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Operation HARDTACK

April - October 1958

Project 1.10

BLAST OVERPRESSURE from VERY-HIGH-ALTITUDE BURSTS (U)

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HEADQUARTERS FIELD COMMAND
DEFENSE ATOMIC SUPPORT AGENCY
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WT-1615

OPERATION HARDTACK—PROJECT 1.10

BLAST OVERPRESSURE from VERY-HIGH-ALTITUDE BURSTS (U)

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FOREWORD

This report presents the final results of one of the projects participating in the military-effect programs of Operation Hardtack. Overall information about this and the other military-effect projects can be obtained from ITR-1660, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

ABSTRACT

The objective was the measurement of time of arrival, peak overpressure, and pressure versus time at five balloon-borne canisters suspended at various distances below a low-yield device (Shot Yucca) detonated at a very-high altitude. In order to circumvent telemetry blackout, the pressure data war to be stored on internal recorders and then played back into the telemeter transmitters, as well as telemetered directly. A power failure in the receiving station just before shot time rendered the command transmitter inoperative; in consequence, the canister recorders could not be turned on, and no delayed telemetering was possible. Direct telemetering was blacked out at the three closest canisters and the transmitter in the fourth had not responded to the turn-on command signal before power failure occurred, but a direct telemetering signal was received from the most-distant canister. An apparent pressure signal was recorded, but the wave form was abnormal, and the time of arrival and peak overpressure appeared to be mutually inconsistent. It is believed that the signal was spurious and may have been produced by damage to the canister. About 0.3 second after the arrival of the questionable pressure signature, the radio-frequency carrier from this canister was lost, and no further data was obtained. It is possible that the loss of signal represents the actual shock-arrival time.

PREFACE

One aspect of the very-high-altitude canister effort which demands recognition is the fact that Projects 1.10, 2.7, 8.2, and 9.2b simultaneously developed instrumentation and equipment that was required to function electronically and mechanically as a system. Because of the limited time available for research and development, some of the final modifications to ensure compatibility had to be carried out in the field in the last few days before the shot. The fact that the equipment for the entire program was ready on time and was launched with a reasonable hope of a successful outcome can be attributed, to a great extent, to the complete cooperation and intensive coordination that existed among project personnel, contractors, and the interested parties.

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INTRODUCTION

1.1 OBJECTIVE

Planning for the use of nuclear weapons in air defense requires knowledge of the way in which the basic weapon outputs—blast, thermal radiation, and nuclear radiation—vary with the altitude of detonation. The objective of the participation in Shot Yucca was to provide information on the variation with altitude of the blast output by obtaining measurements of blast overpressure versus distance at the highest altitude at which direct measurements of this kind were deemed feasible. For the measurement of peak overpressure, primary reliance was placed on the measurement of shock-arrival time, from which peak overpressures may be computed by means of the Rankine-Hugoniot equations. Direct measurements of pressure-versus-time wave forms were also desired as a secondary objective.

1.2 BACKGROUND

The feasibility of conducting a weapon-effect test at an altitude in the neighborhood of 100,000 feet was studied by the Air Force Special Weapons Center (AFSWC) with the cooperation of the Air Force Cambridge Research Center (AFCRC) during 1954 and 1955. After examining various possible methods of deployment of a nuclear device with an instrument array accurately positioned with respect to the point of burst, it was decided (Reference 1) that the method offering the greatest probability of success would be to deploy both the nuclear device and the telemetering instrumentation array on a dragline from a single balloon.

A proposal for a test based on this method of deployment was presented to the Armed Forces Special Weapons Project (AFSWP) on 17 November 1955. In order to minimize development time and cost, it was proposed to employ, so far as possible, the same blast-pressure telemetering system previously developed for AFCRC by the Pacific Division, Bendix Aviation Corporation, and used successfully during Operations Buster-Jangle, Snapper, Ivy, Upshot-Knothole, Teapot, and Redwing to measure blast pressures on arrays of parachute-borne gages.

During Shot 10 of Operation Teapot (Reference 2), detonated at an altitude of 36,645 feet, data from the two closest parachute-borne canisters at slant ranges of 640 and 720 feet was lost due to a brief blackout of the telemetering signal immediately after shot time. It was believed that the blackout was caused by ionization of the surrounding air by prompt gamma radiation. Because the theory of this effect did not appear to be sufficiently well developed to permit a reliable prediction of what the attenuation would be at much higher altitudes, or whether blackout could be avoided by going to higher carrier frequencies for telemetering, it was decided that, as insurance against loss of data, the instrumentation should provide for data storage and delayed telemetering.

The upper limit of the range of blast-pressure measurements was chosen on the basis that it should be as close as possible, and still provide a reasonable probability that the instrumentation would survive the thermal and blast environment long enough, after the disappearance of the expected ionization blackout, to transmit at least the time of shock arrival. With an assumed yield of 2 kt, a range of 750 feet was considered as the minimum for instrumentation of the type planned. For scaling test data to other yields and altitudes, the slope of the curve of peak overpressure versus distance is an important factor. It was therefore considered preferable to spread the limited number of measurements possible over a fairly long baseline, rather than concentrate them in the more-limited range of overpressures high enough to be of direct interest in connection with effects on targets. An outer range limit of about 3,000 feet was considered adequate to establish the general trend of the curve for overpressure versus distance and not too long to be accommodated by the proposed dragline deployment system.

Estimated weights of the proposed instrumented canisters, nuclear device, and command systems, together with the known load-versus-altitude capability of the 128-foot tapeless polyethylene balloon that had been selected as the carrier, indicated that six instrumented canisters would be carried to approximately the desired altitude. To allow for a margin of error in the preliminary estimate of the canister weights, the number was reduced to five. The distances from the burst were chosen to be 750, 1,050, 1,500, 2,100 and 3,000 feet, forming an approximately geometrical progression between the end points.

1.3 THEORY

1.3.1 Sachs Scaling. Results from previous tests at lower altitudes indicated that the Sachs scaling (Reference 3) gives an adequate representation of the effect of altitude of burst up to the height of Shot 10 during Operation Teapot. This scaling law may be expressed as follows: If f(R) is the free-air peak overpressure at slant range R for a 1-kt burst in a homogeneous atmosphere at sea-level pressure and temperature, then the peak overpressure at slant range R at the altitude h of the burst of a device of yield W is

$$P(R,h) = k^3 f(kR/S) \qquad (1.1)$$

Where: $k^3 = P_0(h)/P_0(o)$

$S = W^{1/3}$

$P_0(h)$ = ambient pressure at burst altitude

$P_0(o)$ = ambient pressure at sea-level in the standard atmosphere to which the function f(R) is referred (here taken as 14.70 psi)

If $\tau(R)$ is the duration of the positive overpressure phase for 1 kt in the standard sea-level atmosphere, the Sachs scaling law for positive-phase duration may be written as

$$t_+(R,h) = \frac{S}{k}\frac{c(o)}{c(h)}\tau(kR/S) \qquad (1.2)$$

Where: c(h) = ambient sound velocity at burst altitude

c(o) = ambient sound velocity in the standard sea-level atmosphere (here taken to be 1,116 ft/sec)

Shock travel time scales in the same way.

Thermal-radiation phenomena do not scale with either altitude or yield in the same way as hydrodynamic motions. Therefore, the early stages of a nuclear explosion, during which there is appreciable coupling between radiative transport and hydrodynamic motion, cannot be expected to follow Sachs scaling. So long as the amount of energy emitted as thermal radiation during these early, strongly coupled stages is small, this will have little effect on the hydrodynamic motion at later times, when there is negligible coupling between radiation and hydrodynamics; therefore, Sachs scaling should be applicable to the blast wave to a good approximation. If the energy of the early thermal radiation is not a negligible fraction of the total yield, Sachs scaling cannot be expected to be directly applicable. However, it may still be possible to retain the form of Sachs scaling and determine a correction factor to be applied to the yield to define an effective blast yield W_h for insertion in Equations 1.1 and 1.2.

1.3.2 Variation of Effective Blast Yield with Altitude. References 4 and 5 give an approximate theoretical treatment of the altitude dependence of the effective blast yield. In those calculations, the stage of appreciable radiation-hydrodynamic coupling is assumed to extend to the time at which the temperature at the shock front is about 3,000 K and the thermal radiation emitted prior to this time is assumed to be lost energy, so far as further propagation of the blast wave is concerned. On this basis, the effective blast yield is expressed as:

$$\log (W_h/W) = \left(\frac{\rho(o)}{\rho(h)} - 1\right) \log (1 - \alpha) \qquad (1.3)$$

Where: $\rho(o)$ = sea-level density in the standard atmosphere
$\rho(h)$ = ambient atmospheric density at burst altitude
α = the fraction of the total yield that is emitted prior to the 3,000 K shock stage in a sea-level burst

In Reference 4 the constant α was estimated to be about 0.01. The more detailed calculations given in Reference 5 lead to a value of 0.0075. For the ambient conditions during Shot 10 of Operation Teapot, the value of $\rho(o)/\rho(h)$ was 3.57. For this case, Equation 1.3 gives W_h/W = 0.974 if α = 0.01 and W_h/W = 0.981, if α = 0.0075. In either case, the reduction in effective blast yield is so much less than the probable error of the actual yield that no observable departure from Sachs scaling was expected and, within the normal range of variability of blast pressure measurements, none was observed. For the expected ambient conditions of Shot Yucca the value of $\rho(o)/\rho(h)$ is about 50. Equation 1.3 then gives a value of 0.61 for W_h/W if α = 0.01 and a value of 0.69 if α = 0.0075. The latter figure, with an assumed yield of 2 kt, was used in making preshot predictions for the purpose of choosing gage ranges and determining other parameters needed in the design of instrumentation.

Later and more detailed theoretical studies of the high-altitude burst problem (see, for example, References 6 and 7) have led to the conclusion that Equation 1.3 probably overestimates the effect of reduced ambient density by a rather large factor at altitudes above 100,000 feet. Consequently, an equation of that form is now considered obsolete and is mentioned here only because of its use in preshot planning.

1.3.3 Effect of Difference in Altitude Between Burst and Gage. Equations 1.1 and 1.2 refer to the case in which the overpressure is measured at the same altitude as the burst. It has been found from measurements on parachute-borne gages and aircraft at low to moderate shock strength (i.e., ratio of overpressure to ambient pressure) that a satisfactory empirical correction for the difference in ambient conditions between burst point and gage may be obtained by replacing the ambient pressure at shot altitude, $P_0(h)$, with the ambient pressure at gage altitude, $P_0(z)$, in defining the scale factor k that appears in these equations. In Equation 1.2 the sound velocity at shot altitude, c(h), is to be replaced by the average sound velocity between burst and gage altitudes. There is some question as to whether this method of correction is applicable at very-low shock strengths and large differences in ambient pressure or at very-high shock strengths, but it is probably sufficiently accurate for the present purpose, because it is a small correction in any case, amounting to only 5 percent at the lowest canister.

1.3.4 Calculation of Peak Overpressure from Shock Velocity. At the closer gage locations, where shock strengths and temperatures are high, the problem of pressure-gage calibration is a serious one. Although a calibration for effects of steady-state flow at appropriate Mach numbers has been carried out in a wind tunnel, as described in Appendix C, the peak overpressures derived from shock-velocity measurements by means of the Rankine-Hugoniot equations are believed to be more reliable. The pertinent equations in a form suitable for application of the National Bureau of Standards (NBS) thermodynamic tables for air (Reference 8) are as follows:

$$\left(\frac{U}{c_0}\right)^2 = \frac{P_0}{\rho_0 c_0^2} \cdot \eta \frac{\xi - 1}{\eta - 1} \tag{1.4}$$

$$(\xi - 1)\left(1 + \frac{1}{\eta}\right) = 2\frac{\rho_0}{P_0}(H_S - H_0) \tag{1.5}$$

$$\eta = \xi \frac{Z_0 T_0}{Z_S T_S} \tag{1.6}$$

Where: Subscript zero = reference to ambient conditions ahead of shock front

TABLE 1.1 SHOCK-VELOCITY FUNCTION VERSUS SHOCK STRENGTH

Ambient conditions T_0 = 225.4 K, P_0 = 15.85 mb. This table was computed before the shot, for the expected ambient pressure and temperature. The values given in the third column would not be significantly changed if the actual ambient conditions, P_0 = 27.4 mb, T_0 = 223.2 K had been used.

Shock Temperature	$\xi - 1$	$\frac{(U/c_0)^2 - 1}{\xi - 1}$
K		
230	0.0727	0.859
250	0.4289	0.857
270	0.8369	0.857
300	1.5117	0.857
350	2.732	0.856
400	4.010	0.856
500	6.657	0.855
600	9.394	0.853
700	12.216	0.851
800	15.116	0.849
900	18.093	0.847
1,000	21.14	0.845
1,100	24.25	0.844
1,200	27.42	0.842
1,300	30.64	0.840
1,400	33.92	0.839
1,500	37.25	0.837

Subscript s = reference to conditions immediately behind the shock front
P = absolute pressure
ρ = density
T = absolute temperature
U = shock velocity
c = sound velocity
H = enthalpy
Z = compressibility factor = $P/\rho RT$
R = gas constant for air
ξ = P_S/P_0
η = ρ_S/ρ_0

It is convenient to define a quantity α by the relation

$$H = \alpha P/\rho = \alpha ZRT \tag{1.7}$$

so that Equation 1.5 becomes

$$\eta = \frac{1-\xi+2\alpha_s\xi}{\xi-1+2\alpha_0} \tag{1.8}$$

Equations 1.6 and 1.8, together with the NBS tables, which give Z and H as functions of temperature and pressure, determine η as a function of ξ. This is most conveniently found by taking a sequence of values of the shock temperature T_s and computing approximate values of ξ by substituting the ideal gas values, $Z = 1$ and $\alpha = 3.5$, in Equations 1.6 and 1.8. Since Z and α are only slightly dependent on the pressure in the range of interest here, Z_s and α_s may be determined by entering the NBS tables with the given values of T_s and the pressures corresponding to the approximate values of ξ. Equations 1.6 and 1.8 are then solved for ξ and η using these values of Z_s and α_s. $(U/c_0)^2$ is then determined from Equation 1.4. For ambient conditions $T_0 = 225.4$ K, $P_0 = 15.85$ mb, the NBS value of the coefficient $P_0/\rho_0 c_0^2$ in Equation 1.4 is 0.71373. Values of the ratio $[(U/c_0)^2-1]/(\xi-1)$ as a function of $\xi-1$ calculated in this way are given in Table 1.1. Even at the highest shock strengths with which we are concerned here, this ratio differs very slightly from the ideal diatomic gas value of six sevenths.

In converting the measured average shock velocities over the intervals between canisters into peak overpressures by means of the ratios given in Table 1.1, it will be assumed that the interval velocity is equal to the value of the instantaneous velocity at the mid-point of the interval. This assumption has been checked by numerical integration, using the expected form of the curve for peak overpressure versus distance, and found to be sufficiently accurate for practical purposes within the range of intervals used here.

Chapter 2
PROCEDURE

2.1 OPERATIONS

Canister checkout, which began on D−7, was completed on D−1 when oscillograph recordings were made of simulated operations. At H−6¼ hours canisters were loaded in the deployment tube and a final check was made of the telemeter receiving equipment. Balloon launch was at H−3¼ hours; during the balloon ascent to burst zero position, the USS Boxer was proceeding to a point 30 miles north of predicted surface zero.

At H−7 minutes the canisters' transmitters and miniature-tape-recorder electronics were turned on by command. At H−2 minutes, the first acoustic charge contained in Canister 5 was to have been deployed and detonated (detonation to occur about 64 feet below Canister 5, since the charge contained a 2-second delay fuze). At H−2 minutes and 10 seconds, the receiving-station tape recorder was turned on to record telemetered acoustic arrival times from each canister. At H−15 seconds, both oscillograph recorders were turned on and allowed to run until H+3 minutes. One recorder registered the telemetered radio frequency, including the radio-frequency signal strength, from Canister 5, and the second recorder registered signal strengths of the radio-frequency transmissions from Canisters 1, 2, 3, and 4, in addition to recording the signal strength of the radio frequency emanating from the nuclear device. The tape recorders in Canisters 1, 2, 3, and 4 were to be started at H−10 seconds, and at H−9 seconds the second acoustic charge was to be released from Canister 5. A command tone at H−2 seconds was to have fired the Project 2.7 rocket contained in Canister 5, causing that canister to swing approximately 25 feet from the vertical at zero time. The command at H−2 seconds also served to lock the command receiver out of operation in Canister 5.

The receiving-station tape recorder started recording telemetered canister data at H−2 minutes and 10 seconds and continuously recorded until canisters became inoperative. At any time prior to the command at H−10 seconds, canister power could have been turned off at Canisters 1, 2, 3, and 4, and the canisters made ready for a new zero time. A battery life of 30 minutes would thus have permitted several delays.

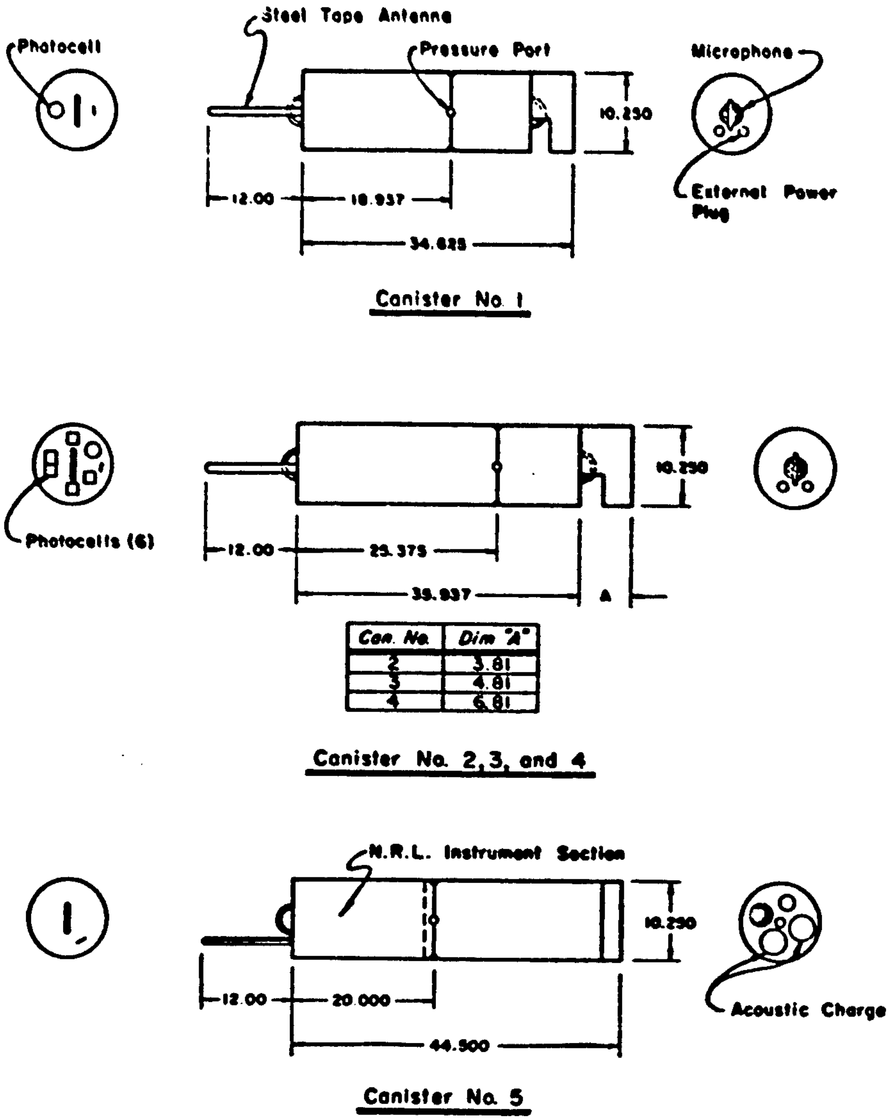
2.2 INSTRUMENTATION

In addition to pressure transducers, the canisters contained thermal-radiation sensors provided by Project 8.2, AFCRC, and nuclear-radiation instrumentation provided by Project 2.7, Naval Research Laboratory (NRL). Pertinent discussion of that instrumentation may be found in the respective project reports. A discussion of Project 1.10 instrumentation follows.

2.2.1 Canisters.

As depicted in Figures 2.1 and 2.2, each canister was simply a right circular cylinder 10.25 inches in outside diameter. Canister lengths and weights are given in Table 2.1. The lengths and weights shown in the table include skirts which varied from canister to canister, depending upon the length of nylon dragline each skirt contained.

A ratio of approximately 2 pounds of instrumentation for each pound of structure was obtained to meet the size and weight limitations necessarily imposed by the balloon carrier system. The use of batteries for internal heating was therefore limited. To achieve reasonable internal temperatures, even though canisters were exposed to ambient temperatures varying from −90 C to −55 C, the canister skin consisted of ⅝-inch styrofoam and ⅛-inch fiberglass sheets covered with an outside layer of heavy (40-mil) aluminum foil. A 4½-pound pack of Yardney silver-cell batteries provided approximately 20 watts of thermostatically controlled internal heat. In addition, solar heating of canisters helped maintain internal temperatures estimated to be no lower than 30 F. Actually, the skin configuration and aluminum-foil surface were a compromise between desired solar heating and required thermal-radiation protection at zero time.



Con. No.	Dim "A"
2	3.81
3	4.81
4	6.81

Figure 2.1 External configuration of canisters.

2.2.2 Telemetering. Each canister contained a Bendix TXV-13, 2-watt transmitter and a variable-reluctance absolute-pressure transducer manufactured by Northam Electronics Company. As indicated in Table 2.1, basic data was to be supplied to transmitters through subcarrier oscillators, which ranged from 7.35 to 70.0 kc. The mixed outputs of the subcarriers modulated the transmitter radio frequency, which was picked up by ground receivers tuned to respective transmitter frequencies.

Canisters 2, 3, and 4 contained five thermal-radiation sensors in addition to a background-radiation detector. In addition to the tape recording of all six thermal measurements in the canister and subsequent playback of the data on a time-sharing arrangement through the 40.0-kc and 70.0-kc subcarriers, two thermal measurements per canister were to be telemetered directly. Overpressures measured at Canisters 1, 2, 3, and 4 were to be telemetered directly in addition to being recorded, played back, and re-telemetered. Overpressure measured at Canister 5 was to be telemetered directly. The top 19 inches of Canister 5 contained NRL instrumentation only. This instrumentation, which measured prompt nuclear radiation, also

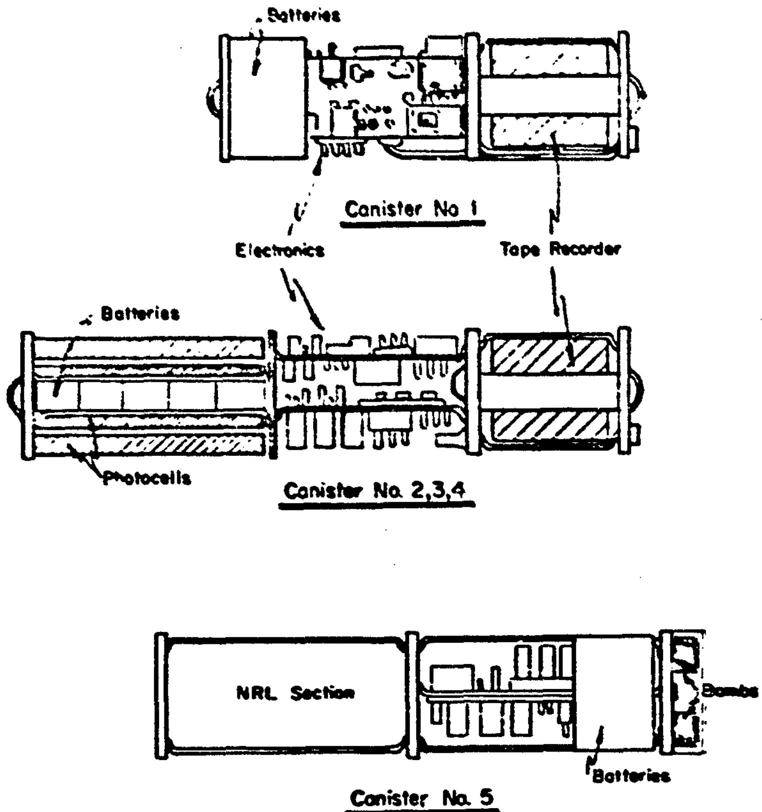


Figure 2.2 Canisters with covers removed.

provided for data recording and playback into the Bendix telemetering system via the 70.0-kc subcarrier oscillators.

On Canisters 1, 2, 4, and 5, a ¼-wave flexible steel antenna mounted off center on the top of each canister provided excellent transmission. For reasons outlined in Section 2.2.5, the steel antenna on Canister 3 was replaced with a dipole antenna constructed from the transmitter's coaxial output line. The coaxial line was not allowed to contact the canister skin and was lashed to the nylon dragline for support. During checkout of equipment of Projects 1.10 and 8.2 in preparation for Shot Yucca, the miniature tape recorders exhibited an intolerable amount of noise in the final stage of their playback amplification. Despite every effort by Project 8.2 personnel to filter the noise and despite efforts by Project 1.10 personnel to eliminate its source, the anticipated signal-to-noise ratio of the recorder's playback system was approximately 1 to 1 on the Project 8.2 portion of the recorder. The Project 1.10 portion of the recorder exhibited normal operation during this checkout. In view of the fact that Project 8.2 personnel estimated that there was little chance of obtaining thermal-radiation data from a tape recorder whose output noise was comparable to the anticipated output signal, it was decided that the modified antenna, which produced no appreciable recorder noise, was worth using, although there was probably only an even chance as to whether the antenna would be working after zero time.

Canister power was provided by a $5\frac{1}{2}$-pound pack of Yardney silver-cell batteries, Types HR-5, HR-1, and HR-01.

2.2.3 Remote-Command System. Since canister operations were timed relative to a flexible zero time, a remote-command system was developed to regulate canister operations at slant ranges of up to 100 miles. Considerable difficulty was experienced with the command system during the preoperational trials before it was determined that radio frequency from the canister transmitter was being radiated and conducted into the command receiver, causing the receiver to shift frequency (Appendix A). Free use of filters and a copper-box shield for the receiver eventually provided operations at sensitivities down to $\frac{1}{2}$ μa.

The command transmitter was located in the receiving-station trailer and radiated approximately 70 watts from a whip antenna located on top of the trailer. The transmitter operated at 42.138 Mc and was designed to transmit five tones, as indicated in Table 2.2.

TABLE 2.1 CANISTER DATA

Function	Canister 1	2	3	4	5
Length, inches	34.625	39.75	40.75	42.75	44.500
Weight, pounds	55.00	72.00	74.50	75.75	84.00
Transmitter frequency, Mc	250.00	251.25	247.50	253.75	256.25
Subcarrier oscillator frequencies:					
Acoustic wave-arrival time and zero time, kc	10.50	10.50	10.50	10.50	10.50
Standard timing, kc	7.35	7.35	7.35	7.35	7.35
Overpressure, kc	14.50	14.50	14.50	14.50	14.50
Thermal radiation, kc	—	40.00	40.00	40.00	—
	—	70.00	70.00	70.00	—
Nuclear radiation, kc	—	—	—	—	70.00

Command Tone D, to be transmitted at H−10 seconds to Canisters 1, 2, 3, and 4, and Tone E, to be transmitted at H−2 seconds to Canister 5, locked Tone C out of operation at each canister. Because the canisters were designed to telemeter continuously after zero time, even though they might be tumbling, the shock-sensitive relays in the command-receiver circuit could not be permitted to turn off canister power inadvertently. A 6-foot length of insulated No. 18 copper wire, hanging from the bottom plate of each canister, served as the command-receiver antenna.

2.2.4 Telemeter Receiving and Recording. The receiving-station trailer was equipped with seven Clarke receivers: five were tuned to canister-transmitter frequencies, one was tuned to a Project 9.2a telemetered frequency emanating from the weapon package, and one served as a spare. Outputs from each operating receiver, in addition to a 1,000-cycle timing reference, were tape recorded on a seven-channel Ampex 800 for subsequent data reduction. Because the immediate loss of radio-frequency signal strength from canisters at zero time provided recordings of zero time, the radio frequency being recorded from the weapon package served as a backup zero-time reference. A Nems-Clarke preamplifier, connected between the helical receiving antenna and the receivers, provided a strong signal strength.

The subcarrier information and radio-frequency signal strength transmitted from Canister 5 was also recorded in real time on one of the ground-station oscillograph recorders. Real-time transmissions of radio-frequency signal strengths from Canisters 1, 2, 3, and 4 were also recorded on a second oscillograph recorder.

Immediately after the detonation, the recorded subcarrier-modulated radio frequencies were to be played back via an Ampex 307 to the receiving-station discriminator, which would filter the mixed subcarriers and reproduce the original modulating signals. These signals were to be fed automatically to galvanometers for oscillograph recordings of pressure-versus-time data. For the data on radiation, the discriminator output was to be fed to the Ampex 800, and the taped information on thermal and nuclear radiation was to be turned over to Projects 8.2 and 2.7, respectively. The telemetered radio frequencies, though recorded on a single tape, were to be played back into the discriminator one at a time, because the trailer contained only one discriminator.

2.2.5 Canister Tape Recorders. A dual-type recorder-playback system was developed by Project 8.2 for joint use of Projects 8.2 and 1.10. Developed under contract by Gulton Industries, Inc., the miniature unit ($8\frac{1}{2}$ inches in diameter, 7 inches long, and 11 pounds in weight) was designed to record six channels of thermal-radiation data on one magnetic tape and one channel of pressure data on the other. Both tapes were driven by a common motor. (The reader is referred to the Project 8.2 report for a description of the recorder's thermal-radiation operation.) The overpressure unit recorded for $2\frac{1}{2}$ seconds at a tape speed of 15 in/sec and played back automatically and continuously at the same tape speed into the canister transmitter. The unit actually was to record the pressure pickup modulation of the 14.5-kc subcarrier, a 7.35-kc timing signal, and a zero-time mark fed directly to the recording head. The timing signal was supplied from a canister oscillator and permitted the monitoring of any variation in tape speed. The zero-time pulse was supplied from a commercial photocell on Canisters 1, 2, 3, and 4. Because pressure data was telemetered "live" from Canister 5, Project 1.10 utilized a zero-time pulse produced by the instantaneous loss of radio frequency at zero time, in addition to a zero-time pulse supplied by the NRL instruments.

TABLE 2.2 COMMAND TONES AND TONE FUNCTIONS

Tone	Tone Frequency	Time of Initiation	Function
	cps		
A	288.5	H−7 min	Turned on transmitter and miniature tape recorder electronics. Also closed NRL power circuit in Canister 5.
B	306.7	H−2 min and H−9 sec	Closed microphone circuit and fired acoustic charges.
C	326.0	—	Capable of turning off canister power.
D	346.0	H−10 sec	Turned on tape-recorder motors and locked tone C out of operation on Canisters 1, 2, 3, and 4.
E	368.5	H−2 sec	Fired the NRL rocket in Canister 5 and simultaneously cut the No. 5 command receiver out of operation.

The nuclear-radiation data to be measured in Canister 5 was similarly to be recorded and played back by a miniature recorder of another design. (The reader is referred to the Project 2.7 report for a description of that operation.)

The history of the miniature tape recorder is rather involved but, nevertheless, demands documentation. The recorders were designed as an integral part of the canister instrumentation, and delivery of finished units was scheduled for September 1957. When the recorders were delivered to Bendix Aviation Corporation in mid-January 1958, it was determined by personnel of Projects 1.10 and 8.2 that they were not acceptable, because of mechanical malfunctioning and poor electronic operation. Northam Electronics Company of Altadena, California, was induced to accept the job of improving the recorder's mechanical operation, while personnel in Projects 1.10 and 8.2 worked together to improve the recorder electronics. A system checkout of the canister and modified recorders was performed at Bendix Aviation Corporation during the 3 weeks prior to departure of Project 1.10 personnel and the Project 8.2 recorder expert to the Eniwetok Proving Ground (EPG).

During the system checkout, in which recorders and canisters were operated under simulated flight conditions in the altitude chamber, the canister transmitter was operated through a wattmeter, rather than through the canister antenna (Appendix B). (The wattmeter had to be used because the canister was operating in a sealed chamber.) During bench checkouts, however, when an antenna could have been utilized (though not very conveniently), a wattmeter was again employed to transmit canister radio frequency to the station receivers, located some 200 feet from the laboratory. Under these test conditions, the canister-recorder system was adjudged to be very satisfactory, and the project personnel hurriedly departed for dry-run commitments at the EPG.

During the routine checkout of the tape recorder in preparation for the first instrumented canister dry run, it was discovered that the canister antenna was radiating a minute amount of radio frequency into the tape-recorder-playback amplifier system. The amount being radiated, however, was magnified through four stages of amplification, until the recorder output had a noise level of 6,000 to 7,000 volts. Personnel of Project 8.2 made free use of radio-frequency chokes and filter circuits and shielded each lead connected to the recorder. In this manner the output noise level was reduced to approximately 2 to 3 volts. The level of the recorder signals, however, was also expected to be approximately 2 to 3 volts.

When it was finally concluded that no further modifications could be performed on the recorder, except under closely controlled laboratory conditions, and that little could be done about modifying the canister antenna system, it was decided to replace the antenna for Canister 3 with a special dipole, as discussed in Section 2.2.2.

2.2.6 Special Instrumentation. In order to compute peak overpressures to an accuracy within 5 percent, it was necessary to know canister separation distances to within 1 percent. The stretch and creep characteristics of the nylon dragline necessitated a measurement of canister separation distances just prior to zero time. This measurement was to be accomplished by generating an acoustic wave from a ½-pound TNT charge expelled and detonated 2 seconds after release from Canister 5. Two such charges were to be released, the first at H−2 minutes and the second at H−9 seconds. A microphone on the bottom of each canister was to register acoustic-wave arrival times, which were to be telemetered to the receiving station. This information, together with ambient temperature provided by radiosonde, would have enabled the distances to be computed.

A rigorous static-load test on identical dragline material was also performed during the canister-development period in order to have additional knowledge of canister separations. This data was to serve as backup information in case of a malfunction of the acoustic system.

2.2.7 Calibration. Calibration of the canister electronics is basically a calibration of the data sensor, subcarrier oscillator, and telemeter transmitter performing together under conditions of known data input, that is, a known input causes a certain subcarrier frequency output. In the case of the canister pressure circuit, shock-box calibration of a sufficient number of pressure inputs to plot a curve was performed, for each canister, in the contractor's plant. Similar, but less comprehensive, calibrations were performed on the thermal- and nuclear-radiation instruments at the contractor's plant and at the EPG. For those instruments, however, primary calibration centered on the data-sensing instruments, rather than on the instrument-subcarrier-transmitter system.

In addition, the possibility of subcarrier center-frequency drift was checked several minutes prior to zero time by the recording of unmodulated telemetered subcarriers and, also, by visual notation of each subcarrier center frequency on ground-station meters.

Because of the disturbance of the shock flow caused by the presence of the canister, the pressure, as seen by the canister gages (ΔP_g), is not generally the same as the free-field pressure (ΔP_s) at high shock strengths. Therefore, dynamic wind-tunnel calibrations of scaled-down canisters were performed at Wright Air Development Center (WADC). The results are presented in Appendix C.

Chapter 3
RESULTS

3.1 OBSERVED DATA

At about H−2½ minutes, a large drop in voltage occurred in the power supply line to the receiving-station trailer. The drop was only momentary, but the current surge on recovery was sufficient to throw the protective circuit breakers in the command transmitter. A delay of the shot was requested immediately, in order to locate and remedy the difficulty. However, a command decision was made to fire at the previously determined H hour. As a result, the command transmitter was inoperative, the acoustic charges could not be fired, and the canister tape recorders could not be turned on. Therefore, no delayed telemetering was possible.

The ionization blackout at zero time quenched the radio-frequency signal from all canisters below the threshold of detectability. The subsequent behavior of the signal from the individual canisters was as follows:

Canister 1: Range was about 758 feet. No radio-frequency signal was regained at any time. Canister instrumentation is presumed to have been destroyed or inactivated by the shock-sensitive command relays.

Canister 2: Range was about 1,062 feet. Signal recovered to detectable level at about 3.2 seconds, reaching approximately preshot level at about 4.65 seconds. Signal strength varied because of tumbling, damage, or both, but would presumably have transmitted data if canister recorder had been in operation.

Canister 3: Range about 1,517 feet. A barely detectable signal began to be received at about 1.05 seconds. Signal strength was small and variable, never reaching the level needed for subcarrier discrimination. It is believed that the dipole antenna on this canister was damaged beyond the point of effective operation.

Canister 4: Range was about 2,124 feet. This canister had not responded to the turn-on command signal before power failure occurred; therefore, no signal was received at any time. Interference from the voice countdown network and the command transmitter gave an indication of signal strength prior to shot time. Another attempt to activate power was being made just as the power surge occurred.

Canister 5: Range was about 3,028 feet. Detectable signal recovery began at about 0.09 second. Subcarrier discrimination began at about 0.19 second. Signal strength remained strong until about 1.39 seconds, then began decreasing. Subcarriers were lost at about 1.421 seconds. Radio-frequency signal was subsequently regained in short bursts until recording was stopped at about H+3 minutes.

A tracing of the directly telemetered pressure record from Canister 5 is shown in Figure 3.1. The pertinent data on the apparent shock arrival shown on the trace is presented in Table 3.1.

Additional information on the telemetry blackout is given in Appendix D.

From radiosonde data provided by the USS Boxer, the ambient temperature at burst altitude was −48 C and at Canister 5 it was −52 C. In interpreting the observed travel time, a mean temperature of −50 C will be used with a corresponding sound velocity of 983 ft/sec.

3.2 CANISTER RANGES

In the absence of acoustic range data, it is necessary to use the estimated stretched length of the nylon draglines to determine the ranges. Data has been provided by the Materials Test-

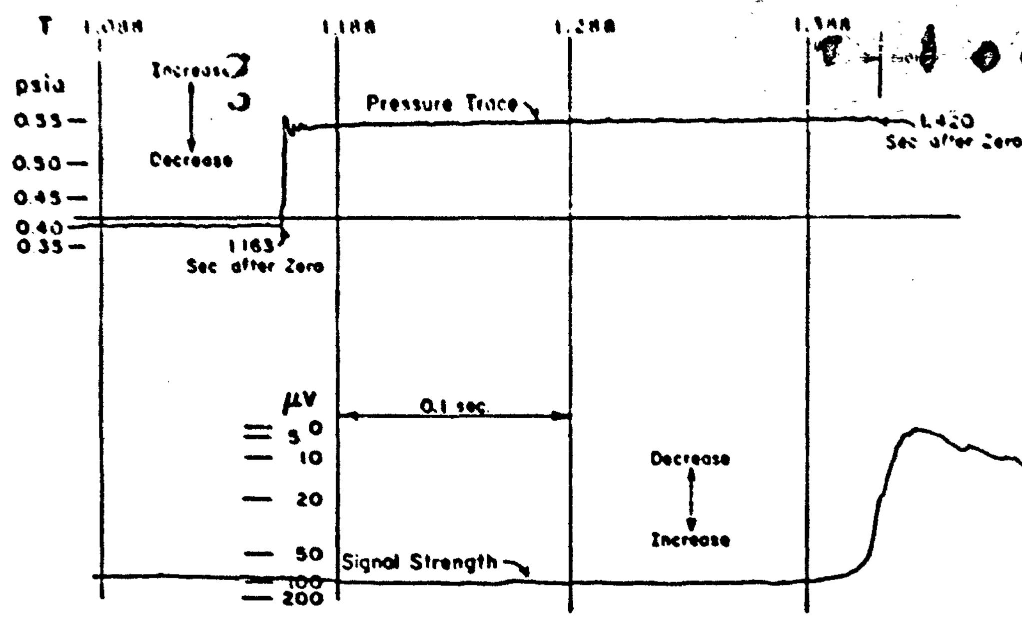


Figure 3.1 Trace of direct telemetering, Canister 5.

ing Laboratory, WADC, on elongation versus load and time for the 1,000-pound test nylon braid used between Canisters 2, 3, 4, and 5, and for one load (276 pounds) on the 1,500-pound test nylon braid used between the nuclear device and Canister 1 and between Canisters 1 and 2. Some extrapolation, using the 1,000-pound curve as a guide, has been necessary to estimate the elongation of the 1,500-pound line under the actual loads (379 pounds between weapon and

TABLE 3.1 OBSERVED DATA FROM CANISTER 5

Ambient pressure, P_0 = 27.4 mb = 0.397 psi
Peak shock overpressure, ΔP_s = 0.141 psi
Time of arrival, T = 1.163 sec

Canister 1, 320 pounds between Canisters 1 and 2). The ranges given in the preceding section are the ranges at zero time, computed from the WADC data taken at 3½ hours after deployment. At this time, the creep rate of the nylon line had settled down to a small value, so that the exact time under load is not important.

The free-fall distance at the time of apparent shock arrival at Canister 5 is 21 feet, giving a range of 3,049 feet for this canister at that time.

Chapter 4
DISCUSSION

The pressure wave form shown in Figure 3.1 is distinctly atypical, in that pressure did not decrease behind the shock front but, instead, appeared to increase slightly up to 0.26 second after shock arrival time, at which point the canister signal was lost for the second time. It is conceivable that the increase in apparent pressure behind the shock front could have been caused by changing orientation of the canister. On the other hand, it is also possible that the canister instrumentation suffered radiation or thermal damage and the apparent pressure signal was actually an artifact caused by malfunctioning of some circuit component.

The calculated travel time to a range of 3,019 feet, computed by modified Sachs scaling for the prevailing ambient conditions, is shown as a function of effective blast yield, W_h, in Figure 4.1. The observed travel time of 1.163 seconds implies an effective blast yield of about 3.5 kt. The accepted yield of the device used in this shot was about 1.7 kt. The value used for the elongation of the nylon dragline may be slightly in error, but no reasonable assumption regarding this factor will reduce the computed effective blast yield below the rated yield, since even if we use the unstretched length of the dragline, the value for computed effective blast yield will be 1.84 kt.

The peak overpressure calculated by modified Sachs scaling for a range of 3,049 feet is shown as a function of effective blast yield in Figure 4.2. As indicated in Figure 4.2, the observed value of ΔP corresponds to an effective blast yield of about 0.46 kt. If the range was less than the assumed 3,049 feet, the computed effective yield would be even smaller. Thus, no reasonable assumptions as to range errors will secure mutual consistency between the observed time of arrival and peak overpressure. We must conclude, therefore, that either the observed pressure signature does not constitute a valid blast-pressure measurement,or the concept of Sachs scaling with an effective blast yield is not applicable at the altitude of this shot.

A possibility that must be considered is that the absorption of thermal radiation ahead of the shock front raises the temperature of the air sufficiently so that it is not legitimate to use the preshot ambient temperature in computing travel times. If we take 0.46 kt as the largest value of the effective blast yield that can be reconciled with the observed peak overpressure, the calculated time of arrival at 3,049 feet, in a −50 C atmosphere, is 1.811 seconds. To reduce this to the observed value of 1.163 seconds would require a mean ambient temperature of +268 C, i.e., a mean temperature increment of 318 C. This is out of the question, since it may be easily calculated that to raise the temperature of a sphere of air 3,000 feet in radius at the altitude of this shot by 318 C would require an energy absorption (at constant volume) of about 2.72×10^{13} joules, or 6.5 kt. It is believed that the most-probable explanation is that the apparent pressure signal is an artifact caused by some kind of damage to the instrumentation.

In this connection it will be recalled that, because the appropriate command signals had not been transmitted, Canister 5 still contained the two ½-pound TNT charges that were to have been dropped and fired before zero time to provide an acoustic measurement of the distances between canisters, and the small rocket that was to have been fired to deflect this canister out of line with the others for the purposes of the Project 2.7 nuclear-radiation measurements. It is conceivable that thermal radiation may have cooked-off the squibs that released the TNT charges, the charges themselves, or the deflection rocket, and thus produced a spurious overpressure signal. Admittedly, it is difficult to explain the comparatively long duration of this overpressure on this hypothesis unless it is also assumed that the instrumentation was damaged

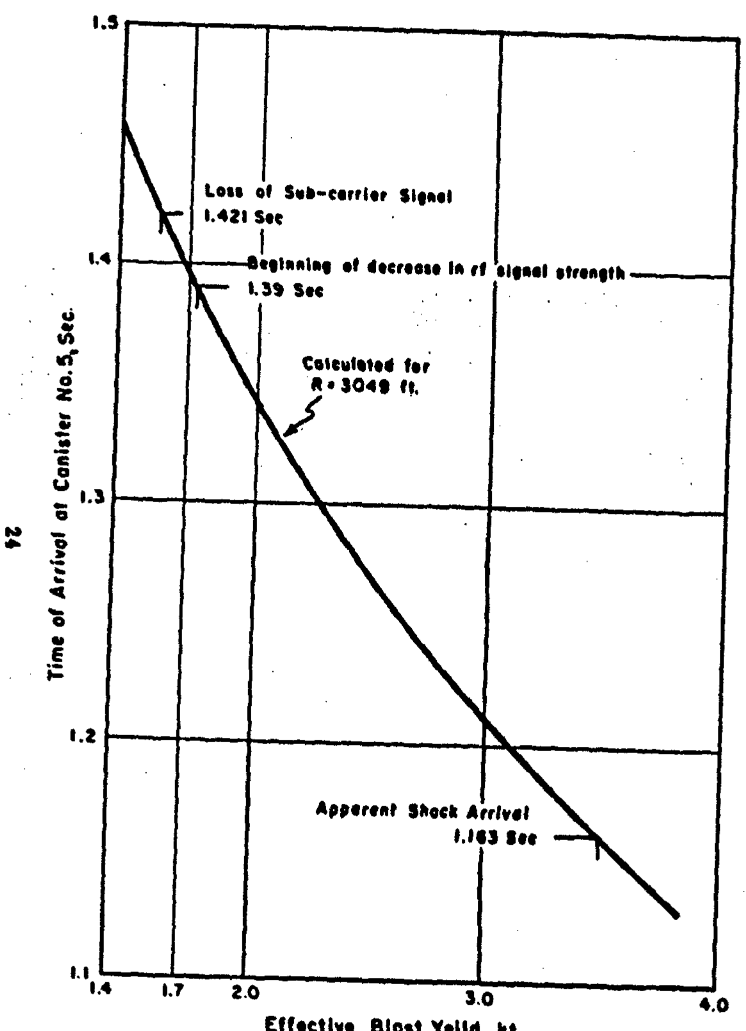


Figure 4.1 Time of arrival at Canister 5 versus effective blast yield.

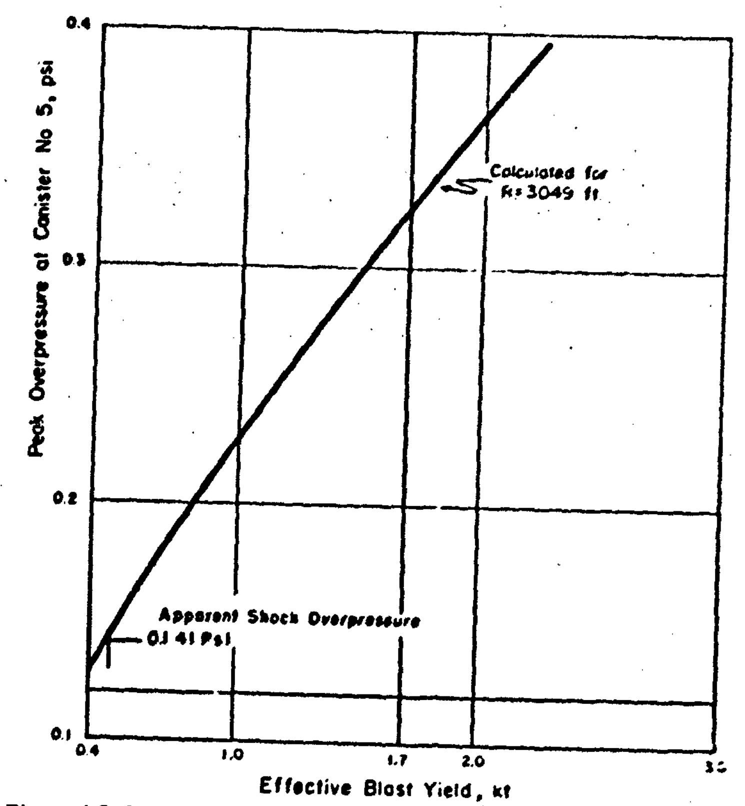


Figure 4.2 Peak overpressure at Canister 5 versus effective blast yield.

in such a way as to produce a permanent shift in the frequency of the subcarrier oscillator that transmitted the pressure signal.

As indicated in Figure 3.1, the radio-frequency carrier signal strength from Canister 5 began to decrease at a time of about 1.339 seconds and the pressure subcarrier channel went into noise abruptly at a time of 1.421 seconds. By referring to Figure 4.1 it may be seen that these times correspond respectively to calculated effective blast yields of 1.74 kt and 1.56 kt. Thus if we assume that the true shock-arrival time occurred somewhere within this interval, the effective blast yield cannot have differed greatly from the actual yield.

In this connection it should be noted that theoretical calculations by the Naval Ordnance Laboratory (Reference 9), using the methods of Reference 7, give a calculated time of arrival at Canister No. 5 of 1.42 seconds, agreeing precisely with the observed time at which the subcarrier channel information was cut off.

Chapter 5
CONCLUSIONS and RECOMMENDATIONS

5.1 CONCLUSIONS

The ambiguities in interpretation were pointed out in the preceding discussion; therefore, the only possible conclusion is that no definitive blast information was obtained from Shot Yucca. If the time at which the subcarrier signal went into noise can be identified with shock-arrival time, an effective blast yield at the altitude of this shot equal to 0.92 times the actual yield is indicated by this one piece of questionable evidence. The long duration of the telemetry black-out at the closer canisters and the possibility of preshock damage to the instrumentation in Canister 5 suggest that the radiation environment—nuclear, thermal, or both—was more severe than had been expected from preshot estimates.

5.2 RECOMMENDATIONS

Because a complete set of backup instrumentation was on hand, Project 1.10 subsequently recommended that a second balloon shot be scheduled during Operation Hardtack. For the second shot the distance to Canister 1 would have been increased, because the permanent loss of signal from this canister indicated that there would be little chance of obtaining data from the original distance, whether the canister tape recorder was in operation or not. The difficulties with the canister tape recorders discussed in Section 2.2.5 refer to the thermal radiation side of the recorder, which used amplitude modulation (AM) recording, but not to the blast pressure side of the recorder, which used frequency modulation (FM) recording. There were, therefore, good reasons to believe that, so far as the Project 1.10 blast measurements were concerned, a second shot would have succeeded in providing the data necessary to meet the objectives. However, on the basis of other considerations, this recommendation was not accepted.

Even if the accidental circumstances of loss of power at the command transmitter at the critical moment are discounted, the available evidence suggests that telemetering of data from points close to a very-high-altitude nuclear burst is a problem of even greater difficulty than had been anticipated. It is therefore recommended that, if a similar test is scheduled in the future, consideration be given to the use of self-recording blast-pressure instrumentation contained in buoyant canisters to be recovered from the sea after the shot. The experience of other Hardtack projects involving instrument recovery at sea may be expected to provide valuable information as to the relative merits of telemetering and recovery of self-recording instrumentation. Such a test could be carried out from a small carrier in the open ocean, entirely independent of any regularly scheduled test series at the EPG.

Appendix A
FIELD TESTS

A.1 PREOPERATIONAL TESTS

In March 1957, prototype canisters were flown in conjunction with Project 9.2b (AFCRC) field tests at San Angelo, Texas. The hastily constructed canisters contained a telemeter system, wet-cell lead acetate batteries which powered the telemeter transmitter during the entire flight, accelerometers, acoustic microphones, and No. 6 seismic blasting squibs wrapped with primacord. Two canisters were flown on each flight, with the last canister on the dragline containing the squibs. Baro switches detonated the squibs at altitudes from 20,000 to 70,000 feet. No conclusive data was obtained from the acoustic-wave distance-measuring technique, because the dynamotor in the telemeter system generated mechanical vibrations, which caused too much background noise on the microphone. During the tests, it was also determined that the canisters were subjected to g loads that varied from 2.0 to 3.5, depending upon the canister's position on the dragline.

The second series of canister flights took place at San Angelo during October 1957. A complete string of five instrumented canisters was available, and testing centered on the command system purchased from C.G. Electronic Company (a subsidiary of Gulton Industries, Inc.). During the tests, an antenna coupler permitted the $\frac{1}{4}$-wave transmitting antenna to be used as a receiving antenna for the canister's command receiver. After several unsuccessful balloon flights and many helicopter flights (in which a canister was lowered approximately 50 feet from the helicopter and flown about the countryside), the tests were suspended until the C.G. Electronic Company delivered a more-elaborate receiver of a new design. At this time, a basic command-receiver circuit was borrowed from Project 9.2a (Sandia Corporation) so that Bendix Aviation Corporation could, in the interim, produce a back-up receiver for the tests scheduled for December.

From 29 November until 17 December 1957, canisters were flown from balloons and helicopters with the same consistent lack of success. After exhaustive tests and modifications on the receiver, canister, and receiver antenna, it was determined that the canister antenna was radiating and conducting radio frequency into the receiver, causing the receiver to shift frequency. After radio-frequency and coaxial filters were applied to the C.G. Electronic and the Bendix receivers, in addition to enclosing the receivers in a copper shield, the Bendix receiver was determined to be the more reliable of the two. On the last balloon flight of the series, in which the Bendix receiver was being used, the canisters free-fell on deployment, and no data was obtained from that flight. It was concluded, however, that the command-receiver problem was at last resolved, and another series of baloon flights was scheduled for January in Vernalis, California. The decision was made, at this time, that Bendix would have to furnish command receivers if the project were to meet its commitment.

During the first week of January 1958, flight tests were initiated at Vernalis Naval Air Station, Vernalis, California. After two inconclusive flights were conducted with dummy canisters instrumented only with a transmitter, command receiver, dry-cell batteries, transmitting antenna, and a 6-foot-long receiver antenna attached to the bottom of the canister, four consecutive successful flights were obtained with instrumented canisters. The smaller balloons used at Vernalis obtained altitudes of 69,000 feet. On the longest flight obtained, the command system functioned perfectly at a range of 117 miles. At that particular range, the canister was well below line of sight from the command transmitter, because the canister was descending by parachute and was only 3 minutes (approximately 5,000 feet) from impact with the ground.

The four canisters had internal heating blankets, which radiated approximately 20 watts of power. With ambient air temperature an average of −60 C, the internal temperature average was 12.5 C. (On one flight at San Angelo an internal temperature of 17 F was recorded 10 minutes after the balloon had reached flight altitude at approximately 87,000 feet. During the flight, no internal heating was supplied prior to initiation of the canister's transmitter 10 minutes after it reached maximum altitude. On that flight the canister transmitter was accidentally initiated by the opening shock of the dragline parachute during cutdown, rather than by the command system.)

After the four successful flights at Vernalis, the command system was adjudged to be reliable. It is noted that, during the field tests, only the Project 1.10 equipment was tested.

A.2 OPERATIONAL DRY RUNS

Project 1.10 participated in the Yucca dry run of 5 April at the EPG with one instrumented canister. Instrumentation to be checked included: photomultiplier unit with neon flasher (Project 8.2), miniature tape recorder (Projects 1.10 and 8.2), command system, telemeter system, and pressure gage.

The test was not successful. Although previous tests of the command (and telemeter) system from canister altitudes of approximately 7,000 and 25,000 feet were successful, the canister failed to respond. It can only be assumed that the command-receiving antenna, which was not lashed to the nylon dragline, was either pulled off the canister or became coiled so as to be rendered ineffective. There is also a possibility that the canister transmitter failed. In addition, the canister was exposed to a rain squall on deployment.

A canister instrumented identically to the one used on 3 April was successfully operated on the dry run of 8 April. The canister was commanded on and off a total of eight times, including the time of the first H hour (1440). A total battery life of 34 minutes was logged until the canister splashed into the ocean. It was noted that the telemeter system functioned adequately during the canister's free-fall descent.

During the last 6 hours of canister checkout prior to the flight of 8 April, it was discovered that the canister antenna was creating radio-frequency interference in the miniature recorder's playback system. With the exception of the tape-recorder noise, the canister and components functioned perfectly.

On 14 April a canister with instrumentation identical to the previous canisters was flown successfully. Each of the components functioned perfectly, except for the excessive noise exhibited by the tape recorder.

On 18 April two canisters were flown for the Yucca high-explosive dry run. Canisters were instrumented as follows. Canister 1: command receiver, telemeter system, pressure gage, acoustic microphone, and zero-time photocell (commercial type). Canister 5: command receiver, telemeter system, pressure gage, acoustic microphone, two $\frac{1}{2}$-pound TNT charges, and NRL dummy unit, including a deflection rocket. All of the items were from Project 1.10, except the NRL dummy unit which was from Project 2.7.

The test was about 90 percent successful. The telemeter system of Canister 5 failed prior to the first scheduled H-hour (1400). Both canisters had been commanded, after the 1000-hour launch, at 1117, and again at 1220 hours. The canister transmitters functioned perfectly on those two occasions. The balloon altitude at 1220 hours was estimated to be about 70,000 feet. From a check of the telemetered record from Canister 1 and from visual observations aboard the USS Boxer, both canisters were commanded successfully during the delayed H-hour (1553). The firing of the NRL rocket and at least one acoustic charge was confirmed by personnel aboard the USS Boxer. The acoustic pulse, generated from the $\frac{1}{2}$-pound charge released from Canister 5 was recorded on the microphone of Canister 1. Therefore, with the exception of the telemeter failure of Canister 5, the canisters appeared to function normally. Although the loss of the transmitter or transmitting antenna compromised the complete success of the flight, the problem was considered to be a rare occurrence. During previous tests, the transmitter-antenna system proved to be very reliable.

Appendix B
CANISTER ENVIRONMENTAL CHECKOUT PROCEDURE

The laboratory checkout procedure listed in outline below was actually a minor portion of the total laboratory checkout. The modifications and testing performed on the minature tape recorder and the canister electronics were extensive in comparison to the basic checkout listed below. Appendix B is included to indicate the scope and nature of laboratory tests that were continually carried out.

Appendix C
WIND-TUNNEL CALIBRATIONS of CANISTER PRESSURE GAGES

Because of the disturbance of the flow caused by the presence of the canister, the pressure as measured at a pressure-input port at a given point on the body of the canister may differ appreciably from the free-field pressure, particularly at high shock-pressure ratios. If the flow beyond the shock front is assumed to have the same configuration as that which would exist in steady flow at the same Mach number, a calibration for this effect may be carried out by static-pressure measurements in a wind tunnel. This has been done with 1/16.4-scale models of the canisters in the 6-by-6-inch supersonic wind tunnel at WADC, at Mach numbers ranging from 0.159 to 0.656 in the subsonic range and from 1.502 to 2.252 in the supersonic range.

The theory necessary to convert the wind-tunnel pressure measurements into correction factors for shock-overpressure measurements is presented in Reference 10.

Although the correction at the shock strength actually existing at Canister 5 is negligibly small, the complete calibration curves are presented in Figure C.1 for possible future reference in case canisters of similar configuration should be used again for blast-pressure measurements. The curves are presented in the form of $\Delta P_s/\Delta P_g$ as a function of $\Delta P_g/P_e$, where ΔP_s is the free-field peak overpressure, ΔP_g is the peak overpressure as measured by the canister gage, and P_e is the ambient absolute pressure. In the figure legend, l_e/d is the distance from the front face of the canister to the pressure-input ports expressed in diameters, and l/d is the overall length-to-diameter ratio.

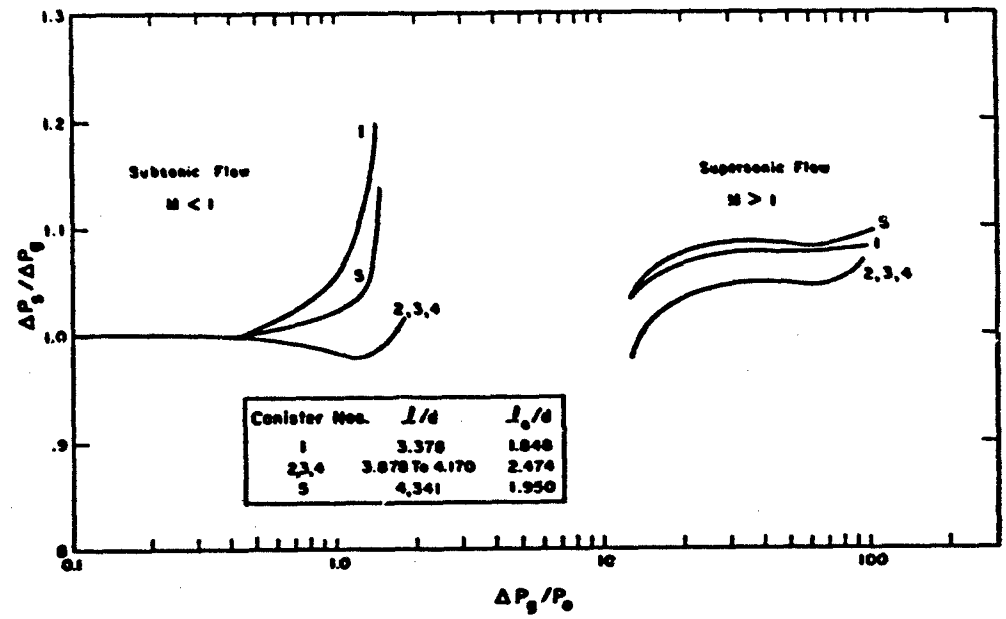


Figure C.1 Peak overpressure correction curves.

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Appendix D
TELEMETRY BLACKOUT

As mentioned in Chapter 3, radio reception was recovered only from Canisters 2 and 5 after the ionization blackout at zero time.

For Canister 2, recovery was only in intermittent bursts, because of erratic tumbling, [illegible]age, or both, and no interpretable curve of radio-frequency signal strength versus time can be drawn.

For Canister 5, the signal strength varied in a reasonably smooth manner for a brief interval following the initial recovery. This is shown in Figure D.1, in which the signal strength in microvolts at the input of the antenna preamplifier is plotted as a function of time from shot time until shortly after the presumed blast-arrival time. Because it is not certain that this canister remained undamaged before blast-arrival time, it is questionable whether the signal-strength recovery curve can be interpreted entirely in terms of the rate of decay of ionization.

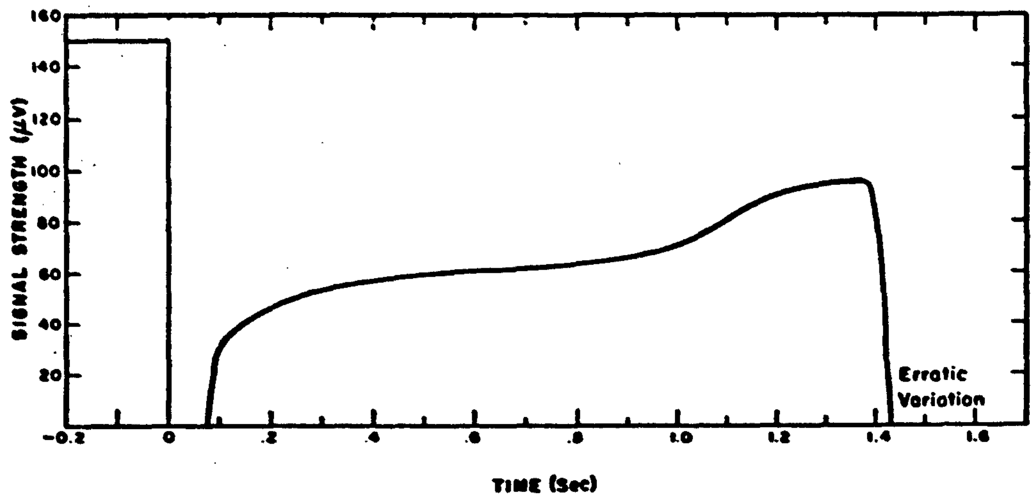

Figure D.1 Radio-frequency signal strength versus time, Canister 5.

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ARMY ACTIVITIES

1 Deputy Chief of Staff for Military Operations, D/A, Washington 25, D.C. ATTN: Dir. of SW&R
2 Chief of Research and Development, D/A, Washington 25, D.C. ATTN: Atomic Div.
3 Assistant Chief of Staff, Intelligence, D/A, Washington 25, D.C.
4 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGMB
5 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGEB
6 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGTB
7- 8 Office, Chief of Ordnance, D/A, Washington 25, D.C. ATTN: ORDTN
9- 11 Commanding General, U.S. Continental Army Command, Ft. Monroe, Va.
12 Director of Special Weapons Development Office, Headquarters CONARC, Ft. Bliss, Tex. ATTN: Capt. Chester I. Peterson
13 President, U.S. Army Artillery Board, Ft. Sill, Okla.
14 President, U.S. Army Air Defense Board, Ft. Bliss, Tex.
15 Commandant, U.S. Army Command & General Staff College, Ft. Leavenworth, Kansas. ATTN: ARCHIVES
16 Commandant, U.S. Army Armored School, Ft. Knox, Ky.
17 Commandant, U.S. Army Artillery and Missile School, Ft. Sill, Okla. ATTN: Combat Development Department
18 Commandant, U.S. Army Aviation School, Ft. Rucker, Ala.
19 Commandant, U.S. Army Infantry School, Ft. Benning, Ga. ATTN: C.D.S.
20 Commandant, U.S. Army Ordnance School, Aberdeen Proving Ground, Md.
21 Commandant, U.S. Army Ordnance and Guided Missile School, Redstone Arsenal, Ala.
22 Commanding General, Chemical Corps Training Comd., Ft. McClellan, Ala.
23 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Cmdt, Engr. School
24 Director, Armed Forces Institute of Pathology, Walter Reed Army Med. Center, 625 16th St., NW, Washington 25, D.C.
25 Commanding Officer, Army Medical Research Lab., Ft. Knox, Ky.
26 Commandant, Walter Reed Army Inst. of Res., Walter Reed Army Medical Center, Washington 25, D.C.
27- 28 Commanding General, Qm R&D Comd., QM R&D Cntr., Natick, Mass. ATTN: CBR Liaison Officer
29- 30 Commanding Officer, Chemical Warfare Lab., Army Chemical Center, Md. ATTN: Tech. Library
31 Commanding General, Engineer Research and Dev. Lab., Ft. Belvoir, Va. ATTN: Chief, Tech. Support Branch
32 Director, Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. ATTN: Library
33 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
34 Commanding Officer, Diamond Ord. Fuze Labs., Washington 25, D.C. ATTN: Chief, Nuclear Vulnerability Br. (230)
35- 36 Commanding General, Aberdeen Proving Grounds, Md. ATTN: Director, Ballistics Research Laboratory
37 Commanding General, Frankford Arsenal, Bridge and Tacony St., Philadelphia, Pa.
38 Commanding Officer, Watervliet Arsenal, Watervliet, New York. ATTN: ORDBF-RR
39 Commander, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala. ATTN: Tech Library
40 Commanding General, White Sands Proving Ground, Las Cruces, N. Mex. ATTN: ORDBS-OM
41 Commander, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ATTN: ORDAB-HT
42 Commanding General, Ordnance Tank Automotive Command, Detroit Arsenal, Centerline, Mich. ATTN: ORDMC-RO
43 Commanding General, Ordnance Weapons Command, Rock Island, Ill.
44 Commanding General, U.S. Army Electronic Proving Ground, Ft. Huachuca, Ariz. ATTN: Tech. Library
45 Commanding General, USA Combat Surveillance Agency, 1124 N. Highland St., Arlington, Va.
46 Director, Operations Research Office, Johns Hopkins University, 6935 Arlington Rd., Bethesda 14, Md.
47 Commanding General, U. S. ORD Special Weapons-Ammunition Command, Dover, N.J.
48 Commander-in-Chief, U.S. Army Europe, APO 403, New York, N.Y. ATTN: Opot. Div., Weapons Br.

NAVY ACTIVITIES

49 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-03EG
50 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-75
51- 52 Chief of Naval Research, D/N, Washington 25, D.C. ATTN: Code 811
53- 55 Chief, Bureau of Naval Weapons, D/N, Washington 25, D.C. ATTN: RRMA-3
56- 60 Chief, Bureau of Naval Weapons, D/N, Washington 25, D.C. ATTN: RAAD-25
61 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
62 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 423
63 Chief, Bureau of Yards and Docks, D/N, Washington 25, D.C. ATTN: D-440
64 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Mrs. Katherine H. Cass
65- 66 Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.
67 Director, Material Lab. (Code 900), New York Naval Shipyard, Brooklyn 1, N.Y.
68 Commanding Officer and Director, Navy Electronics Laboratory, San Diego 52, Calif.
69 Commanding Officer, U.S. Naval Mine Defense Lab., Panama City, Fla.
70- 71 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Tech. Info. Div.
72- 73 Commanding Officer and Director, U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif. ATTN: Code L31
74 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.
75 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
76 Commanding Officer, U.S. Fleet Sonar School, U.S. Naval Base, Key West, Fla.
77 Commanding Officer, U.S. Fleet Sonar School, San Diego 47, Calif.
78 Officer-in-Charge, U.S. Naval School, CEC Officers, U.S. Naval Construction Bn. Center, Port Hueneme, Calif.
79 Commanding Officer, Nuclear Weapons Training Center, Atlantic, U.S. Naval Base, Norfolk 11, Va. ATTN: Nuclear Warfare Dept.
80 Commanding Officer, Nuclear Weapons Training Center, Pacific, Naval Station, San Diego, Calif.
81 Commanding Officer, U.S. Naval Damage Control Tng. Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
82 Commanding Officer, Air Development Squadron 5, VX-5, China Lake, Calif.
83 Commanding Officer, Naval Air Material Center, Philadelphia 12, Pa. ATTN: Technical Data Br.
84 Commanding Officer, U.S. Naval Air Development Center, Johnsville, Pa. ATTN: NAS, Librarian
85 Commanding Officer, U.S. Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.

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[illegible] Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library

[illegible] Commander, Norfolk Naval Shipyard, Portsmouth, Va. ATTN: Underwater Explosions Research Division

[illegible] Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H

80 Director, Marine Corps Landing Force, Development Center, MCS, Quantico, Va.

81 Commanding Officer, U.S. Naval CIC School, U.S. Naval Air Station, Glynco, Brunswick, Ga.

[illegible] Chief, Bureau of Naval Weapons, Navy Department, Washington 25, D.C. ATTN: RRI

AIR FORCE ACTIVITIES

100 Hq. USAF, ATTN: Operations Analysis Office, Office, Vice Chief of Staff, Washington 25, D. C.

101-103 Air Force Intelligence Center, HQ. USAF, ACS/I (AFCIN-3V1) Washington 25, D.C.

104 Director of Research and Development, DCS/D, HQ. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.

105 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division

106 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch

107 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Assistant for Atomic Energy, ADLDC-A

108 Commander, HQ. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDRWA

109 Commander, Air Force Ballistic Missile Div. HQ. ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT

109-110 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2

111-115 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.

116-117 Director, Air University Library, Maxwell AFB, Ala.

118 Commander, Lowry Technical Training Center (TW), Lowry AFB, Denver, Colorado.

119 Commandant, School of Aviation Medicine, Brooks Air Force Base, Tex. ATTN: Research Secretariat

120 Commander, 1009th Sp. Wpns. Squadron, HQ. USAF, Washington 25, D.C.

121-123 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCACT (For WCOSI)

124-125 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.

126 Commander, Rome Air Development Center, ARDC, Griffiss AFB, N.Y. ATTN: Documents Library, RCSSL-1

127 Commander, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Ohio. ATTN: AFCIN-4B1a, Library

128 Assistant Chief of Staff, Intelligence, Hq. USAFE, APO 633, New York, N.Y. ATTN: Directorate of Air Targets

129 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

130 Director of Defense Research and Engineering, Washington 25, D.C. ATTN: Tech. Library

131 Chairman, Armed Services Explosives Safety Board, DOD, Building T-7, Gravelly Point, Washington 25, D.C.

132 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.

133-136 Chief, Defense Atomic Support Agency, Washington 25, D.C. ATTN: Document Library

137 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex.

138-139 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG

140-141 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT

142 Commander, JTF-7, Arlington Hall Station, Arlington 12, Va.

143 Administrator, National Aeronautics and Space Administration, 1520 "H" St., N.W., Washington 25, D.C. ATTN: Mr. R. V. Rhode

144 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: CAMS

145 Commandant, US Coast Guard, 1300 E. St., N.W., Washington 25, D.C. ATTN: (OIN)

146 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N. Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

147-149 U.S. Atomic Energy Commission, Technical Library, Washington 25, D.C. ATTN: For DMA

150-154 Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman

155-159 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.

160-169 University of California Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. ATTN: Clovis G. Craig

170 Weapon Data Section, Office of Technical Information Extension, Oak Ridge, Tenn.

171-200 Office of Technical Information Extension, Oak Ridge, Tenn. (Surplus)

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30 September 1960

ERRATA SHEET FOR WT-1615

BLAST OVERPRESSURE FROM VERY-HIGH-ALTITUDE BURSTS (U)
(OPERATION HARDTACK FINAL REPORT, PROJECT 1.10)

ADD: Pages 29a and 29b, as attached.

Military Distribution Category 12

USAEC OFFICE OF TECHNICAL INFORMATION EXTENSION,
P.O. BOX 401, OAK RIDGE, TENNESSEE

VHA CANISTER ENVIRONMENTAL CHECKOUT PROCEDURE

I. Purpose

The purpose of this test is to evaluate the performance of the components under a simulated flight condition. The flight conditions shall include a temperature change from +70° F to −60° C and an altitude change from sea level to 100,000 feet. These changes shall occur over a two hour period or as close thereto as practicable.

II. Equipment Required

A. External Power Sources as follows:

6 VDC	90 VDC
12 VDC	100 VDC
28 VDC	180 VDC
30 VDC	450 VDC

B. Control Panel

C. Subcarrier Analyzer

D. Command Transmitter (RF Signal Gen.)

E. Command Receiver Test Box

F. Wattmeter

G. Squibs and Detonator Board

H. Two direct reading Temperature Bridges (Copper-Constantan)

I. Two Copper-Constantan Thermocouples

III. Preparation

A. Connect cable to control panel to provide excitation from external power. NOTE: Command receiver must operate from internal supply.

B. Read and record barometric pressure and ambient temperature. (Corrected sea level).

C. Make provision for monitoring the internal temperature at two positions within the package.

IV. Test Procedure (External Power)

A. Apply power to equipment by energizing command tone "A".

B. After two minutes warmup adjust all voltages to the predetermined level (dictated by internal battery supply). Read and record the following currents:

Nominal Voltage	Adjusted Volt	Current
6.0	________	________
28.0	________	________
90.0	________	________
100.0	________	________
180.0	________	________

C. After system has been on for 5 minutes read and record the following:

Transmitter Power:	________ Watts
70 KC Subcarrier:	________ CPS
40 KC Subcarrier:	________ CPS
14.5 KC Subcarrier:	________ CPS
7.35 KC Subcarrier:	________ CPS

D. Turn off equipment by energizing command tone "C".

E. Reduce chamber temperature from room ambient to −60° C in approximately two hours. During temperature descent measure and record the duration and magnitude of the load drawn by the heater blanket. Upon indication of heater load being drawn, read and record the following:

Time on	Time off	Chamber Temp.	Thermocouple #1	Term #2	Current	Simulated Altitude

F. After reaching the -60° C point reduce the chamber pressure to .26 PSIA while continuing to monitor heater blanket current and record in table under "F". This should be monitored through remainder of test.

G. Perform the following operational sequence:

1. Establish a zero time ("X") reference and energize the system at X-10 minutes. Read and adjust if necessary the supply voltage to the levels recorded in IV B.
2. At X-3 minutes start ground station recording (approximately 10 inches/second). Command tone "B" and hold for 30 seconds.
3. After approximately 4 seconds fire squib number 1 and stop recording.
4. At X-15 seconds start recording.
5. At X-10 seconds command Tone "D".
6. At X-9 seconds command tone "B". Hold for 6 seconds.
7. At X-7 seconds fire number 2 squib.
8. At X-3 seconds command tone "E".
9. At X-0 simulate a zero time voltage to canister recorder.
10. At X+10 seconds stop recording.

J. At the conclusion of the above sequence note the power supply currents as follows:

Nominal Volt	Current
6.0	______
26.0	______
28.0	______
100.0	______
120.0	______

K. Read and record the following data:

Transmitter Power	______ Watt
70 KC Subcarrier	______ CPS
40 KC Subcarrier	______ CPS
10.5 KC Subcarrier	______ CPS
7.35 KC Subcarrier	______ CPS
14.5 KC Subcarrier	______ CPS
Indicated altitude determined from 14.5 readings	______ Ft.
Recorded altitude (chamber)	______ Ft.

L. Turn off system by energizing tone "C" and return chamber to room ambient conditions.

V. Test Procedure (Internal Power)

A. After conclusion of external power test switch internal - external power plug on test rack and install battery packs.

B. Repeat the test procedure of Section IV recording data as required.

Room Ambient Conditions

Transmitter Power	______ Watts
70 KC Subcarrier	______ CPS
40 KC Subcarrier	______ CPS
10.5 KC Subcarrier	______ CPS
7.35 KC Subcarrier	______ CPS

Chamber at -60° C and 0.26 PSIA

Transmitter Power	______ Watts
70 KC Subcarrier	______ CPS
40 KC Subcarrier	______ CPS
10.5 KC Subcarrier	______ CPS
7.35 KC Subcarrier	______ CPS
Indicated altitude determined from 14.5 KC reading	______ Ft.
Recorded altitude (chamber)	______ Ft.

VI. Specimen Data

Canister Type	______
Canister S/N	______
Test Date	______
Tested by	______