The override solenoid housing was undamaged except for two melted points on the square plate holding the housing in position on the valve body.

(6) The quick disconnect adapter to the Clary preflight checkout valve was split and the internal parts of the Clary vavles were missing apparently these parts were expelled under internal pressure. The fitting (AN) and the quick disconnect were found at the bottom of the flame deflector plate and were slightly battered. The internal parts of the Clary valve were not found.

(7) The body casting of the PSV showed no evidence of cracks.

(8) The actuation supply screen was intact and clean.

(9) All fittings on this PSV were intact and tight except as noted in 6 above.

The TCVA ports were capped and argon at approximately 5 psi was applied to the PSV actuation port. Leakage occurred out the override overboard ports.

A Simpson meter was used to check the override solenoid at the burned wire ends. Resistance was 0.5 ohm. Normal resistance is 2.0 ohms.

The override solenoid was then removed by removing the Allen screws holding the override cavity section to the PSV body. The following observations were made:

(1) The "O" ring seal between the body sections had melted along approximately 45° of its circumference and had flowed into the override section. The "O" ring retainer was intact.

(2) The -9, -10, and -129 "O" rings (see AGC drawing 1-223750) appeared to have been attacked by heat and had contracted considerably from their original dimensions. (See Attachment 7)

The override solenoid was then removed from the override cavity casting and the following observations made:

(1) The slot in the head of the screw attaching the override piston to the solenoid core was broken out on one side of the screw head. The screw was too tight to be rotated.

(2) The -20 "O" ring had two small cuts but still retained its resiliency. (Approximately 1010" deep, impression about 1/8" wide and at 45° angle.)

(3) The "O" ring on the end of the override piston was intact and resilient.

No further disassembly was made. The valve parts were re-assembled.

Inspection of the plumbing from the PSV to the missile skin indicated that these lines had been properly installed and that the check valves were installed to permit proper flow overboard. If the check valves were installed backwards, abnormal TCV operation can occur because of hydraulic lockup in the system. This lockup usually causes the PSV piston to become unseated and the TCV to close. However, proper operation of the PSV and TCV had been demonstrated when the prefiring checkout of the engine was accomplished.

The preflight checkout connection to the PSV includes a quick disconnect and a Clary shuttle valve. This shuttle valve is such that fuel pressure can be applied to the PSV from the engine fuel discharge line or from an external source. A poppet inside the shuttle valve moves to seal off the engine connection when external pressure is applied and seals the external port when pressure is applied from the engine fuel line during normal firing. The quick disconnect is drilled to prevent hydraulic lockup within the shuttle valve. As previously mentioned, the internal poppet of the shuttle valve was not found. With this poppet missing, engine fuel pressure would be lost from the PSV and it should close. The TCV should then close. The closing of the TCV under these conditions, however, is a much slower operation than that which occurred on the firing under discussion. As noted in Section III under Mechanical Operation, this TCV closing time on two engine acceptance tests was 0.133 seconds and 0.135 seconds. These closures were command shutdowns via the PSV override. A closure resulting from loss of actuation pressure should require approximately 0.30 seconds. On an earlier XLR 91 firing on Test Stand D-1 a pressure decay closing occurred and the time was 0.33 seconds. Therefore, the TCV closing time for this firing under discussion does not appear to be a pressure decay closure since the time was 0.12 seconds.

It should be noted at this time that the method of recording the engine fireswitch signals should be changed from the present method of superimposing than on the timing signals to a method utilizing a separate recorder. A 6-channel Sanborn recorder will be adequate to record all fire switch signals: XLR 87 FS_1, XLR 91 $GGFS_1$, XLR 87 FS_2, XLR 91 FS_1, XLR 51 FS_2, and XLR 91 $GGFS_2$. Time correlation can be effected easily utilizing the existing timing signals.

It is possible with the present method of recording these signals that a fireswitch signal can occur simultaneously with a timing signal. The net result is that both signals are obscured and cannot be separated.

Additionally, the point of origin of the recorded signals should be such that there is no possibility of a fire switch signal being recorded that is not necessarily received by the engine(s) control system. The list below suggests the signals to be utilized.

XLR 87 FS_1 = GGXOV Energized

XLR 87 FS_2 = (1 & 2) GGVPV

XLR 91 $GGFS_1$ = XGVAP

XLR 91 FS_1 = HGVPV(O)

XLR 91 FS_2 = HGVPV(C)

XLR 91 $GGFS_2$ = (3) GGVPV

If insufficient recording channels are available XLR 91 $GGFS_1$, XLR 91 FS_1, and XLR 91 FS_2 can all be obtained from HGVPV(C).

On this run there were several fire switch signals recorded after the explosion which did not affect the operation of the engine and are believed to be false signals originating from some other source.

D. DAMAGE

(A) Engine Hardware

1. Engine Compartment

This portion of the overall report deals with a description of the physical characteristics of engine compartment hardware with respect to damage that occurred from the conflagration. Additionally, some information is included regarding normal configuration and operation of certain engine hardware that could possibly cause a malfunction such as that which occurred.

Briefly, the malfunction that occurred was that the thrust chamber valves (TCV) closed while other engine components were operating apparently normally. This resulted in a high pressure surge, which caused a rupture of the engine lox pump housing. The detailed information herein deals primarily with the components on the engine that affect the operation of the TCV actuator. These components are:

(a) Pressure Sequencing Valve (PSV)

(b) Thrust Chamber Valve Actuator (TCVP)

(c) Plumbing connecting the PSV and TCVA.

Other descriptions contained below deal with the appearance of engine compartment components as observed during post-explosion inspections.

(a) The TCVPSV actuation line was intact from the fuel elbow to the PSV. The actuation line from PSV to actuator and return line from actuator to PSV were intact. All overboard lines from PSV were burned at the "B" nut.

(b) APDA still in place less the 2" hot gas return line to helium heat exchanger.

(c) Helium start valve and bottle still in place but badly burnt.

(d) Vernier ducts blown, vernier bearing boxes and actuators melted.

(e) Lox pump and gear box disintegrated. Fuel pump blown up approximately 3-5" from normal, turbine with spline shaft located 3-5" down from normal.

(f) Helium heat exchange badly eroded.

(g) Fuel line marman flange at torus inlet gone and line separated.

(h) Injector face appears normal.

(i) Injector torus badly dented but not blown.

(j) Thrust chamber badly eroded, epoxy gone and wire wrapping loose.

(k) Fuel and lox thrust chamber valves and actuator arms still intact.

(l) Instrumentation and control harnesses burnt out.

(m) Airborne sequence box disintegrated.

a. <u>Thrust Chamber Assembly</u>

The thrust chamber assembly appears to have been damaged due to excessive temperature on the outside rather than from an internal explosion. The upper portion was relatively intact with most damage to the combustion chamber tubes and nozzle below the injector. Several large holes were burned through this tubular chamber walls. Molten aluminum drippings from above remain on the chamber. Some of these coolant tubes appeared to have burned through only this outer wall, probably because of liquid oxygen (lox) striking the hot metal.

The apoxy resin over the wire wrapping of the thrust chamber was extensively burned away and the wire wrapping was loose and partially unwound from the chamber. No separation of the tubes in the chamber was noted except as mentioned above.

The fuel and lox manifolds had several dents but no breaks in the metal were noted. The marman flange on the burst diaphragm elbow flange was apparently burned through during the fire. The face of the injector appeared undamaged, and the external portion of the top of the injector was intact. Approximately 50% of this igniter holder was still screwed into the injector face.

b. Pump Drive Assembly

The lox pump housing and impeller were shattered into many small fragments and scattered generally about the test stand area in front of the flame deflector plate.

The fuel pump housing remained attached to the fuel suction line but was separated from the pump gear box.

Fragments of the gear box were also scattered over the area. Several of the gears have not yet been found.

The turbine nozzle box and the turbine including the fuel pump impeller shaft were hanging from the remains of one of the vernier exhaust ducts. A portion of the heat exchanger shell was burned away but the main body remained attached to the turbine shroud.

The gas generator assembly and the hot gas valve (HGV) were damaged but remained attached to the engine. The HGV actuator was fractured into several pieces and through out of the compartment.

The vernier exhaust ducts were burned away and were scattered about the area.

c. Auxiliary Pump Drive Assembly (APDA)

The APDA was still in position on the engine but was fire-blackened. The APDA lox suction line was burned away between the prevalve and the pump inlet. The APDA exhause stack was burned away approximately 10 inches below the APDA.

d. Miscellaneous Engine Hardware

Practically all other parts of the engine suffered fire damage. Electrical wiring, small diameter tubing, etc. was burned. Details of this type of damage are not included. The airborne electrical sequencer was demolished, the casing and components scattered over the test stand.

e. Missile Hardware in Engine Compartment

The lox prevalve was found in front of the flame deflector and was partially melted. The lox suction line elbow was deflected to one side and pushed up against the bottom of the lox tank.

2. Test Components Found Below Test Stand

An inspection committee inspected the area located below decks on Stand D-1 following the run. Numerous missile components were located in various degrees of damage. It is believed that the location of all hardware is not of significance except the piece of lox pump housing which was wedged in broken gunite on the east side of the stand. This indicates the piece was blown to its location and not washed there by water flow.

At this writing, no portion of the lox pump impeller was found and only one gear box gear was located. Generally the hardware was badly burned and fractured. Tubing was both burned and broken off, transducers shattered, and evidence of the explosions was quite apparent.

The following is a complete list of components found in the damage area. These parts have been collected and were made available for inspection in the restricted hardware area located at Test Stand D-1.

(1) Lube oil cooler for PDA.

(2) Lox pump discharge flange and part of pump housing and line

(3) PSV quick disconnect (complete).

(4) Flight control valve manifold assembly.

(5) 3/4" check valve and line attached.

(6) 1" check valve.

(7) PDA bearing race (outer).

(8) Gearbox and PDA assorted small parts of housing.

(9) Numerous pieces of hot gas ducting and supports.

(10) PDA accessory drive gear.

(11) Lox prevalve; blade was open, both Marmon flanges missing, part of housing missing.

(12) Lube oil reservoir (lying on Stage II deflector plate flush header).

(13) Assorted electrical cabling and Cannon plugs.

(14) Assorted flex lines (PSV drain line).

(15) Assorted small pieces of missile skirt.

(16) Various transducers and pieces of transducers.

(17) Assorted pieces of airborne sequencer (relays, etc.).

(18) PDA pillow block.

(19) Marmon clamp from fuel discharge line elbow inlet to manifold (burned off at T-bolt fasteners).

(20) ½" quick disconnect cap.

(21) Piece of hot gas valve actuator with check valve (1-216452).

(22) Flash bulb holder.

(23) RTB P/N 1-12221212 A/ S/N 0-135.

(24) Thrust chamber wire wrapping.

(25) APDA exhaust duct.

(26) Lox prevalve flange.

(27) 10" x 14" piece of TC ignitor shield (Stage II).

(28) Various flight control tubing.

(29) Flight control relief valve.

(30) Piece of lox pump.

(31) ¼" orifice fitting with tubing on both ends.

Various and assorted pieces of fittings, tubing, wire, etc. were located which were unidentifiable.

(B) Instrumentation

The following is an itemized list of all cables, transducers, junction boxes, and umbilical access cable exposed to the explosion and/or fire with varying degrees of damage.

1. 10 each Bridge Access Cables
   10 " Pot Access Cables
   4 " Flow Access Cables
   4 " HF Access Cables
   4 " HF Adaptor Cables
   2 " Chromel-Alumel T/C Access Cables
   4 " Copper-Constantan T/C Access Cables
   3 " GSE Instrumentation Access Cables

2. 1 each J-Box, Dwg. No. 327-0474243

3. All instrumentation cables covered on the following drawings:

327-0474501	327-0474543
" " 503	" " 544
" " 505	" " 545
" " 507	" " 546
" " 508	" " 565
" " 509	" " 568
" " 511	" " 569
" " 512	" " 570
" " 513	" " 571
" " 515	" " 573
" " 516	" " 574
" " 517	" " 578
" " 518	" " 579
" " 519	" " 580
" " 520	" " 581
" " 525	" " 582
" " 526	" " 583
" " 527	" " 586
" " 528	" " 589
" " 529	" " 591
" " 530	" " 594
" " 531	" " 595
" " 532	" " 598
" " 534	" " 626
" " 536	" " 630
" " 542	" "

4. The brackets on the drawing listed above are damaged except those on the drawings listed below:

327-0474501	327-0474526	327-0474568	327-0474583
" " 503	" " 527	" " 569	" " 586
" " 507	" " 530	" " 571	" " 591
" " 508	" " 531	" " 574	" " 594
" " 509	" " 532	" " 578	" " 598
" " 511	" " 534	" " 579	" " 626
" " 525	" " 543	" " 581	" " 630

5. The following transducers were damaged:

PS831500003D-1	2 each	Thermistors
PS831500014D-7	4 each	"
PS831500015D-3	1 each	"
PS831500001D-1	1 each	"
PS831500006D-1	1 each	"
PS831500012D-3	2 each	"
PS961000000D-3	3 each	Pressure Transducers
PS961000000D-7	2 each	" "
PS961000000D-13	6 each	" "
PS961000000D-15	1 each	" "
PS961000004D-1	4 each	" "
PS961000004D-5	1 each	" "
4D-11	2 each	" "
4D-13	2 each	" "
4D-27	2 each	" "
5D-1	2 each	" "
5D-3	2 each	" "
5D-5	2 each	" "
9D-1	3 each	" "
9D-3	1 each	" "
9D-5	2 each	" "
10D-1	2 each	Accelerometer
12D-1	1 each	Pressure Transducer
12D-11	1 each	" "
15D-1	1 each	" "
15D-5	2 each	" "
18D-3	1 each	" "
20D-5	1 each	" "
20D-7	1 each	" "
Tabor 176 0-300 lb.	2 each	" "
Tabor 176 0-1000 lb.	1 each	" "
A320	1 each	Accelerometer
PS802000004D-3	7 each	Accelerometer Amplifier
T-95-2-2D	3 each	Thermocouple
Ce 504-18-DT	1 each	5 Ft. Ceramo Thermocouple (CU/CN)

6. The following are Aerojet furnished transducers that were damaged:

201027	2 each	Flowmeters
201927	2 each	"
1-213205-24	3 each	Thermocouple (CR/AL)
1-213205-48	2 each	"
1-213204-18	1 each	" (CU/CN)
1-213204-24	1 each	" "
1-224275	1 each	" "
1-214554-2	1 each	Thermistor
1-222121-/-	5 each	Resistance Temp. Bulb
1-227196-28	2 each	Thermistor
1-224446	1 each	Thermistor

(C) Flight Controls Hydraulic System

The following is a list of the Flight Controls Hydraulic System damage:

Actuators:

#5 (Sustainer)	Wiring 80% gone, rod end seal gone, valve badly blackened.
#6 (Sustainer)	Wiring intact, seals and bearings appear good, lightly blackened over all.
#1 (Vernier)	Total loss, exploded, valve not recovered.
#2 (Vernier)	Wiring 100% gone, cable and pistons in good condition. Valve and pots probably beyond repair.
#3 (Vernier)	Wiring about 90% destroyed, but actuator may be serviceable after rewiring and Delta-P transducer replacement.
#4 (Vernier)	Wiring gone, covered with copper and slag. Probable unrepairable internal damage.

Motor Pump:	Wire leads intact. Terminal box torn open. Pump may be serviceable but motor probably sustained severe damage. Extent of damage to pump depends on whether motor continued to operate after loss of hydraulic fluid from system.
Accumulator:	Destroyed. Not recovered.
Reservoir:	High pressure cylinder destroyed.
Disconnect Nipples:	Not recovered.
Disconnect Couplers:	Dirty, slightly burned, probable damage to seals.
Tube & Fittings:	Not recoverable. Only steel tubes to #6 actuator remained intact.

(D) Tankage and Pressure Systems

An inspection of the Lot B Stage II battleship tanks on Feb. 27, 1959, revealed the following damage to the Propulsion Propellant and Pressurization Systems by the malfunction which occurred during Run 10.

The following equipment requires removal and replacement.

Part Number	Item	
PS472500001D-5	Check valve, lox topping.	
PD456000037-9	Quick Disconnect, Lox Topping	
PS570000000D-7	Quick Disconnect, Pneu. 3/8"	
PS482300012D-1	Shut-Off Valve, Fuel 2"	
PS471400015D-1	" " " , Lox 2"	
PS482300013D-1	" " " , Fuel 4"	
PS471400016D-1	" " " , Lox 6"	
PD471400018-9	" " " , Lox 1" (APDA)	
PS604200020D-1	Bellows, Fuel, 2" (F & D)	
PS604200019D-1	" , Lox, 2" (F & D)	
PD604200023-1	" , Fuel Section Line 4"	
327-7050117	Line, Propellant 4"	
327-7050150	Fill & Drain Line, Lox	
327-7050021	Fill & Drain Line, Fuel	
PD604200026-19	Line, APDA Lox 1"	
327-7050054	Line, Lox Topping	
PD320100009-1	Bellows, Lox Topping	
PD6050062-29	Heater, Lox Quick Disconnect	
327-00011-9	Heater, Fuel Suction Line	
PD4750072	Shutoff Valve - Manual	
1-209303 (AGC)	Helium Heat Exchanger (GFE)	
PD456000055	Disconnect, Fuel Fill & Drain	Flight
PD456000034	" , Lox Fill & Drain	Halves
PD961000034-19	High Level Sensor, Lox	
327-0454125	Elbow, Lox Suction Line	

In addition to the items listed above are numerous small items, such as clamps, brackets, flex hosing, fittings, gaskets and tubing too numerous to mention in this report, but which will require replacement.

The preceding list is limited, almost entirely, to the equipment located in the engine compartment. It was not possible to examine that equipment mounted between tanks or forward of the fuel tank.

Based upon the appearance of the exterior of the tanks it is assumed, for the purposes of this report, that the equipment in the other compartments was not damaged.

There was major structural damage observed to the tank skirt which will require replacement. Damage to the lox tank could not be evaluated and judgement as to its serviceability must be postponed until more detailed examination, and possibly hydro-static testing, can be accomplished.

The helium gas storage container 327-045-025, will require detailed examination.

(E) Airborne Electrical

1. Electrical Wiring

a. Engine Compartment -

The electrical wiring in the engine compartment is a complete loss. The heat of the fire in certain areas completely burned away bundles of wire. In other areas, where the wires were not directly in the flame, the insulation of the wires were badly charred including high temperature wire. There was evidence of wire bundles completely broken apart by the blast or explosion and/or flying debris.

b. Wiring on Outside of Tanks -

The interface connectors between the umbilical cables and the airborne wiring located on the north side of the engine skirt were damaged by fire. Wiring external to the lox tank up to the between-tank area was damaged. External wiring at the between-tank area appears to be satisfactory pending a continuity check.

2. Hardware

a. Interim Hydraulic Battery -

Examination of the IHS battery after the fire revealed that it had exploded from the intense heat of the fire. The copper tubing inside the battery that is part of the activating system had failed (blown open) at a coupling resulting in a battery case failure. Half of the front face of the battery was blown open and peeled back 180° across itself. The mounting of the battery had completely failed due to the heat and the battery fell and became wedged between the tank skirt and the engine.

NOTE - Since the battery is a primary type (one shot) it can be considered an expendable item.

b. Airborne Sequence Unit -

The airborne sequence unit (supplied with engine) was destroyed due to its location in proximity to the propellant suction lines and prevalves where the initial explosions developed. Components of the unit were found at the base of the deflector - two relays were found on the engine where they had fallen or were thrown by the explosion as the unit disintegrated.

3. Circuit Analysis

a. Shutdown Capability -

A GSE originated malfunction, which ultimately results in a shutdown, did not occur when the thrust chamber valves returned to the closed position. The Aerojet GSE design incorporates a TCVS lock-in with the malfunction circuit which does not permit a shutdown to occur through malfunction channels after TCVS has been made. The malfunction that was experienced approximately thirty seconds following 91FS, was caused by a lox suction pressure Stage II kill through the normal MOC control channels. Traces of $GGFS_2$ and $91FS_2$ occurred at this time on the Martin Brush recorder. These traces were generated by Aerojet GSE and were entirely divorced from the airborne unit.

A malfunction shutdown is specified to include the MOC for positive control of all subsystems.

b. Fire Switch Indications -

Numerous fire switch indications were noted on instrumentation recordings following $91FS_1$. The initial explosion disabled electrical cabling causing many short circuits. Power is supplied through many wires in the engine compartment and upon blowing loose came in contact with those wires which supply instrumentation with fire switch indications. $91FS_1$ and $GGFS_1$ wires were supplying the stray signals because $91FS_2$ and $GGFS_2$ were not noted separately until approximately thirty seconds later.

(F) GSE Electrical

The following is an assessment of the damage to the GSE Electrical System:

1. Umbilical Cables -

All umbilical cables (electrical) from Umbilical Control Box to the Stage II interface and their associated disconnects show fire damage.

2. BLH Electrical System -

Electrical wiring to BLH load cells shows heat damage.

3. Stage II Erector Electrical System -

Shows no apparent damage.

4. Propellant and Pressurization Patch Panel -

Damage to patch cords for pins 28L and 28U.

5. Receptacles -

Receptacles on platform and deck show possible water damage.

6. Telephone System -

System shows possible water damage.

7. Vernier Duct Cooling Control System -

Electrical wiring to junction box shows fire damage.

(G) GSE Mechanical and Facilities

A quick assessment on the morning of 27 February 1959, of damage to facilities on the Stage II side, Test Stand D-1, reveals the following:

1. Umbilical lines and disconnects, probable loss due to heat.
2. Under deck flex sections of vernier duct water lines damaged by heat.
3. Replaceable stainless steel flame shielding, around the thrust mount "A" frame arms, burned and warped due to heat.
4. "A" frame to missile adapter ring shows evidence of heat on the adapter ring and upper "A" frame attachment heads.
5. Upper joint of vernier ducting indicates heat damage.
6. The IR-TV camera housing and blast lens show signs of direct heat.
7. The deck grating support beams adjacent to the flame hole and the front box beam show signs of seemingly superficial heat damage. (The extent of heat damage may be limited to paint only.)
8. The BLH, weight and thrust system, wiring and load cells show signs of heat exposure.
9. The special instrumentation for APDA bleed is damaged.

In order to thoroughly assess the detailed damage the following additional sections have been authorized.

(a) Hardness test of:

(1) Front box beam.

(2) Deck beams adjacent to the sides of the flame hole.

(3) Thrust ring (specifically the north and west sides).

(4) "A" frames, "A" frame heads, and the adapter ring.

(5) Stub-cantilever thrust mount supports.

(b) Physical inspection for cracks due to heat or lox damage.

(1) All under deck BLH load cells.

(2) StageII deflector plate.

(3) IR-TV camera.

(4) Box beams and "C" frames.

(5) Stub-cantilevers.

(6) Thrust ring and "A" frame assembly.

(c) Electrically inspect.

(1) BLH load cells.

(2) BLH wiring from load cells to "J" boxes.

(3) Control wiring to engine deluge valves.

The following is a summary concerning the design and use of the facilities for this particular run.

1. The storage capacity, for test area process water, is insufficient considering that the whole complex depends on this supply for fire fighting water. The water header pressure, at Stand D-1, dropped to approximately 35 psi shortly before the fire in the engine compartment stopped burning. At this pressure the useable supply of fire fighting water is essentially depleted. Continued burning of this fire or occurrence of another fire in the area could have resulted in much more serious consequences. A study is presently underway at Martin-Denver.

2. It is unlikely that additional water capacity would have materially changed either the duration or extent of damage involved in this fire. A larger storage capacity would have allowed the use of more water for cooling of the test article and the test facility although the value of such action in this case would be difficult

to ascertain. It is unlikely that the method of use of the water system and supply could have been different to any material advantage.

3. The engine deluge system provides insufficient volume of water for adequate control of this type fire. During the height of the fire observers noted that engine deluge had little effect except to partially contain the fire in the engine compartment.

4. The CO_2 system proved insufficient in fighting this type of fire. It is a secondary source of fire extinguishment and was not intended to combat major fires but only minor pilot flames so as to afford the opportunity to continue running. Moreover the skirt ruptures caused by the explosion prevented effective accumulation of CO_2 gas in the engine compartment.

IV. CONCLUSIONS

1. The Stage II engine, serial number AJE-00203, was destroyed and associated ground support equipment, instrumentation, cameras and flight controls hardware, in and around the engine compartment, were damaged or destroyed.
2. Damage to the test stand was of a minor nature.
3. No personnel casualties or injuries were sustained.
4. There is virtually no impact on the test program.
5. The test was accomplished in accordance with an approved Test Directive.
6. Proper completion of procedures were executed during preparations for this test.
7. The **countdown** was accomplished and proceeded normally in accordance with an established **countdown procedure.**
8. No operating test crew errors or neglegence were involved.
9. The Stage I engine maintained a level of normal operation through out the test and indicated no abnormalities in its start or **shutdown** phases.
10. The Stage I engine initiated the staging **timer** through the use of the thrust chamber pressure switches as planned and had no bearing on the activities of the Stage II engine.
11. The start and operation of the Stage II engine in initial vernier phase was normal.
12. 1.27 seconds after Stage II Thrust Chamber ignition, the fuel and lox Thrust Chamber Valves closed rapidly causing a high fluid pressure surge and resulting in the rupture of the Lox Pump discharge volute at 1.45 seconds.
13. The Thrust Chamber Valves closed due to a non-programmed shuttling of the Pressure Sequencing Valve. At this date, the two most likely alternatives responsible for this action appear to be:

a) Mechanical failure of the Pressure Sequencing Valve control system causing fluid leakage internal to the valve.

or b) A high "g" load in the same plane as the Pressure Sequencing Valve causing the override solenoid piston to move and shuttle the valve. This alternate is presently under study by Martin-Denver and Aerojet-Sacramento.

14. It is indicated at this time that the location and capacity of the engine deluge nozzles and system was inadequate.

15. A quantity of water was lost because of the lack of blockhouse control over the deflector wash manifold on both test positions.

16. The present method of recording engine fireswitch signals is inadequate since they are now superimposed on the timing signal and makes it difficult to obtain a precise fireswitch signal and time correlation.

17. The pre-fire lox and fuel sample analysis were within specification limits. (see attachment 14)

18. The water supply system was marginal for the control of fires of this type and duration.

V. RECOMMENDATIONS

As a result of the preliminary investigation by the committee, the following action was taken prior to any additional Stage II engine firings at the Denver Test Stands. Similar action will be taken for test stands at Florida:

1. Interlock the Thrust Chamber Valve Pressure Sequencing Valve Switch with Gas Generator Fireswitch-two ($GGFS_2$) so if the micro-switch (PSVS) opens prior to FS_2 , engine shutdown will be initiated immediately and prevent a reoccurrence of the pump over-pressure condition. This can be accomplished in Aerojet Ground Support for captive tests. This change has also been incorporated in the malfunction relay circuit. (Reference: Aerojet ECP 2050)

It is recommended that the following actions be initiated as soon as possible:

1. All fireswitch indications be monitored separately on an instrumentation brush recorder to insure positive correlation of fireswitch points on all records.[1]

2. Move the engine deluge nozzles closer to the engine compartment and increase their flow capacity at Denver and Florida Complexes.[2]
3. Deflector-wash manifolds should be remotely controlled from the blockhouse at Denver and Florida Complexes to provide considerable saving of water both before the run and during a fire.[3]
4. Initiate a formal study of water supply capacities at Martin-Denver in respect to fire fighting capabilities.[4]
5. Initiate a study for the interlocking of the lox and fuel pre-valve closure circuits and lox tank vent system with any non-programmed shut-down, and including a study for the moving of the Stage II fuel pre-valve to a location between tanks.[5]

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1. Instructions Issued
2. Liaison Call Sheet Written
3. Liaison Call Sheet Written
4. Presently Underway
5. Directive To Be Issued