7	-1.3	-3.5	-1.6	-4.7
14	-2.1	-3.0	-2.4	-3.9	-9.7	-2.5	-0.8	-2.5
18	-0.6	-1.5	-0.5	-2.5	-0.1	1.6	-0.2	-1.2
20	0.8	-0.2	1.9	-1.8	0	3.1	1.0	-0.8
21	1.2	0	2.5	-0.7	0	3.7	2.5	-0.6
23	0.8	0	2.0	-0.5	0	0	2.0	0.1
25	0	0	1.5	-0.1	0	0	1.2	0.2
29	0	0	0	0	0	0	0.2	0

R = Radial distance from zero in feet. Ea = Apparent Crater elevation in feet. Er = Real crater elevation in feet.

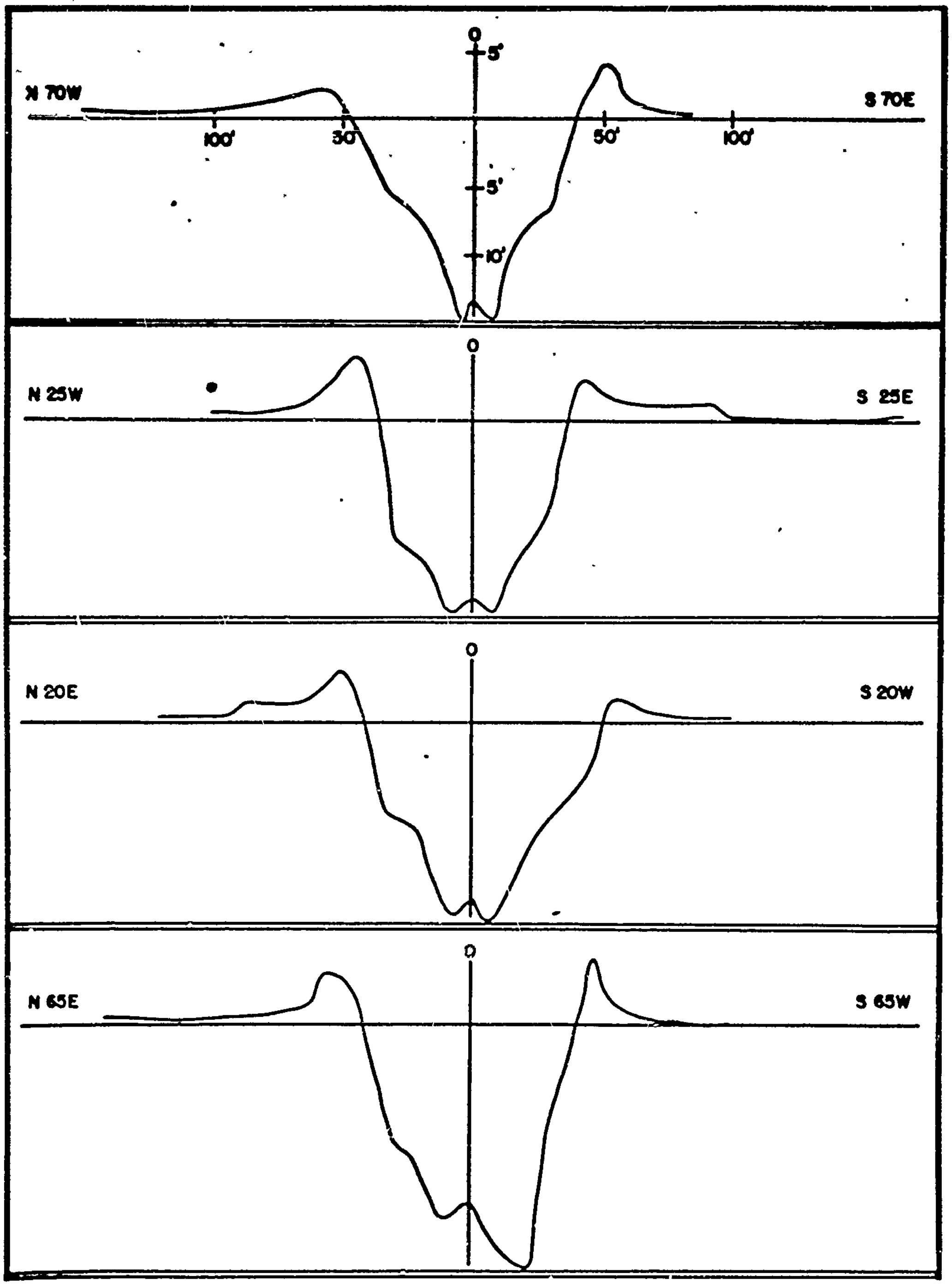


Fig. 2.1 Average Crater Contours for 40,000 Pounds of TNT on Shot HE-2

northerly direction. A crater remained which had a diameter of approximately 80 feet and a depth of 15 feet. A careful excavation was made to remove the fall-back material, however, the earth shattered to such an extent that no good data could be obtained. One hard spot was located at the center approximately 11½ feet below the level of the apparent crater.

Information on winds aloft at the test site just prior and after the detonation is given in Table 2.3.

TABLE 2.3

Wind Data, Shot HE-2

TIME - 0845			TIME - 0915		
Altitude Above Ground (Feet)	Velocity mph	Wind From	Altitude Above Ground (Feet)	Velocity mph	Wind From
0	5	S	0	6	S
1300	7	S	1000	6	S 20° E
2300	4	S	2200	4	S 10° E
3600	3	S	3400	3	S 20° E
4600	9	S 30° E	5600	14	S 40° E
5600	12	S 30° E	7800	7	S 20° E
			10,600	15	S 45° W

The surface temperature at the time of the explosion was 80.6° F and the relative humidity was 14 per cent.

As a last minute attempt to obtain some crude information on the close-in fall-out, 36 pie pans were distributed around the target area. Information from the pie pans as well as the observed distance of the ground discoloration (carbon fall-out) is given in Table 2.7.

Instrumentation performance was excellent as there were practically no failures. Performance was such that the Naval Ordnance Laboratory and the Ballistic Research Laboratories did not require additional tests (HE-3 and HE-4) prior to the nuclear shots. The Stanford Research Institute fully instrumented the remaining tests.

Results are reported by the participating agencies[1]. However, some tentative indications follow:

a. The ground acceleration phenomenon falls at a different attenuation factor than anticipated in the predictions from Lampson's work. This factor more nearly fits a square function than a fourth power law.

[1] See project reports of the Naval Ordnance Laboratory, the Ballistic Research Laboratories, Stanford Research Institute, and the David Taylor Model Basin published in the JANGLE report series.

PROJECT 1(9)-3

TABLE 2.4

Permanent Displacements
(Hubs on S 20° W Blast Line)
Shot HE-2

Radial Distance From Zero, Pre-Blast	Final Position, Post-Blast		
	North	East	Elev (+Up)
59.09	-1.03	0.22	0.38
71.06	-0.53	-0.09	0.28
86.05	-0.10	0.29	0.07
102.67	-0.08	-0.40	0.04
123.20	0.05	0.14	0.03
147.61	0.08	0.08	0.03
177.86	0.07	0.05	0.02
217.03	0.03	0.05	0.03
262.17	0.01	-0.02	0.03
314.98	0.01	-0.04	0.03
378.25	-0.02	-0.10	0.02

b. There is good agreement between the HE-1 and HE-2 results and it should be possible to extrapolate from HE to the nuclear.

c. Air blast has scaled from 1 pound of TNT to the large HE shots and should continue to the nuclear range. Air pressure measurements showed a true blast wave. Considerable underground shock can be anticipated from the air blast.

d. The various methods of measurement between different agencies were in excellent agreement. There should be no question concerning the measurement technique on the nuclear tests.

e. HE-2 crater contours are shown in Figure 2.1.

2.3 SHOT HE-4 (λ_c=-0.15)

This charge, the third in order of firing, consisting of 2560 pounds of TNT, was fired at 0940 PST on 9 September 1951. Its center of gravity was 24½ inches above the ground surface with the lower edge tangent to the earth surface. The detonation was of a high order.

A cloud of dust was raised from the earth's surface to heights estimated by observers to be between 1,000 and 1,500 feet. This cloud traveled in a southerly direction and was dissipated within a half hour. The prevailing winds which have been observed by test personnel in this location are from the south. On two occasions the wind has been from

TABLE 2.5

Apparent Crater, Shot HE-2

N 70° W		N 25° N		N 20° E		N 65° E		S 70° E.		S 25° E		S 20° W		S 65° W	
R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E
0	-13.4	0	-13.4	0	-13.4	0	-13.4	0	-13.4	0	-13.4	0	-13.4	0	-13.4
6	-14.0	7	-14.6	6	-14.2	9	-14.5	8	-14.8	9	-14.4	5	-14.7	7	-15.3
20	- 7.3	18	-16.4	23	- 7.5	21	-10.1	23	- 7.5	20	- 9.5	22	-18.0	20	-10.5
30	- 5.8	27	- 9.4	31	- 7.2	26	- 9.4	30	- 6.5	27	- 7.9	33	- 5.4	28	- 7.7
55	2.1	44	4.8	49	3.7	45	2.5	42	1.5	43	3.1	45	3.5	45	3.9
85	1.0	48	4.5	61	1.4	54	3.9	51	4.0	48	3.1	47	4.8	55	1.8
150	0.5	58	1.7			59	1.5	56	1.9	59	1.3	51	2.8	68	0.7
200	0.0	72	0.5	84	1.4	100	0.3	75	0.6	94	1.3	60	0.9	100	0.2
		100	0.5	91	0.4	140	0.3			100	0.2	100	0		
		200	0.1	100	0.2					165	- 0.1				
				117	0.1										

R = Radial Distance in feet.

E = Elevation in feet (+ up).

TABLE 2.6

Permanent Displacements, Shot HE-2

Radial Distance	N 25° W			N 65° E			S 25° E			S 65° W		
	Δ R	Δ T	Δ E	Δ R	Δ T	Δ E	Δ R	Δ T	Δ E	Δ R	Δ T	Δ E
50.00	2.79	0.04	1.15	2.25	0.00	0.94	3.18	-0.05	2.02	1.95	-0.05	1.23
60.00	1.66	0.10	0.55	1.12	0.00	0.31	1.44	0.01	0.33	0.62	-0.12	0.32
70.00	0.80	0.07	0.21	0.96	0.00	0.08	1.07	0.15	0.13	0.35	-0.02	0.16
80.00	0.58	0.02	0.14	0.63	0.03	0.05	0.57	0.09	0.10	0.16	-0.02	0.13
90.00	0.34	0.06	0.12	0.45	-0.02	0.05	0.49	0.07	0.07	[illegible]	-0.04	0.04
100.00	0.23	0.06	0.04	0.20	-0.03	0.02	0.28	0.03	0.00	-0.17	-0.03	0.04
110.00	0.22	0.01	0.05	0.02	-0.04	0.02	0.09	0.03	0.00	-0.24	-0.04	0.02
120.00	0.10	0.05	0.03	-0.02	-0.08	0.01	0.02	0.05	0.00	-0.33	-0.03	0.00
130.00	0.10	0.04	0.01	-0.07	-0.08	0.00	-0.02	0.05	-0.01	-0.35	-0.05	0.01
140.00	0.10	0.04	0.00	-0.13	-0.07	0.00	-0.03	0.05	-0.02	-0.42	-0.06	0.01
150.00	0.04	0.03	0.00	-0.10	-0.09	-0.01	-0.03	0.05	-0.02	-0.36	-0.02	-0.02
160.00	0.05	0.07	-0.01	0.10	-0.01	0.00	-0.03	0.06	-0.03	-0.25	-0.01	0.00
170.00	0.02	0.03	0.00	0.05	0. 0	-0.01	-0.02	0.05	-0.03	-0.26	-0.04	0.00
180.00	0.05	0.02	0.01	0.08	0.02	-0.02	-0.02	0.05	-0.03	-0.22	-0.02	0.00
190.00	0.02	0.03	-0.02	0.14	0.02	-0.02	-0.04	0.06	-0.03	-0.28	-0.02	-0.01
200.00	0.05	0.03	-0.01	0.27	0.00	-0.04	+0.04	0.05	-0.02	-0.28	-0.03	-0.01
210.00	0.10	0.02	-0.02	0.10	-0.14	-0.02	0.00	0.09	-0.03	-0.07	-0.04	-0.02

Δ R = Radial Displacements - Positive is direction away from charge in feet.
Δ T = Tangential Displacements - Positive is to left of radial line in feet.
Δ E = Vertical Displacements - Positive is up in feet.

TABLE 2.7

Pie Pan Dust Collectors
Shot HE-2

Dist. From Zero (Ft.)	N		N 60° W		S 60° W		S		S 60° E		N60° E	
	A	B	A	B	A	B	A	B	A	B	A	B
400	48.3*	10% to ½" 90% silt	14.6*	few to 3/8"	16.7*	100% silt	3.1*	Part to 3/8"	23.0**	Part to ½"	96.0	50% to ½" 50% silt
600	29.2#	few to 3/8"	upended		0.9#	100% silt	0.3	Part to 3/8"	2.7#	Part to 3/8"	20.8	few to ½"
800	30.3#	100% silt	3.0#	1 - 3/8" rest silt	0.7#	100% silt	2.4	Part to ¼"	0.6	100% silt	8.1	1 - ¼" rest silt
1000	25.7#	100% silt	4.5	1 - 3/4" rest silt	0.3	100% silt	0.1*	100% silt	0.2	100% silt	3.4	100% silt
1500	8.0	100% silt	0.1	100% silt	0.1	100% silt	0.1	100% silt	0.1	100% silt	0.3	100% silt
2500	1.4	100% silt	0.1	100% silt	0.1	100% silt	0.1	100% silt	0.1	100% silt	0.1	100% silt
Dist. to Edge at Darkened Area	2500 ft.		850 ft.		450 ft.		250 ft.		650 ft.		1200 ft.	

* = Displaced but not overturned
\# = Overturned (Measurement off bottom)
** = Bent, displaced but not overturned

A = Weight of contents of pan in grams
B = Nature of contents of pans
Pie plate area = 430 cm^2

TABLE 2.8

Wind Data, 0 to 11,010 Feet Altitude, Shot HE-4[a]

Altitude[b]	TIME - 0930		TIME - 0950	
	Wind[c] Direction	Wind[d] Velocity	Wind Direction	Wind Velocity
0	090	15	020	13
1170	020	21	020	16
2310	020	24	010	14
3450	020	21	350	10
4560	360	15	300	15
5670	310	16	300	19
6700	290	17	310	21
7830	290	21	310	22
8910	290	23	320	16
9960	300	18	350	9
11,010	320	10	340	9

TABLE 2.9

Wind Data, 12,030 to 19,800 Feet Altitude, Shot HE-4[a]

Altitude[b]	TIME - 0930		TIME - 0950	
	Wind[c] Direction	Wind[d] Velocity	Wind Direction	Wind Velocity
12,030	330	8	340	9
13,020	340	13	340	9
14,010	340	15	350	16
15,000	340	26	340	23
15,960	340	30		
16,920	350	25		
17,880	350	34		
18,840	360	34		
19,800	010	30		

[a] The surface temperature at the time of the explosion was 84.2° F and the relative humidity was 12 per cent.
[b] Expressed in feet above ground surface.
[c] 360° = N, 90° = E.
[d] Expressed in miles per hour.

TABLE 2.10

Pie Pan Dust Collectors
Shot HE-4

Distance From Zero (Feet)	N	N30°E	N60°E	E	S60°E	S30°E	S	S30°W	S60°W	W	N60°W	N30°W
400	4.5	1.4	0.6	1.8	1.7	0.5	1.0	1.7	0.4	12	12.6	3.5
600	4.2	0.5	1.0	0.1	0.5	0.2	0.1	2.7	4.9	0.7	4.8	0.2
800	1.0	0.3	0.05	0.05	0.05	0.05	0.1	0.2	1.3	0.2	0.6	0.4
1000	0.5	0.2	0.2	0.05	0.1	0.1	0.05	0.6	0.05	0.2	0.5	1.6
1500	0.1	0.05	0.1	0.05	0.2	0.05	0.1	0.1	0.2	0.1	0.05	0.1
2000	0.1	0.0	0.0	0.0	0.0	0.3	0.1	8.1	0.05	0.4	0.0	0.1

Readings are in grams.

the north. By coincidence, these were the days of tests HE-1 and HE-4. Since the winds were gusty, any individual set of observations may not give a completely true picture, however, some readings taken just prior and after the detonation are given in Tables 2.8 and 2.9.

Some aerial dust samples were collected by a C-47 equipped with Stanford Research Institute filters. Pie pan collectors were used for ground fall-out measurements. Results are given in Table 2.10. There appears to be no consistency in these measurements and this may be attributed to the nature of the wind at the time of the test and between the time of the test and collection.

The Stanford Research Institute performed all medium instrumentation. Recording was 100 per cent successful with the exception of one air pressure gage which was damaged by the blast. A hasty examination of the records indicated that there may have been a larger coupling than was anticipated.

TABLE 2.11

Permanent Displacements
(Hubs on S 50° W Blast Line)
Shot HE-4

Radial Distance	Final Position, Post-Blast		
From Zero, Pre-Blast	North	East	Elev (+Up)
23.48	0.06	-0.14	-0.04
28.56	0.03	0.05	-0.04
33.93	0	0.02	-0.06
41.17	0.02	-0.08	-0.06
44.59	0.03	-0.06	-0.04
59.06	-0.01	-0.01	-0.06
71.08	-0.01	0.10	-0.05
85.82	0.02	-0.05	-0.05
102.63	0	-0.02	-0.03
148.32	0.05	-0.06	-0.05

2.4 SHOT HE-3 ($\lambda_c = 0.5$)

Shot HE-3 (the fourth in order of firing) was a charge of 2560 pounds of TNT with the center of gravity 6 feet 9½ inches below ground surface and the upper edge 4 feet 9 inches below the ground surface. It was fired at 0840 PST on 15 September 1951. The detonation was of a high order and completely successful.

TABLE 2.12

Permanent Displacements, Shot HE-4

Radial Distance	S 5° W			N 5° E			S 85° E			N 85° W		
	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE
28.00	S	S	S	S	S	S	S	S	S	S	S	S
32.00	S	S	S	S	S	S	S	S	S	S	S	S
36.00	S	S	S	0	0.04	-0.06	S	S	S	S	S	S
40.00	0.03	-0.06	?	0	0.03	-0.07	S	S	S	0.07	0.03	-0.04
44.00	S	S	S	0.01	0.04	-0.07	-0.05	0.02	-0.03	0.06	0.04	-0.01
48.00	0.06	-0.06	-0.03	0.01	0.03	-0.05	-0.07	0.03	-0.05	0.08	0.04	-0.02
52.00	0.05	-0.06	-0.03	0.01	0.04	-0.04	-0.06	0.03	-0.01	0.06	0.04	-0.02
56.00	S	S	S	0.02	0.03	-0.04	-0.06	0.03	-0.02	0.07	0.04	-0.02
60.00	S	S	S	0.02	0.04	-0.05	-0.06	0.03	-0.03	0.07	0.05	-0.02
64.00	0.06	-0.05	-0.01	0	0.04	-0.07	-0.06	0.04	-0.02	0.07	0.04	-0.02
68.00	0.06	-0.06	-0.02	0.02	0.02	-0.05	S	S	-0.02	0.10	0.04	-0.02
72.00	0.07	-0.06	-0.02	0	0.01	-0.05	-0.05	0.03	-0.03	0.11	0.05	-0.01
76.00	0.07	-0.06	-0.02	0	0.01	-0.05	-0.05	0.03	-0.02	0.10	0.06	-0.01
80.00	0.06	-0.06	-0.05	0	0.01	-0.03	-0.09	0.01	-0.01	0.11	0.03	-0.01
84.00	0.07	-0.06	-0.02	-0.03	0.02	-0.03	0	0.03	-0.03	0.13	0.03	-0.03

Δ R = Radial Displacements - Positive is direction away from charge in feet.
Δ T = Tangential Displacements - Positive is to left of radial line in feet.
Δ E = Vertical Displacements - Positive is up in feet.
S = Shattered Stake.

PROJECT 1(9)-3

TABLE 2.13

Crater Data, Shot HE-4

R	N 5° E		R	N 50° E		R	S 85° E		R	S 40° E	
	Ea	Er		Ea	Er		Ea	Er		Ea	Er
0	-1.9	-2.1	0	-1.9	-2.1	0	-1.9	-2.1	0	-1.9	-2.1
2	-1.9	-2.1	2	-1.9	-2.0	2	-1.9	-2.0	2	-2.0	-2.2
5	-0.1	-1.5	5	-0.3	-0.9	5	-0.2	-1.1	6	-0.1	-0.4
8	0.2	0.2	8	0.2	0	7	0.7	0.4	9	0.2	0.1
25	-0.1		14	0.3	0.2	27	0.2		31	-0.2	
51	-0.1		30	0.2		47	-0.7		55	0	
84	-0.1		87	0.4							
R	**S 5° W**		**R**	**S 50° W**		**R**	**N 85° W**		**R**	**N 40° W**	
	Ea	Er		Ea	Er		Ea	Er		Ea	Er
0	-1.9	-2.1	0	-1.9	-2.1	0	-1.9	-2.1	0	-1.9	-2.1
2	-2.1	-2.2	2	-1.8	-1.9	3	-1.6	-1.8	2	-1.9	-2.0
6	-0.2	-1.2	6	-0.4	-1.2	5	-0.4	-0.6	6	-0.3	-1.3
9	0.2	0.1	8	0.1	-0.1	8	0.1	-0.2	7	0	-0.2
24	0		22	0.1		28	-0.1		23	-0.2	
61	0					56	0		50	-0.2	

R = Radial distance in feet.

Ea = Apparent crater elevation (+ up)

Er = Real crater elevation (+ up)

Information on winds aloft at the test site just prior and after the detonation of HE-3 is given in Table 2,14.

TABLE 2.14

Wind Data, Shot HE-3[a]

Altitude[b]	TIME 0930		TIME 0950	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
0	050	16	030	18
1,170	050	17	030	27
2,310	070	13	050	24
3,450	090	8	070	17
4,560	080	9	080	10
5,670	080	9	080	6
6,750	090	7	070	6
7,830	110	7	080	7
8,910	130	6	150	7
9,960	140	7	130	7
15,000	-	-	150	12
16,920	-	-	130	2
20,760	-	-	260	7

a The surface temperature at the time of the explosion was 76.4° F and the relative humidity was 32 per cent.
b Expressed in feet above ground surface.
c 360° = N, 90° = E.
d Expressed in miles per hour.

A considerable throw-out was observed as the result of shot HE-3 with trajectories between 30° and 45°. The majority of this throw-out appeared to fall within a few hundred feet of ground zero. A crude examination of the ground around point zero after the shot gave the large particle count per square foot as shown in Table 2.15.

A number of rocks fell at distances greater than 280 feet. One rock, approximately $1\frac{1}{2}$ inches in diameter and weighing 114.9 grams, was observed to fall 3,500 feet from ground zero.

TABLE 2.15

Large Particle Count Around Zero, Shot HE-3

Max. Dimension	Inside 70 ft	70 ft-140 ft	140 ft-210 ft	210 ft-280 ft
4 inches	7	1/10	None	None
2 inches	16	2	1/5	1/10
1 inch	27	6	1	1/5

The explosion appeared to break through the ground in a manner similar to that observed for the previous tests (HE-1, HE-2, Dugway, etc.). The plume rose to approximately 500 feet. At a time between 10 and 20 seconds after the explosion, a base surge formation appeared through the throw-out dust. Initially, this base surge had equal dimensions around the zero point, however, in short order the upwind travel ceased and the surge moved with the wind in a southwest direction. The plume almost immediately descended into the surge so that the height of the dust cloud was approximately 100 feet. The downwind (leading edge) of the base surge reached the 2,000 foot mark 50 seconds after the detonation and reached 5,000 feet 2 minutes and 20 seconds after the zero time. Between one and two minutes after the detonation, the surge expanded so that the top was roughly at 500 feet as the cloud passed the 5,000 foot mark. Travel in a direction normal to the direction of the wind was similar on both radii. By the time the surge reached the 5,000 foot mark, the "normal" diameter was estimated by observers to be between 3,500 and 4,000 feet. The upwind face of the surge followed the cloud movement and was estimated to be approximately 750 feet in the direction downwind from ground zero at 2 minutes and 20 seconds after zero time. The base surge eventually became an appreciably sized cloud of dust. It was 500 feet high at 5 minutes after zero time and was moving in the southwest direction. It was observed in a somewhat diffused condition 30 minutes after the blast.

Some samples of dust were collected on shot HE-3 by a C-47 equipped with Stanford Research Institute filters. Eighty four pie pan collectors, such as those used for shots HE-2 and HE-4, were used for ground fall-out measurements. Results are given in Table 2.16.

The Stanford Research Institute performed all medium instrumentation on shot HE-3.

TABLE 2.16

Fall-Out Study with Pie Pan Dust Collectors, Shot HE-3

Distance From Zero (Feet)	N	N30°E	N60°E	E	S60°E	S30°E	S	S30°W	S60°W	W	N30°W	N60°W
400	1.9	0.2	1.4	1.6	0.05	24.5	5.5	32.8	11.5	8.9	0.8	0.3
600	0.3	0.2	0.05	0.1	0.05	0.1	3.8	13.6	33.7	0.1	0.2	0.05
800	0.05	0.2	0.3	0.05	0.1	0	0.9	8.0	7.8	0.05	0.05	0.05
1000	0.2	0.05	0.3	0.05	0	0	0.05	4.3	7.1	0	0.2	0.05
1500	0.05	0.1	0.0	0	0.05	0	0.05	1.8	1.5	0.1	0.05	0
2000	0	0	0.2	0	0.2	0	0.05	0.9	0.4	0	0.05	0
2500	0	0	0	0	0	0	0	0.1	0.5	0.5	0	0

Readings are in grams.

PROJECT 1(9)-3

TABLE 2.17

Crater Data, Shot HE-3

R	N 5° E		N 50° E		S 85° E		S 40° E	
	Ea	Er	Ea	Er	Ea	Er	Ea	Er
0	-10.8	-11.0	10.8	11.0	10.8	11.0	10.8	11.0
3	-10.8	—	-10.8	—	-10.9	—	-10.9	—
9	- 8.0	- 8.3	—	—	—	—	—	—
13	—	—	—	—	- 5.5	- 5.9	—	—
15	—	—	- 4.9	- 5.6	—	—	- 5.9	- 6.3
23	2.1	1.0	1.3	0.7	1.8	1.4	0.8	- 0.3
36	0.1	0.1	0	0	0.1	0.1	0.1	0.1

R	S 5° W		S 50° W		N 85° W		N 40° W	
	Ea	Er	Ea	Er	Ea	Er	Ea	Er
0	-10.8	11.0	-10.8	-11.0	-10.8	-11.0	-10.8	-11.0
3	-10.8	—	10.5	—	—	—	—	—
9	—	—	—	—	—	—	- 6.9	- 7.6
13	—	—	- 6.1	- 6.8	—	—	—	—
15	- 5.9	- 6.5	—	—	- 5.2	-5.9	- 5.5	- 6.1
23	0.8	- 1.2	1.6	- 0.3	1.0	- 0.1	1.1	0.5
36	0.1	0.1	—	—	0.1	0.1	—	—

R = Radial Distance From Zero In Feet.

Ea = Apparent Crater Elevation In Feet.

Er = Real Crater Elevation In Feet.

TABLE 2.18

Permanent Displacements
(Hubs on S 50° W Blast Line)
Shot HE-3

Radial Distance From Zero, Pre-Blast	Final Position, Post-Blast		
	North	East	Elev (+ Up)
28.70	-1.59	-0.56	0.58
34.04	-0.02	-0.31	0.12
41.17	-0.01	-0.05	0.07
49.30	0.01	0.02	0.03
59.04	-0.04	0	0.04
71.17	-0.02	-0.09	0.01
85.53	-0.07	0.02	0.01
102.68	0	-0.01	-0.01
148.13	-0.05	0.01	0.01
178.22	0	-0.01	0

TABLE 2.19

Permanent Displacements, Shot HE-3

Radial Distance	N 5° E			S 85° E			S 5° W			N 85° W		
	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE	ΔR	ΔT	ΔE
28.00	1.13	0.13	0.43	0.49	0.09	0.44	S	S	S	0.94	-0.16	0.42
32.00	0.42	0.15	0.37	0.26	0.03	0.21	0.36	0.23	0.20	0.32	-0.11	0.21
36.00	0.35	0.06	0.12	0.22	0.09	0.14	0.32	0.17	0.10	0.24	-0.05	0.13
40.00	0.19	0.04	0.08	0.14	0.06	0.10	0.21	0.12	0.07	0.07	-0.04	0.07
44.00	0.13	0.05	0.02	0.09	0.06	0.04	0.17	0.13	0.04	0.02	-0.03	0.05
48.00	0.06	0.03	0.02	0.02	0.08	0.05	0.04	0.11	0.03	-0.01	-0.01	0.03
52.00	0.05	0.03	0.01	0	0.05	0.06	0.03	0.09	0.03	-0.04	-0.02	0.03
56.00	0.03	0.04	0.01	0.01	0.05	0.04	0	0.08	0.01	-0.02	-0.03	0.03
60.00	0	0.04	0.01	-0.03	0.04	0.01	0	0.09	0	0	-0.03	0.03
64.00	0.02	0.02	0	-0.03	0.02	0	0.01	0.07	0	-0.02	0	0.02
68.00	0	0	0.02	-0.02	0.01	0.01	0	0.07	0.01	---	---	0.01
72.00	0.01	0.02	-0.01	-0.02	0.01	0.01	0.09	0.10	0	-0.03	0	0.01

ΔR = Radial Displacements - Positive is direction away from charge in feet.
ΔT = Tangential Displacements - Positive is to left of radial line when looking away from charge.
ΔE = Vertical Displacements - Positive is up in feet.
S = Shattered Stake.

2.5 SHOT HE-5 (λ_c=0.30)

Shot HE-5 was the first of the second series of shots since only four were planned originally. The first four shots were fired in upper Yucca Flat and this second series was fired in Frenchman Flat.

On 30 September 1951 at 0800 PST, shot HE-5, consisting of 2560 pounds of TNT, was fired. Observers noted a considerable throw-out of streamers in the initial phases. A column of dust estimated to be 80 feet in diameter rose to between 450 and 500 feet. At 10 seconds after the detonation a base surge was observed to form. This surge traveled outward reaching a 500 feet radius in 30 seconds and a 750 feet radius at one minute. The central plume appeared to form one mammoth cloud of dust which floated away with the wind.

Camera stations were placed 5,000 feet east and 5,000 feet south of the center point of the explosion area. HE-5 was fired 100 feet S 22° E of the center of the explosion area.

Camera targets consisting of boards 8 feet square having alternating two feet squares were placed on lines through the center of the explosion area and at right angles to the line of camera sight as follows: 1,000 feet north; west and east; 1,615 feet south.

Crater and weather data are shown in Tables 2.20 and 2.21.

2.6 SHOT HE-6 (λ_c=0.22)

At 0800 PST on 2 October 1951, shot HE-6 consisting of 2560 pounds of TNT was fired. As in previous shots, a considerable throw-ou out was noted in the initial phases. A number of six to ten inch boulders was found up to 200 feet from the crater. A careful examination of the photographic records will be required to differentiate the degree of throw-out between shots HE-5 and HE-6*. The dust column rose to between 600 and 700 feet in the first 10 to 15 seconds. At eight seconds after the detonation a base surge was observed through the throw-out. This surge was of less magnitude than those previously produced. The actual travel, as a base surge, was something over 500 feet which was reached in 50 seconds. The ultimate height, as a base surge cloud, was about 200 feet. The central plume remained above the base surge. A horizontal shear was noted at an altitude of approximately 450 feet with the surge cloud moving in one direction and the top of the plume in another.

Camera stations were placed 5,000 feet east and 5,000 feet south of the center point of the explosion area.

* This information is reported in the report of JANGLE Project 1(9)-4.

TABLE 2.20

Crater Data, Shot HE-5

From North to South			From West to East			From N45°W to S45°E			From S45°W to N45°E		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
56.6	0	0	46.9	0	0	40.0	0	0	42.0	0	0
32.6	-0.3	0	35.0	-0.2	0	30.0	-0.8	0	31.4	-0.2	1.9
22.7	-1.8	-0.9	30.0	-0.7	0.2	22.0	-1.3	0.8	24.1	-2.3	2.6
20.0	-1.3	0	27.0	-1.1	1.0	15.0	1.9	4.3	20.0	-0.3	3.2
15.0	1.2	2.8	23.0	-1.3	2.7	9.3	5.9	6.0	14.0	4.2	6.5
10.3	5.5	6.1	20.0	-0.6	3.6	7.2	5.9	7.5	10.0	4.3	5.1
8.2	5.5	6.6	15.0	3.0	5.2	5.0	7.0	9.1	3.1	7.8	8.9
5.0	6.8	8.0	11.0	5.2	6.1	3.3	7.3	9.6	0	7.5	9.5
3.0	8.1	10.1	7.0	6.0	6.5	0	7.5	9.5	3.1	7.9	10.2
0	7.5	9.5	3.3	7.4	9.2	3.3	7.4	9.3	7.0	6.9	3.6
2.7	7.8	10.2	0	7.5	9.5	7.0	6.0	7.9	11.3	7.4	5.4
5.0	6.0	8.7	3.3	7.8	11.1	10.1	4.4	6.3	20.0	-0.1	2.2
9.0	5.1	6.8	7.0	6.1	7.9	14.0	4.0	5.5	24.7	-1.7	1.5
11.7	3.7	5.5	9.6	5.3	6.6	15.5	3.1	5.4	32.0	-0.6	0.5
13.6	3.8	5.5	24.3	-0.8	2.5	20.0	1.0	3.7	44.0	0	0
20.0	0	2.0	30.0	-0.3	0.5	23.4	-0.4	2.4			
23.3	-1.1	1.3	35.0	-0.1	0.1	26.5	0	1.6			
30.0	-0.8	0.5	50.0	0	0	46.0	0	0			
35.0	-0.4	0.5									
60.0	0	0									

W = 2560 Pounds of TNT. $W^{1/3} = 13.68$.
$\lambda_c = 0.30$. Earth Over Charge = 2.0 Feet.
All Values Are in Feet. Minus Indicates Above Grade.

TABLE 2.21

Weather Data, Shot HE-5[a]

Altitude[b]	TIME - 0740		TIME - 0815	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	Calm	Calm	Calm	Calm
1170	290	6	150	5
2310	190	14	180	10
3450	170	23	180	16
4560	180	24	190	26
5670	190	30	190	31
6750	200	33	190	32
7830	190	33	200	39
8910	200	29	200	47
9960	200	29		
11,010	210	33		

[a]Temperature at Ground Level - 56° F. Relative Humidity at Ground Level was 51%.

TABLE 2.22

Weather Data, Shot HE-6[a]

Altitude[b]	TIME - 0755		TIME - 0805	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	180	4	180	4
1170	230	11	230	10
2310	230	13	230	7
3450	210	7	230	18
4560	230	4	220	8
5670	240	6	190	6
6750	210	5	190	7

[a]Temperature at Ground Level - 54° F. Relative Humidity at Ground Level was 51%.
[b]Expressed in feet above ground surface.
[c]360° = N, 90° = E.
[d]Expressed in miles per hour.

TABLE 2.23

Crater Data, Shot HE-6

From South to North			From East to West			From S45°E to N45°W			From S45°W to N45 E		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
40.0	0	0	45.0	0	0	40.0	0	0	40.0	0	0
29.5	-0.2	0.6	36.0	-0.2	0.3	33.0	-0.3	0.2	30.0	-0.2	0.1
23.0	-1.2	1.8	30.0	1.0	0.8	30.0	-0.6	0.9	23.3	-2.0	2.1
15.0	2.3	4.8	24.3	1.6	1.5	25.3	-1.3	1.8	20.0	-0.6	2.4
12.0	3.4	6.0	20.0	0.5	2.1	20.3	-2.5	2.0	16.0	1.9	4.2
9.5	3.9	7.0	12.4	4.2	5.3	16.0	1.1	3.9	11.5	4.3	5.8
6.0	5.0	7.0	9.2	4.8	5.9	11.2	4.7	5.9	7.0	5.0	6.3
3.5	6.4	9.0	4.0	7.0	9.6	7.7	5.3	6.6	4.0	6.2	8.5
0	6.1	10.1	0	6.1	10.1	3.8	7.6	8.8	0	6.1	10.1
4.0	6.3	8.4	1.2	5.8	9.0	0	6.1	10.1	4.5	6.5	8.0
8.4	4.2	6.3	4.5	6.2	8.4	1.1	5.9	9.1	9.1	4.2	5.4
12.7	4.2	5.4	7.8	5.1	7.0	4.5	6.4	9.0	11.3	4.4	5.2
20.0	-0.1	2.0	10.9	4.9	6.0	9.0	4.7	6.0	16.6	2.5	3.3
24.0	-1.5	0.9	16.0	1.3	4.1	12.2	4.3	5.6	19.0	1.2	1.8
30.0	-0.9	0.3	20.0	-1.0	3.1	18.0	0.8	3.0	22.0	-0.7	0.8
35.0	-0.3	0.1	22.0	-1.6	2.8	24.0	-1.6	1.8	26.1	-1.2	1.1
40.0	-0.1	0	32.0	-0.3	0.2	30.0	-0.5	1.1	30.0	-0.7	0.6
			50.0	0	0	35.0	-0.1	0.1	35.0	0.3	0.1
						40.0	0	0	40.0	0	0

W = 2560 Pounds of TNT. $W^{1/3} = 13.68$.
$\lambda_c = 0.22$. Earth Over Charge = 1.0 Foot.
All Values in Feet. Minus Indicates Above Grade.

HE-6 was fired 75 feet N 23° W of the center of the explosion area.

Camera targets consisting of boards 8 feet square having alternating two feet squares were placed on lines through the center of the explosion area and at right angles to the line of camera sight as follows: 1,000 feet north, west and east; 1615 feet south.

Weather and crater data are given in Tables 2.22 and 2.23.

2.7 SHOT HE-7 (λ_c =0.19)

At 0700 PST on 4 October 1951, shot HE-7 was fired. A large column of dust was thrown more than 1,000 feet in the air. At 20 seconds after the detonation there was a feeble indication of a base surge in the throw-out area at the bottom of the column. The top of the plume started moving with the wind and at 3 minutes after zero time had drifted 5,000 feet with the wind. One hour after the shot the remains of the dust cloud were still visible five to six miles to the southwest.

Camera stations were placed 5,000 feet east and 5,000 feet south of the center point of the explosion area.

HE-7, 2560 pounds of TNT, was fired 150 feet west of the center of the explosion area.

Camera targets consisting of boards 8 feet square having alternating two feet squares were placed on lines through the center of the explosion area and at right angles to the line of camera sight as follows: 1,000 feet north, south, east and west.

Crater and weather data are given in Tables 2.24 and 2.25.

The base surge formation from shot HE-7 was so slight that it was not considered necessary to fire any additional shots to confirm the curve given in Figure 1.1.

2.8 SHOT HE-8 (λ_c=0.18)

At 0700 PST on 13 October 1951, shot HE-8 was fired. The TNT was an assembly of 216 pounds while the Pentolite weighed 177 pounds. (See Figures 3.1 and 3.2.) The Pentolite explosion was of high order, sending a slender column of smoke and dust high into the air and producing a magnificent smoke ring. A minor base surge was formed which, to observers, appeared similar to that produced by shot HE-6 with λ_c = 0.22. The priming was not adequate on the TNT portion of the test

TABLE 2.24

Crater Data, Shot HE-7

From South to North			From East to West			From S45° E to N45° W			From N45°E to S45°W		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
50.0	0	0	45.0	-0.5	0	40.0	0	0	50.0	0	0
35.0	-0.1	0.3	35.0	-0.9	0	33.4	-0.6	0.3	40.0	-0.3	0
30.0	-1.0	0.6	33.6	-1.8	0	24.0	-1.8	1.7	26.6	-1.8	0
23.3	-2.2	0.8	30.5	-0.6	0	19.0	0	2.1	22.4	-1.1	0.6
18.0	0.2	2.8	23.6	-1.8	2.2	13.6	2.8	3.2	14.0	2.8	3.2
13.8	3.4	4.9	20.0	0	2.8	9.7	4.0	5.6	7.7	4.1	5.0
8.2	5.1	6.0	15.3	3.0	3.8	3.9	6.0	7.4	3.1	5.5	8.0
3.2	7.1	8.0	9.1	3.5	4.1	0	6.7	8.6	0	6.7	8.4
0	6.7	8.6	5.4	5.0	6.9	2.8	6.8	8.4	2.3	7.3	8.6
2.2	6.9	8.5	1.6	6.1	7.5	7.8	4.2	5.5	8.0	4.9	6.6
6.8	5.0	6.1	0	6.7	8.6	13.6	3.3	4.2	11.5	4.0	5.9
10.0	4.8	5.5	1.8	7.3	8.7	17.0	1.7	3.6	18.0	0	1.5
12.1	4.2	5.1	7.0	4.6	5.5	20.8	-1.1	2.4	20.0	-1.5	1.2
17.0	1.0	4.0	12.9	3.0	4.5	26.1	-0.7	0.3	23.1	-1.9	0.7
22.4	-1.5	2.4	18.0	0	2.6	28.8	-1.4	0.3	27.8	-0.9	0.2
29.0	-0.3	0.5	21.3	-1.5	2.0	31.2	-0.3	0.2	33.0	-0.2	0
36.0	0	0	26.6	-1.6	0.3	40.0	0	0	40.0	0	0
			34.2	-0.3	0						
			40.0	0	0						

W = 2560 Pounds of TNT. $W^{1/3} = 13.68$.
$\lambda_c = 0.19$. Earth Over Charge = 0.5 Foot.
All Values in Feet. Minus Indicates Above Grade.

TABLE 2.25

Weather Data, Shot HE-7[a]

Altitude[b]	TIME - 0655		TIME - 0705	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	Calm	Calm	Calm	Calm
1170	010	13	020	13
2310	020	15	020	15
3450	020	15	020	15
4560	020	15	010	15
5670	020	11	020	8
6750	020	7	030	3
7830	340	6	300	5
8910	320	8	280	10
9960			270	16
11,010			270	24
12,030			280	28
13,020			280	31
14,010			280	42
15,000			280	50

[a]Temperature at Ground Level - 56° F. Relative Humidity - 46%.

TABLE 2.26

Weather Data, Shot HE-8[a]*

Altitude	TIME - 0655		TIME - 0705	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	140	3	080	6
720	0[illegible]	7	010	7
1380	020	14	010	12
2040	030	15	020	12
2670	050	10	050	11
3300	050	10	040	11
3700	050	8	050	11

[a]*Temperature at Ground Level - 56° F. Relative Humidity - 51%.
[b]Expressed in feet above ground surface.
[c]360° = N, 90° = E.
[d]Expressed in miles per hour.

PROJECT 1(9)-3

TABLE 2.27

Crater Data, Shot HE-8 (Pentolite)

From North to South			From East to West		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
24.0	0	0	23.0	0	0
15.5	-0.3	0.1	16.1	-0.1	0.1
13.0	-0.8	0.9	12.1	-0.3	0.1
11.2	-1.0	1.7	10.7	-0.9	1.7
8.4	0.6	2.2	8.5	0	2.7
5.1	2.3	3.4	5.5	1.9	3.7
4.0	2.6	3.8	4.1	2.7	3.8
1.6	3.3	3.6	3.1	2.8	3.5
0	3.3	4.3	1.6	3.2	3.7
2.0	3.1	4.3	0	3.2	4.3
3.0	2.8	4.0	1.8	3.4	4.5
6.3	0.9	3.0	4.0	2.6	4.2
8.5	0.1	3.3	5.3	2.3	4.2
10.9	-0.8	2.8	7.5	0.6	3.1
13.2	-0.1	0.3	9.3	-0.5	2.6
19.0	0	0	10.5	-0.7	2.2
			14.7	-0.3	0.6
			22.8	0	0

and explosion of roughly one half of the charge resulted. Weather data will be found in Table 2.26. The TNT crater was not measured but data on the Pentolite crater will be found in Table 2.27.

For shot HE-8, the center point of the area was moved 1,000 feet south of the center of the area used for shots HE-5, 6, and 7.

Shot HE-8 (TNT) was fired 100 feet east of the center of the explosion area and shot HE-8 (Pentolite) was fired 100 feet west of the center of the explosion area.

One camera station was placed 4,000 feet south of the center point of the area. The camera targets (same type as used for HE-5, 6 and 7) were located on an east-west line at right angles to the line of camera sight as follows: 500 feet east, center, and 500 feet west.

2.9 SHOT HE-9 (λ_c=0.14)

At 0705 PST on 14 October 1951, shot HE-9 was fired. Both Pentolite and TNT produced high order explosions. The above ground activity appeared similar for both explosions. A considerable throw-out was noted which produced a cloud around the base of the plume. The cloud had some expansion and a careful examination of the photographic records will be required to determine if there was any base surge contribution, (Refer to JANGLE Report 1(9) - 4, "Base Surge Analysis for HE Tests".) It is certain that a large plume remained above the base activity. Crater and weather data are given in Table 2.28, 2.29 and 2.30.

Shot HE-9 was fired in the same explosion area used for HE-8.

Shot HE-9 (TNT) was fired 200 feet east of the center of the explosion area and shot HE-9 (Pentolite) was fired 200 feet west of the center of the explosion area.

One camera station was placed 4,000 feet south of the center point of the area.

The camera targets (same type as used for HE-5 through HE-8) were located on an east - west line at right angles to the line of camera sight as follows: 500 feet east, center, and 500 feet west.

2.10 SHOT HE-10 (λ_c=0.5)

At 1130 PST on 14 October 1951, shot HE-10 was fired. Both the Pentolite and TNT produced high order explosions. A massive base surge was produced by each explosion. The TNT produced what was virtually 100 per cent base surge just as it was in shot HE-3. Some

TABLE 2.28

Crater Data, Shot HE-9 (Pentolite)

From North to South			From East to West		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
18.4	0	0	18.6	0	0
12.9	-0.4	0.7	12.4	-0.4	0.7
10.5	-0.8	2.5	10.2	-0.9	2.6
9.9	-0.6	2.8	8.0	0.5	2.7
7.5	0.8	3.2	3.9	2.3	3.5
4.8	1.5	3.5	1.0	3.5	4.4
2.4	2.7	4.1	0	3.4	4.0
0	3.4	4.0	1.4	3.3	3.9
1.8	3.1	3.9	4.0	2.0	3.2
5.9	1.4	3.6	6.4	1.2	3.1
7.1	1.0	2.4	10.7	-1.2	1.8
10.2	-0.8	2.9	11.8	0	1.0
11.3	-0.5	2.5	16.0	0	0
13.0	-0.2	0.3			
20.5	0	0			

TABLE 2.29

Crater Data, Shot HE-9 (TNT)

From North to South			From East to West		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
17.5	0	0	18.0	0	0
12.9	-0.7	0	13.0	-0.3	0.5
10.3	-0.5	2.5	10.5	-0.7	2.5
7.9	0.1	2.1	9.7	-0.6	2.6
6.2	1.0	3.0	6.0	1.1	3.2
4.5	1.5	4.0	1.5	3.3	4.5
3.4	2.4	3.7	0	4.0	3.5
2.1	2.6	3.7	1.5	4.0	3.5
0.9	3.5	4.1	3.6	2.5	3.0
0	3.5	4.0	4.9	2.1	3.4
1.8	3.0	4.0	8.1	0.2	2.3
4.7	1.9	3.0	10.4	-0.7	1.5
6.1	1.7	2.7	13.9	-0.2	0.5
10.4	-0.6	1.9	22.0	0	0
12.7	-0.1	0.7			
19.8	0	0			

TABLE 2.30

Weather Data, Shot HE-9[a]

Altitude[b]	TIME - 0700		TIME - 0710	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	320	7	300	5
720	020	7	030	6
1380	040	9	050	9
2040	060	9	060	9
2670	080	8	080	7
3300	090	6	100	6
3900	090	6	100	5
4500	090	4	100	4
5100			120	4

a Temperature at Ground Level - 48° F.
Relative Humidity at Ground Level - 62%.

TABLE 2.31

Weather Data, Shot HE-10a*

Altitude[b]	TIME - 1128		TIME - 1133	
	Wind[c] Direction	Wind[d] Velocity	Wind[c] Direction	Wind[d] Velocity
Surface	090	3	100	3
720	150	4	170	5
1380	170	5	180	5
2040	180	6	180	6
2670	170	5	170	6
3300	150	7	160	8
3900	150	8	160	10
4500	160	6	160	8
5100	160	6	170	7

a* Temperature at Ground Level 68° F.
Relative Humidity at Ground Level - 55%.

b Expressed in feet above ground surface.

c 360° = N, 90° = E.

d Expressed in miles per hour.

TABLE 2.32

Crater Data, Shot HE-10 (Pentolite)

From North to South			From East to West		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
22.0	0	0	23.2	0	0
16.2	-0.2	0.7	16.0	-0.4	0.1
13.2	-1.0	1.9	13.5	-1.0	0.5
12.1	-1.0	2.5	11.6	-0.7	1.5
9.7	0.2	2.7	8.1	2.0	2.8
8.6	1.7	2.9	4.4	3.5	4.1
6.3	2.6	3.8	2.3	3.7	4.7
5.6	3.4	4.3	1.7	4.1	4.8
3.9	3.9	5.0	0	4.1	5.4
2.1	5.0	5.2	1.5	4.5	5.3
1.1	3.5	5.4	4.4	3.4	4.6
0	4.1	5.5	5.4	3.1	4.2
0.9	4.3	4.8	6.3	3.0	3.6
3.8	3.5	4.6	8.4	1.8	2.7
5.2	3.4	4.3	9.8	0.3	2.8
10.2	-0.5	2.8	12.5	-0.9	2.0
11.7	-0.7	2.2	14.9	-0.4	0.1
15.2	-0.3	0.3	21.3	0	0
21.3	0	0			

TABLE 2.33

Crater Data, Shot HE-10 (TNT)

From North to South			From East to West		
Radial Distance	Apparent Depth	Real Depth	Radial Distance	Apparent Depth	Real Depth
22.0	0	0	21.2	0	0
16.2	-0.2	0.3	19.0	-0.5	0.2
12.9	-0.8	3.0	16.9	-0.5	1.9
12.0	-0.7	3.0	13.0	-0.5	2.5
6.6	2.6	4.1	6.8	2.9	3.5
2.5	4.7	5.9	5.6	3.0	4.9
0	5.5	6.3	1.8	5.0	5.6
1.7	5.1	6.1	0	5.5	6.3
7.2	3.3	3.6	1.4	4.9	6.4
11.6	0.5	3.5	6.1	2.7	3.5
12.8	-0.8	2.6	10.5	0.7	2.9
17.2	-0.1	0.2	12.1	-0.8	2.4
26.5	0	0	13.3	-1.2	1.8
			16.8	-0.5	0.3
			24.0	0	0

minor plume remained in the air above the Pentolite base surge. The contribution to the surge was estimated by observers to be greater than that produced on HE-5 with λ_c=0.3. Weather and crater data are given in Tables 2.31, 2.32 and 2.33.

Shot HE-10 was fired in the same explosion area used for shots HE-8 and 9.

Shot HE-10 (TNT) was fired 450 feet east of the center of the explosion area. Shot HE-10 (Pentolite) was fired 450 feet west of the center of the explosion area.

One camera station was placed 4,000 feet south of the center of the area.

The camera targets (same type as used for HE-5 through HE-9) were located on an east - west line at right angles to the line of camera sight as follows: 500 feet east, center, and 500 feet west.

PROJECT 1(9)-3

SECTION 3

RESULTS

3.1 RELATIVE GROUND ACTIVITY PRODUCED BY TNT AND PENTOLITE

One is inclined toward a tentative conclusion that there is little difference in the above ground activity produced by TNT and by Pentolite, which occupied 76 per cent of the TNT volume (V_{TNT} =3823 in^3 and V_p = 2936 in^3), when both explosives were fired with the center of gravity at the same depth.

3.2 EFFECTS OF SIZE OF CHARGE

Since the nuclear explosion will present virtually a point source when compared to the equivalent energy of a 34 foot diameter ball of TNT, an investigation of the effect of size was conducted. Three simultaneous explosions of 216 pounds of TNT and the equivalent energy in 177 pounds of Pentolite were conducted as shown in Table 3.1.

TABLE 3.1

Relative Energy of Pentolite and TNT

Shot	Depth to c.g. (inches)	λ_c	Earth Cover Over Charge (inches)	
			TNT	Pentolite
HE-8	13	0.18	3	4-1/8
HE-9	10	0.14	0	1-1/8
HE-10	36	0.5	26	27-1/8

The TNT charge was built up with 1, 5, 20 and 100 pound blocks as shown in Figure 3.1. The vertical dimension of the charge was 20 inches. The Pentolite charge was made up of two hemispheres having diameters of 17 and 3/4 inches as shown in Figure 3.2

3.3 OBSERVING AND RECORDING DATA

All information on the above ground action is based on eye witness observations and is subject to modifications based on careful analysis of the photographic data. Some comparative photographs of base surge formation are shown in Figures 3.3 through 3.12. The Sandia Corpora-

PROJECT 1(9)-3

Fig. 3.1 216 Pound TNT Assembly

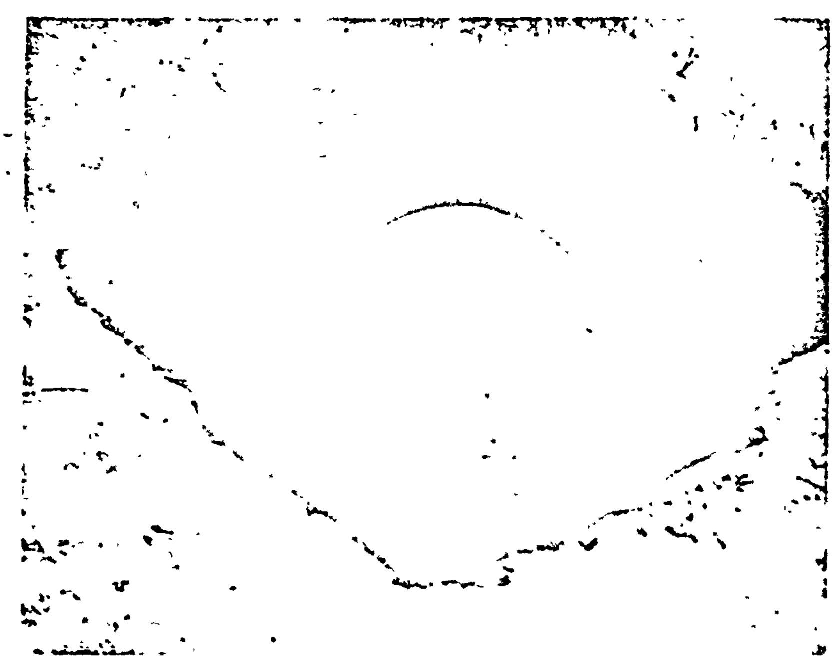


Fig. 3.2 177 Pound Pentolite Sphere

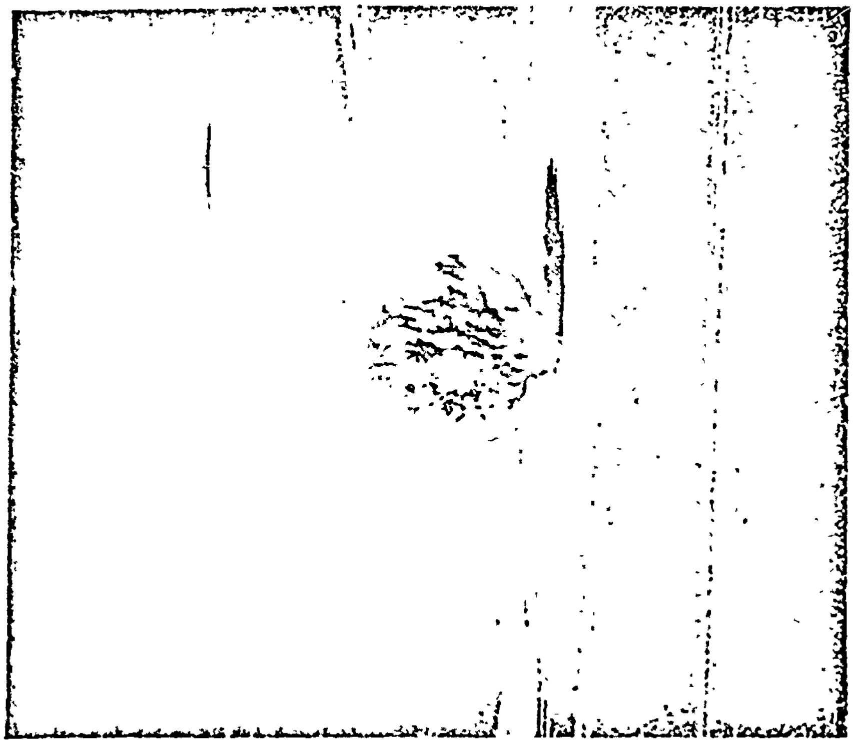


Fig. 3.3 HE-3. Time between zero and 1 second. 2560 Pounds of TNT with λ_c = 0.5.

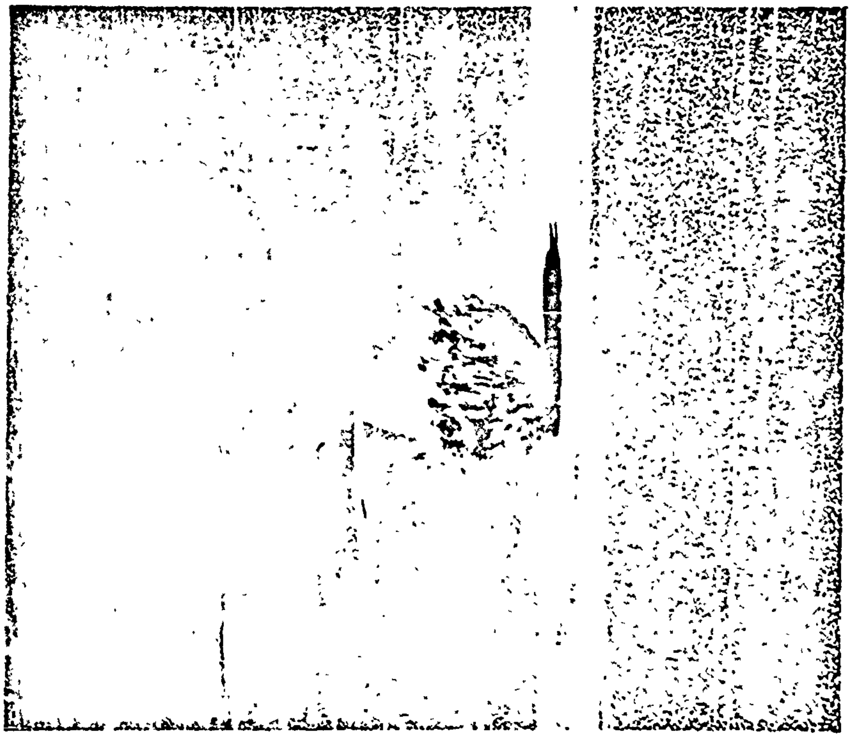


Fig. 3.4 HE-2. Time between zero and 1 second. 40,000 Pounds of TNT with λ_c = 0.135.

PROJECT 1(9)-3

Fig. 3.6 HE-2. Time plus 10 seconds.

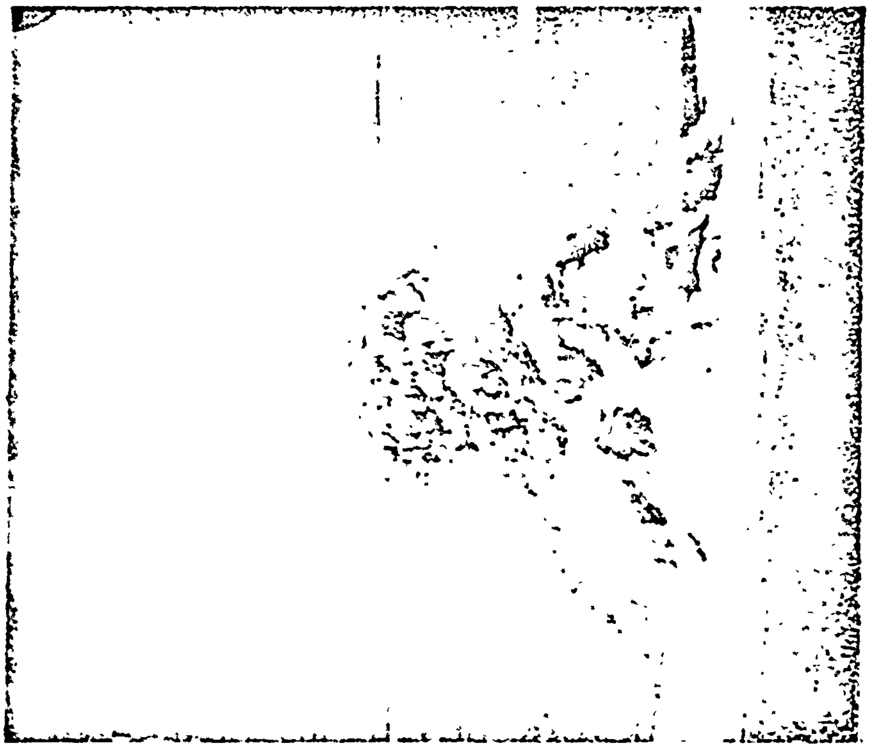


Fig. 3.5 HE-3. Time plus 10 seconds.

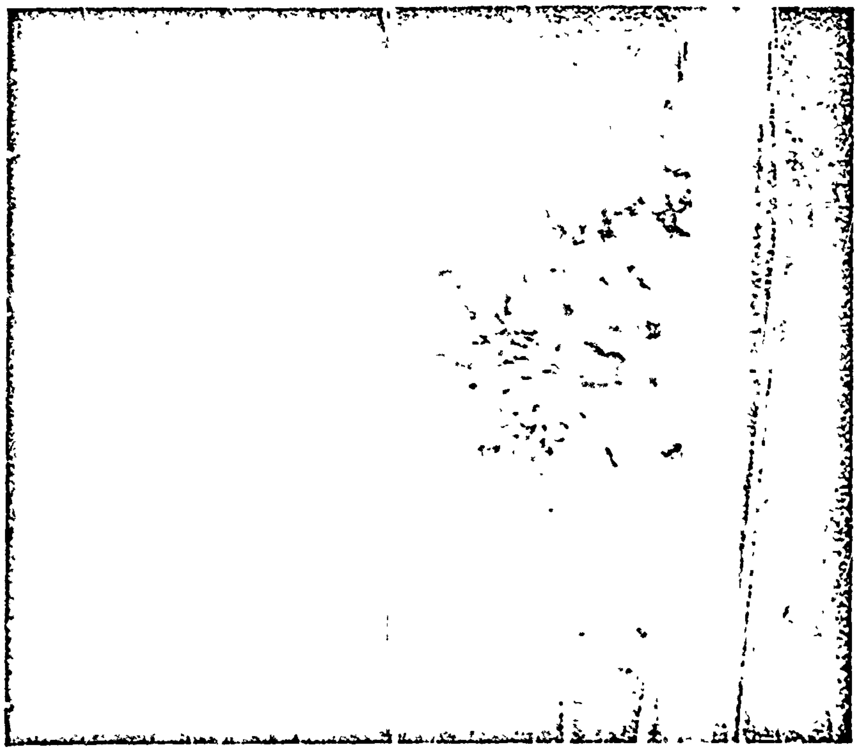


Fig. 3.7 HE-3. Time plus 20 seconds. Base surge in initial phases.

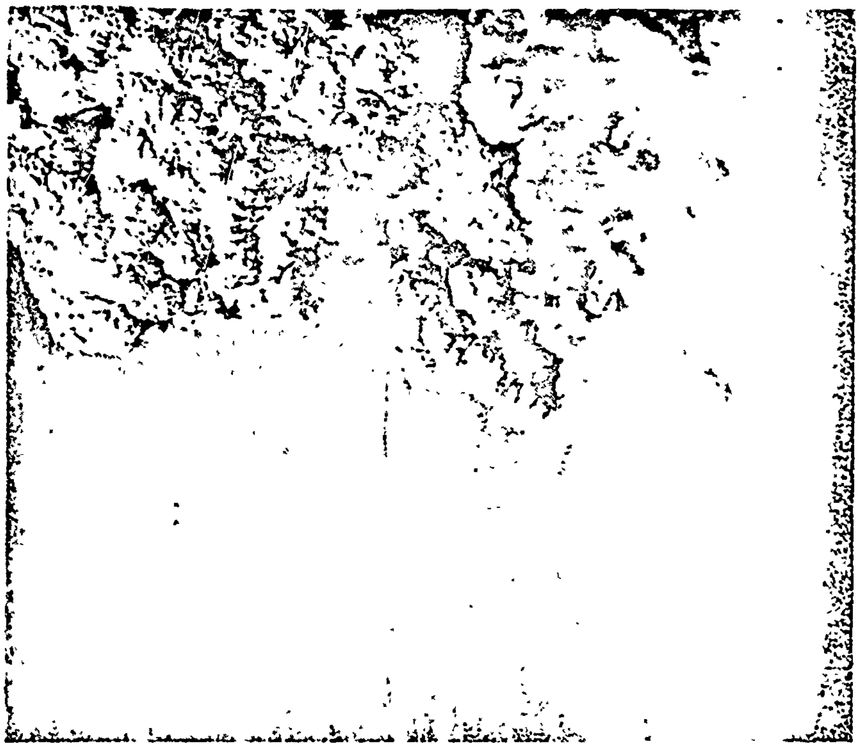


Fig. 3.8 HE-2. Time plus 20 seconds. Roughly one-half of the volume is shown.

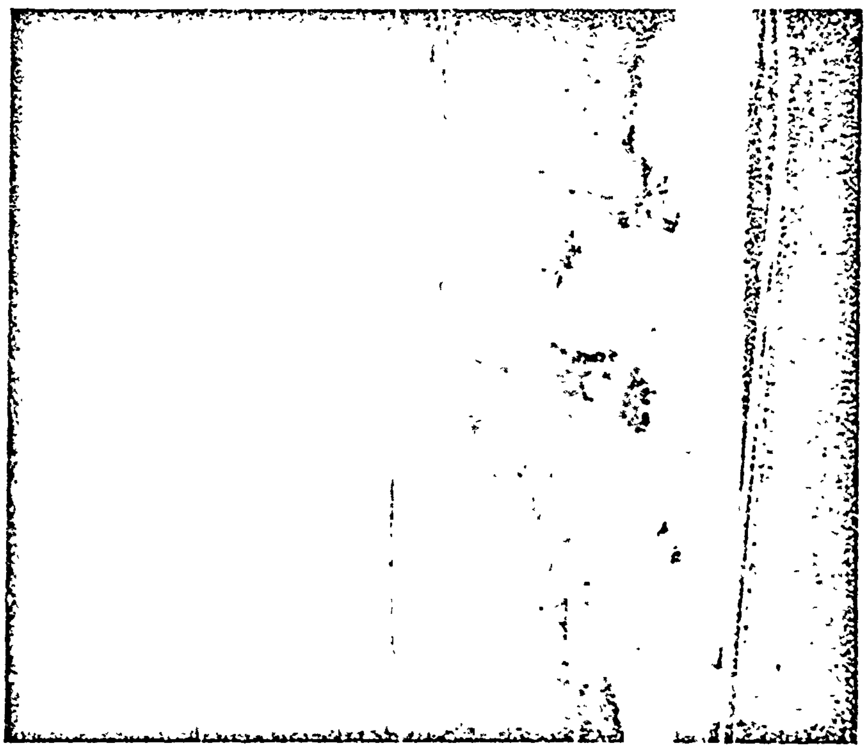


Fig. 3.9 HE-3. Time plus 30 seconds. Plume falling into base surge.

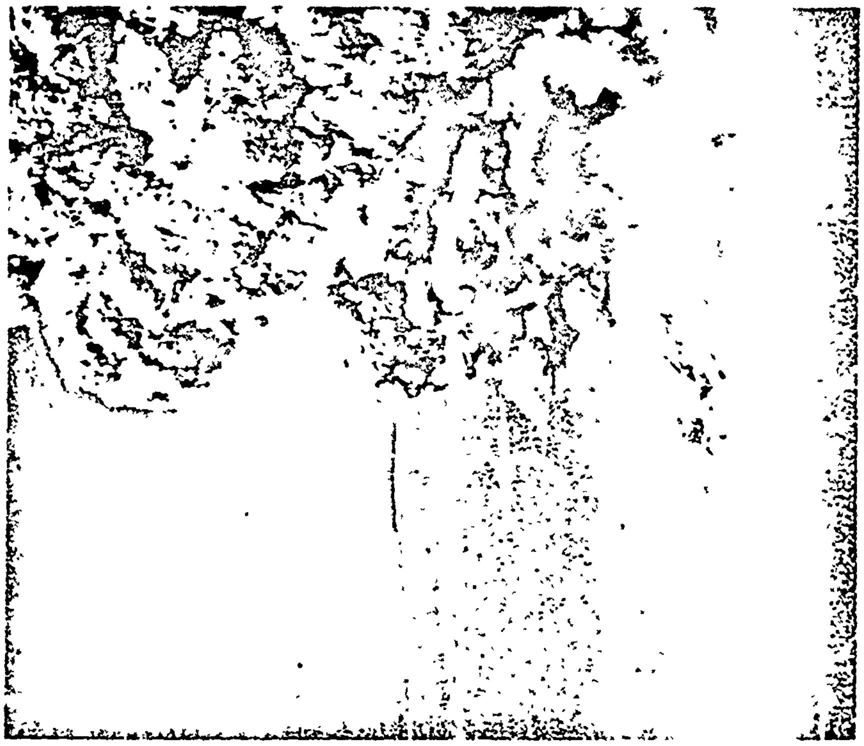


Fig. 3.10 HE-2. Time plus 30 seconds. Plume still rising.

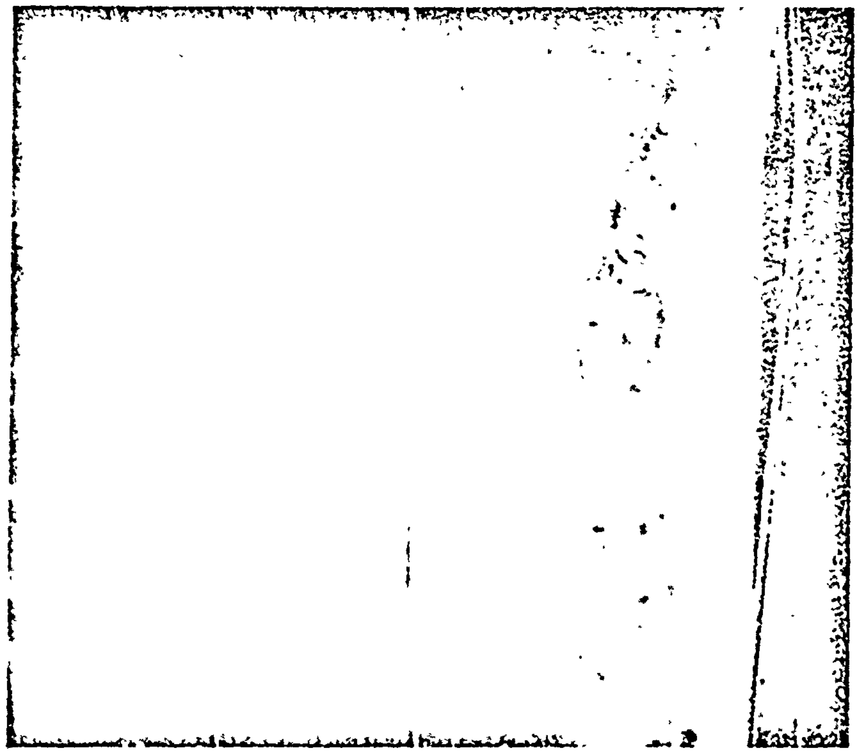


Fig. 3.11
HE-3. Time plus 40 seconds. 100 per cent base surge formation moving with wind toward left side of picture.

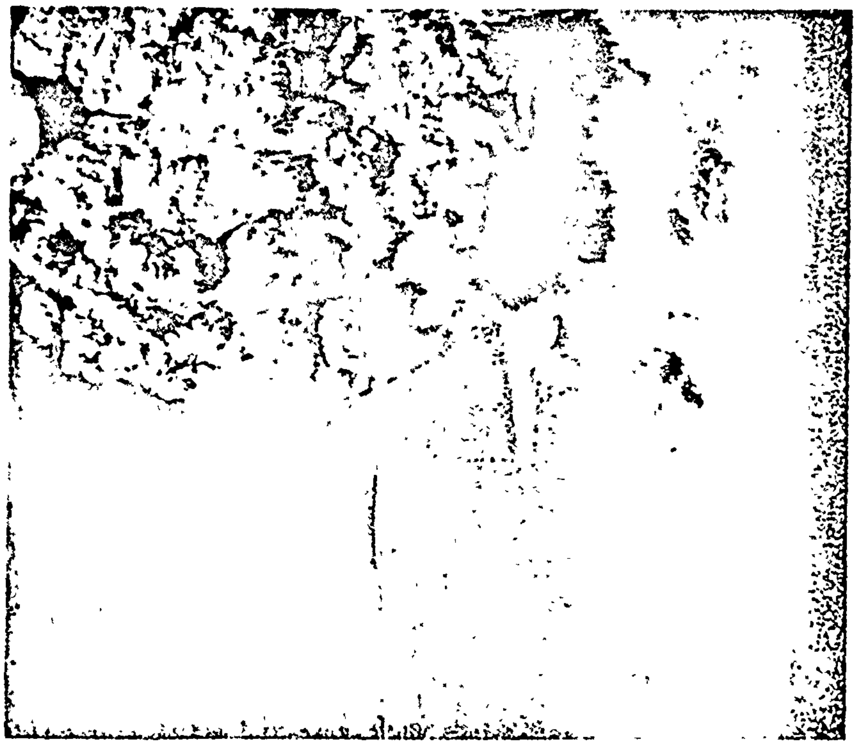


Fig. 3.12
HE-2. Time plus 40 seconds. Roughly one-half of the plume is shown. Plume is still rising. Little, if no, base surge was formed. Some throwout is still visible.

tion, through Program Four, has been requested to make measurements[1] from the 35mm motion pictures of the various HE shots as follows:

a. Rate of rise of plume. Rate of descent into base surge.
b. Diameter of plume, at several elevations, as a function of time.
c. Time and location of first appearance of base surge.
d. Radial travel of base surge as a function of time.
e. Height of base surge as a function of time and distance.
f. From aerial pictures of Shot HE-3, determine shape and volume of base surge as a function of time.

3.4 BEHAVIOR OF BASE SURGE AND CRATER SIZE PHENOMENA

Lacking the photographic analysis, it is possible only to make some rough estimations as to the mechanism producing the base surge and what can be predicted to occur during the nuclear tests. It is certain that some minimum density of soil is required in the plume in order to produce the downward sweep of dust which, at ground level, moves outward as the base surge. The density is produced by blowing a large volume of earth a relatively short distance up into the air. The closer the charge to the surface (smaller values of λc), the smaller the crater and greater the height of plume, hence, lower density and less base surge contribution. Average crater contours are given in Figures 3.13 through 3.17 and are summarized in Tables 3.1 and 3.2. It is known from the work of Dr. Curtis Lampson and others that a large number of tests are required to obtain data that is good to within 35 per cent, therefore, only generalities can be obtained from this crater data.

Crater radii may be calculated from the following equation:

$$R = 1.3\ C\ E\ k^{1/12} \quad (3.3\text{-}1)^2$$

Where

R = the radius in feet
$C = 0.4$ (for $\lambda c = 0.135$)[3]
$k = 11{,}000$ (for a seismic velocity of 4,000 feet per second)

A comparison of calculated and observed values of radii is given in Table 3.2 and is plotted in Figures 3.18 and 3.19. It will be noted that there is some difference between the values of the crater radius as calculated, extrapolated from observed data, and that previously predicted in the WINDSTORM Handbook. A plot of crater depth and lip height is given in Figure 3.20.

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[1] This analysis is reported in Project 1(9)-4
[2] The Effects of Atomic Weapons, Washington, GPO, June 1950, App. B, p. 421.
[3] Ibid., Figure B29, p. 421.

PROJECT 1(9)-3

TABLE 3.2

Comparative Crater Data

2560 Pounds of TNT ($W^{1/3} = 13.68$)									
Depth to c.g. (inches)	Cover Over Charge (inches)	λ_c	Crater Volume (Ft^3) Apparent a	Real	Fall Back b	Crater Depth (Feet) Real c	Apparent c	Apparent Crater Radius (Feet) d
24	0	0.15	2200	4100	3200	6.8	7.6	18.4
30	6	0.19	3300	6180	5400	6.7	8.6	19.0
36	12	0.22	3600	8800	7200	6.1	10.1	19.8
48	24	0.30	4000	8700	7000	7.5	9.5	19.4
81.6	57.6	0.50	6000	7600	3000	10.8	11.0	19.8

216 Pounds of TNT and 177 Pounds of Pentolite[e]										
Depth (inches) Charge	c.g.	Top of Charge	λ_c	Crater Volume (Ft^3) Apparent a	Real	Fall Back b	Crater Depth (Feet) Real c	Apparent c	Apparent Crater Radius (Feet) d
P	10	1-1/8	0.14	290	1310	1020	4.0	3.4	8.6
TNT	10	0	0.14	270	1120	980	4.0	3.5	8.3
P	13	4-1/8	0.18	380	1310	1130	4.3	3.3	8.7
P	36	27-1/8	0.5	520	1460	1330	5.5	4.1	9.6
TNT	36	26	0.5	860	2600	1370	6.3	5.5	11.3

a = Volume below original ground level.
b = Difference between real and apparent crater volume plus lip volume.
c = Depth from original ground level.
d = Radius at original ground level.
e = $W^{1/3} = 6$

TABLE 3.3

Observed and Calculated Crater Radii

W	$W^{1/3}$	Radius in Feet	
		Calculated	Observed
216	6	6.8	8.3
2560	13.7	15.5	18.5
40000	34.2	38.5	38.5
1 KT	126	150	——

$$\lambda_c = 0.135$$

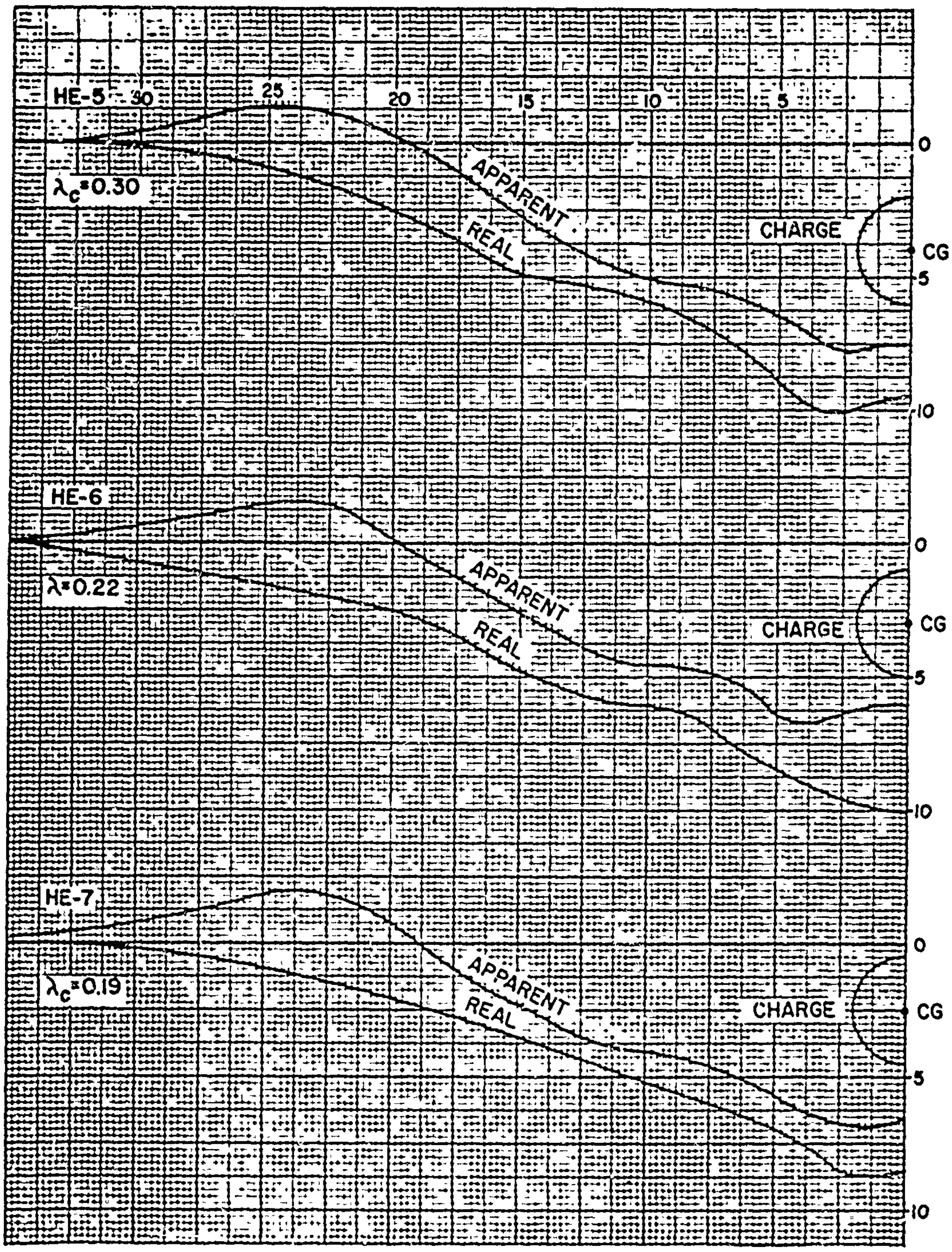

Fig. 3.13 Average Crater Contours for 2560 Pounds of TNT in Shots HE-5, HE-6, and HE-7

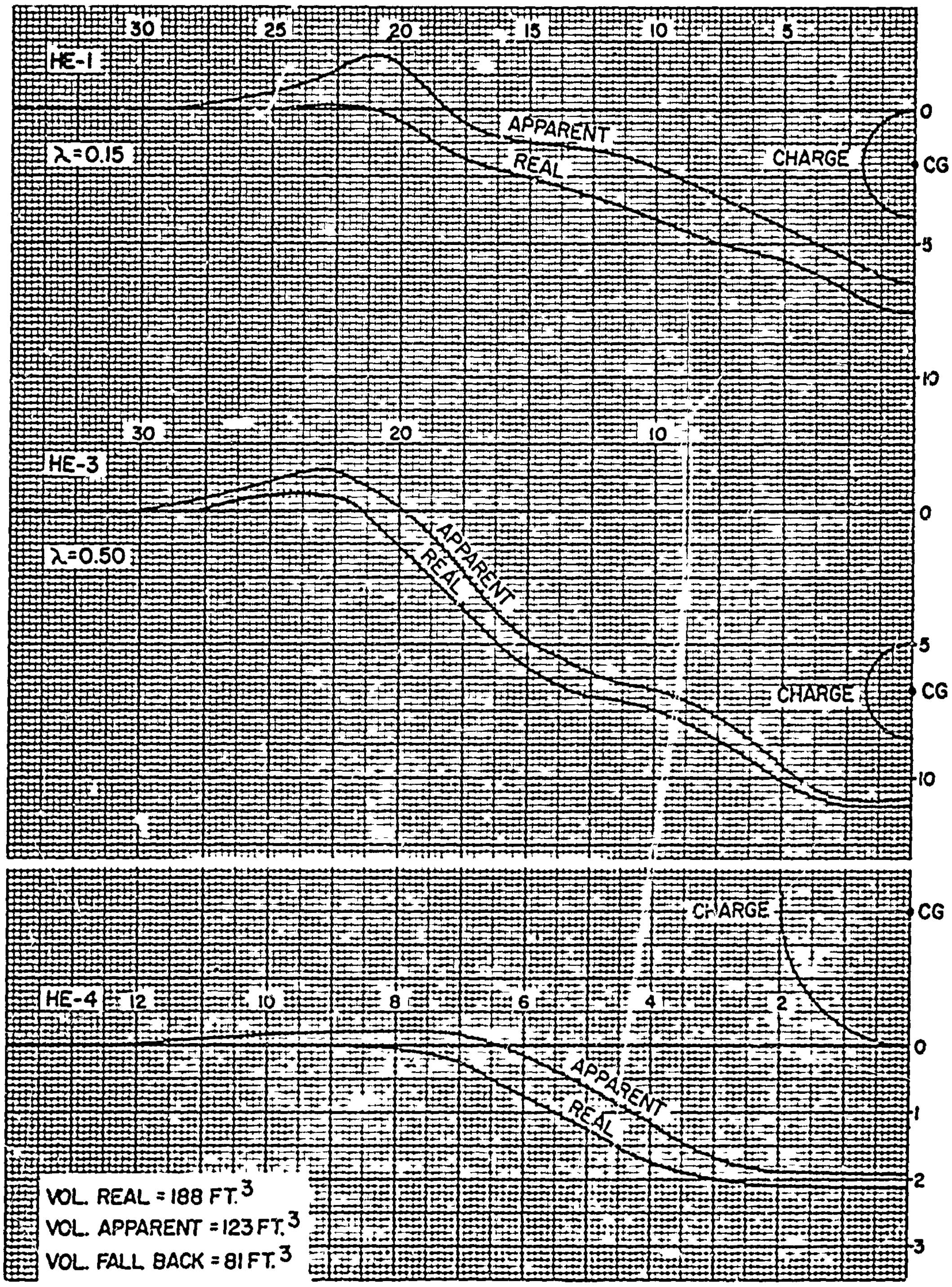

Fig. 3.14 Average Crater Contours for 2560 Pounds of TNT in Shots HE-1, HE-3 and HE-4

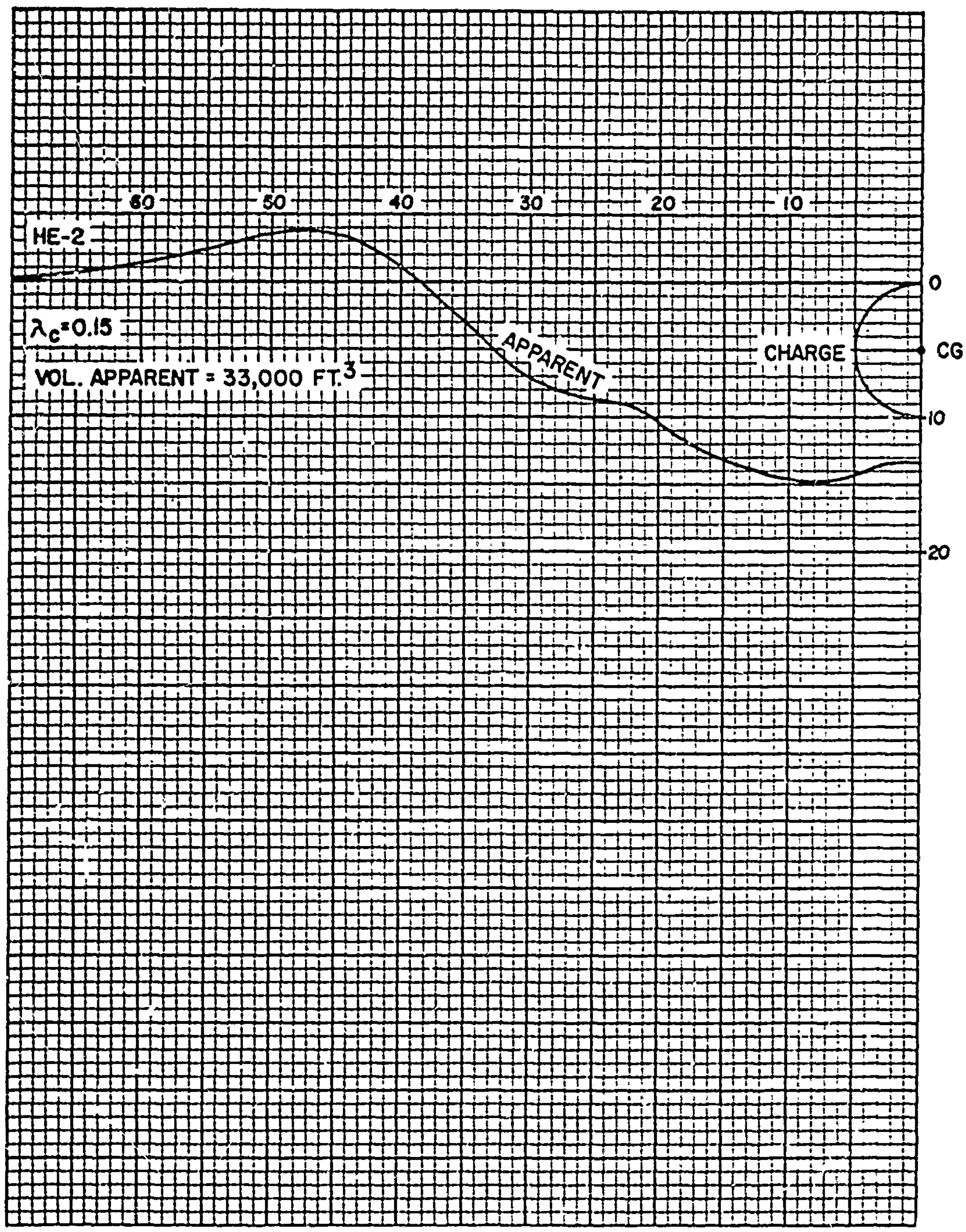

Fig. 3.15 Average Crater Contours for 40,000 Pounds of TNT in Shot HE-2

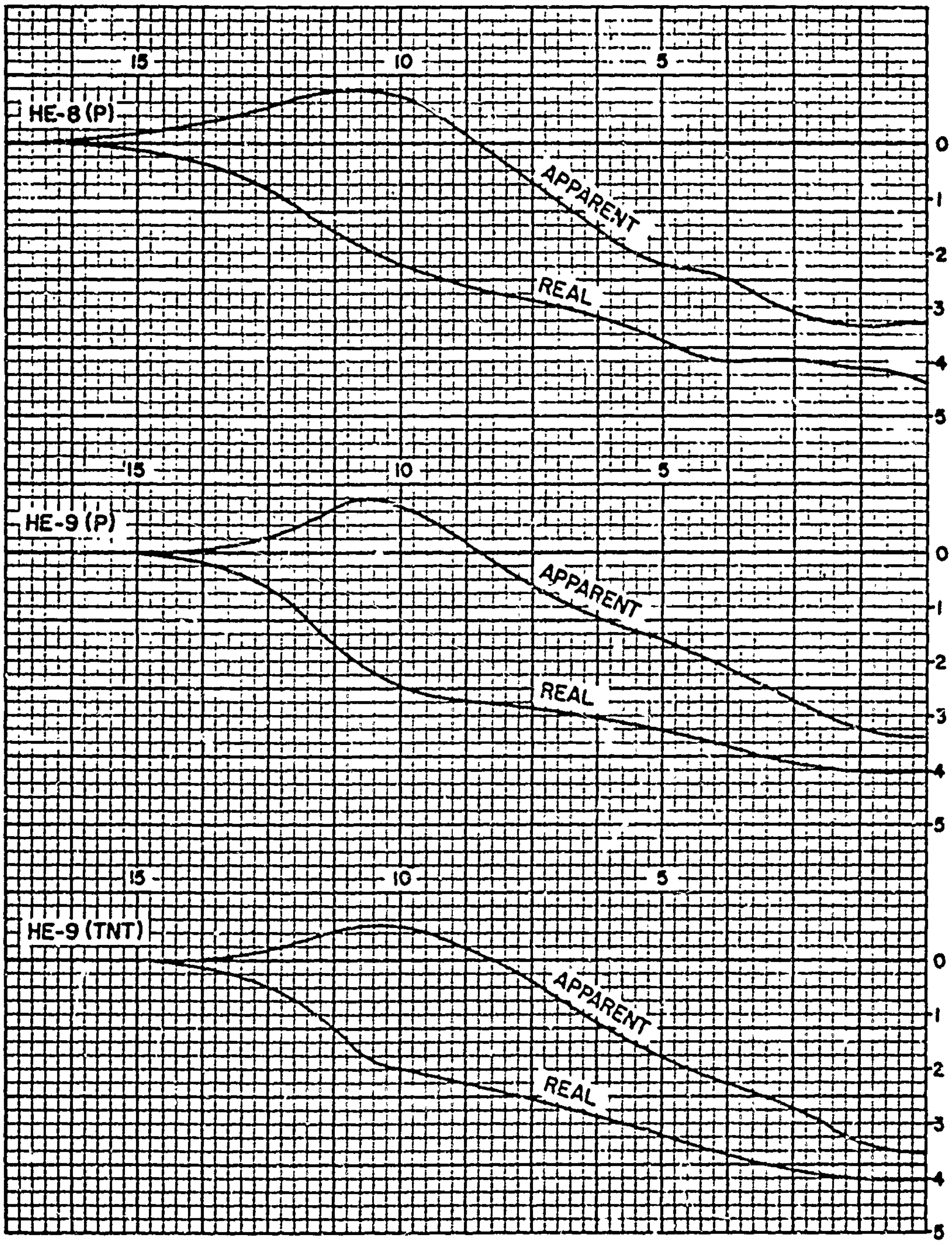

Fig. 3.16 Average Crater Contours for 216 Pounds of TNT and 177 Pounds of Pentolite in Shots HE-8 (P), HE-9 (P) and HE-9 (TNT)

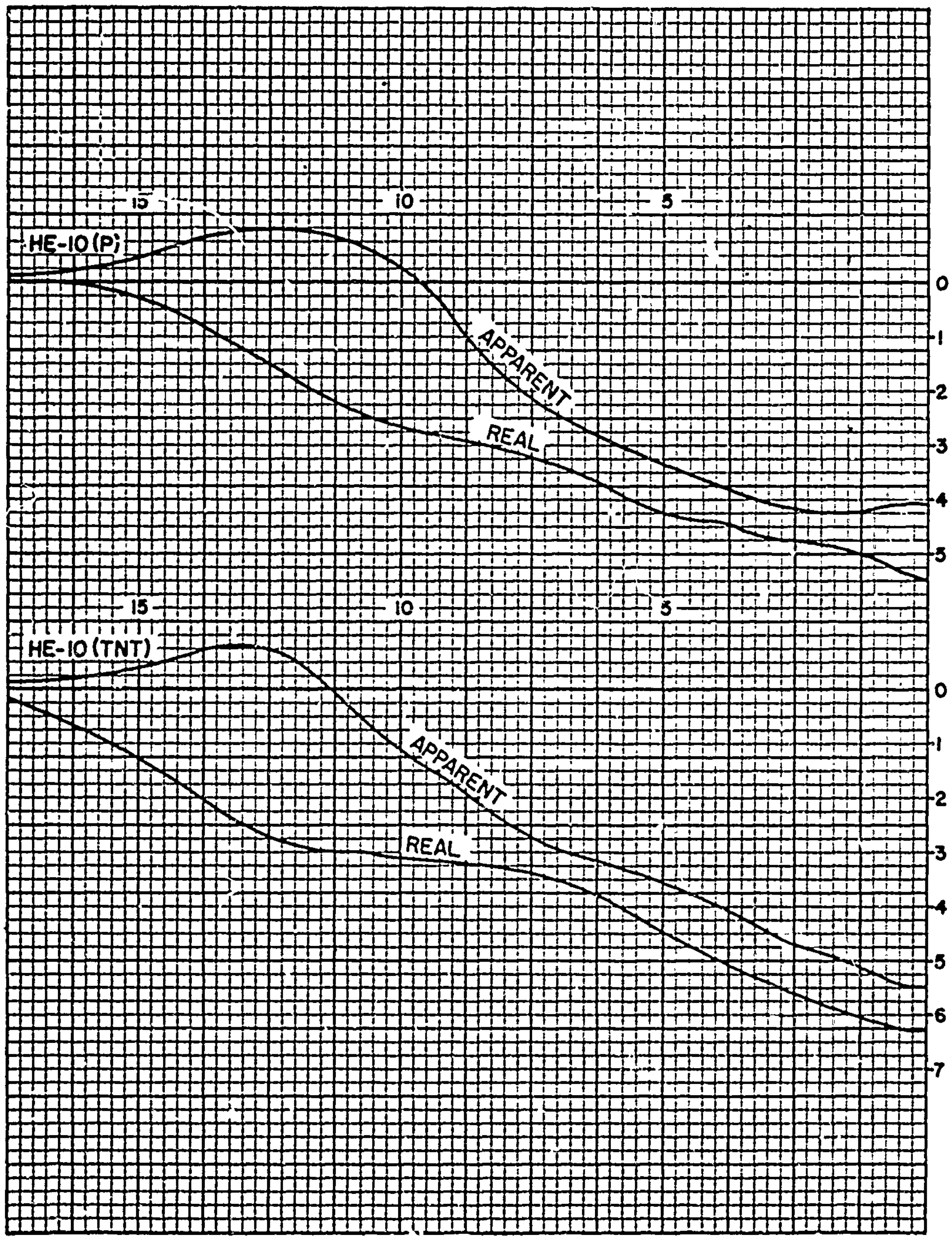

Fig. 3.17 Average Crater Contours for 216 Pounds of TNT and 177 Pounds of Pentolite in Shots HE-10 (P) and HE-10 (TNT)

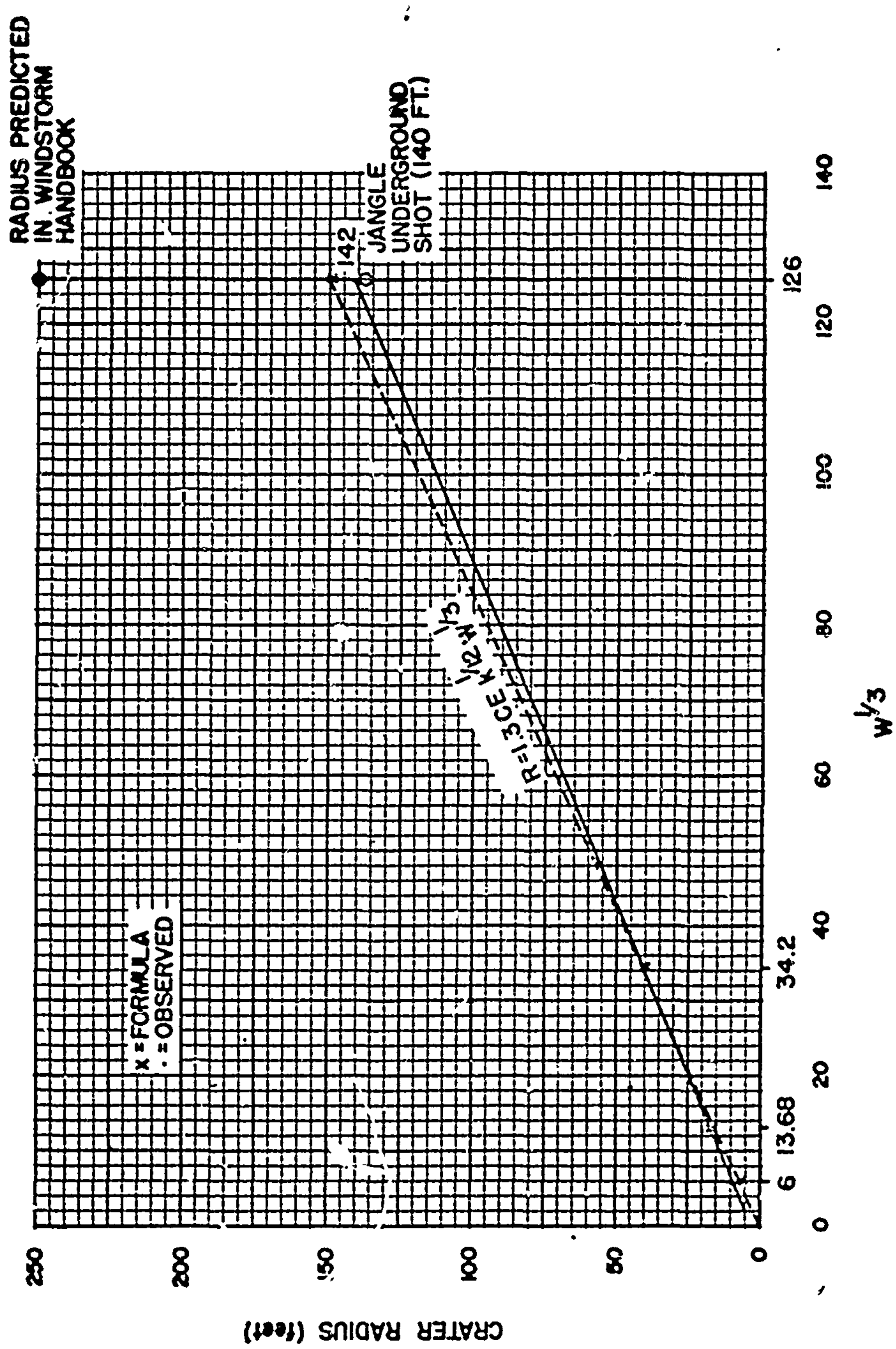

Fig. 3.18 Calculated and Observed Values of Crater Radius for Charge CG Underground

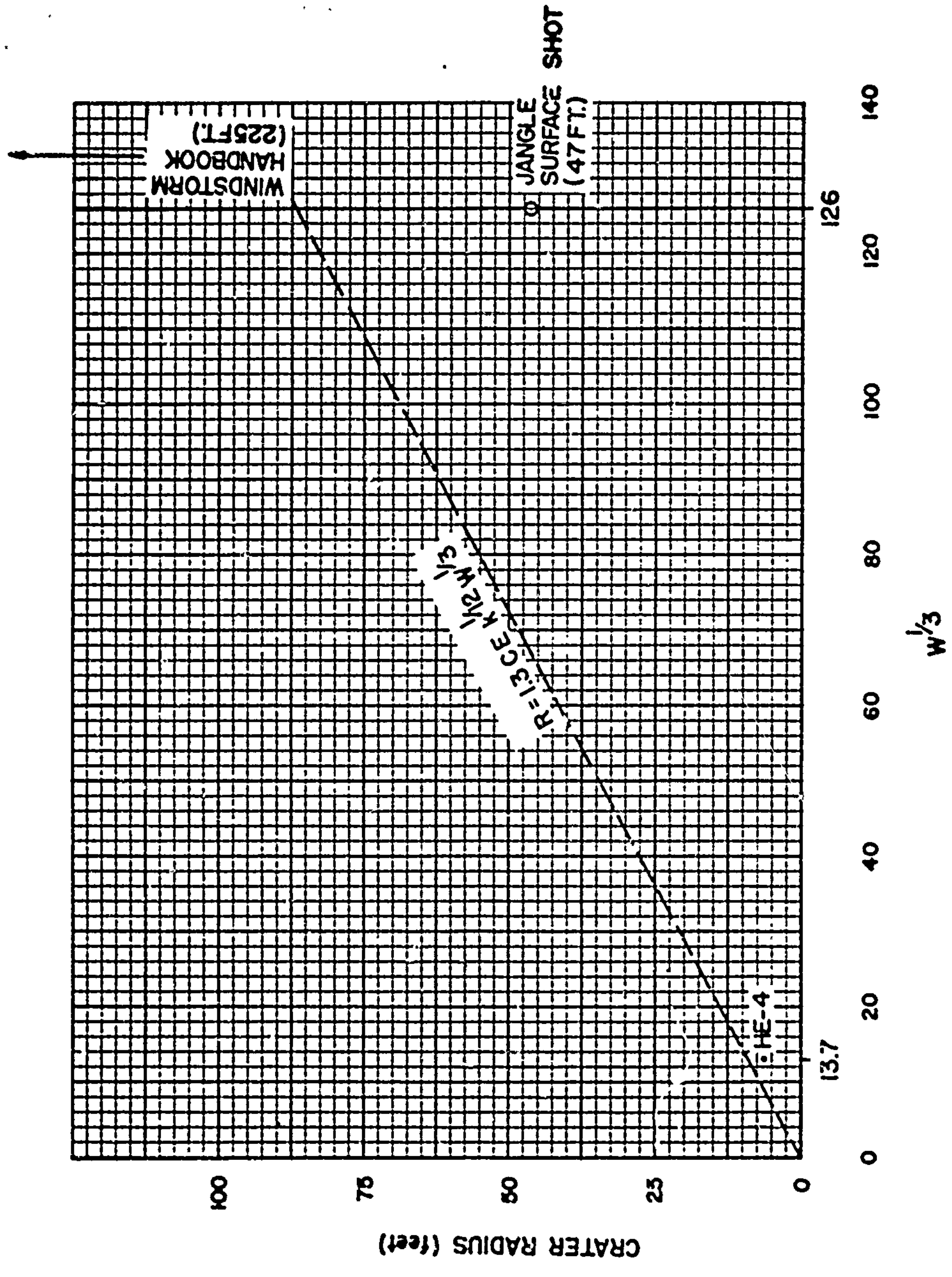

Fig. 3.19 Calculated and Observed Values of Crater Radius for Charge CG at Surface

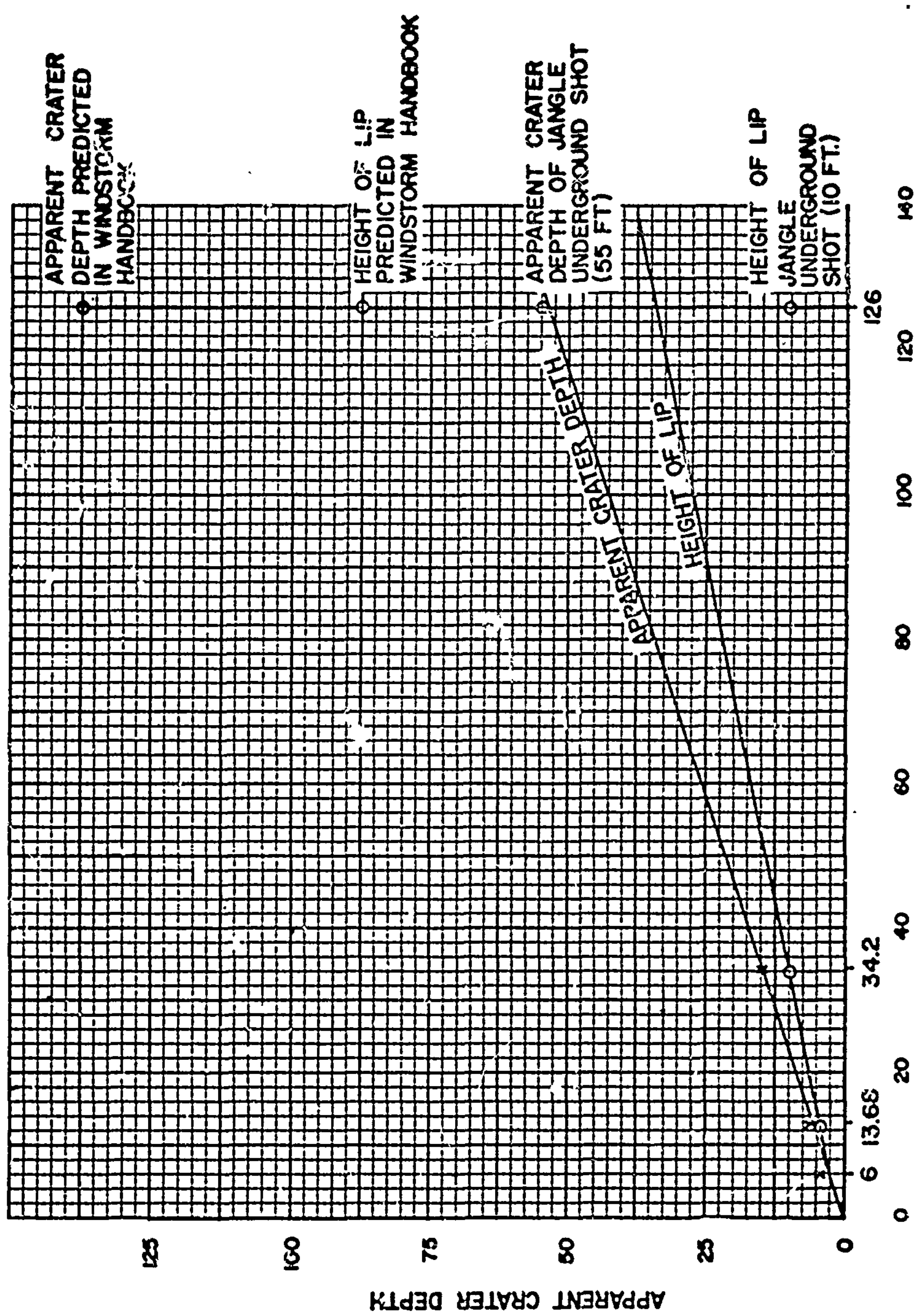

Fig. 3.20 Crater Depth and Height of Lip for Charge CG Underground

PROJECT 1(9)-3

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

From the information presented herein, the interested reader can form his own opinion as to what can be anticipated from the nuclear tests. The phenomenology is so complex that limited tests, based primarily on eye witness observations, cannot lead to any clear cut set of conclusions. However, the following guesses are the best that the writer can make.

4.2 SURFACE NUCLEAR SHOT

a. A base surge appears very unlikely.
b. There will be a good sized cloud produced at ground level by the passage of the air blast wave which may be mistaken for a base surge.
c.

Crater Radius	80-90 feet
Crater Depth	25-30 feet
Crater Area	25,000 feet^2
Crater Volume	25,000 cubic yards
Lip Radius	170 feet
Lip Height	7 feet
Maximum Altitude of Cloud	12,000 feet

4.3 UNDERGROUND NUCLEAR SHOT

a. There will be a considerable throw-out at the base of the plume which may be mistaken for a base surge.
b. The probability of a base surge appears very small. If a base surge forms the magnitude will be small.
c. A ground level dirt cloud will be produced by the air blast wave but will probably not cause as much interference with photography as that which occurred at GREENHOUSE.
d.

Crater Radius	140-150
Crater Depth	50-60 feet
Crater Area	60,000 feet^2
Crater Volume	60,000 cubic yards
Lip Radius	375 feet
Lip Height	14 feet
Maximum Altitude of Cloud	6,000 feet

e. Since it is an observed fact that the crater diameter is a readily scaled parameter for underground TNT explosions, then the immediate observation (photographic or otherwise) of the underground crater diameter may be a simple and reliable method for determining equivalent TNT mechanical yield of the nuclear weapon.

4.4 RECOMMENDATIONS

Of course, if predictions were always right there would be no need for experimental programs and field tests. The writer is inclined to believe that the firing of one underground and one surface atomic weapon will not give sufficient information on which to make reliable predictions for either offensive or defensive planning. A large number of well planned HE tests, all required to lead into a smaller number of nuclear tests, are necessary in order to produce reliable results.

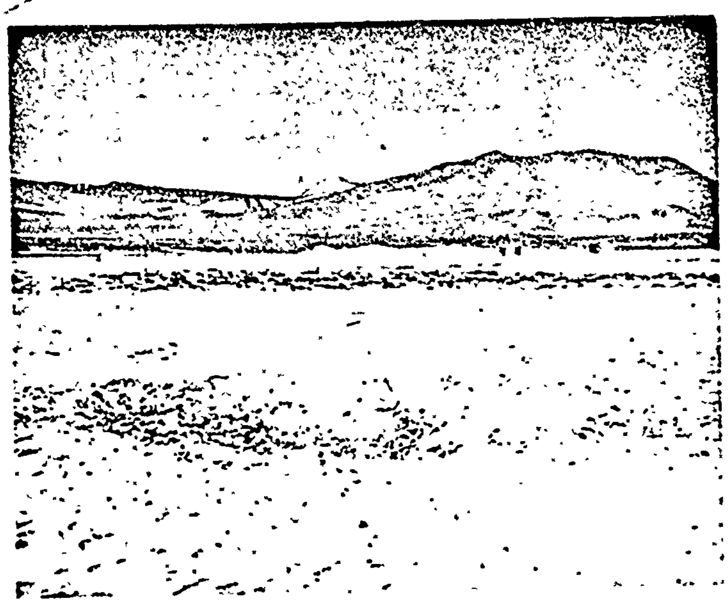

Fig. 4.1 Crater from Shot HE-4. On a small scale, this is probably an indication of the crater on the Surface Shot.

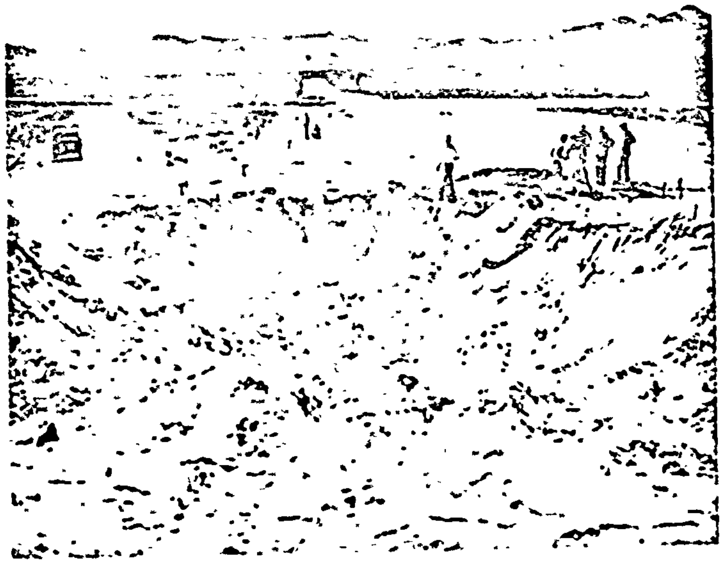

Fig. 4.2 Crater from Shot HE-2. The Underground Shot will probably be very similar with the diameter increased 3 1/3 times.