DISTANT RUNNER RESULTS

A 5 Event High Explosive Test Series
Involving U.S. Air Force 3rd Generation
Aircraft Shelters

by

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BACKGROUND

In Europe, real estate restrictions make siting aircraft shelters and munitions facilities increasingly difficult. Property constraints which limit air base expansion; and Quantity Distance (QD) criteria which tend to increase inter-facility spacing, are competing factors. Overly restrictive criteria may compromise operational considerations and impede readiness.

(QUANTITY DISTANCE)

The QD criteria now in use in Europe for the separation of hardened aircraft shelters housing aircraft loaded with explosives from other resources; and for the separation of explosive storage sites or operating sites from runways, taxiways, and other A/C shelters were derived from standards for A/C parked in the open and are generally considered overly conservative.

The scope and cost of the current United States Air Force Europe Air Base Survivability Program construction effort demand that facility siting be accomplished with criteria that adequately reflect the risks from potential explosion sites. Over the past 5 years and after lengthy discussions and analysis only two small reductions out of the many applicable QD factors have been approved. At this point, and with two major policy decisions, one by the DoD Explosive Safety Board "That further reductions would not be considered without supporting test data," and the other by DoD "that all new construction would be sited waiver free," it became apparent that a major test program was necessary if any further QD reductions were to be achieved.

PROGRAM

DISTANT RUNNER is the nickname for this program. It was a 4.7 million dollar, five event high explosive test series, conducted by the Defense Nuclear Agency (DNA). This test series, an integral part of the overall DNA Theater Nuclear Forces Survivability, Security and Safety ($TNFS^3$) program, was conducted at the White Sands Missile Range, New Mexico, during the September-November 1981 time period.

IT

The DISTANT RUNNER program was primarily directed at addressing the suitability of current explosive safety quantity-distance (QD) criteria for the hardened Air Force third-generation aircraft shelters and adjoining runways and taxiways.

The overall program goal together with the four specific test objectives are shown in Figure 1.

DISTANT RUNNER TEST PROGRAM

GOAL

- **PROVIDE ADEQUATE EMPIRICAL DATA TO ASSESS AND REVISE CURRENT QUANTITY-DISTANCE CRITERIA.**

OBJECTIVES

1. **ASSESS CAPABILITY OF AIRCRAFT SHELTERS TO PROTECT AIRCRAFT, MUNITIONS, AND PERSONNEL FROM EXTERNAL EXPLOSIVE EFFECTS**
2. **ASSESS CAPABILITY OF AIRCRAFT SHELTERS TO PREVENT OR SUPPRESS THE PROPAGATION OF INTERNAL DETONATION EFFECTS**
3. **ASSESS COLLATERAL DAMAGE EFFECTS TO AND VULNERABILITY OF NEARBY RUNWAYS/TAXIWAYS**
4. **ACCOMMODATE WEAPONS STORAGE TESTING**

Figure 1

TESTBED

The general testbed location was in the northern portion of the White Sands Missile Range in the Queen 15 area. This site was chosen specifically for its high water table of 6-10 feet below the surface. This geology represented the typical worst case high water table geology for the European Theater.

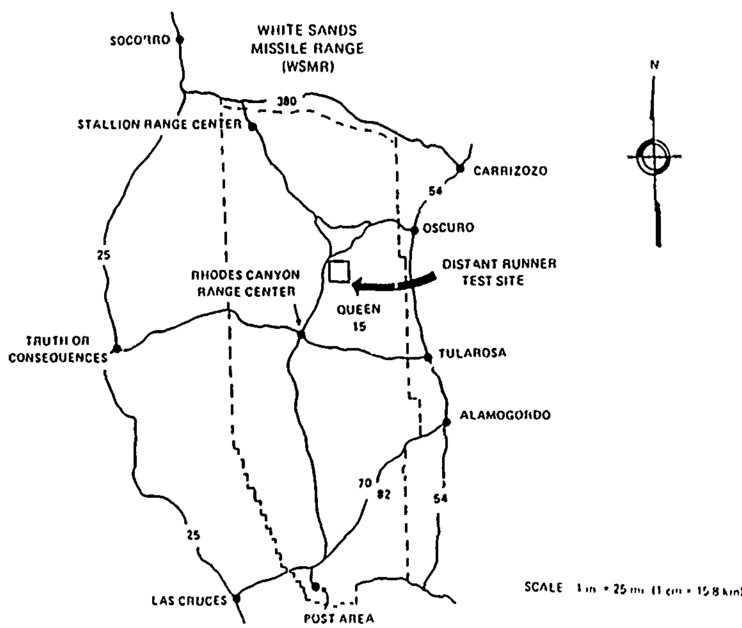


Figure 2

DISTANT RUNNER

TEST BED CONFIGURATION

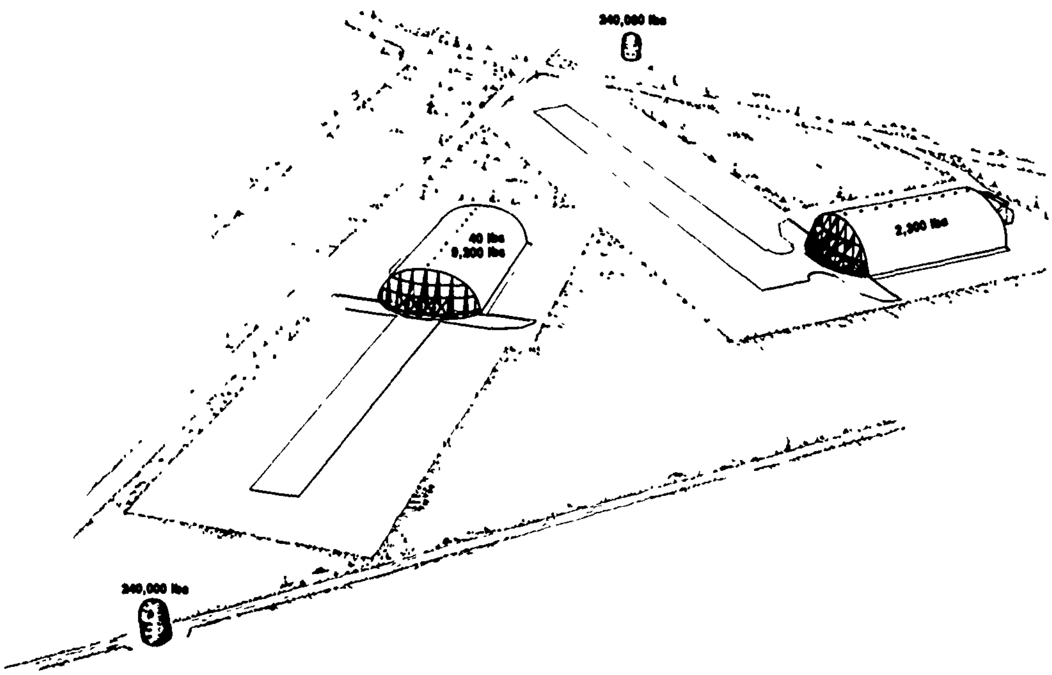


Figure 3

Shown in Figure 3 is the DISTANT RUNNER testbed. The two aircraft shelters depicted here were constructed from drawings provided by USAF Europe. The shelters were built exactly to those specifications with the following few minor exceptions - the footings were 2 feet wider than usual due to local soil conditions. No electrical work was done and the door opening mechanism was not installed. The orientation of the shelters was designed so that the required information could be obtained from the minimum number of external events. The runways/taxiways were also of standard USAF construction. The angled taxiway was designed to allow for a range of damage from both ground shock and debris damage. The other taxiway leading directly into the shelter was also configured to measure a range of damage levels and was oriented in line with ground zero. Because of this orientation, the damage mechanisms were expected to be different with more buckling expected.

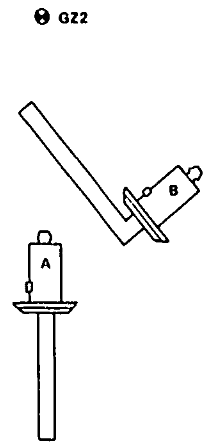
Construction began in September 1980 and although there were several minor problems construction progressed on schedule. In August 1981 the construction company turned the two full-scale 3rd generation A/C shelters over to the government and the test series was ready to commence. To add further authenticity to this test program two F101's were obtained and emplaced in the shelters during the test series.

RESULTS

The first two events were external events specifically designed to meet the first test objective of assessing the protective capability offered by the shelters from external explosive events. The first event was conducted on 2 Sept. 1981. In this test, both third generation aircraft shelters and the adjacent aircraft pavement were subjected to an external blast loading from 120 tons of Ammonium Nitrate and Fuel Oil (ANFO) as shown in Figure 4.

2 SEPTEMBER 1981

- 240,000 LBS ANFO
- 15 psi SHELTER B SIDE-ON
- 15 psi SHELTER A END-ON
- F101B AIRCRAFT IN EACH SHELTER



15 psi EQUATES TO A QD OF 8 $W^{1/3}$ FOR A SURFACE EXPLOSION
15 psi EQUATES TO A QD OF 5 $W^{1/3}$ FOR A CONTAINED EXPLOSION

Figure 4

This blast was designed to provide a 15 psi (103 kPa) overpressure and 490 psi-ms (3378 kPa-ms) impulse environment on the rear of one shelter and the side of the other shelter.

As shown in Figure 5 the actual free field airblast pressure environment was slightly lower than predicted. Measured pressures at the edge of the shelter averaged 13 psi. Free field positive phase overpressure impulses were also lower than desired, averaging 404 psi-ms (2785 kPa-ms).

DISTANT RUNNER 2 SEP 81 - BLAST ENVIRONMENT

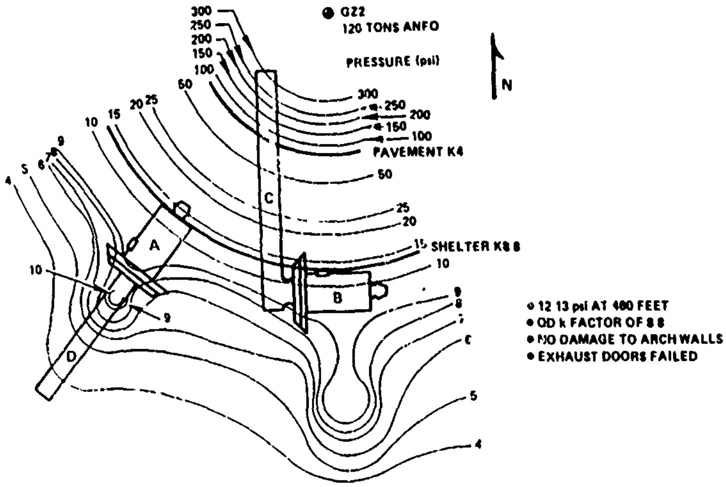


Figure 5

Damage to both shelter arches was slight with only minor cracking of the concrete on top of the shelter. In the shelter oriented rear on to the blast, both rear doors were blown off their hangers and thrown approximately 22 feet into the shelter. Additionally the steel guide angle iron running along the top of the rear door frame was pulled off.

In the shelter with a side on orientation only one rear door was blown off. Additionally the bolts holding the two cam followers nearest the Shelter center line on both front doors broke. The bolts holding the rest of the cam followers and blast deflector plates yielded as evidenced by loose washers and loose blast deflector plates.

The next two Figures depict the peak internal overpressures. In the shelter with the rear-on-exposure, pressure varied from .6 to 1.4 psi.

2 SEP 81 INTERNAL PRESSURE ISOBAR CHART

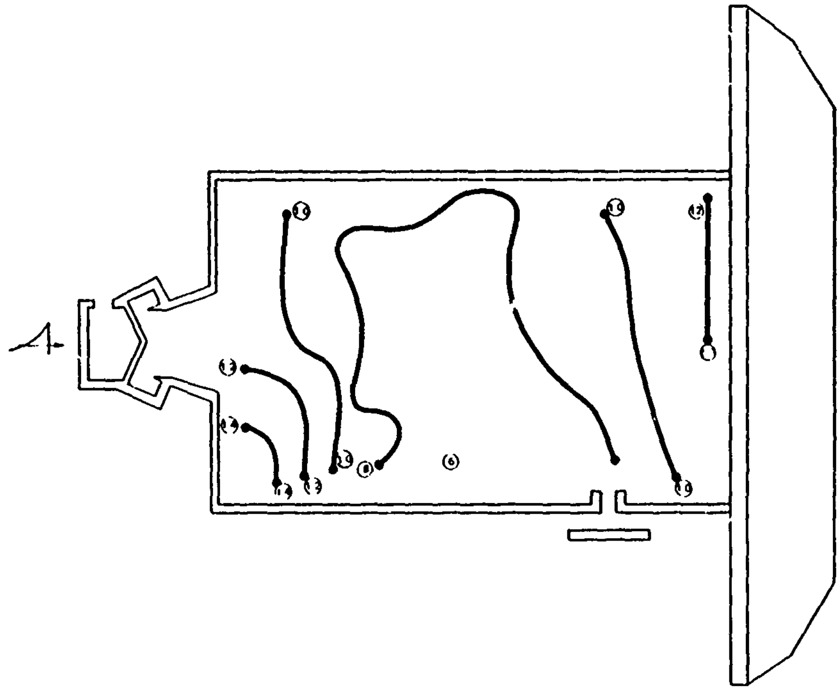


Figure 6

In the shelter with the side on orientation, internal overpressure ranged only from .2 to .6 psi.

2 SEP 81 INTERNAL PRESSURE ISOBAR CHART

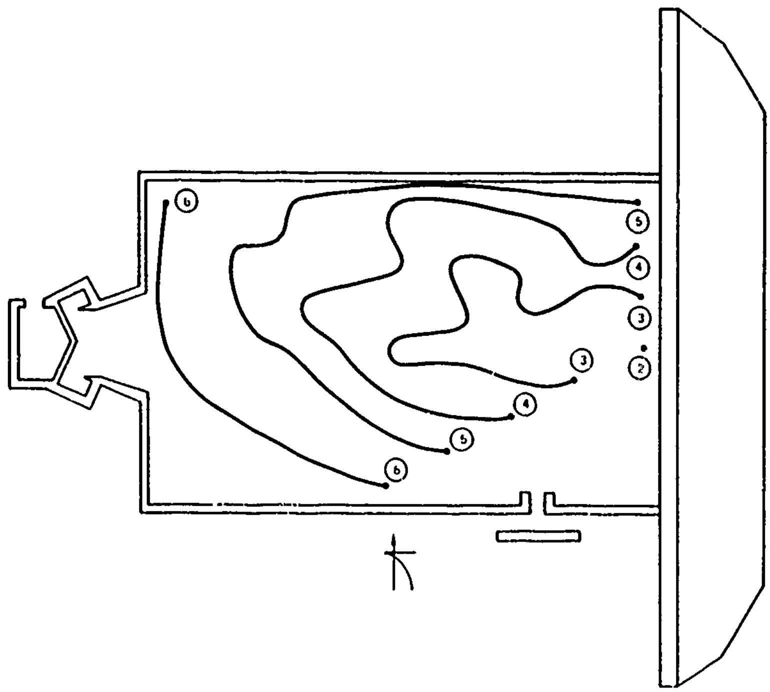


Figure 7

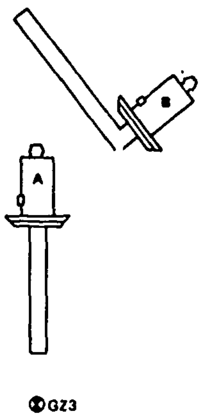
As far as damage to the taxiways went it was minimal. The taxiway that was the closest to ground zero sustained only two small 1/8" wide cracks and the other taxiway sustained no damage at all.

The second external event took place on 7 October 1981.

This was also a 120 ton ANFO charge oriented to provide 15 psi overpressure and 490 psi-ms impulse on the front of one shelter as shown in Figure 8.

7 OCTOBER 1981

- 240,000 LBS ANFO
- 15 psi SHELTER A FRONT-ON
- 7.8 psi SHELTER B OBLIQUE
- F101B AIRCRAFT IN EACH SHELTER



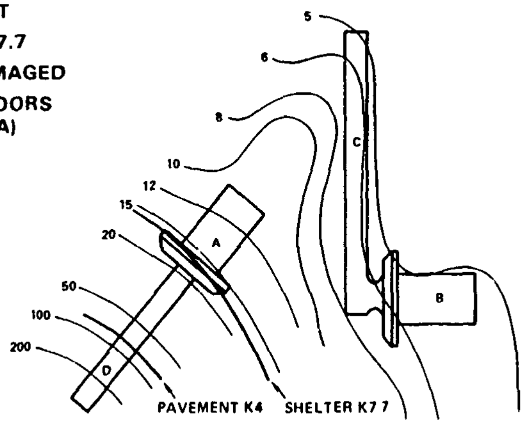
15 psi EQUATES TO A QD OF 8 $W^{1/3}$ FOR A SURFACE EXPLOSION
15 psi EQUATES TO A QD OF 5 $W^{1/3}$ FOR A CONTAINED EXPLOSION

Figure 8

Overpressure readings were higher on this event averaging 17 psi on the front of the shelter with an average impulse of 487 psi-ms. The free-field blast environment for this event is shown in Figure 9.

DISTANT RUNNER 7 OCT 81 BLAST ENVIRONMENT

- 17 PSI AT 460 FEET
- QD K FACTOR OF 7.7
- FRONT DOOR DAMAGED
- EXHAUST PORT DOORS FAILED (SHELTER A)
- NO DAMAGE TO SHELTER WALLS



GZ3 Figure 9

Damage to the arch was slight with only some chipping of the concrete noted along the front edge of the arch. Even though the rear doors had been welded back into place after the 1st event, this shot caused some welds to be broken on one of the doors while the other one failed completely.

The front doors of the nearest shelter received considerable damage from the blast. The tops of the shelter doors were bent and approximately 18 inches and buckling was noted in the supporting truss work. All of the bolts holding the cam followers and blast deflector shields failed, in fact, both front doors moved outward, that is toward GZ, approximately 14-16 inches.

Internal peak positive pressure ranged from .4 to 1.1 psi as shown in Figure 10.

7 OCT 81 INTERNAL PRESSURE ISOBAR CHART

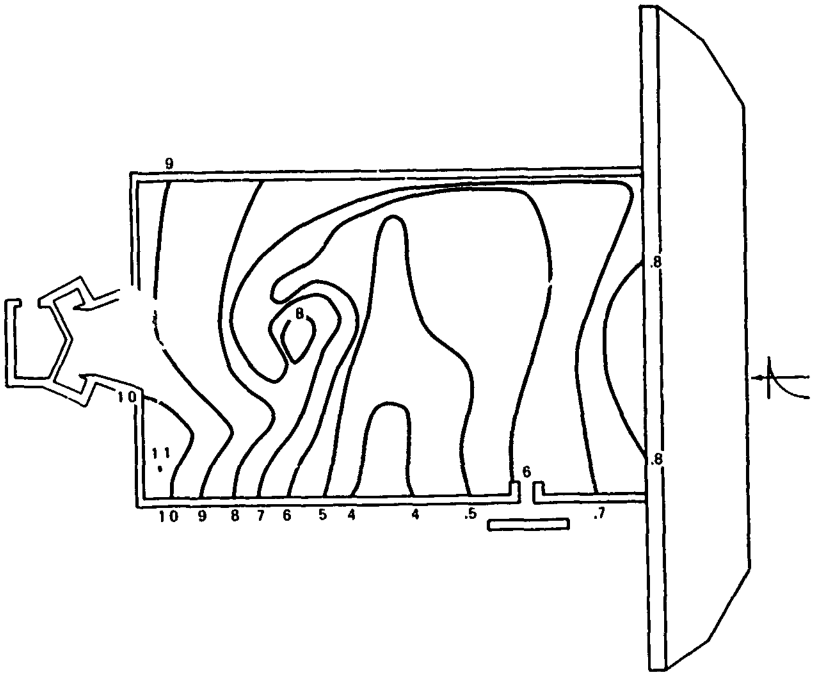


Figure 10

Visible damage to the taxiway was minimal, only slight buckling and a couple of thin cracks were seen. there was a permanent displacement of 1.08 inches down at the end of the taxiway nearest GZ.

There were no significant observations on the shelter or taxiway, receiving the oblique blast effects from this event.

As a result of these two external events the following conclusions were reached.

(1) The shelters are capable of withstanding overpressures of approximately 17.6 psi which equates to Q.D. of 7.7.

(2) The exhaust port doors failed at Q.D. of 8.8.

(3) Pressure buildup inside the shelters was generally below 1.6 psi.

(4) The front doors in all cases remained intact and movable, however, they sustained moderate damage.

(5) Taxiway/runway pavement damage was negligible.

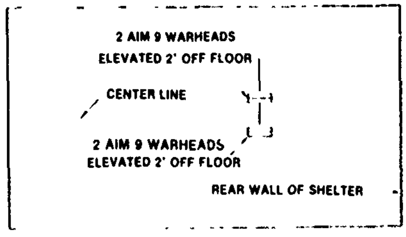
Next we come to the three internal events - these events were designed to determine the blast attenuation characteristics of the third generation aircraft shelters.

The smallest event took place on 6 Nov 1981.

In this test four AIM-9 warheads, 42 lbs net explosive weight, were detonated. This simulated the detonation of a weapons load for an aircraft loaded with air-to-air weapons. As shown in Figure 11 the warheads were located in the shelter as if they were on a plane. Detonating of all warheads was simultaneous.

6 NOVEMBER 1981

- **4 AIM-9 AIR TO AIR MISSILES (42 LBS NEW)**



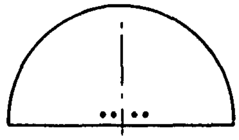


Figure 11

Damage to the shelter arch was minimal. Shrapnel from the warheads spalled the shelter floor and dented and penetrated the rear doors. The front doors were pushed forward approximately 21 feet.

External free field peak overpressure levels are shown on Figure 12.

DISTANT RUNNER 6 NOV 81 BLAST ENVIRONMENT

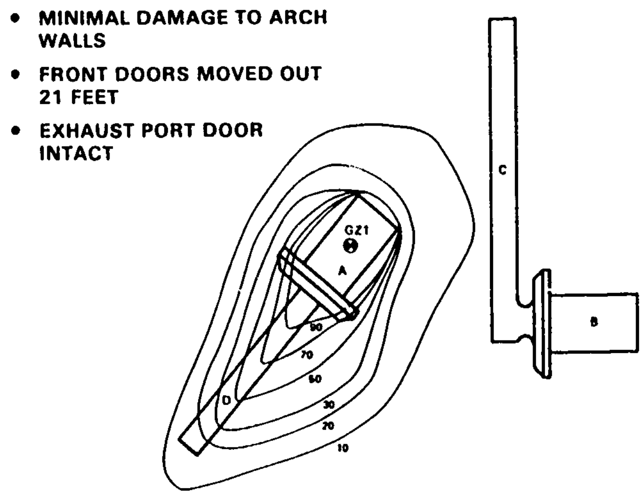


Figure 12

The next internal event in size took place on 28 Oct 1981. In this test 12 MK-82 bombs totaling 2,292 lbs of explosives were detonated inside a shelter. The test configuration is shown in Figure 13.

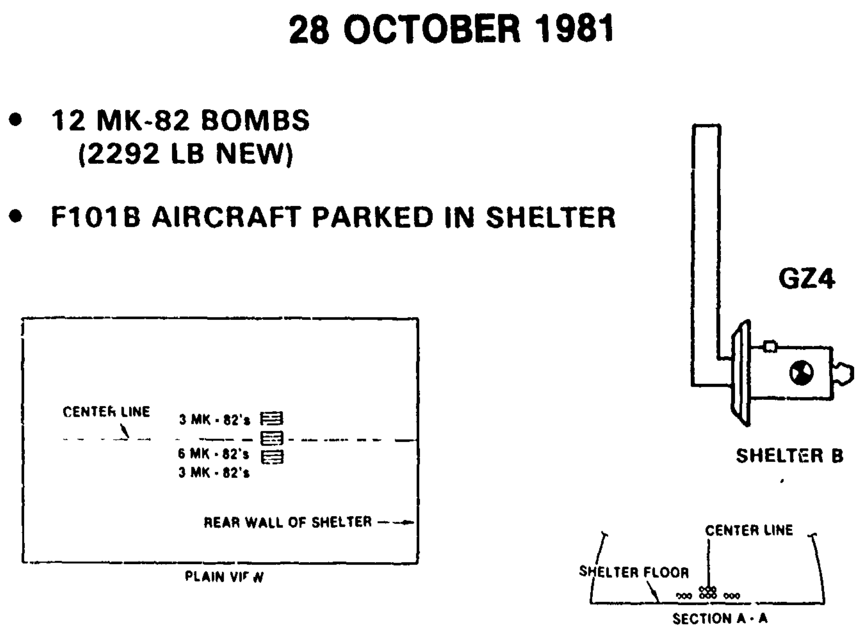


Figure 13

These bombs, which represented a typical air-to-ground sortie load, were placed under a F101B aircraft in a typical load configuration. Actual weapons and a plane were used in order to evaluate debris patterns accurately. The purpose of this event was to investigate the blast pressure and debris hazards created by an accidental explosion in the shelter. This event also served to test a prototype weapons storage vault which had been emplaced inside the shelter. (No damage to the vault or its contents was evident. A final report on the weapons storage vault will be issued by the Air Force Weapons Laboratory.)

As a result of this test the shelter was completely destroyed. A preliminary review of high speed technical photography indicated the following sequence of events.

The explosion first caused all the doors to fail. Next, the arch was lifted and separated from the foundation at their interface. As it was lifted the two halves of the arch separated at the crown and were propelled outward before breaking up. Large sections of the arch were thrown horizontally approximately 200 feet.

DISTANT RUNNER 28 OCT 81 - BLAST ENVIRONMENT

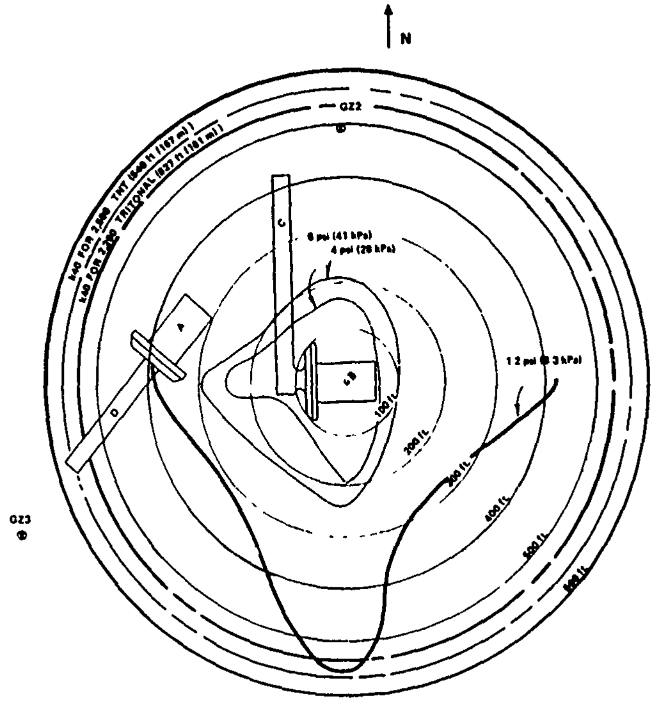


Figure 14

Figure 14 depicts the free field overpressure from the event. In general, at the same range, higher peak overpressures occurred at the front and sides of the shelter than at the rear. The relatively lower overpressures in the free field to the rear of the shelter were probably due to the protection provided by the massive blast deflector and generator room at the rear of the shelter.

As debris is also a major contributor to QD determination, a debris survey was conducted following the event. As this specific effort will be reported on by Dr. Jerry Ward of NSWC in a separate paper Figure 15 depicting the large debris map is all that will be shown here. The maximum range of 1722 feet of surveyed debris on this event was for a section of ring beam weighing 355 lbs.

DISTANT RUNNER 28 OCT 81 - LARGE DEBRIS MAP

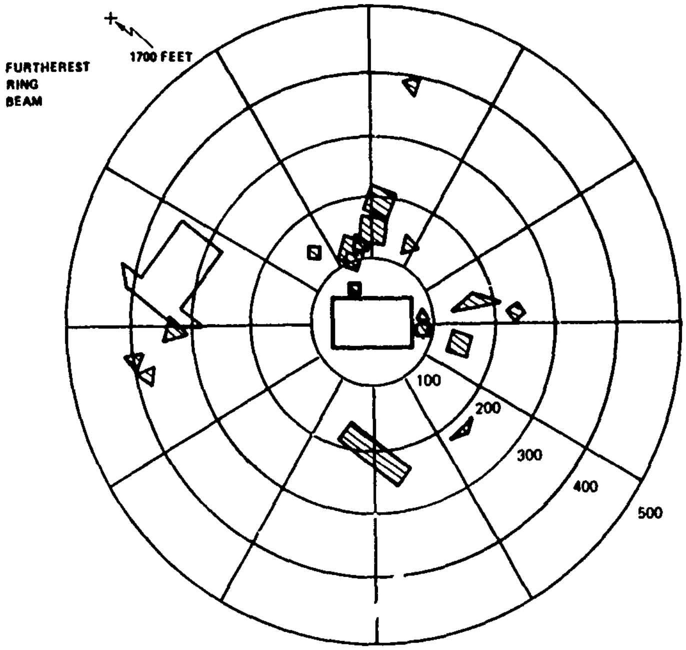
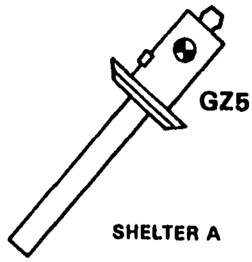


Figure 15

The last internal event occurred on 18 November 1981. In this test 48 MK-82 general purpose bombs totaling 9168 lbs. were detonated inside the remaining shelter. Twelve of the bombs were positioned beneath an F101 aircraft to simulate an aircraft loaded with air-to-ground munitions. The other 36 bombs were positioned near the airplane and at the front corners of the shelter (as shown in Figure 16) to simulate additional weapons also stored within the shelter. Again the purpose of the test was to investigate external blast pressure and debris hazards caused by the accidental simultaneous detonation of explosives stored inside an aircraft shelter.

18 NOVEMBER 1981

- **48 MK-82 BOMBS (9168 LB NEW)**
- **F101B AIRCRAFT PARKED IN SHELTER**



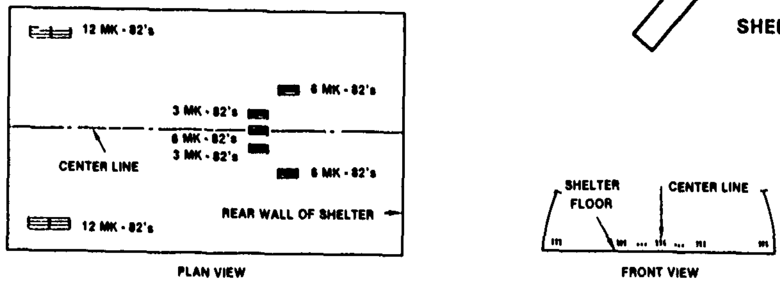


Figure 16

The shelter was completely destroyed. Again the front doors were the first to fail followed by the rear blast deflector doors and then the personnel access door. Next the arch failed at the foundation interface and at the crown at approximately the same time. The two halves of the arch were propelled outward horizontally before breaking up.

Figure 17 shows four peak pressure isobars for the free field. The 10 psi, 5 psi, and 1.2 psi isobars were not extended to the northwest side of the shelter due to a lack of gages in that area.

DISTANT RUNNER 18 NOV 81 - BLAST ENVIRONMENT

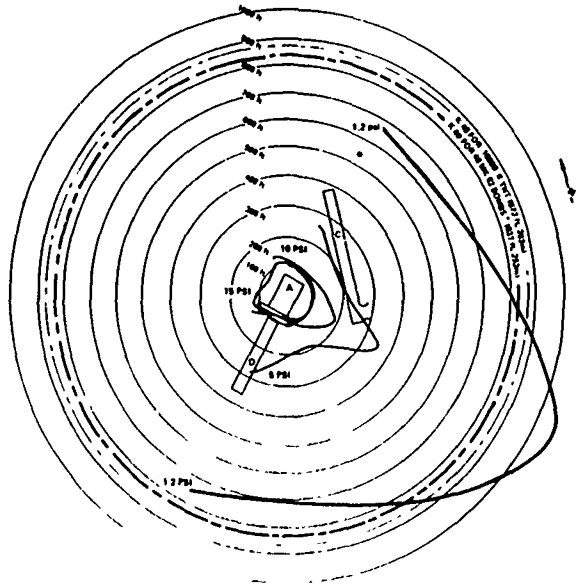


Figure 17

Pressures to the side of the shelter were again generally higher than either to the front or rear. As far as debris was concerned the shelter broke up in many large parts with a fairly uniform pattern. Putting all three internal events together the following conclusions are evident:

First-the shelter will contain an accidental explosion of a typical air-to-air sortie load.

Secondly there appears to be a slight overpressure suppression to the front and rear of the shelter, however, there also appears to be an overpressure enhancement on the side of the shelter opposite the personnel door largely due to the shelter failure mode.

And lastly there appears to be a significant debris hazard.

Figure 18 combines the results of the 5 events together and translates them into recommended changes to the safety quantity distance factors.

DISTANT RUNNER TEST PROGRAM — RECOMMENDATIONS

RECOMMENDED QD CRITERIA

EXPLOSIVE SITE	PROTECTED SITE	EXISTING QD	RECOMMENDED QD	RECOMMENDED SEPARATION DISTANCE
EXPLOSIVE STORAGE IGLOO (275 000 LB (125 000 KG) TNT)	AIRCRAFT SHELTER	$30\ W^{1/3}$	$5\ W^{1/3}$*	325 FT (99 M)
EXPLOSIVES IN OPEN STORAGE (100 000 LB (45,400 KG) TNT)	AIRCRAFT SHELTER	$30\ W^{1/3}$	$8\ W^{1/3}$	371 FT (113 M)
EXPLOSIVE STORAGE IGLOO (275,000 LB (125 000 KG) TNT)	TAXIWAY/RUNWAY	$18\ W^{1/3}$	$4\ W^{1/3}$	260 FT (79 M)
EXPLOSIVES IN OPEN STORAGE (100 000 LB (45,000 KG) TNT)	TAXIWAY/RUNWAY	$18\ W^{1/3}$	$4\ W^{1/3}$	186 FT (57 M)
AIRCRAFT SHELTER (2,292 LB (1,040 KG) TRITONAL (2,590 LB TNT))	OCCUPIED	$40\ W^{1/3}$	$40\ W^{1/3}$**	549 FT (167 M) (TNT)
AIRCRAFT SHELTER (9,168 LB (4,159 KG) TRITONAL (10,360 LB TNT))	OCCUPIED	$40\ W^{1/3}$	$40\ W^{1/3}$**	872 FT (266 M) (TNT)

*REDUCTION IN QD BELOW $8\ W^{1/3}$ IS BASED ON RESULTS OF BRL TESTING OF EXPLOSIVE STORAGE IGLOOS
**PENDING FINAL DEBRIS ANALYSIS RESULTS

Figure 18

Note the significant decreases recommended as a result of the external explosive tests.

On the other hand no change of QD factors involving the suppression capability of the shelters is recommended pending a detailed review of the debris hazard.

These recommendations are DNA's, the decision authority of course rests with the DoD Explosive Safety Board.

As a final footnote to this entire test series: several actions have already happened as a direct result of these 5 events.

First-in February 1982 the DODESB changed the QD factors for munitions storage area: to A/C shelters from K=30 to K=5 for storage igloos and K-8 from open storage sites.

Additionally the U.S. has presented a working paper to NATO Subgroup AC/258 recommending similar changes to NATO standards.

On the structural side--the AF Engineering & Services Center is reviewing for possible modification.

1. The shelter foundation to arch bond
2. The possible use of shorter ring beams
3. Redesign of exhaust post doors
4. Redesign of exhaust deflector
5. Use of higher strength bolts on blast deflector.
6. Possible elimination of horizontal guide rollers.

In summary, this test series has been highly beneficial to everybody concerned and the results will be felt for years to come.