Had the sump pump been in continuous operation from the time the high operating level would have been reached in the sump room until the "Flash Report" inspection took place approximately one hour later, it could have pumped out a maximum quantity of 6000 gallons, leaving a total of 2500 gallons still in the sump area. At the time of said inspection, no water was in the area, and the flame deflectors showed no evidence of having received any quantity of water. Actual operation of the water system was therefore questioned and investigated.

Subsequent examinations indicate that the water system could not have operated on command due to failure of the control circuit for the four-way solenoid valve (which actuates the 6" ball valve on the spray ring) connected through CB-30 in panel B-4 at approximately T+63 seconds.

The sump pump could not have operated due to power outage to panel DP-1, through which both power and control circuits for the sump pump are fed. Exact time for this loss of power has not been established, however, it is known that the breaker was tripped when the safety team first returned to the SLTF site, and it is reasonable to assume that it occurred within two minutes after lift-off.

The total quantity of carbon dioxide discharged through the system is determined by weighing the ten storage bottles both before and after a firing.

The system was activated approximately five minutes after launch and de-activated by the switch on the remote launch console approximately four minutes later. Weighing of the bottles indicated that approximately 200 lbs. of CO_2 had been expended during this period. This discharge is considerably less than the design rate of 200 lbs. per minute, which had previously been verified during performance of the system GSTP and during post-captive firing operations. The total capacity of the system is 600 lbs. (min.) to 750 lbs. (max.), and at the design flow rate the bottles should have been exhausted completely in the four minute period that the system was actuated.

A subsequent test of the system indicated normal operation and rate of discharge with no restriction of flow through the four nozzles. The system was activated through the switch on the SLTF launch console, indicating that there were no circuit problems.

It is conceivable that the reduced flow rate occurring after the firing could have been caused by the cold, liquid, CO_2 coming in contact with the hot pipes downstream of the electrically controlled valve, causing the fluid to gasify and thus create a back pressure in the system, thereby offering a restriction to normal flow.

9.9.3 Photographic Coverage

Photographic coverage of the major items reported herein for document purposes has been completed.

9.9.4 Itemized Damage

For convenience of reporting, the facility has been broken down into the following general areas, and itemized damage enumerated accordingly:

Above Ground Area,

Silo Equipment Areas,

Launch Duct Area, and

Exhaust Duct Area and Flame Deflector.

9.9.4.1 Above Ground

1. The South elevator cover door was blown open and the hinge bolts torn from mounting frame. The elevator was not functioning. Later inspection indicated dirt in the relay contacts was responsible and the elevator has been returned to service.

2. On the East side of the silo, the communications panel showed evidence of high vibration which resulted in the panel being bent slightly away from the silo and the safety horn assembly torn loose from the panel.

3. Vent hoods showed pressure distortion but were still in position. One tie down brace was torn loose from the silo deck.

4. The Flyaway Umbilical (3B1T) did not release at the missile quick-disconnect but instead, separated at the airborne fail-safe coupling. The reflective aluminum protective tape was in good condition showing no signs of heat damage.

5. The flood light receptacle and reflector on the North-west quadrant adjacent to access ladder hatch was broken completely away. The missing parts were found in drain ditch approximately 125 feet north of silo.

6. The sheet metal drain lip was torn loose from south end of silo cover, (approximately 6 feet in length).

7. The following list of fragments were found in the immediate area of the silo:

   a. A module support member, twisted and bent, on top of silo cover near south end.

   b. Small piece (4-inch cube) of gunite concrete was found about 15 feet east of silo cover door at approximately mid-length of cover away from silo.

   c. Unidentified piece of twisted sheet metal lying loose in the beam between the south exhaust duct and the launch duct at center line of silo. Possibly this unit was the back sheet of an acoustical module.

   d. A badly twisted acoustical module cage about 50 feet south of the silo.

   e. Fragments of acoustical cages and metal backing were found at a radius of approximately 250 feet on downwind side of silo (South).

   f. On the day following the launch, some smoldering was noticed in the plywood back-up under the gunite at top of the south exhaust duct.

   More detailed inspection revealed that in both south and north exhaust ducts, charring occurred at several isolated points where the gunite facing had small broken spots, permitting exposure of the plywood backing.

g. The umbilical flexible air conditioning duct, believed to be either 1B1A or 2B1A was discovered in the OSTF fenced area approximately 350 feet southeast of the silo. It was in good condition with no signs of damage due to burning, however the quick disconnect was missing.

8. At The Martin Company office and storage yard, approximately 300 feet southeast of the silo, the following items were noticed:

   a. The temporary wooden elevator shelter which was stored in the yard was blown over resulting in one crushed side.

   b. The chemical toilet positioned in same area, was blown over. Damage was not assessed.

   c. The office building overhead (tilt-up) doors (2) were blown open.

   d. The windows on the northwest end of the building were broken.

   e. A number of fluorescent light fixtures were loosened from their support chains.

9. The lanyard to the 6-inch diameter LOX tank vent at the LOX pond was broken and lying on the ground.

9.9.4.2 Silo Equipment Areas

1. In general, it can be stated that no damage occurred in the equipment areas. There was no structural damage apparent. Electrical power equipment was uneffected. There was no loss of function to any mechanical equipment once power was re-established. A progressive type of heat damage was apparent in the paint where the equipment areas interface with the exhaust ducts. The only severe blistering was at and below Platform #6, at which point the internal acoustic lining of the exhaust duct terminates, decreasing to no damage between the 4th and 5th Level.

2. The Gaseous Oxygen Analyzer on Level 4 east indicated a pump failure with a resultant warning horn alarm at the time of flash inspection. Subsequent checks have failed to reveal any cause or reason for this malfunction other than possible damage (local) to the alarm relay caused by vibration.

3. The two temperature recorders located on Level 6 were found to be in good condition and operating normally.

   a. The east side recorder indicated an ambient temperature of 47° at time of engine ignition. The temperature climbed from 47° at 1:13 P.M. to a maximum of 70° at 2:30 P.M., then began to recede. This recorder was placed in the vicinity of the LOX catch pot, which would account for the relatively low increase.

   b. The west side recorder showed an ambient temperature of 53° at 1:13 P.M., an immediate rise to 125°, then a drop to 83° at 1:25, 80° at 2:00, and 75° at 3:00 P.M.

   c. The sensing elements of the recorders were placed approximately one foot from the wall of the exhaust duct.

9.9.4.3 Launch Duct Area

1. Relative to the acoustical modules within the launch duct area, severe thermal and pressure damage was evident in increasing amount from top of silo to bottom of launch duct. All pliofilm envelope material on the external faces of the modules was gone except on Platform Level #6 directly behind the retracted platforms. (These platforms previous to firing had 6 inches of acoustic material attached to bottom surface, which is now essentially gone, though the cages remained intact.) At each instance where a module was not installed in the wall because of such items as cameras, lights, antenna, etc., an apparent turbulence caused areas of extremely heavy fiberglass insulation loss, as much as 60 to 70% of material. In modules immediately below such openings this turbulence effect was evident and also adjacent to cameras where wall plane changes direction.

The thermal action consisted of reduction of the surface fiberglass to a fused condition, varying in depth from 2 inches at the top to 12 inches at lower levels in a mottled pattern of random cavities.

2. The top row of modules at the rim of silo and adjacent to the exhaust ducts were severely deformed with a loss of most of their fiberglass. All module cages remained in proper position. Below Platform Level #6, the entire bottom row of radius modules was gone except for a few empty cages. In the second row from the bottom, six cages were detached in Quadrant 3 and the balance of the modules in this row were entirely deformed and void of filler material. The test modules furnished by the Ralph M. Parsons Company and the Koppers Company stood up well on the exterior surfaces. In order to test the mechanical survivability of various acoustical liner constructions, sample acoustical modules of two types were constructed by the Parsons Company. Modules of each type were installed at Levels 1, 3, and 5 on the walls of the launch duct during the launch. After the launch, the condition of these samples ranged from fair to very good.

One of the sample type modules has a 3/16 inch thick perforated metal facing backed by a layer of fly screen and packed with TWF glass fiber material. This type was found to be in fair condition, although the fiberglass material had fused just behind the screen in some places. In addition, the packing of some samples was displaced downward.

The other sample type module has a layer of Refrasil (high temperature fiberous material) sandwiched in fly screens between the 3/16 inch perforated metal facing and the TWF glass fiber packing. This type module was found to be in very good condition after the launch, and is reusable without refurbishing.

In addition to the Parsons Company sample modules, three Koppers Company modules were also installed near Levels 3 and 5 in the silo. These modules differed only in thickness (two of 6 inches and one of 12 inches) and were constructed of a 3/16 inch perforated metal facing backed by a 14 ga. perforated, corrugated metal sheet; another perforated flat sheet; a layer of stainless steel screen; a layer of Refrasil cloth and a dense packing of TWF glass fiber material. Both Koppers modules were found to be in excellent, reusable condition after the launch, with absolutely no signs of scorching, fusing or other heat damage internally.

3. The following specific items were noted:

   a. All umbilicals at the various launch duct levels showed severe damage as a result of burning. The reflective surface of the aluminum protective wrapping tape was almost all burned away. The three Missile Air Conditioning umbilicals were missing entirely except for the inner wire coils of two of these. (See also Item 9.9.4.1 (7g)). Such damage is expected and a burnout kit is provided for replacement as a routine operation. TMC Procedure 327R9030635A-4 reports on each umbilical in detail.

   b. The paint was scorched on the reflectors of the launch duct lights. However, all subject lights operated following restoring of power.

   c. Stage I LOX Vent Duct (1C1LV) was in good shape except for the electrical wiring which was burned and heat scorch evident on the mesh sleeve.

   d. The missile support ring and deflector plates were generally in good shape. Paint was burned from the entire assembly on sides exposed to the missile exhaust. The deflector plate was bent somewhat at its upper portions. Some of the connecting welds attaching the sections of the stainless steel cap plate to the main support ring were broken and the sections were separated in the quadrants directly under the thrust chambers.

   e. The damage to the LOX probe was extensive. Wiring was burned off, the cover was missing, and the entire assembly was severed from its outer support and was bent down and resting on the support ring.

   f. The missile spray ring drain line was broken off at the ell where it departs from the ring. The spray nozzles were deflected downward in varying degrees.

   g. The CO_2 tubing was bent in the unsupported areas exposed to the missile exhaust pressures. Subsequent actuation indicated no functional failure.

h. Damage to the OSBV drain lines was extensive. Portions were burned away entirely.

i. Evidence of a fire was noted above Platform #6 in the area between Segments A and B on the outside of the missile spray ring, where a group of heavily insulated umbilicals are supported. Follow-on investigation confirms that this fire was the result of spilled hydraulic fluid. Unburned hydraulic fluid was still in the area. It is probable that this fluid came from Umbilical 3D1H. Fire damage to the facility was insignificant.

9.9.4.4 Exhaust Duct and Flame Deflector

1. The exhaust ducts and flame deflector has been subjected to inspection on both sides.

2. The acoustical lining showed very light warping of the perforated covers in the upper area which progressively became more extensive at the bottom. This warping in the worst condition can be called severe. The exhaust impingement was apparently more intense on the outside wall surface and at each side of the duct. A few bolts for the module covers were missing. Several areas were noted where the module surface was dented apparently from flying objects. In the lower areas, the fiberglass filler batts suffered severe loss. Covers were removed from selected modules and contents inspected. This examination indicated that the upper eleven of the total of eighteen rows of modules suffered very minor damage and slump of filler material. The next three rows showed damage varying from 0 to 40%. The lower four rows had loss of filler approaching 80% of the original amount. The most severely damaged areas occurred in the bottom row, immediately above the lower fairing section. The filler material remaining in this row was only that which had been protected by the horizontal structural steel members. In all cases the damage to the retaining mesh screen was approximately proportional to the loss of acoustical filler. In the lower four rows some fusion of the filler was evident. The bottom leading edge fairing is in excellent condition. The departing edge at top was also in very good condition. Slight warping was evident but is inconsequential.

3. The metal fairing for the lateral strut crossing the exhaust duct at the missile support ring level shows severe steel erosion on the lower edge.

4. In the flame deflector the condition of the steel lining is nearly identical to that following the Captive Test, even though no water was used after the launch. Severe **warping** is apparent in the 3/8-inch plate at the departing edge. This **warping** is from 1 to 2 feet from a true line. In the bottom of the deflector, a rise of approximately 8 inches was noted. In the area of the 3/4-inch plate, the **warping** was slight and would be considered about the same as the pre-flight condition. No evidences of new erosion were noted on the 3/4-inch plate.

5. Several acoustical module cages from the launch duct were left in the flame deflector area and on both sides of the exhaust duct similar debris was caught on the pitot tube rakes.

9.10 COMMUNICATIONS

Significant modifications to the communications equipment were accomplished between the Captive Firing and the Flight Test. The system was aptly demonstrated by the complete absence of reported communication failures in the twenty-four hour period preceding and including the launch.

Damage to communications as a result of the launch was very minor. One headset, which had been left plugged into a jack in the silo was destroyed by flame. One weatherproof cabinet located at the Propellant Loading Station at the top of the silo was damaged. The pedestal was bent and the cover was blown off. All of the dial lines, jacks and networks remain in an operable condition with no visible sign of scorched cable or wiring.

10.0 CONCLUSIONS

1. The feasibility of launching a TITAN missile in an "in-silo launch" configuration is confirmed.

2. Further testing (including flight test) is not required to satisfy program objectives since all identified program objectives were successfully accomplished.

3. The flight integrity of the VS-1 missile was not adversely affected by the in-silo environment.

4. Damage incurred by the facility as a result of the launch was minor in all areas except the launch duct, flame deflector and exhaust ducts. The damage in the duct areas was not extensive and considerably less than anticipated. A comparatively modest refurbish program could again put the facility in a "GO" condition.

5. The performance of the TITAN destruct system for PMR has been adequately demonstrated.

6. All airborne systems and ground operating equipment performed satisfactorily throughout the test.

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7. The in-silo acoustic environment is reproducible within the accuracy of the acoustic measurements. (Equivalence of captive and flight data.)

8. For the case, as in this test, where exhaust duct liners are employed, the above-silo acoustic environment does not differ significantly from the in-silo acoustic environment. Therefore, missile components which can withstand the in-silo environment will probably withstand the acoustic environment above the silo.

9. No identified damage was sustained by the PLPS GSE/GOE in the Control Center, above ground, or in the Equipment Area of the missile silo, however the PLPS equipment in the launch duct sustained extensive damage. A 100 percent replacement or rework of the PLPS equipment in the launch duct would be required to place the system to an operational status.

10. The Launch Duct heating system was found to be unnecessary from the standpoint of maintaining suitable engine compartment temperatures between start of LOX loading and engine ignition. (The system did provide personnel comfort working in the launch duct and improved reception on silo TV monitors by dispelling fog.)

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11. The only fire of any consequence was caused by hydraulic oil leakage from the hydraulic umbilical at silo level 6. The damage caused by this hydraulic oil fire was superficial.

12. The communication system was essentially undamaged by the launch. The communications system could support additional tests at the Silo Launch Test Facility with no more preparation than the normal forty-eight hour communication check.

13. In silo transient pressure scaling was satisfactorily demonstrated.

14. The terminal count "remote control" capability has been adequately demonstrated.

11.0 RECOMMENDATIONS

1. The telemetry R.F. link must be improved for in-silo launchings.

2. Vibration measurements taken in the engine area require an understanding of the environment in this area during bolt firing in order to properly select the transducer, its location and mounting technique.

3. The apparent damage to lift-off switches due to explosive bolt detonation would indicate that additional consideration be given to the problem of ensuring reliable component operation in this environment. When similar explosive bolts are used, additional damping or isolation from the shock forces should be provided. Since a lift-off signal is now required by PMR for Range Safety Tracking, all TITAN firing facilities at Vandenberg Air Force Base should be studied to determine the adequacy of their lift-off signal circuits and reliability of their components in the use environment.

4. The logic of the Ground Operating Equipment should be designed to supply a lift-off signal to all subsystems in order to disable the NO/GO capability. This would allow the subsystems, such as Flight Controls, to remain in a GO status following a normal launch.

5. The supply voltages to launch duct functions such as the LOX vent umbilical and lift-off switch circuits should be fused. Since fire damage to this type of wiring is anticipated, this protection would isolate the damaged functions from the supply buses in the GOE, reducing the possibility of GOE damage and allowing normal indication on the GOE panels during launch.

6. The extensive damage in the Launch Duct (particularly to the PLPS System) warrants an investigation to reduce the damage to this system if used again or applied to similar systems of an "in-silo launch", which have a more than one firing use cycle. It is recommended that at least the following specified areas be investigated:

   a. Provide a protective cover for the LOX fill probe.

   b. Relocate hard plumbing in the Launch Duct out of the "high heat" area or provide protective covering.

   c. Wrap or coat the pneumatic umbilicals with a heat-resistant material.

   d. Provide a restraining lanyard on the OSBV Umbilicals (1E2L and 1E3L) to hold umbilicals clear of engine flame pattern.

e. Provide air conditioning umbilicals of sufficient strength to withstand and eliminate the possibility of disturbing other umbilicals in the Launch Duct.

f. Rework or relocate hydraulic umbilicals to minimize fire damage to surrounding equipment.

7. In-silo launch ducts should require the use of heat-resistant conductors in all electrical circuits located within the Launch Duct.

8. In the launch duct, the platforms, work level doors, and other mechanically connected components which report status through limit switch actuation, should require the use of a type of switch providing a longer travel between the "make" and "break" points to circumvent false alarms due to minor motion caused by vibration.

9. The "shunt-trip" function in the facility design is unnecessary.

10. Unless operating in a dust-controlled area, all control relays, limit switches, and other like devices should have dust-tight enclosures.

11. Acoustic treatment in both the top and bottom rows of the launch duct liner should be designed of a more stable type structure which will provide airfoil effect and positive anchorage. Acoustic value within these areas is negligible.

12. To eliminate adverse thermal and eddy effects caused by projections and cavities from the plane of the acoustical surface, design effort must be made to minimize these interferences in facilities planning a more than one firing cycle.

13. In the areas of the missile support system and associated spray rings, sufficient design consideration must be made to provide maximum protection from firing stresses and temperatures with optimum freedom of operating space.

14. Since the acoustic modules located behind retracted platforms showed no significant damage, because supplementary protection afforded by the expanded metal screen on the bottom of each platform, a similar air space and over-riding metal screen should be designed into future launch duct acoustical modules in facilities planning a more than single firing cycle. (Though a similar type of construction is already incorporated into one type of experimental module tested during the launch, this particular module was more sophisticated and more elaborately constructed than is necessary.)

15. The environmental data available from this test and the previous captive test in respect to base pressure, SPL radiation, and convection temperatures should be compiled and the main objective of this data would be to establish a criteria for design of airborne and ground equipment on TITAN II ground and airborne equipment.

16. A study should be conducted with available data from this launch to determine the feasibility of LOX exhaustion shut-down capabilities of TITAN I missiles, 1st stage, using the DCV's as a propellant utilization valve to achieve maximum flight time.

17. In the event that additional TITAN I launches may be performed from this silo, it is recommended that second stage flight hardware and ground equipment be used which would, in turn, demonstrate the capability of servicing a Stage II engine in this area since this was not accomplished in the initial phase of this program at SLTF.