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DEVELOPMENT OF THE BDU-17/B PRACTICE BOMB

by

Albert Kokalari
Lt USAF

April 1963

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FOREWORD

The author wises to acknowledge the cooperation of Mr. Kenneth H. Cordes, Division 7134, Sandia Corporation, for his assistance in providing theoretical aerodynamics analysis in this development.

ABSTRACT

This program was established to develop an inexpensive miniature practice bomb for retarded weapon delivery training. An Air Force preliminary design was modified and produced by a civilian contractor; further modification was accomplished after an Air Force testing program. Preliminary results indicate successful accomplishment of the program objectives. It is expected that the end item should be an inexpensive inventory item which will increase the validity and realism of delivery-crew training.

PUBLICATION REVIEW

This report has been reviewed and is approved.

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DEVELOPMENT OF THE BDU-17/B PRACTICE BOMB

1. Introduction - The object of this development program is to provide an inexpensive, expendable, high drag miniature practice bomb that can be used to train pilots in the delivery of retarded special weapons. The development of the BDU-17/B was initiated 1 November 1961 on a money tree project based on the reduction of training weapon cost. Completion of this program is expected by 1 July 1963.

Miniature practice bombs have been in use by the Air Force and Navy for almost 20 years. A few examples of these are the MB-2A, MK-23, MK-76, MK-89 and MK-106. Of these bombs, only the MK-106 had the high drag configuration adaptable to retarded weapon delivery training. Undesirable features of the MK-106 included structural failures in high mach delivery conditions and unvariable ballistics. Approximately 295,000 MK-106 Practice Bombs are used annually at a cost of about $4.50 per bomb according to data provided by the San Antonio Air Materiel Area.

A target cost of $2.50 per bomb was established as the goal of this development program. This would result in an annual savings of $590,000. $50,000 was authorized for the BDU-17/B development program.

The BDU-17/B will be compatible with the MN-1A Trainer and will incorporate a MK-4, Mod 3 Practice Bomb Signal for spotting purposes. This spotting charge ignites when the bomb impacts, providing ground or air observers with a means of scoring the pilot's accuracy.

It will be capable of duplicating parent weapon ranges for retarded special weapons delivered in level or LADD deliveries.

2. Design Criteria - The following is a list of design criteria for the BDU-17/B Practice Bomb:

a. Cost - The BDU-17/B should be designed to have the lowest possible unit cost. A Headquarters USAF goal was established at $2.50 each in production quantities.

b. Ballistics

(1) The BDU-17/B Practice Bomb must be stable and have a predictable and repeatable trajectory. The maximum limit set on the Mil-Dispersion of the bomb is 50 mils; the same as the MK-106.

c. Mechanical Features

(1) The bomb must have a reliable and safe spotting system, similar to the MK-4, Mod 3 Practice Bomb Signal.

(2) The bomb should be compatible with the MN-1A Trainer and associated handling equipment.

(3) The bomb should not be easily damaged on shipment or handling and should be easily maintained.

(4) Assembly and disassembly should require no special tools.

d. Environmental Requirements - The practice bomb will be required to operate under the following conditions:

(1) Temperatures ranging from 71°C. (160°F) to -54°C. (-65°F).

(2) Vibrations experienced during service use.

(3) Salt spray such as is likely to be encountered during storage, use or transportation near a large body of salt water.

e. Special Requirements

(1) The bomb should be capable of external carriage at supersonic speeds thus certifying the bomb for present and/or future external carriage applications for miniature bombs.

3. Discussion - The following describes the development program of the BDU-17/B.

a. Selecting a bomb configuration.

The original bomb shape selected was configuration No. 7 of a Sandia Corporation Technical Memorandum SCTM 92-61 (71) entitled: "Wind Tunnel Force Tests of Several Finless Model Configurations." This was considered a desirable high drag bomb configuration because it did not have thin fins or any other easily damaged protrusions. It had a cylindrical body that can be manufactured in large quantities by simple molding methods. The actual model tested in the wind tunnel was 1.10 inches in diameter which was scaled up to a 3.00 inch diameter, the same as the MB-2A Practice Bomb. Standardizing on this diameter would preclude the requirement for changing shoes or ejection positions in the MN-1A Trainer. Presently ejector position and/or ejector shoes must be changed when converting from the MB-2A to the MK-106 or the MK-76 Practice Bombs.

b. Low Manufacturing Cost.

Several materials and methods of manufacture were considered for bomb construction. It was determined that a plastic bomb case would be an ideal manufacturing material for large quantities of bombs.

Although the per pound cost of reinforced plastics is usually higher than metals, other properties of plastics supply the following advantages for our purposes:

(1) Adaptability to mechanized manufacture in large quantities.

(2) High strength to weight ratio.

(3) Absence of corrosive characteristics and flexibility of coloring.

(4) Good vibration and damping characteristics which would preclude shipment and handling damage.

c. Ballistic Simulation

(1) The unique ballistic characteristic of the BDU-17/B is the capability to duplicate the parent weapon range for retarded special weapons in level and LADD deliveries.

This design requirement will result in a practice bomb which will provide realistic training for pilots since the release to impact range of the practice bomb will be almost identical to the parent weapon. Ballistic simulation is especially desirable for level deliveries since the pilot must use an "eye ball" method for delivering the weapon when the time of release is based on his judgement of distance.

(2) The trajectory of ballistic shapes corresponds to the relationship W/C_DA where W is the weight, C_D the drag coefficient and A the cross sectional area. For drogue retarded weapons W/C_DA changes during its trajectory due to the deployment of a parachute. To duplicate this trajectory with a practice bomb, W/C_DA of the practice unit must have a similar variation, which during the free fall period would require a relatively complex and expensive mechanism.

(3) Duplication of parent weapon range as opposed to duplication of trajectory requires only that the practice bomb impact in the same location as the parent weapon would for a given delivery condition. Figure 1 shows a bomb with constant ballistic parameters duplicating the range of a retarded weapon even though their trajectories differ. A change in delivery height will cause a discrepancy in range, making it necessary to vary the ballistics of the practice bomb to duplicate the range of the parent weapon at the new delivery condition. This variation in W/C_DA for the BDU-17/B is accomplished by varying its weight from 2.1 lbs to 4.5 lbs with the addition of four ballast rings each weighing 0.6 lb.

(4) The advantages of varying the weight rather than the coefficient of drag or the area of the bomb are:

(a) Since the diameter and area of the bomb is constant, the problem of fitting various shapes into the loading mechanisms or ejection mechanism of the MN-1A Trainer is avoided.

(b) One bomb configuration simplifies the requirement for drop tests for verification of the wind tunnel data and stability parameters.

(c) A requirement for several bomb configurations would necessitate the fabrication and stocking of several different bombs.

LEVEL DELIVERY

DUPLICATION OF PARENT WEAPON RANGE

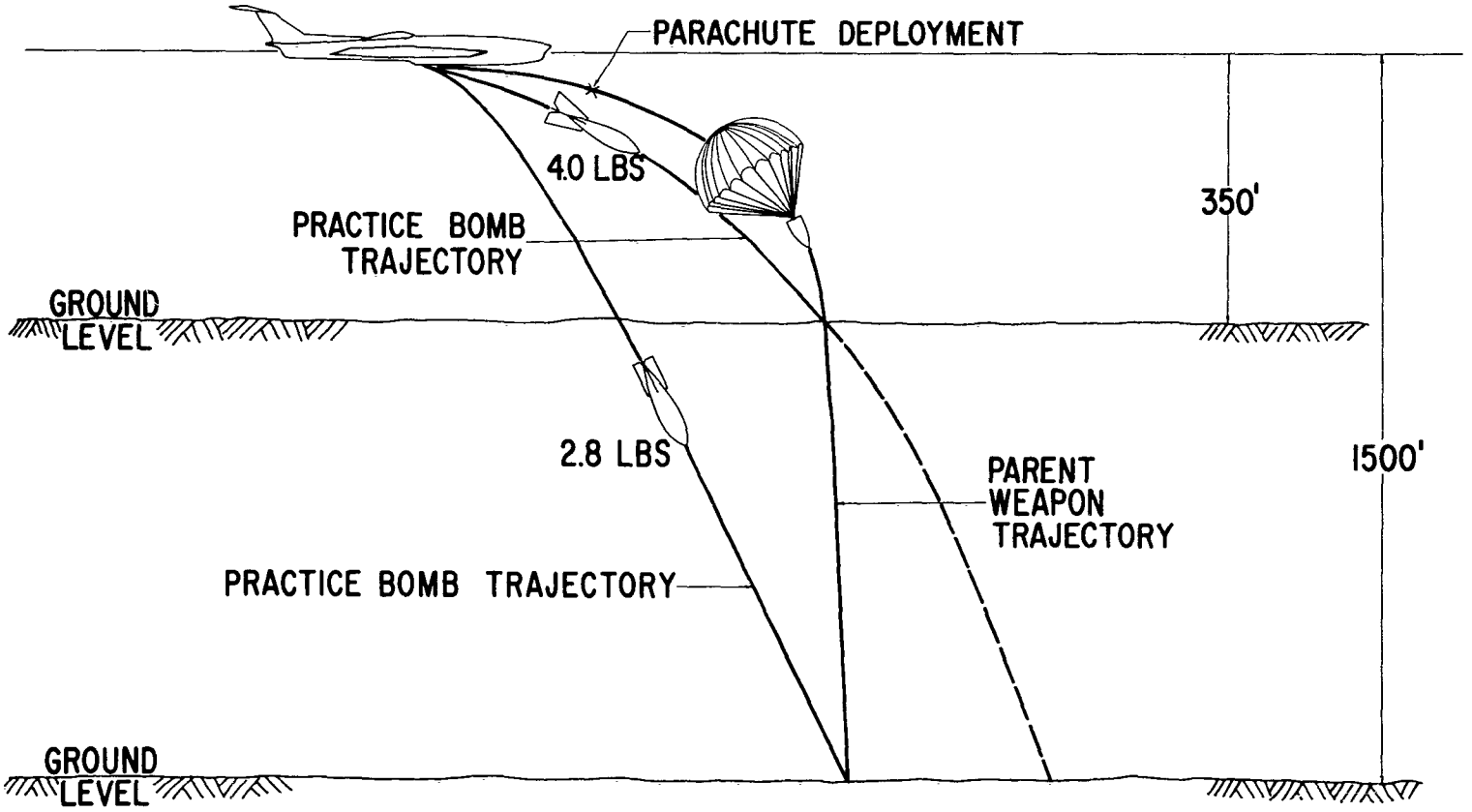


FIGURE 1

(d) Closer simulation of parent weapon range can be easily obtained by reducing the weight increments of the ballast rings. Variation in weight also allows this versatile practice bomb to duplicate the range of other present and/or future weapons, possibly including napalm bombs, sea mines, or other high drag shapes.

(5) Figures 2 and 3 point out the release altitude versus range for level and 45° LADD deliveries using the various weights of the BDU-17/B, three full scale retarded shapes and the MK-106 Practice Bomb. The slopes of the curves of the retarded bombs are greater than the practice bombs because the deployment of the parachute rapidly decreases its horizontal velocity which results in an almost constant range for higher delivery altitude. For the 45° LADD delivery variation of range of both the practice bomb and the retarded bombs with release altitudes is small. This is due to the nature of the delivery as seen in figure 4.

d. Spotting System.

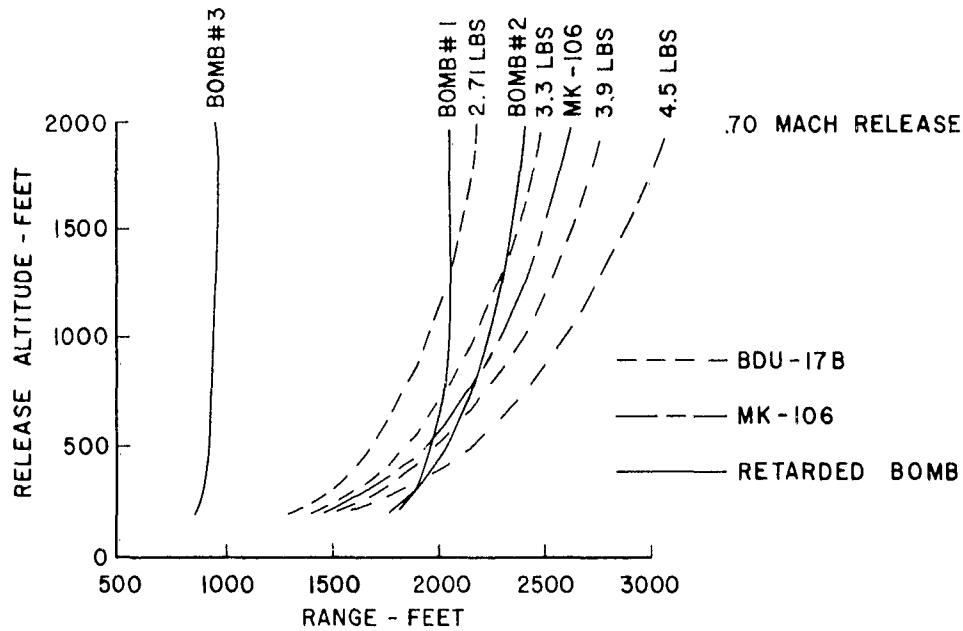
For simplicity and standardization it was decided to incorporate the existing spotting charge used in other miniature bombs. The first device considered for the detonation of this cartridge was the standard crush cup. Studies of this system indicated that a spring and firing pin would present the following improvements:

(1) Safety.

The safety feature of the BDU-17/B is provided by a safety pin which is inserted into the bomb preventing the Practice Bomb Signal from striking the firing pin, and the bomb is loaded in the MN-1A Trainer in this configuration. If a crush cup were used instead of a spring, insertion of a safety pin would be impossible. In addition, the bomb was designed to make insertion of the firing pin the last step of the assembly procedure. If the assembled charge support were to be dropped, there would be no firing pin to detonate the cartridge.

(2) Versatility.

Using a spring instead of a crush cup allows for versatility. Although all the bombs drop tested to date have used a cartridge with an inertia tube, it is believed that the inertia tube can be eliminated because a spring strength



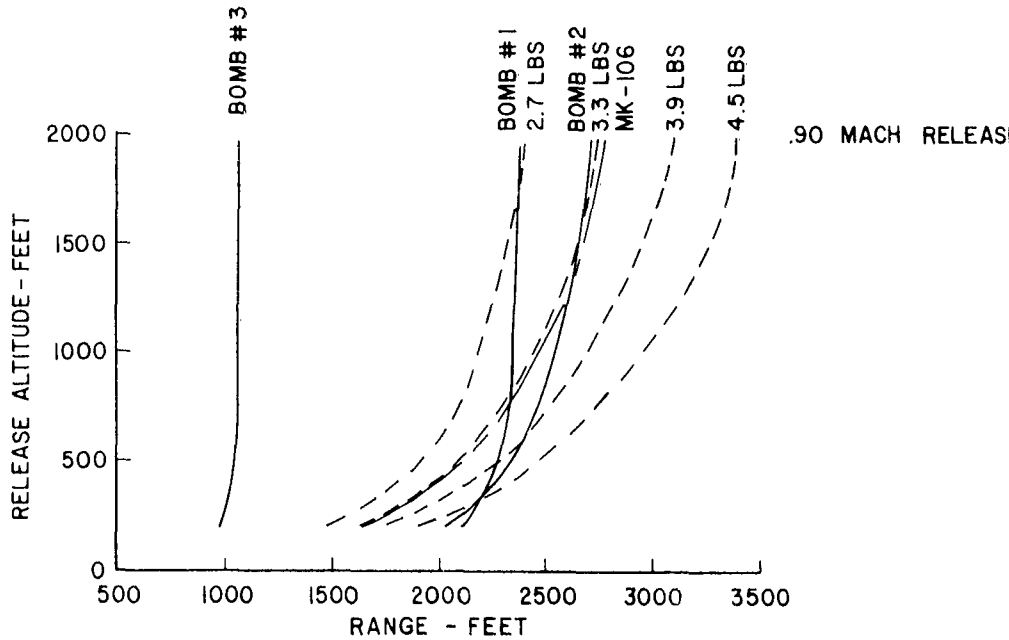
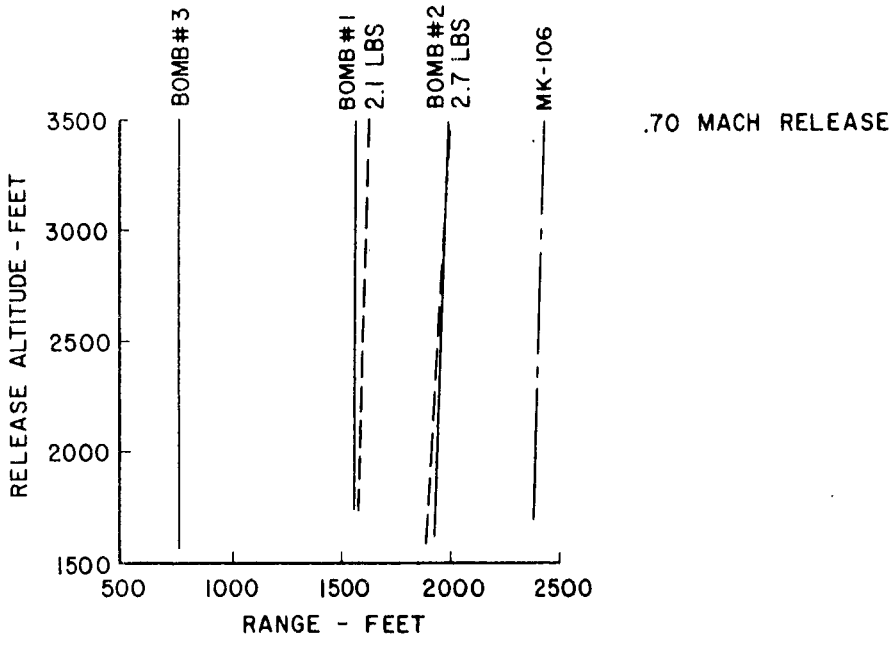


FIGURE 2 LEVEL DELIVERY



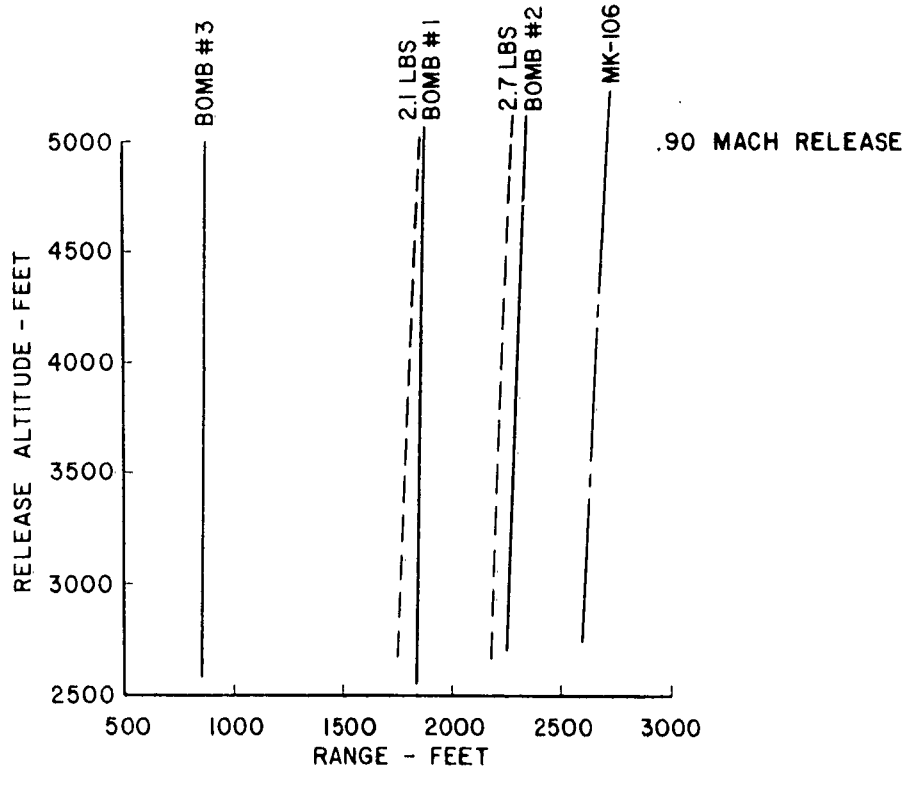


FIGURE 3 45° LADD DELIVERY

45° LOW ANGLE DROGUE DELIVERY (LADD)

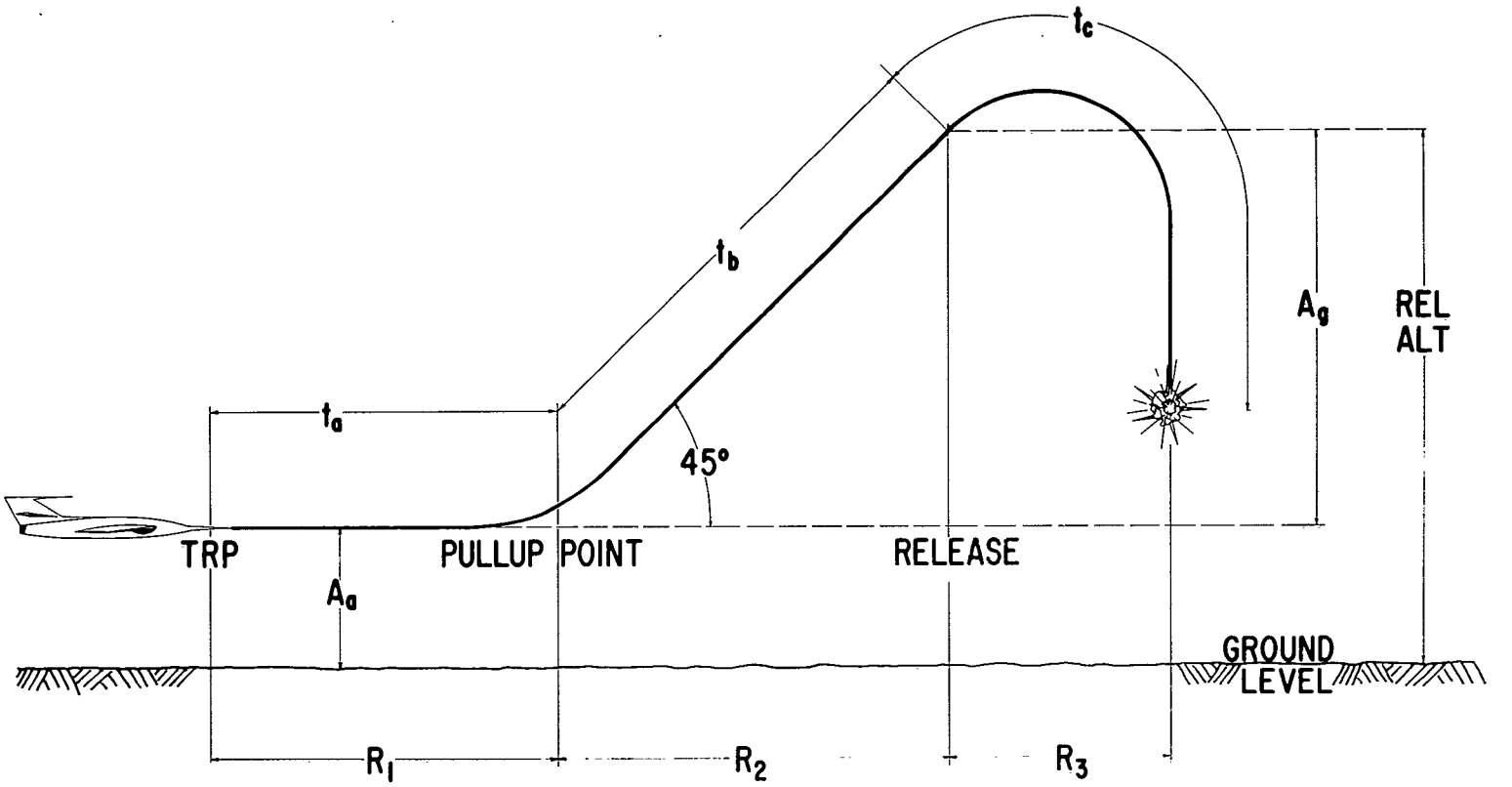


FIGURE 4

can be selected to compensate for the loss in weight. The possibility of eliminating the inertia tube will be investigated on future drops. Reduced cost, added reliability and simplicity of assembly would be benefits gained through this elimination.

Springs can be readily procured for any new cartridges as they are developed.

4. Description of the BDU-17/B Practice Bomb

The BDU-17/B consists of three basic components: the firing pin, the bomb shell and the charge support assembly. These units are assembled by screwing the firing pin through the bomb body into the charge support assembly. The charge support assembly consists of the charge support, spring, ballast rings, inertia tube, the Practice Bomb Signal and cotter pins.

Figure 5 shows a cut-away diagram of a prototype BDU-17/B. The final design will consist of four larger ballast rings that will straddle the center of the charge support assembly, instead of the five rings shown. The cotter pins, used to fasten the ballast rings, may be replaced due to the increase in size of these rings. Additional modifications will include removal of plastic material within the nose of the bomb to reduce its weight and cost.

The bomb body is molded from a Fiberglas reinforced plastic in a one-piece assembly. The nose ballast is molded in place to minimize assembly operations. The Fiberglas construction and compact design permits economical and simple packaging and shipping of the bomb. The aft end of the bomb body is completely open to allow smoke produced from the detonation of the cartridge to be discharged without obstruction. Four wedge fins and a drag plate are molded as an integral part of the bomb case. The body of the bomb has two holes for the detent pins on the loading device and ejection mechanism. Two small holes in the forward portion of the bomb case are provided for insertion of the safety pin.

a. Physical Characteristics

(1) Weight of Basic Bomb - 2.10 lbs.
Weights Available Through Use of Ballast Rings: 2.70, 3.30, 3.90 and 4.50 lbs.

(2) Over-all Length - 15.00 inches

(3) Body Diameter - 3.00 inches

(4) Drag Plate Diameter - 4.45 inches

(5) Fin to Fin (Maximum Diameter) - 5.4 inches

(6) Fin Box - 4.45 inches.

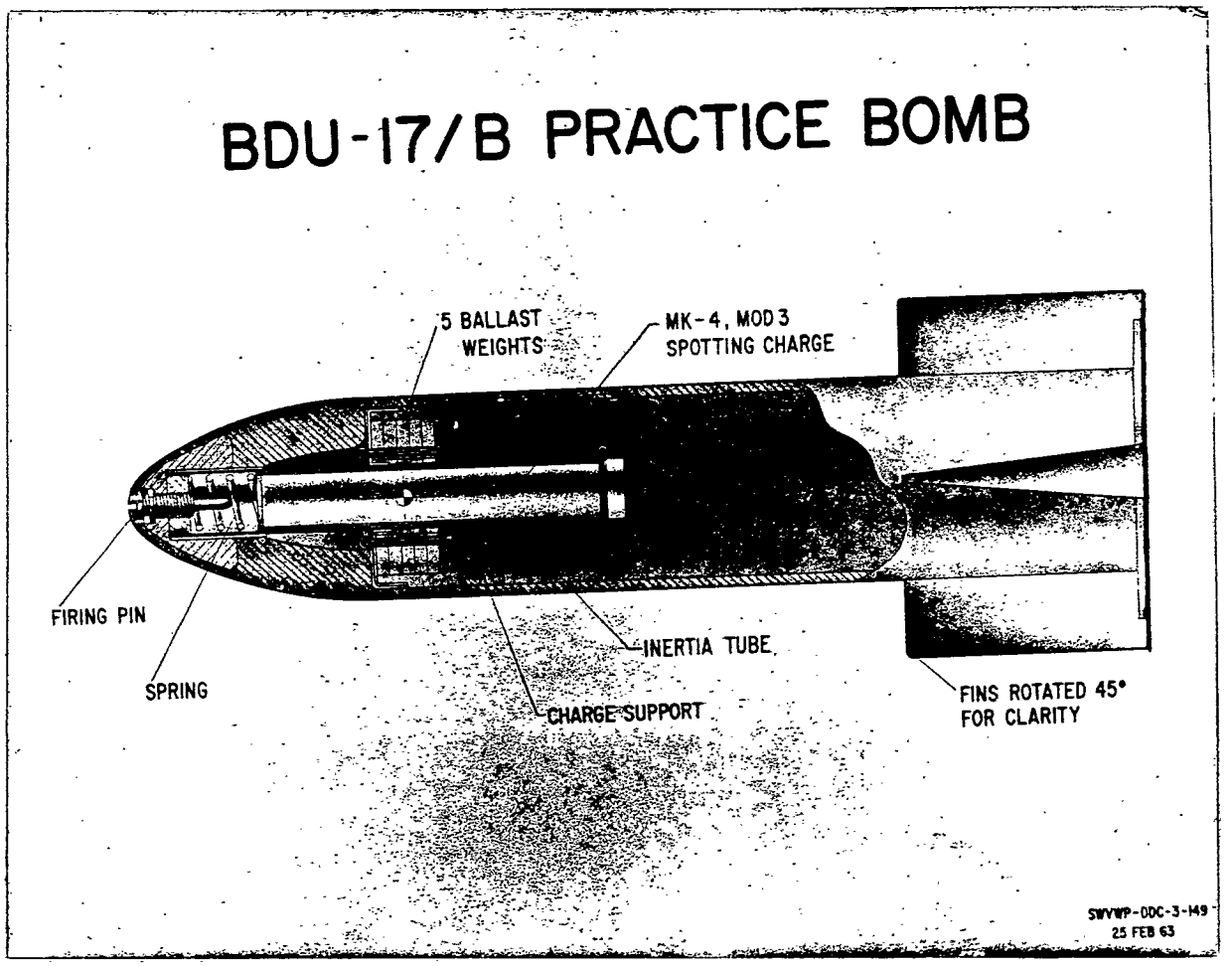

BDU-17/B PRACTICE BOMB
5 BALLAST WEIGHTS
MK-4, MOD 3 SPOTTING CHARGE
FIRING PIN
SPRING
INERTIA TUBE
CHARGE SUPPORT
FINS ROTATED 45° FOR CLARITY
SWVWP-DDC-3-149
25 FEB 63

FIGURE 5

b. Assembly Equipment

(1) Screw Driver

(2) Pliers

c. Cost. (Based on Development Contractors Data)

The cost of the BDU-17/B, not including the cartridge, is estimated to be a maximum of $2.50 per bomb in quantities of 100,000.

5. Testing Program - The following is a brief description of the tests performed on the BDU-17/B Practice Bomb.

a. Static Test

(1) Procedure

The static load tests were made utilizing an ejector mechanism from an MN-1A Trainer which was modified by replacing the existing main spring with a spring designed to deliver 1.25 of the normal load, that is a 400 pound load when compressed in the mechanism. The bomb case material finally selected was Plumb Chemical Company's Fibercore 1000. The bomb body was loaded into the ejector mechanism and then placed in an oven at 165°F for a period of 12 hours. (See Figures 6 and 7.) The assembly was then removed from the oven and placed in a cold chamber at -65°F for 12 hours. This test was repeated in a pressure chamber simulating barometric conditions encountered at 40,000 feet. In each test before, during, and after loading, micrometer measurements were taken of the bomb diameters at various stations on the bomb case, perpendicular to the direction of the load.

(2) Results

The maximum deformation observed during this test was 24 thousandths of an inch which occurred while the bomb was in the hot chamber. The maximum permanent deformation was 7 thousandths of an inch which was also measured after the hot chamber test. There was no significant increase in deformation under load during the last 10 hours of the twelve hour 165°F cycle indicating good fatigue properties.

The only deformation associated with the 40,000 foot altitude chamber test occurred after loading the bomb in the ejector mechanism. There was no significant deformation resulting from the conditions of this test.

b. Salt Spray Test

(1) Procedure

The salt spray testing of the BDU-17/B Practice Bomb was performed in accordance with paragraph 9.6.1 of MIL-E-5272C. This is a standard accelerated-corrosion test which constitutes an arbitrary performance test that is not intended to simulate common conditions of service use. During the test the bomb was subjected to a fine mist of a 5% sodium chloride solution at 95°F for a period of 168 hours. The

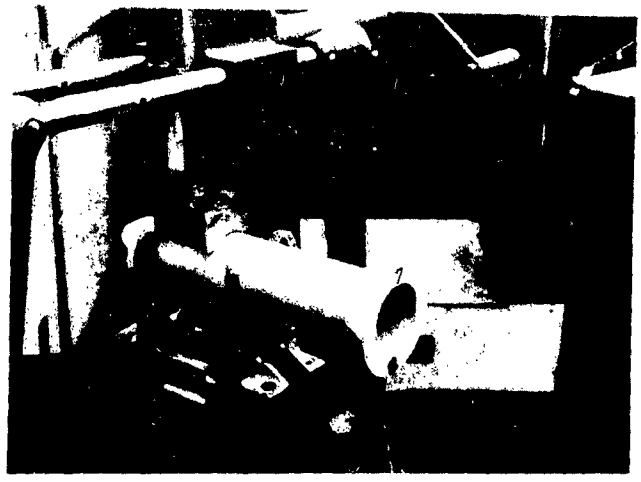


FIGURE 6
BDU-17/B LOADED IN EJECTION
MECHANISM

FIGURE 7
EJECTION MECHANISM AND BOMB
IN -65°F CHAMBER

exposure chamber used for this test was designed so that no spray or dripping of the condensate impinges directly on the test specimen. The relative humidity inside the chamber is maintained at 95 to 98 per cent.

(2) Results

The charge support assembly was heavily corroded at the end of the test while the plastic bomb case was unaffected. Either a change in material or an improved method of protective coating will be incorporated in the final design.

c. Vibration Test

(1) Procedure

A vibration test was performed on three BDU-17/B's in accordance with Procedure 12 of MIL-E-5272C. The bombs were assembled with a firing pin containing no special locking device, and a charge support assembly with inert charge and spring and with five prototype ballast rings. During the test, bomb resonance occurred at 40 to 50 CPS and at 200 to 250 CPS. The bombs were vibrated at each of these resonant frequencies for half an hour and then cycled between 5 and 500 CPS in fifteen minute intervals for a period of two hours. The total vibration time was three hours.

(2) Results

Although the ballast rings chattered during the test, none of the components of any of the bombs vibrated loose. It is interesting to note that although no malfunctions occurred during this test it was later necessary to modify the firing pin to include a lock washer due to the firing pin vibrated loose on several of the drop missions.

d. Fly-around Test

(1) Procedure

During this test the bomb was suspended from an F-104 with a special test fixture designed for this purpose. The aircraft was flown at Mach 1.32 at 10,000 Mean Sea Level which corresponds to a dynamic pressure of 1,770 lb/ft^2.

(2) Result

No damage of any kind.

e. Safety Test

(1) Procedure

The safety test was performed by dropping the bomb, nose down, six feet above a concrete floor. The first bomb tested used a crush cup for detonation of the cartridge. The next series of bombs tested had springs with spring constants varying from 57.2 to 171.6 pound/inches and a firing pin. The bomb was also tested with a safety pin inserted through the the spring between the cartridge and firing pin.

(2) Results

All bombs without a safety pin detonated when they struck the concrete. With the safety pin installed the bomb was dropped from a height of approximately 35 feet without detonation. It was interesting to note that the bomb case was undamaged in this test.

f. Drop Tests

(1) Procedure

There has been a total of seventy-four (74) bombs dropped to date at White Sands Missile Range. Of these bombs only the last thirty-three (33) bombs were modified with wedge shaped fins. These bombs were dropped at 500 and 600 Knots True Air Speed, 1500 feet above the target in a level mode of delivery. The MN-1A Trainer was carried on the left intermediate pylon position of the F-100.

(2) Results

Observation of the bomb dropped without wedge fins indicated that this configuration resulted in a neutrally stable bomb. That is, if the bomb were pitched down on ejection, it would continue to oscillate until it hit the ground. If the bomb were ejected level into the air stream it would remain in this attitude. A pitch down was noticed on almost all drops from the forward and center positions (these positions are numbered 1, 3, 5 and 6 in the MN-1A Trainer) of the Trainer while the bombs ejected from the aft two position (numbered 2 and 4 in the Trainer) of the Trainer remained level. This may be due to turbulence in the forward portions of the Trainer, or to the larger aft door, which may allow these bombs to be ejected into the air stream through a more gradual velocity gradient.

Of the forty-one (41) bombs dropped without wedge fins, ten did not spot. Of the thirty-three (33) bombs dropped with the fins, two did not spot. It was later determined that one of the two spotting failures was caused by the firing pin vibrating loose. This has since been prevented by using a lock washer attached to the firing pin. The other NO-SPOT could not be determined.

During the drop test program it was reported by test pilots that the BDU-17/B spots as well, if not better than any other miniature practice bomb. This may be due to the light construction of the bomb case, and the large opening provided in the bomb body for escaping smoke.

The Mil-Dispersion of the bombs with the fins, reported by the Ballistics Directorate at Eglin Air Force Base, is 37 mils.

6. Summary.

The BDU-17/B has met or exceeded all the design objectives established for this bomb. It is rugged, inexpensive and easy to handle and assemble. Drop tests show that the bomb is stable, and has a reliable spotting system. The next group of bombs will be drop tested in the final configuration in level and LADD deliveries, at several release altitudes and speeds, on ground and water ranges, to continue the verification of the ballistics and spotting reliability. Potential using commands will be invited to participate in this final phase of evaluation and testing.

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1. Bombing techniques
2. Practice bombs
3. Retarded weapons
4. Training weapons

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