TALOS STRUCTURAL FIRING TEST ABOARD THE USS LITTLE ROCK (CLG-4)

U. S. NAVAL WEAPONS LABORATORY - DAHLGREN, VA

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by: J. W. Loving, T. I. Dodson, C. W. Fischler, P. E. Wine

ABSTRACT

Six TALOS Mk 11 Mod 2 boosters with concrete slugs were fired aboard the USS LITTLE ROCK (CLG-4) to investigate the adequacy of the protection for the TALOS launching system personnel against blast effects and to determine the effects of the booster blast on the ship's structure. The test vehicles were fired at various angles such that the exhaust stream was directed at areas where damage, flame, or toxic gas leakage had occurred during the structural firing tests aboard the USS GALVESTON (CLG-3). These tests were also utilized to evaluate the design changes in the ship's structural components that were necessitated by the results of the GALVESTON tests. Measurements were made of pressures in the exhaust stream, structural strains, toxic gas concentrations, noise levels, flame penetrations at door seals and temperature changes inside the ship. High-speed motion pictures were taken on all tests.

The results indicated gas and flame leakage around the blast doors, toxic gas leakage into the ventilation systems, and minor structural damage to equipment mounted on the sides of the missile house and the main deck. A detailed description of all data obtained and ship damage incurred is included in this report.

FOREWORD

This is the final report on the TALOS Structural Firing Tests Aboard the USS LITTLE ROCK (CLG-4) conducted under BUWEPS Task Assignment NO 512-535/55008/69-064 Amendments No. 1 and 2 of 17 June 1959 and 10 August 1960, respectively. These tests were performed as part of the BUWEPS Ship Qualification Tests for the USS LITTLE ROCK,(CLG-4) conducted by the Applied Physics Laboratory of the John Hopkins University (APL/JHU) for the Bureau of Naval Weapons and in accordance with Test 8 of the test program, reference (a). These tests were conducted to determine the effects of the TALOS booster blast on the ship's structure, and to establish the adequacy of protection for the TALOS launching system personnel against blast effects.

This report was reviewed by the following members of the Weapons Development and Evaluation Laboratory:

J. J. WALSH, Head, Physical Projects Section
D. C. ROSS, Head, Experimental Branch
H. R. PRYOR, Head, Development Division
D. W. STONER, Deputy Director
M. W. WHITAKER, Captain, USN, Director

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APPROVED FOR RELEASE:
/s/ R. H. LYDDANE Technical Director

INTRODUCTION

Before assigning personnel to operational areas in the proximity of the TALOS launcher, it was necessary to determine whether the structures provide adequate protection from the booster blast. In order to determine the effects of the booster blast on the ship's structure, six Launcher Test Vehicles (LTV), each composed of a Mk 11 Mod 2 booster with a concrete slug, were fired at various angles such that the exhaust stream was directed at areas where damage, flame or toxic gas leakage had occurred during the structural firing tests aboard the USS GALVESTON (CLG-3). These tests also served to evaluate the design changes in the ship's structural components that were dictated by the results of the blast tests conducted aboard the GALVESTON. Tests were also conducted to determine the adequacy of the door seals, ports, and equipment exposed to the direct booster blast. Detailed test objectives are given in the test plan, reference (a), and repeated in Appendix A.

The tests also determined the effects of the booster blast on an instrumented simulated emergency igniter injector unit for the TALOS launching system. The results of the igniter injector unit tests were reported in reference (b).

On board the USS LITTLE ROCK (CLG-4) were instrumentation teams for measuring toxic gas concentrations, noise pressure levels, structural strains, pressures in the exhaust stream, structural accelerations and temperature changes inside ship compartments, for providing high-speed photographic coverage, and for observing the extent of flame entrance at door seals. The instrumentation was moved for each test in order to make all measurements in the same configuration with respect to the impingement areas. The detailed test results are grouped according to type of measurement, rather than by test. This arrangement avoids repeated references to the type of measurement considered.

An assist ship, USS SHAKORI (ATF-162), was in close company and furnished over--all high-speed photographic coverage of the booster
exhaust stream.

TEST PROCEDURES

The instrumentation was installed and operated by Naval Weapons Laboratory personnel with the assistance of members of the ship's company assigned to the various groups. The equipment used to record pressure, strain and temperature was installed in a 28' x 8' instrumentation trailer located on the starboard side of the 02 level at approximately Frame 95. Signal cables were connected between the instrumentation trailer and the transducers, which were located throughout the after part of the ship at the areas under test. For each test a TALOS Mk 11 Mod 2 booster with a concrete slug was launched from either the "A" rail or the "B" rail of the Mk 7 Mod 0 Guided Missile Launcher.

The launcher angles, impingement areas, and the sequence in which the tests were conducted are indicated in the table below:

Test No.	Rail Loaded	Train	Elevation	Impingement Area
1	8-29-60	144.44 deg	14 deg	Missile House Observation Port
2	8-29-60	156.05 deg	12.30 deg	Slanting Bulkhead two feet aft of Door (D-1-119-2)
3	8-29-60	207.59 deg	10.53 deg	Main Deck Frame 121 starboard side
4	8-30-60	220.58 deg	10 deg	Starboard Blast Door
5	8-30-60	39 deg	43 deg	Deck aft of launcher
6	8-30-60	145 deg	75 deg	Deck forward of launcher

The tests were conducted as part of the BUWEPS Ship Qualification Tests for guided missile ships and were fired in the Virginia Capes Operational Area.

After each test a description of the damage was recorded, and damaged areas were photographed. The test data were returned to the Naval Weapons Laboratory for detailed analysis and reporting.

The procedures followed by the different groups in obtaining each type of measurement or observation are described in the following paragraphs:

1. CAMERA COVERAGE

Camera coverage was arranged to provide information on structural damage, for observing extent of flame entrance at door seals and to document the other test instrumentation on all tests. Details for each camera including its location, type, speed and coverage are included in Table 1.

2. TEMPERATURE MEASUREMENTS

The air temperature was monitored in the missile house, and in other operational areas that would be manned during missile launchings, to record any changes in temperature attributable to the firing of the boosters.

Iron-constantan thermocouples fabricated from No. 24 Brown and Sharpe gauge thermocouple wire and connected to a recording potentiometer were used to monitor the temperature. The equipment was capable of indicating a temperature change of one degree Fahrenheit. The thermocouples were installed in the areas indicated in the table below:

Location	Test No.
Wing and Fin Assembly Area	1
Port Checkout Area	2
Starboard Checkout Area	3
Wing and Fin Assembly Area	4
After Repair Station No. 3	5
After Repair Station No. 3	6

The recorder was operated over a period beginning 5 minutes before firing and ending 15 minutes after firing the boosters.

3. TOXIC GAS SAMPLING

Shipboard toxicity tests were conducted to determine the presence and the concentrations of noxious gas leakage into the interior of the ship. Among the expected products of combustion were carbon monoxide, lead, and oxides of nitrogen.

Air samples were collected at the completion of each test with Mine Safety Appliance (M-S-A) gas sampling equipment to determine the presence and concentrations of these substances. The types of gas samplers employed are indicated in the following table.

Gas	Sampler
Carbon Monoxide	M-S-A Tester, Type By-47133 M-S-A Indicator, Type DS-43823
Oxides of Nitrogen	M-S-A Detector, Type 83100 Drager-Gas Detector
Lead	M-S-A Lead-In-Air Detector

Lead concentrations were also determined by using a motor operated vacuum pump which collected air samples in a solution for laboratory analysis.

Before each test air samples were collected to determine if lead was present from the previous test.

4. SOUND PRESSURE LEVELS

Sound pressure level measurements were made in areas adjacent to the missile launcher to provide information on the high intensity noise levels generated by the firing of the TALOS booster. This information will be furnished to BUMED for determination of physiological hazards to the personnel manning these areas.

The outputs from condenser microphones employed for obtaining the sound pressure level measurements were recorded on magnetic tapes and later analyzed with an audio frequency spectrometer. Sound level meters were also employed to obtain peak level readings for on-the-spot evaluation of the sound pressure levels generated by the firing of the boosters. The microphones were located for each test as indicated in Figure 1 and identified by Table 4.

Before each test the microphone systems were calibrated by applying a pure 400 cycle tone at 121 db with respect to the reference level, 0.0002 dynes/cm2 .

5. PRESSURE MEASUREMENTS

Pressure measurements were obtained during Tests 2 and 3 to determine the forces acting on the sides of the missile house from low angle firings which impinged directly on or along side of the deck house. Pressure measurements were also obtained during Tests 5 and 6 to determine the forces acting on the main deck from high angle firings which impinged directly on the main deck.

Unbonded strain gauge transducers were employed to obtain the pressure measurements. The outputs from the transducers were recorded on an electromagnetic oscillograph using galvanometers with sensitivities of 10.7 micro-amperes per inch of deflection.

The pressure measurerments were obtained with the gauges sensing the pressure through holes normal to the surface of the structure. The locations of the holes in the sides of the missile house are indicated in Figure 2. The holes through the main deck were located within the area formed by the intersection of the supersonic cone of the exhaust stream with the main deck. Figures 3 and 4 represent the arrangement of the holes in the main deck for Tests 5 and 6.

6. STRAIN MEASUREMENTS

Strain measurements were made during Tests 2 and 3 to determine the effect of the booster blast on major structural components of the missile house under various types of loading. The LTV in Test 2 was fired at such an angle that the exhaust stream impinged directly on the slanting bulkhead of the missile house. Test 3 was arranged so that the exhaust stream impinged on the main deck approximately three feet outboard of the bulkhead.

Resistance strain gauges were employed to obtain the strain measurements. The strain gauges were bonded at equally spaced intervals on each of the vertical stiffeners at Frame 120 on the port and starboard sides of the missile house as indicated in Figure 2. the strain gauges were recorded on an electromagnetic galvanometers with sensitivities of 10.7 micro-amperes per inch.

7. ACCELERATION MEASUREMENTS

An attempt was made to obtain acceleration measurements during Tests 2 and 3 to provide information about the acceleration forces tending to dislodge the blow-out patches at Frame 109 on the port and starboard sides of the missile house. However, the acceleration measurements obtained during the conduct of Test 2 indicated that high frequency transients overloaded the amplifiers in the recording system. It was not practicable to obtain acceleration measurements during Test 3 because the accelerometer signals were obscured by 60-cycle electrical noise induced in the accelerometer recording system.

8. FLAME INDICATORS

Flame indicators were used to provide evidence of flame or hot gas leakage past the seals of doors, hatches, or ports into the interior of the ship. The flame indicators employed were 2-inch squares of rayon-acetate taffeta wine colored cloth, weighing approximately 3 ounces per square yard. This material has an ignition energy of 2 calories per square centimeter according to the government publication of *"The Effects of Nuclear Weapons"* dated June 1957.

The flame indicators were installed around the interior periphery of the Port and Starboard Blast Doors, the Checkout Compartment Doors (D-1-119-1) and (D-1-119-2), Hatches (H-1-130-1) and (H-1-130-2), and the Observation Port for all of the tests. At the completion of each test the cloth tufts were examined to determine whether any had been displaced, melted, or burned. If any of the tufts showed indication of exposure to hot gases or flame, they were replaced and the location noted.

RESULTS AND DISCUSSION

The structural firing tests were successfully completed on 30 August 1960. No major structural deficiencies were observed during or after the tests. However, there was a large amount of gas and flame leakage around the blast doors, into air vents, and some minor damage to equipment mounted on the sides of the deckhouse and on the main deck. Detailed discussions of the damage incurred and of each type of measurement are included in the following paragraphs.

1. CAMERA COVERAGE

A film report is being prepared for the Bureau of Naval Weapons from the 16 mm motion picture film. A series of frames from the 16 mm film taken inside of the ship showing flame and smoke entering around the port and starboard blast doors are shown in Figures 10, 11 and 17. Photographic coverage of the damage and of the leakage around the blast doors are shown in Figures 8 through 20.

2. TEMPERATURE MEASUREMENTS

There were no appreciable variations in the temperature of the areas monitored except during Test 4. This maximum temperature rise of 20 deg. F was attributed to the large amount of flame and hot gas leakage past the seals of the starboard blast door, Figure 17. A temperature versus time curve for Test 4 is shown in Figure 5. The temperature variations obtained during the conduct of the tests ate included in Table 2.

3. TOXIC GAS SAMPLING

The concentrations of carbon monoxide, lead and oxides of nitrogen obtained after each test are included in Table 3. The high concentration of lead, 0.40 milligrams per meter 3 (mg/m 3), observed in the CPO living quarters after conducting Test 3 was attributed to exhaust gases entering the exhaust ventilation system on the main deck. Toxic gases were also detected in the missile house after conducting Tests 1 through 4 as a result of gas leakage around the periphery of the blast doors and the personnel access doors (D-l-119-1) and (D-1-119-2) into the missile checkout compartments. Figured 10, 11 and 17 indicate the severe leakage past the seals of the port and starboard blast doors during the conduct of Tests 1 and 4 respectively.

Information on toxic gases in this report will be furnished to BUMED for evaluation of the hazards to personnel. The threshold limits of toxicity for carbon monoxide and lead from the Bureau of Medicine and Surgery Instruction 6270.3 are indicated below:

CO	100 parts per million (ppm)
Pb	0.20 mg/m3

4. SOUND PRESSURE LEVELS

A spectrum analysis of each noise recording was made using a Bruel and Kjaer spectrum analyzer. The output signals from the magnetic tapes were applied successively to each filter of the 1/3 octave spectrum analyzer and a complete time history for each filter was plotted using a high-speed level recorder and the maximum noise level was noted. The maximum (over-all) sound pressure levels for each test which were obtained from the time-history curves and from the sound level meters are indicated in Table 4. The more detailed information obtained from the spectral analysis will be furnished to the BUMED for evaluation of the hazards to personnel.

Threshold limits should be used only as guides in the control of health hazards and should not be regarded as fine lines between safe and dangerous conditions.

5. PRESSURE MEASUREMENTS

The pressure measurements obtained during the conduct of Tests 2 and 3 indicated pressure variations from -11.0 psig to +14.0 psig acting on the sides of the missile house. The peak positive and negative pressures obtained are indicated in Table 5.

The results of the high angle firings, Tests 5 and 6, indicated pressures up to 270 psig acting on the main deck. The maximum value was obtained in an area bounded by Frames 125 and 126 and longitudinal beams 2 and 3 during Test 5. The peak pressures obtained are listed in Table 6 and the locations identified by Figures 3 and 4.

6. STRAIN MEASUREMENTS

The strain measurements obtained during the conduct of Tests 2 and 3 indicated damped, essentially sinusoidal vibrations at 30 cycles per second. None of the strains indicated excessive loading to the vertical stiffeners. Test 3 produced strains of the greatest magnitude in the starboard vertical stiffener in which the strains varied from 500 micro-inches per inch of tension (toward the center line of the ship) to 500 micro-inches per inch of compression. The peak strains measured in the port and starboard vertical stiffeners are indicated in the following table.

Test No.	Gauge Location on Vertical Stiffener		Micro-inches per inch Tension	Compression
2	Port	-Top	110	30
		-Center	115	150
		-Bottom	190	195
3	Starboard	-Top	190	180
		-Center	500	500
		-Bottom	420	445

The strain gauge located in the center of the starboard vertical stiffener did not return to zero after Test 3, but indicated a residual strain (in tension) of 125 micro-inches per inch. This residual strain persisted at nearly a constant level until the end of the record period (approximately two seconds after firing). Figure 6 is a reproduction of the strain record for Test 3.

7. FLAME INDICATORS

The results indicate that severe leakage occurred during Tests 1 and 4 around the port and starboard blast doors, respectively. Figures 10, 11 and 17 show the leakage past the blast door seals during the above mentioned tests. The results obtained on all tests are indicated in Table 7 and identified by Fig 7.

8. STRUCTURAL DAMAGE

The firing sequence for this series of tests, as indicated earlier was 1, 2, 3, 4, 6, and 5. Since damage and paint erosion were cumulative, the discussion of the damage has been arranged to follow the sequence in which the tests were conducted. The damage incurred
and the flame and smoke leakage around the blast doors resulting from the firing of the boosters are shown in Figures 8 through 20.

The severe leakage of flame, smoke, and hot gases past the seals of both blast doors (Figures 10, 11 and 17) during Tests 1 and 4 would have seriously jeopardized the safety of the operating personnel in Area I of the missile house.

There were minor structural deficiencies noted after several of the firings both on the inside and the outside of the ship. An inspection plate approximately 3 feet by 2 feet for ventilation reheater 167P C-202-L at Frame 115 in the overhead of the CPO mess, sheared the stud bolts holding it to the reheater on three sides during Test 2, Figure 13. Smoke was also observed entering the CPO living space through the exhaust vent during the conduct of Test 3. The damage to the equipment mounted on the sides of the missile house and on the main deck is shown in Figures 8 through 20.

CONCLUSIONS

It is concluded that the damage caused by the blast of the TALOS Mk 11 Mod 2 booster during the structural firing tests was minor. It appears that a redesign of the latching mechanism and the seals for the blast doors, the installation of manually operated closures for the intake and exhaust vents located close to the after edge of the missile house, and the relocation of fragile items on the sides of the missile house and main deck would eliminate most of the damage.

It is further concluded that it is safe to conduct tactical exercises provided that the missile firings are so arranged that the booster blast does not impinge on the face plate of the missile house until further tests have been conducted to insure that the blast doors are flame proof.

No conclusions will be drawn by the Naval Weapons Laboratory regarding the effect of the noise level and toxic gases on personnel, since the information obtained will be furnished to BUMED for further study.

Conclusions regarding the effect of strains and forces on the structural surfaces will be drawn by BUSHIPS.

RECOMMENDATIONS

It is recommended that certain alterations be made on all the CLG-3 class ships. In general this will include removing, where permissible, projections and fittings from the sides of the missile house.

The firings on the LITTLE ROCK indicated that the following items proved to be inadequate to withstand the blast from the boosters. It is recommended that they be redesigned or relocated as noted:

1. Redesign the latching mechanism and the seals of the blast doors to insure that the latter are flame proof.

2. Design and install manually operated closures for the intake and exhaust vents, located close to the after edge of the missile house, to prevent the booster blast from entering the ship through the venti- lation system.

3. Redesign the fire hose covers to make them flame proof.

4. Relocate all projections in the after section of the ship, for example, electrical outlet stands.

It is recommended that the blast doors and the checkout compartment doors be tested on all CLG-3 class ships prior to assigning personnel to Area I of the missile house. The test should consist of the booster blast of a fly-away missile impinging on or near the structures.