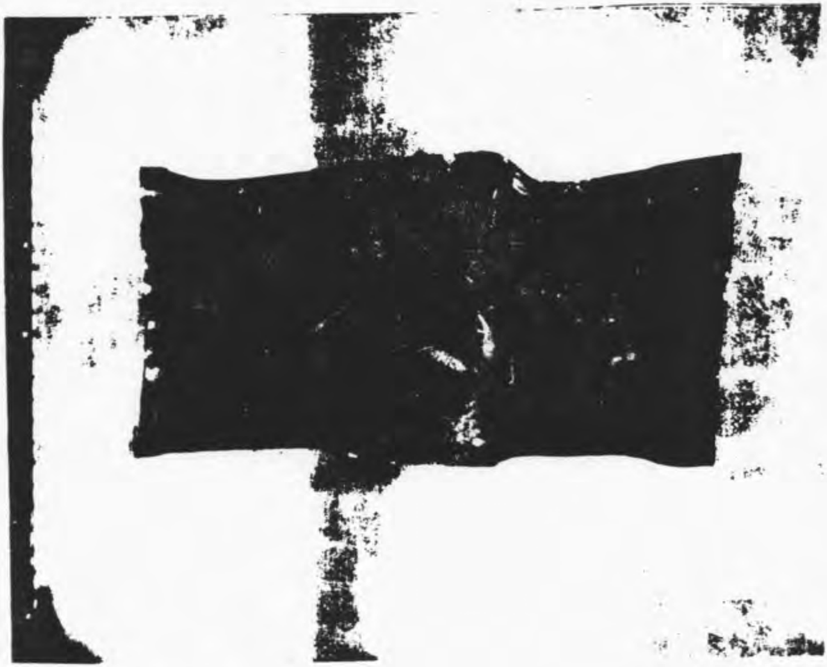


Photo 9

Sample #8

Mode of Failure: Tensile shear and tear by object impact. Travel of failure was right to left in a downward direction.

12 May 1975

MME-5/Capt Gregory/Capt Scheiding/57845 MANCE (Metallurgical Laboratory)

Lower Skin 2 May 1975

Task #1128, Attachment 34 142

Metallurgical Analysis

1. Five segments of the lower skin of the ramp section were submitted to the Metallurgy Laboratory for analysis in support of attachment 34, task number 1128.

2. The five segments were photographed and numerically identified as #1 thru #5. The areas they were taken from on the ramp section were identified with corresponding numbers, to facilitate in identification (photo #1).

a. Sample #1 exhibited a tensile shear by a tearing overload in a downward direction (photo #2).

b. Sample #2 exhibited a reversing tensile shear. The skin had experienced severe buckling and tearing in an upward left to right direction (photo #3).

c. Sample #3 exhibited two reversing tensile shear fractures brought about by impact overload. Shear direction was downward with a tearing force.

d. Sample #4 showed enumerous tensile shearing by a flexing, buckling, and tearing impact mode of failure. This failure developed in an upward moment. Severe tearing around the rivet areas was prevalent.

e. Sample #5 exhibited tensile shear by impact, accompanied with a tearing action around the rivet areas. This impact resulted in an upward direction.

3. Conclusion - the bottom skin damage showed no evidence of object damage. The loading media to cause the flexing, buckling, tearing, shearing was probably caused by either air or water impact.

W. H. CROCKER
Metallurgist

D. BARRERA
Metallurgist

O. H. DOUGLASS, JR
Ch, Metallurgical Laboratory Section
MA

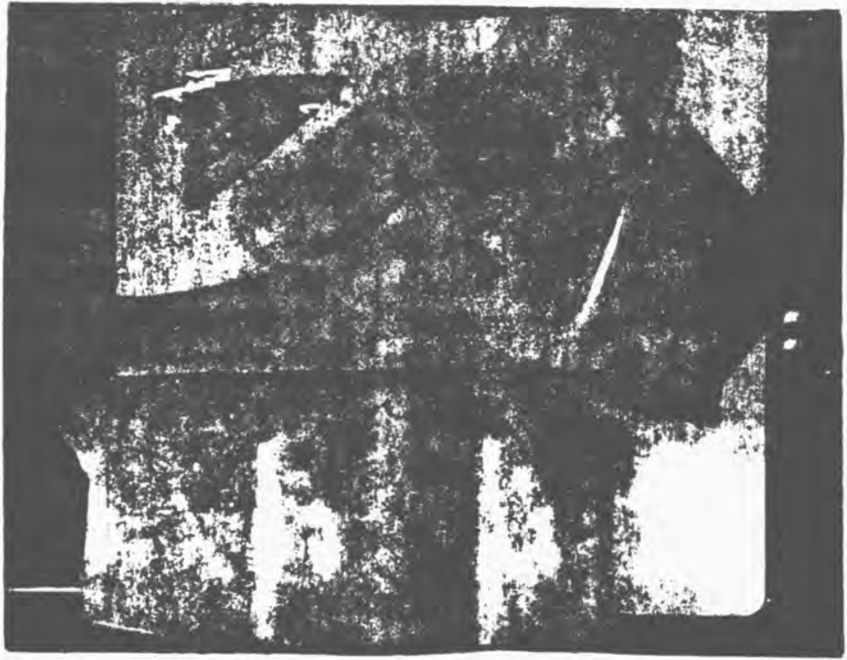


Photo #1. Identifies the five selected skin samples.

Photo 2, Sample 1. Mode of fracture - tensile shear, tearing overload by impact. Arrows indicate shear direction.

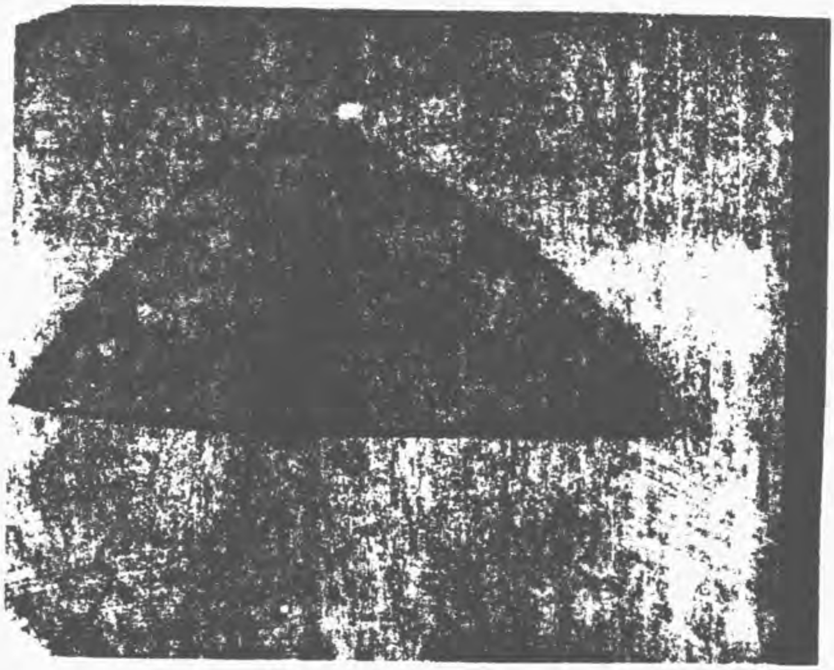


Photo 3, Sample 2. Mode of failure - reversing tensile shear. Severe buckling and tearing in an upward direction. Arrows indicate shear direction.

Photo 4, Sample 3. Mode of failure - reversing shear by impact overload. Arrow indicates shear direction.

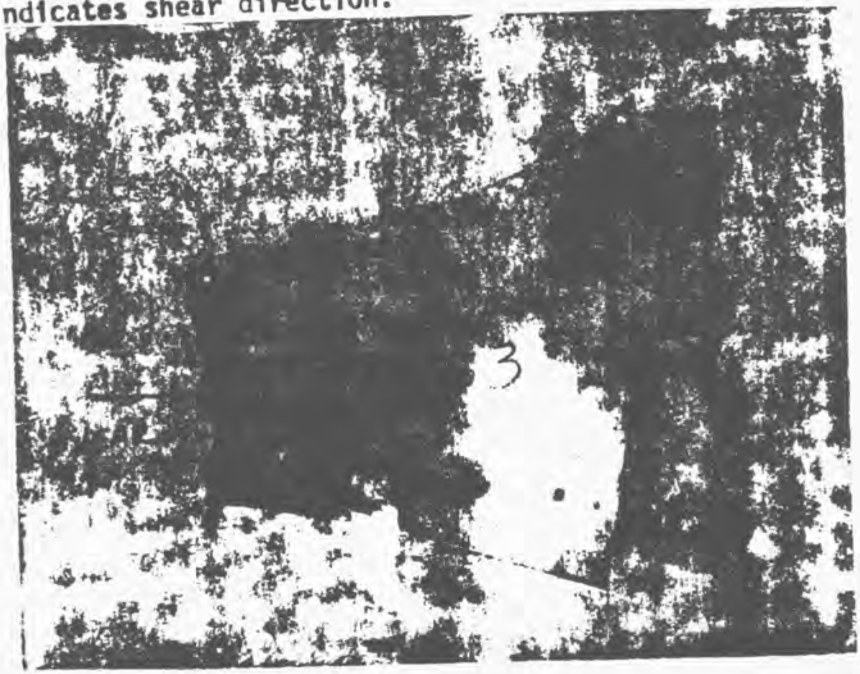


Photo 5, Sample 4. Mode of failure - enumerous tensile shearing, flexing, buckling and tearing. Arrows indicate shear direction.

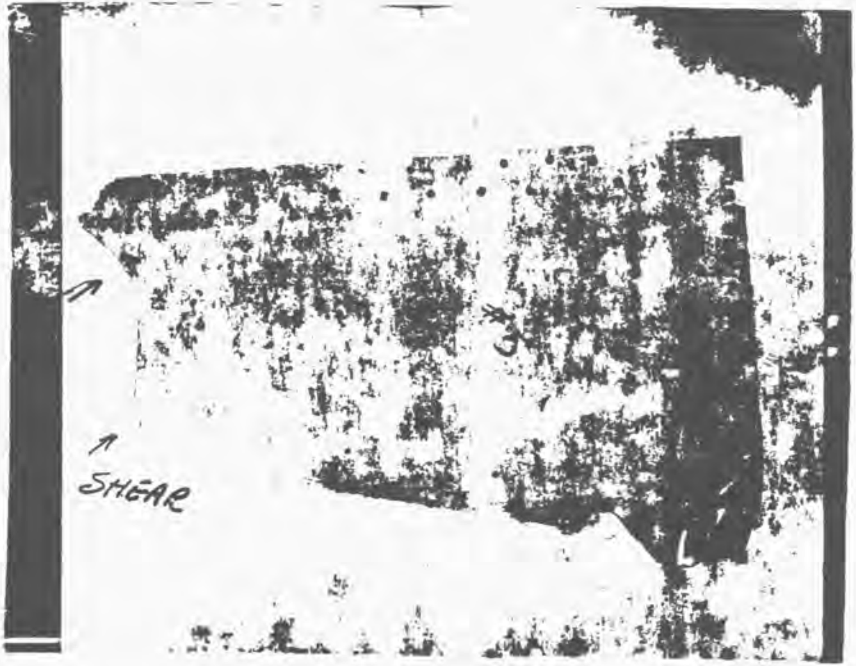


Photo 6, Sample 5. Mode of failure - tensile shear by impact overload. Severe tearing action around rivet holes. Arrows indicate shear tear direction.

GG-1

LABORATORY ANALYSIS REPORT AND RECORD

DATE: 22 May 1975

TO: MME-5/Capt Gregory/Capt Scheiding/57845

FROM: MANCE (Metallurgical Laboratory)

SAMPLE IDENTITY: Yoke Tensile Test

DATE RECEIVED: 23 Apr 75

SAMPLE FROM: Task #1128, Attachment #35

LAB CONTROL NO: #142

TEST FOR: Metallurgical Analysis

1. Four yokes were submitted to the Metallurgy Laboratory in support of Task 1128, Attachment 35, yokes were to be tested to failure.

   a. One good yoke.

   b. One yoke with a crack indication on the monoball.

   c. One yoke with a confirmed crack on the monoball.

   c. One yoke with pieces missing out of the monoball.

2. The good yoke was mounted on a bracket prior to tensile test. Photos 1 & 2. The yoke failed at 82,500 lbs ultimate load. The yoke elongated and fractured as indicated in Photo #3.

3. The yoke with a crack indication on the monoball failed at 88,500 lbs ultimate load. Photos 4, 5, 6, & 7. The monoball failed at the above strength value. The yoke with a confirmed crack on the monoball failed at 83,500 lbs ultimate load. Photos 8, 9, 10 & 11. The monoball failed at the above strength value. The crack indication of cracked monoballs were loaded with the crack direction downward.

4. The yoke with pieces missing out of the monoball, Photo 12, failed at 41,000 lbs ultimate load. The yoke elongated at the yoke end until fracture. Photo 13. Parts will be retained at the Metallurgy Laboratory for pick-up by Project Engineer.

W. H. CROCKER, Metallurgist

1 Atch
Photos 1 thru 13

O. H. DOUGLASS, JR.
Chief, Metallurgical Lab Section
MA

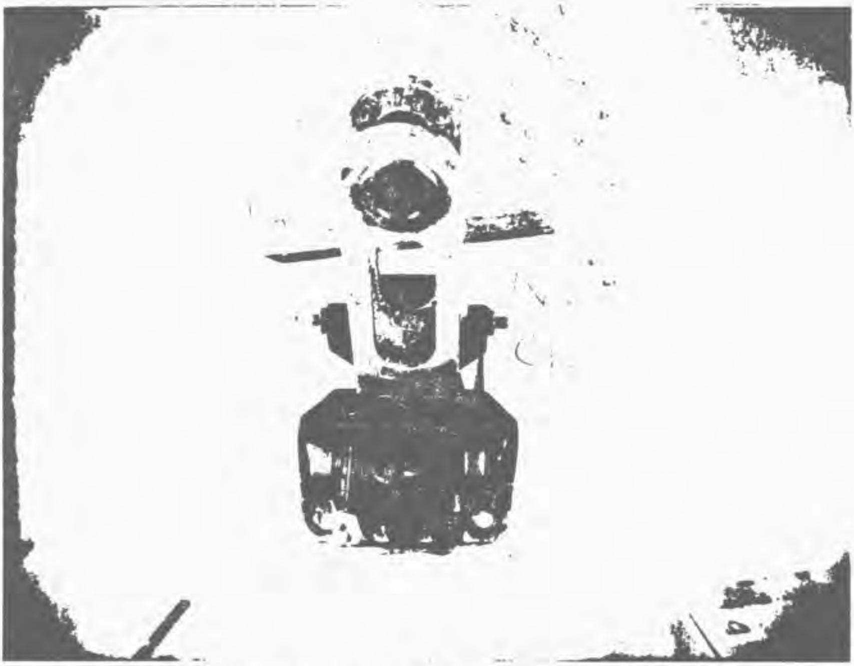


Photo #1 Good Yoke - No cracks.

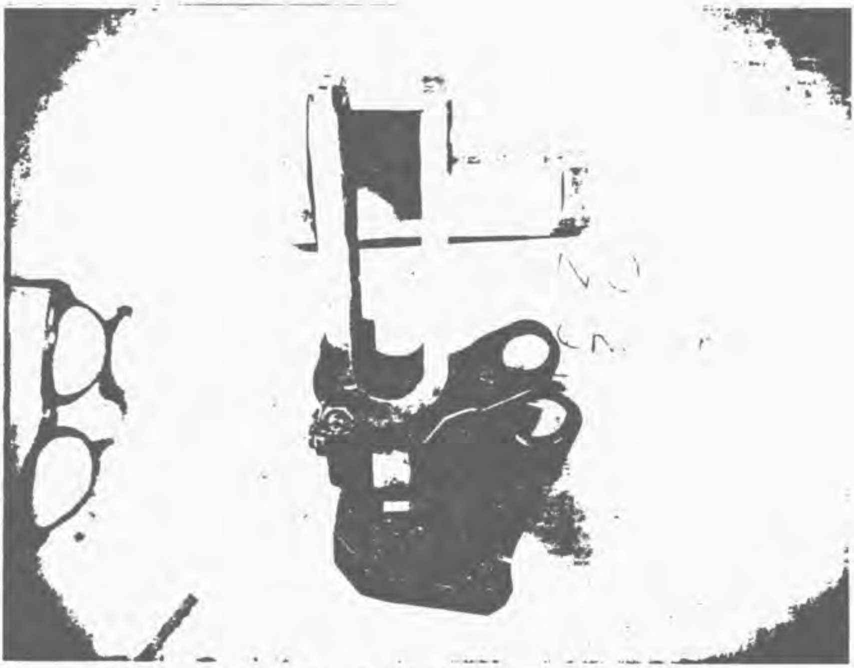


Photo #2 Good Yoke, no cracks.

Photo #3 Yoke failed at 83,000psi.

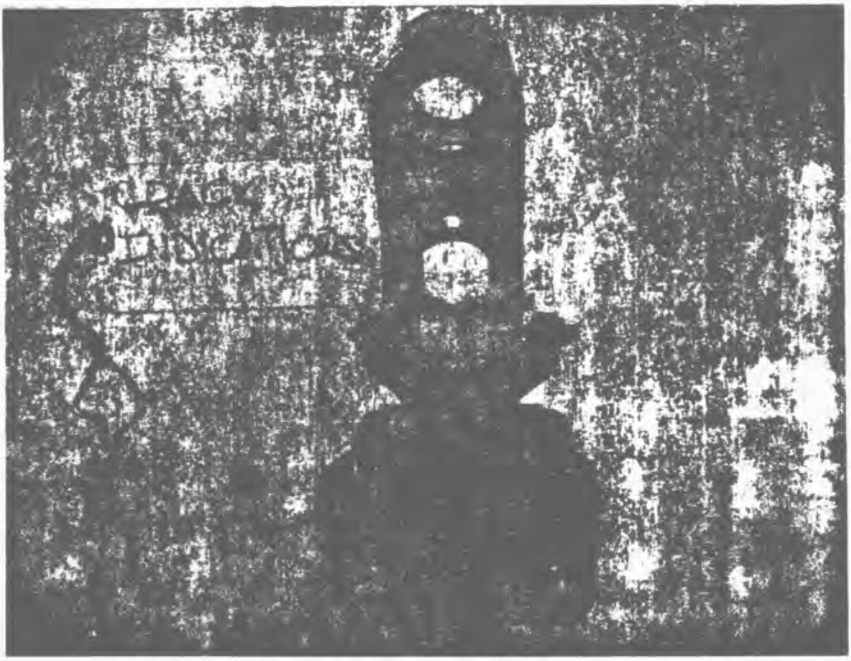


Photo #4 Crack indication on the monoball.

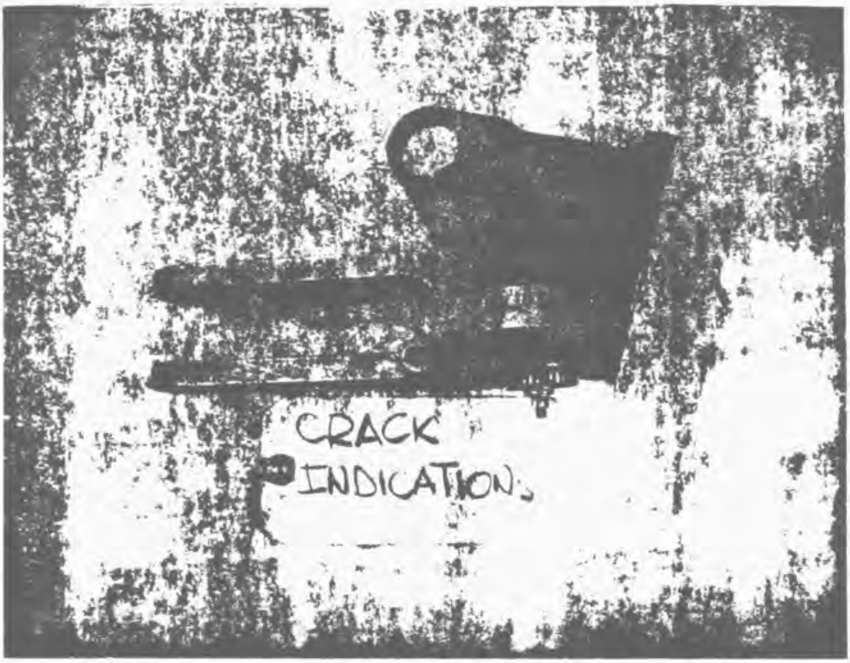


PHOTO #5 Crack indication of the monoball.

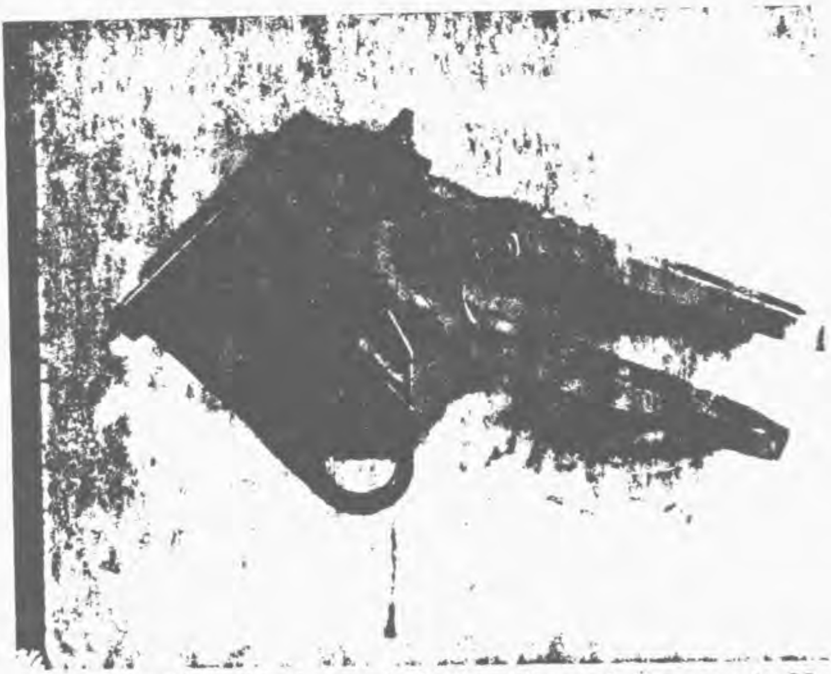


PHOTO #6 Failed crack indication of the monoball.

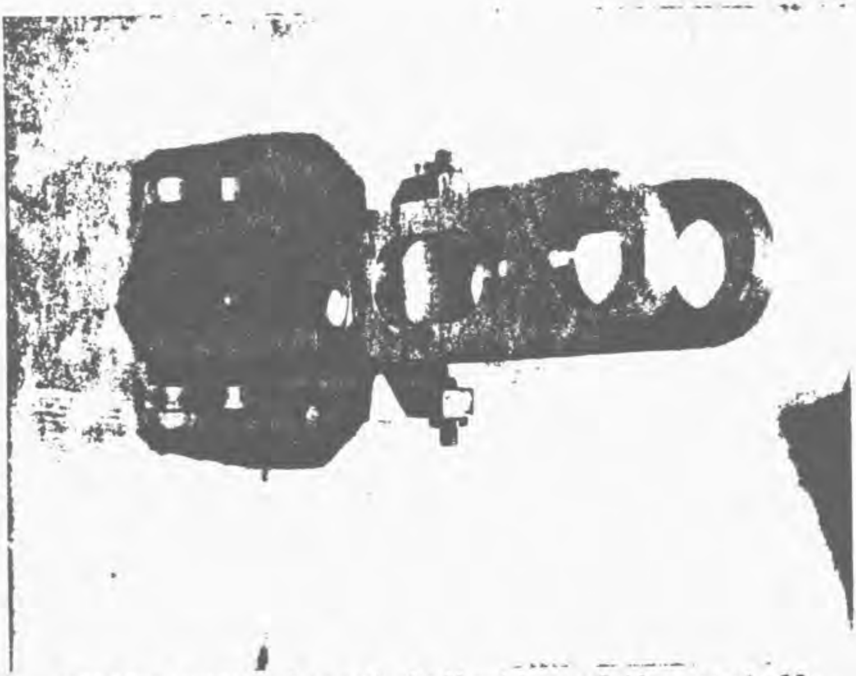


Photo #7 Failed crack indication of the monoball.

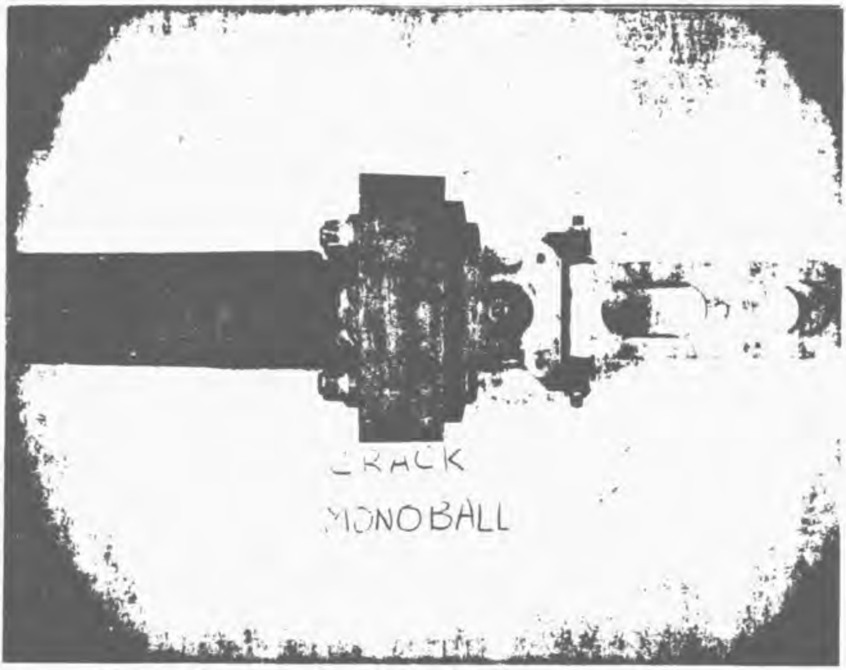


Photo #8 Cracked monoball.

Photo #9 Cracked monoball.

Photo #10 Failed cracked monoball.

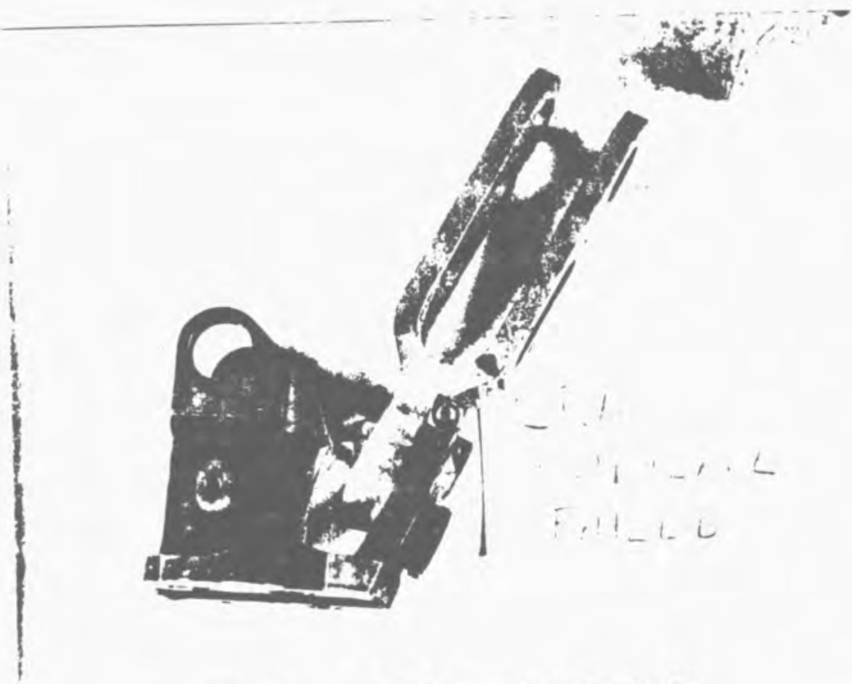


Photo #11 Failed cracked monoball.

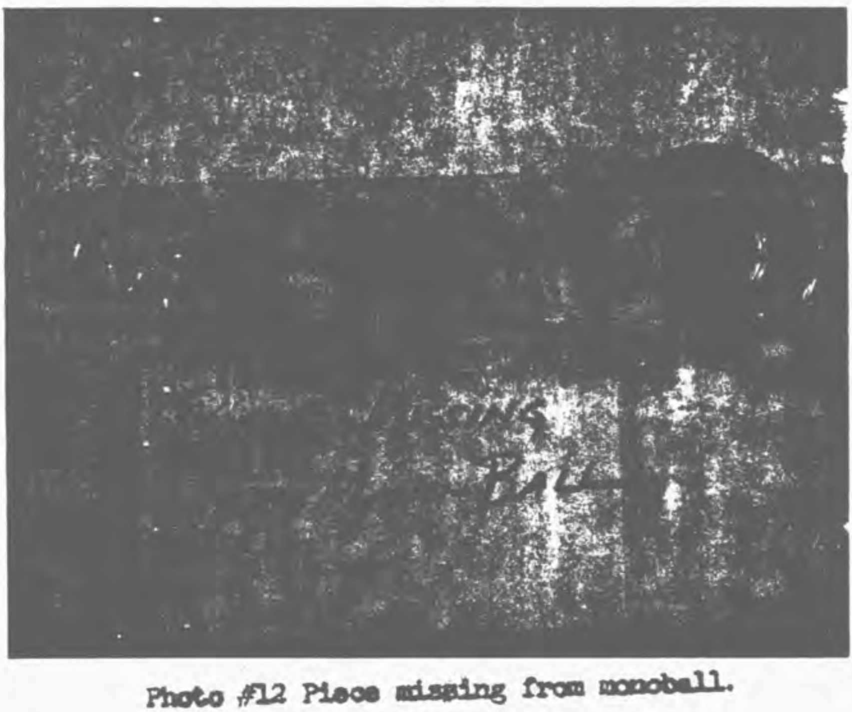


Photo #12 Piece missing from monoball.

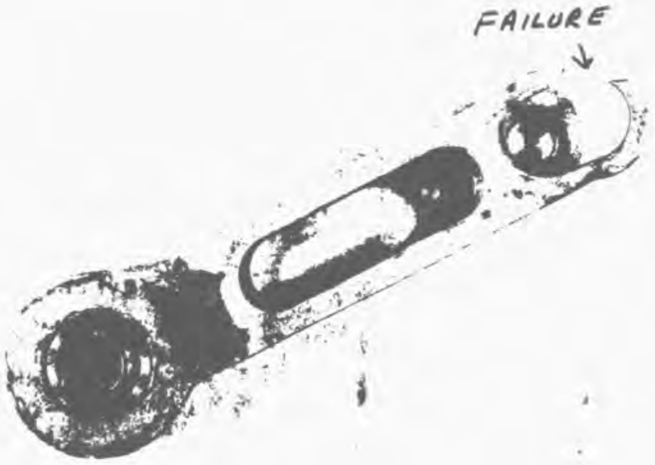


Photo #13 Piece missing from the monoball. Failed.

SOUTHWEST RESEARCH INSTITUTE

8500 CULEBRA ROAD • POST OFFICE DRAWER 28510 • SAN ANTONIO, TEXAS 78284

Department of Materials Sciences
May 7, 1975

San Antonio ALC/MME-5
Kelly Air Force Base, Texas 78201
Attention: Capt. D. V. Scheiding

Subject: SwRI Project 02-4082-037
"Fractographic Examination of Failed Bell Crank Fittings"
FINAL REPORT

Dear Capt. Scheiding:

This letter is to report the observations made in a limited examination of five parts of failed bell crank fittings which were submitted to SwRI on April 28, 1975. Four of the five parts submitted are shown in Figure 1. The fifth part was a small portion of a fitting broken out at one of the pin holes in the bell crank.

KAFB personnel reported that the fitting material was 7075-T651 aluminum alloy bar stock. Metallographic and fractographic examinations of the fittings had been performed at KAFB prior to submission of the parts to SwRI.

A verbal report of the observations made in the examination of the parts at SwRI was made in a meeting with KAFB personnel on April 30th.

The fracture surfaces of all samples were examined visually and at low magnification (10-40X). The macroscopic features of the fracture surfaces of all five samples were essentially identical. Each sample exhibited fracture zones with a dark, corroded appearance and in cases where the specimens had been broken open in the laboratory the fresh overload fracture zone could be readily distinguished. The visual appearance of the fracture surfaces, together with the background information provided by KAFB personnel, indicates that the dark portions of the fracture surfaces represent service-induced cracking.

At low magnification, the service-induced crack surfaces exhibited a "woody" layered texture. Also, the macroscopic appearance indicated that the dark appearance was associated with a thin, tightly adhering corrosion product rather than with a loose scale or foreign matter. Subsequent attempts to clean the surfaces by stripping plastic replicas failed to remove any of the surface deposits.

Representative portions of the fracture surfaces were examined on the scanning electron microscope. The fine-scale topography of all service-induced crack surfaces examined was characterized by elongated flat facets with evidence of a corrosion product on the surfaces. The observed facets are typical of intergranular fracture in wrought high-strength aluminum alloys. No significant zones of dimples were observed in the service-induced crack surfaces. Typical fractographs from the service-induced cracks are shown in Figure 2. Particular attention was directed to the zone at the end of the service-induced crack in Sample No. 3. No evidence of fatigue crack propagation was observed in this particular area or at any location on any of the samples.

The laboratory overload fracture surfaces were also examined on the SEM. These surfaces also exhibited elongated flat facets, but narrow zones of dimples were apparent between the facets. Also, there was no evidence of a corrosion product on the surfaces. Typical fractographs from the overload fracture surfaces are shown in Figures 3 and 4. The presence of identifiable zones of dimples and the absence of corrosion product serves to differentiate the overload fracture surfaces from the service-induced crack surfaces.

The macroscopic and microscopic features of the service-induced crack surfaces are consistent with stress-corrosion cracking. This observation, together with the observed features distinguishing the service-induced crack surfaces from the overload fractures and the absence of any evidence of fatigue crack propagation, indicates that the failures occurred by stress-corrosion cracking.

As shown in Figure 5, secondary cracking was observed adjacent to the main fracture surface in Sample No. 3. KAFB personnel reported that evidence of secondary cracking was also observed in metallographic sections in the previous examinations of these fittings. The presence of such secondary cracking is further evidence of stress-corrosion.

The investigation reported herein was limited in scope and does not constitute a complete analysis of the failures. However, all of the observations made, together with the information from the previous examination as reported by KAFB personnel, indicate that failure of the fittings occurred by stress-corrosion cracking.

If you have any comments or questions concerning this investigation, or if there is a need for further metallographic examinations, do not hesitate to contact me.

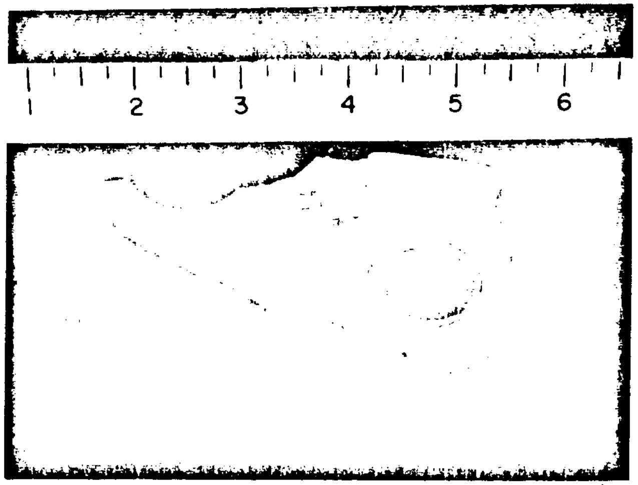
Very truly yours,

H. C. Burghard, Jr.
Project Manager

HCB/mb
Enclosures

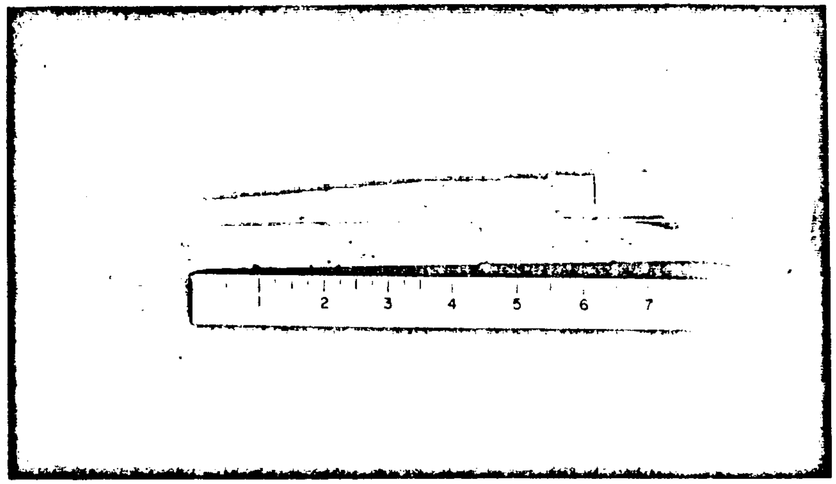
APPROVED:

U. S. Lindholm, Director
Department of Materials Sciences



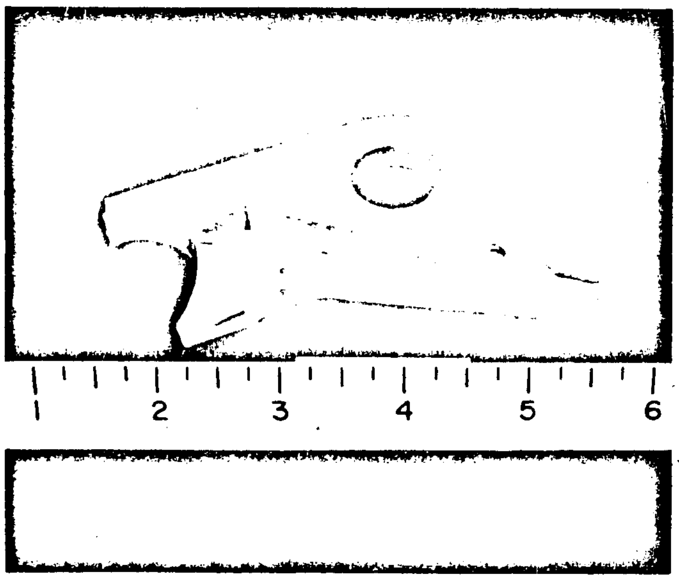
2-23354

(a) Sample 4R



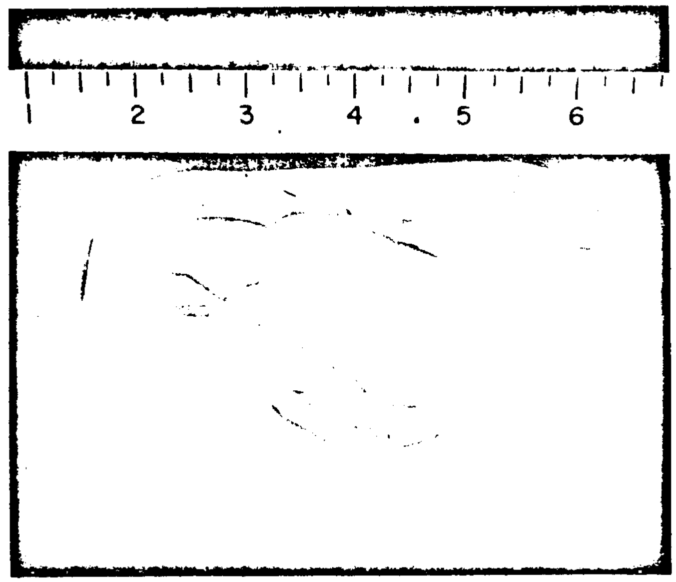
2-23351

(b) Sample 4L



2-23353

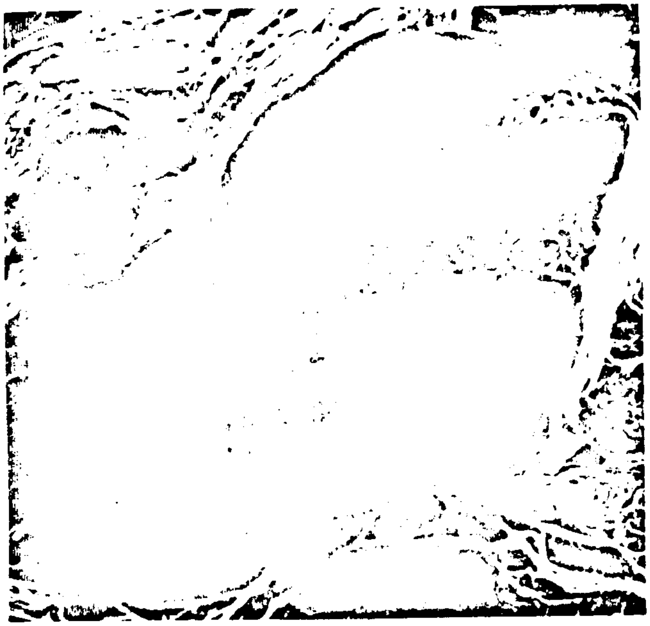
(c) Sample 3



2-23352

(d) Sample 6L

FIGURE 1. BELL CRANK SAMPLES - AS RECEIVED.

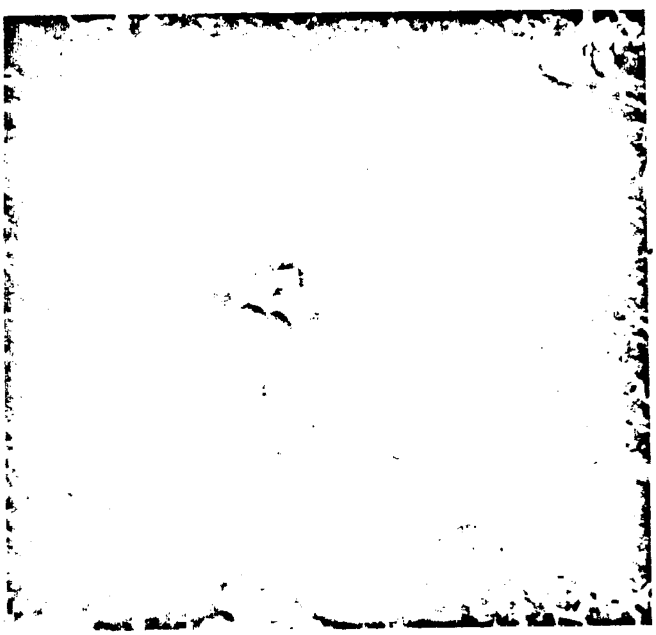


2-23387 400X

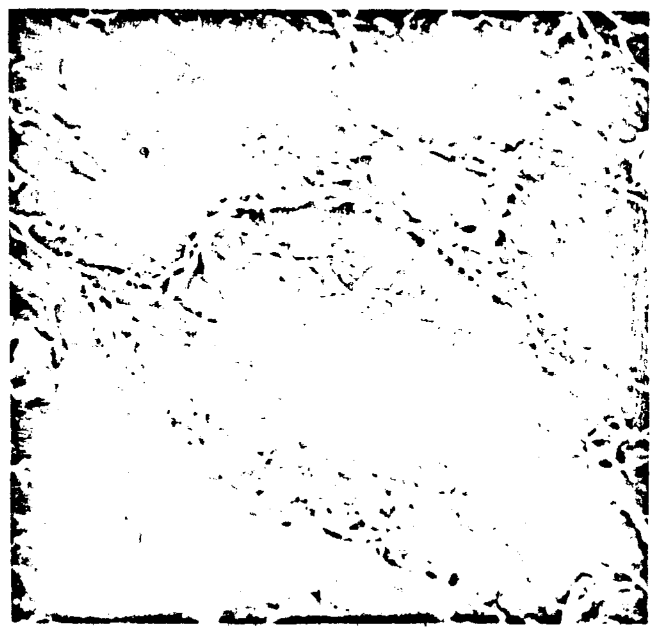
(a) 4L

2-23388 800X

(b) 4L

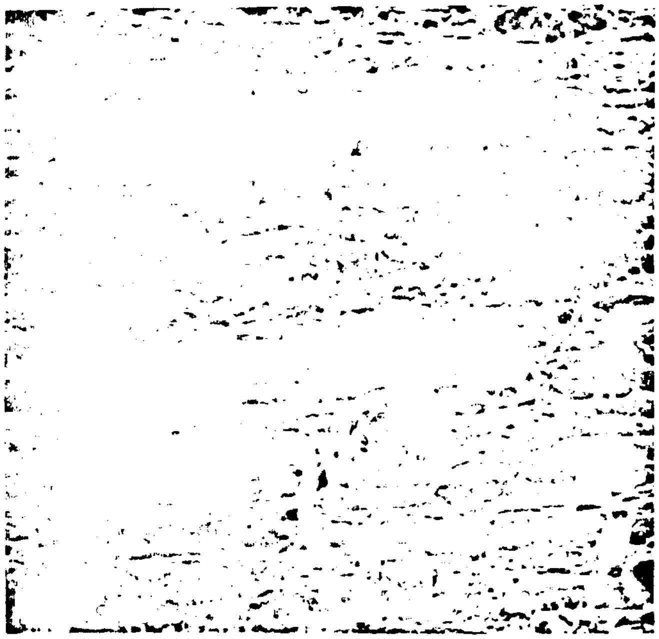


2-23384 300X

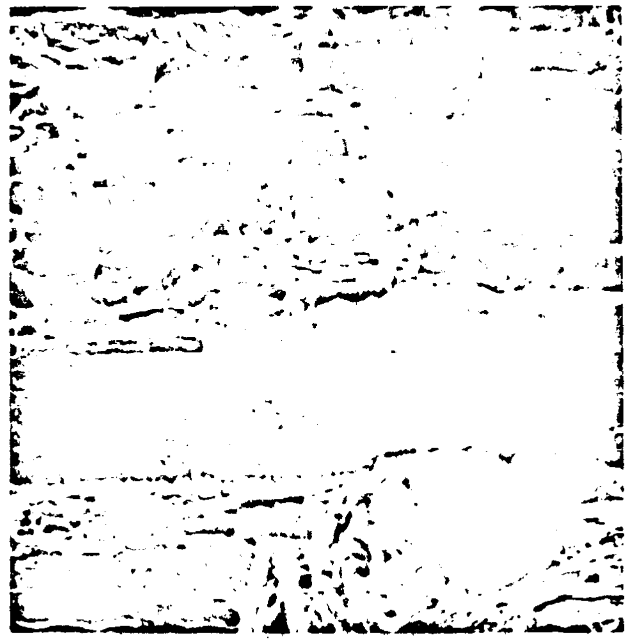


2-23382 400X

FIGURE 2. SEM FRACTOGRAPHS FROM SERVICE-INDUCED CRACK SURFACES.

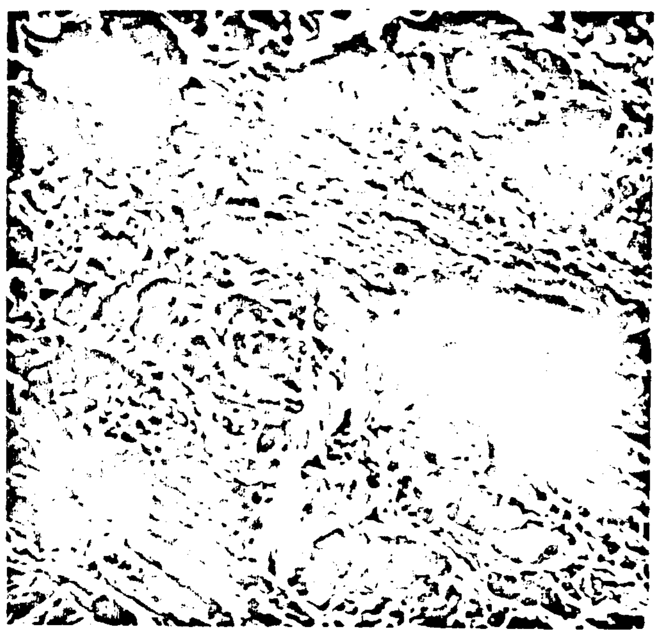


2-23389 400X



2-23392 800X

FIGURE 3. SEM FRACTOGRAPHS FROM FRESH OVERLOAD ZONE - SAMPLE 4R.



2-23380 400X

FIGURE 4. SEM FRACTOGRAPH FROM FRESH OVERLOAD ZONE - SAMPLE 3.

2-23386 10

FIGURE 5. SECONDARY CRACKING ADJACENT TO FRACTURE SURFACE SAMPLE 3.

SAALC/MM Letter

Summary Analysis

of

Metallurgical Laboratory Analysis

14 July 1975

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SAN ANTONIO AIR LOGISTICS CENTER (AFLC)
KELLY AIR FORCE BASE, TEXAS 78241

1 4 JUL 1975

REPLY TO ATTN OF: MM

SUBJECT: Request for Summary Analysis of Metallurgical Laboratory Analysis, C-5A S/N 68-218 (Your Ltr, 19 Jun 1975)

TO: Office of the Staff Judge Advocate
22 Air Force (MAC)
Travis AFB, CA 94535
ATTN: Col Bernard A. Waxstein, Jr.

In response to paragraph 4, subject letter, the attached material is presented. The scope of the information was limited to those areas specifically requested.

FOR THE COMMANDER

Edward G. Bishop

EDWARD G. BISHOP, Colonel, USAF
Director of Materiel Management

1 Atch
Metallurgical Analysis Reports

SUMMARY OF METALLURGICAL ANALYSIS REPORTS

Accomplished by

SAN ANTONIO ALC METALLURGICAL LABORATORY

1. Reference Hq 22AF/JA letter, 19 June 1975, paragraph 4.

SA/ALC Task #1128, Attachment 1, No. 6 Left Side Bellcrank and Pushrod

The bellcrank material was determined to be 7075-T6 aluminum alloy. The laboratory concluded that the initial failure of this bellcrank was due to stress-corrosion. In addition, the laboratory concluded that other fractures on the assembly failed due to overload (impact) type failures.

SA/ALC Task #1128, Attachment 2, Left Side No. 6 Saddle Fitting

The saddle fitting material was determined to be 7075 aluminum alloy. Fractographic failure analysis of the crack failure surface resulted in the conclusion that the failure was a shear overload failure caused by an impact load from a foreign object.

SA/ALC Task #1128, Attachment 3, No. 7 Hook Bellcrank Assembly

The failure of this bellcrank was attributed to stress-corrosion. Other fractures were found to be overload type failures. NDI inspection of the ferromagnetic parts of the assembly revealed no discrepancies in these parts.

SA/ALC Task #1128, Attachment 4, Aft Ramp Section 4-4

Macro and microscopic investigation of the failure surface of this section of aft ramp resulted in the conclusion that failure occurred due to tearing or shearing action propagated by overload. The direction of loading was determined to have initiated underneath the left side of the leading edge of the aft ramp section and progressed upwards and diagonally across the ramp section to the right side. A second load was applied on the top right side of this section.

SA/ALC Task #1128, Attachment 5, Right B. L. 84 Hinge

The hinge material was determined to be 7075-T6 aluminum alloy. Failure analysis of the fractured surfaces was concluded to have occurred from tensile tear or shear due to overload.

SA/ALC Task #1128, Attachment 6, Left B. L. 84 Hinge

Visual and microscopic examination resulted in the conclusion that the fracture was caused by a cycling tensile shear mode brought about by overload. The initial load applied was a tension pull, with a secondary load developing in tensile shear. The cycling application resulted in extensive rubbing on the fracture surfaces.

SA/ALC Task #1128, Attachment 7, Right No. 4 Bellcrank

Fractographic examination of a crack found in the bellcrank resulted in the conclusion that the initiating cause was due to stress-corrosion. However, this crack was not the primary cause of bellcrank failure since it was away from the major failure zone. Analysis of the major failure zone revealed a combination of overload failures and "stress-corrosion type" separation zones.

SA/ALC Task #1128, Attachment 8, Right No. 5 Hook, Bellcrank and Pushrod

The major failure zone of this bellcrank was attributed to tensile impact overload. An additional crack was found away from the major fracture area. Fractographic analysis of this crack resulted in the conclusion that its cause was stress-corrosion. Examination of the pushrod fracture surface resulted in the conclusion that failure was due to a combination of rapid bending and torsional shear. NDI of the hook did not reveal any discrepancies.

SA/ALC Task #1128, Attachment 9, No. 1 / No. 3 Bellcrank Pushrod

Failure analysis of the fracture surface of the pushrod resulted in the conclusion that failure occurred due to flexing tensile shear mode of failure due to overload. Failure analysis of the bellcrank lugs also revealed a tensile shear mode of failure attributed to overload. There was no indication of material defects which would contribute to the ultimate failure.

SA/ALC Task #1128, Attachment 10, Left Side #5, Hook Bellcrank Assembly

The bellcrank material was determined to be 7075 aluminum alloy. The pushrod material was found to be 2024 aluminum alloy. Visual and microscopic examination of the pushrod fracture surfaces resulted in the conclusion that failure was due to a combination of tensile and torsional overload condition. Attachment 12 analyzed the matching failure surface and confirms this conclusion. The bellcrank was found to be cracked. Transmission Electron Microscope (TEM) analysis of this crack resulted in the conclusion that the cause was due to stress-corrosion. NDI inspection of the hook revealed no surface discontinuities, There was some impact damage on left side of the hook.

SA/ALC Task #1128, Attachment 11, Left Side No. 5 Saddle Fitting

The fitting material was identified as 7075-T6 aluminum alloy. Visual and microscopic examinations of the fractured surface resulted in the conclusion that the failure was caused by impact.

SA/ALC Task #1128, Attachment 12, Left 4 to 5 Pushrod

Microscopic analysis of the fractured surfaces lead to the determination that the failure mechanism was due to an overload in a bending and twisting motion. A tensile shear mode of fracture was observed on all fracture surfaces.

SA/ALC Task #1128, Attachment 13, No. 4 Left Side Hook and Bellcrank Assembly

NDI inspection of the bellcrank revealed a crack indication. Fractographic analysis of the crack attributed the crack cause to stress-corrosion. NDI inspection of the ferromagnetic components revealed no discrepancies.

SA/ALC Task #1128, Attachment 14, No. 7 Yoke Guide (Left) Support Backup Structure

Microscopic investigation of an elongated attachment fastener hole revealed no evidence of a recent repair or installation of a new fastener, nor any indication of the hole being re-drilled.

SA/ALC Task #1128, Attachment 15, No. 5 Pressure Door Roller Bracket

The bracket material was identified as 7075-T6 aluminum alloy. Metallurgical and TEM analysis revealed the mode of failure of the bracket was initiated by stress-corrosion of a crack initiated from both sides of the part. Other fractures on the bracket were found to be of the overload type (impact) failure.

SA/ALC Task #1128, Attachment 16, No. 7 Right Hook and Bellcrank Assembly

The failed bellcrank was subjected to a microscopic investigation which revealed no discrepancies other than the impact to one side of the hook.

SA/ALC Task #1128, Attachment 17, Ramp (Right Side) Part 4-8

The fracture surface of this ramp section was subjected to a microscopic examination to determine mechanism and mode of failure. It was determined that the failure was attributed to excessive shearing and tensile overload. The direction of failure was determined to be from right to left.

SA/ALC Task #1128, Attachment 18, Aft Ramp (Parts Labeled 4-6 and 4-5) Sections

Visual and magnified examination of the fracture surfaces of these ramp sections revealed a tensile and shear cleavage failure mode caused by overload. The direction of failure was determined to be from left to right.

SA/ALC Task #1128, Attachment 19, Aft Ramp Section (4-3)

Microscopic examination of the fracture surface revealed the mode of failure to be tension or tensile shear and/or cup overload, similar to the other ramp sections. An overall direction of failure pattern was not given.

SA/ALC Task #1128, Attachment 20, Aft Ramp Section Labeled (4-1)

Macro and microscopic investigation of these sections' fracture surfaces indicated all fractures modes were due to a tension overload. Many of the fractures show cycling, bending, twisting and vibration while being subjected to a tension force. The direction of failure pattern was indicated to be from right to left.

SA/ALC Task #1128, Attachment 21, Control Cables

Cable material was determined to be AISI302 stainless steel in the full hardened condition. The cable lock clad material was determined to be 6061-T6 aluminum alloy. Visual and microexamination of the fractured cables and their lock clad cover was attributed to a combination of tensile and torsional overloading.

SA/ALC Task #1128, Attachment 22, Hydraulic Lines

Two failed hydraulic lines taken from the hayloft area were analyzed. The lines had been dented, torn, kinked and finally failed through shear cleavage.

SA/ALC Task #1128, Attachment 23, Ramp Bulkhead

A small "bullet like" hole was analyzed in the bulkhead. A chemical spot test for lead traces proved positive but was inconclusive due to the primary presence of lead in the bonding medium between skin and honeycomb. No evidence of a projectile was found in the honeycomb material. The damage was concluded to be a glancing blow (projectile or obtrusion) encountered on impact, rather than by an impacted projectile. There also was no evidence of intense heat.

SA/ALC Task #1128, Attachment 24, Bellcrank and Pushrod

Three pieces of failed pushrod and a failed section of bellcrank from an unknown location were analyzed under this task. Examination of the fracture surfaces resulted in the determination that the fractures were caused by an overload condition attributed to bending, twisting, tension and impact. Material deficiency or defects were not considered as contributing to the failure.

SA/ALC Task #1128, Attachment 25, No. 2 Right Side Yoke Assembly

NDI inspection along with visual and microscopic examination of the assembly revealed only minor discrepancies. No evidence of overload was found on this assembly.

SA/ALC Task #1128, Attachment 26, Ramp Floor Fracture Surface

Microscopic investigation of the fracture surfaces of the ramp section recovered from the ocean floor revealed that the mode of failure was a combination of tensile shear and tensile cup attributed to overload. This mode of failure was accompanied by shearing, tearing and bending action. The direction of failure initiated on the right side of the ramp floor with an upward bending movement, followed by a tensile downward movement in overload.

SA/ALC Task #1128, Attachment 27, No. 3 Right Side Yoke Assembly

NDI inspection along with visual and microscopic examination revealed only minor discrepancies. There was some slight evidence of shear on the upper and lower yoke pin shafts. However, the amount of shear present does not indicate an overload condition.

SA/ALC Task #1128, Attachment 28, No. 5 Right Side Floor Bracket

Visual and microscopic examination of this floor bracket revealed indications of an extensive loading having been applied in a straight up direction.

SA/ALC Task #1128, Attachment 29, No. 4 Right Side Floor Bracket

Visual and microscopic examination of this floor bracket also revealed indications of extensive loading having been applied in a straight up direction.

SA/ALC Task #1128, Attachment 30, No. 6 Right Side Yoke and Floor Bracket Assembly

Visual and microscopic examination of this assembly revealed only minor discrepancies. The yoke mono-ball bearing was found to be cracked.

SA/ALC Task #1128, Attachment 31, No. 7 Right Side Yoke and Floor Bracket Assembly

Visual and microscopic examination showed extensive shear damage on the lower eccentric pin shaft. The mono-ball bearing at the bottom of the yoke was cracked in two places. The upper eccentric shaft on the yoke had a crack at each end. The upper arm portion of the yoke was slightly bent. It was concluded that the assembly was subjected to excessive loading.

SA/ALC Task #1128, Attachment 32, Burned Fragments and Gray Flake

The analysis of the burned fragments yielded a very heterogeneous mixture of molten metal, unmelted metal scraps, metal foil, straw, etc. The water extraction test yielded a neutral colorless solution with a medium amount of chloride. The gray flake was determined to be calcium carbonate and of marine origin.

SA/ALC Task #1128, Attachment 33, Winch Well Area

The majority of the fractures analyzed in the Winch Well area failed by the mode of tensile shear and/or tensile cup. The direction of impact load was from right to left with a slight aft movement. The bulkheads failed under a compressive load.

SA/ALC Task #1128, Attachment 34, Lower Skin

It was concluded that the bottom skin showed no evidence of object damage. The failing mode to cause the flexing, buckling, tearing, shearing was probably caused by either air or water impact.

SA/ALC Task #1128, Attachment 35, Southwest Research Report, "Fractographic Examination of Failed Bellcrank Fittings"

Five parts of failed bellcranks were analyzed. Fractographic examinations indicated the failure mode occurred by stress-corrosion. There was no evidence of fatigue crack propagation.

2. Reference Hq 22AF/JA letter, 19 Jun 1975, paragraph 4, a, b, and c.

DISCUSSION:

a. Response to 4a: Visual observation in conjunction with the results from the above 35 metallurgical laboratory analysis reports of the recovered parts support and confirm that the aft ramp came loose from the right side. The ramp was then torn right to left across the front of ramp station 33 bulkhead and rotated downward from its normal horizontal position to a near vertical position about the left side locking system before departing the aircraft.

This is supported by observation of the failure pattern of the recovered left hand side ramp locking hardware (floor brackets and yoke assemblies). All left hand floor brackets and yokes failed in a manner that indicates they were carrying load and the ramp rotated about a hinge line formed by these seven locks. Laboratory analysis of the recovered right side ramp locking hardware, in lock positions 4, 5 and 7, revealed failure due to excessive overload in the vertical direction. The hardware from lock positions 2, 3 and 6, were in good condition and the laboratory analysis of this hardware did not reveal signs of excessive overload. The hardware from lock position 1 was not recovered.

This evidence indicates that some of the right side locks were not carrying their share of the load. The direction of failure of the locks that were carrying load places the ramp in the normal horizontal position at the start of the sequence. In addition, the ramp rotation is confirmed by visual evidence found on the exterior skin of the recovered mating ramp to fuselage sloping longeron section. This evidence was in the form of scratches on the fuselage skin that match button head fasteners that are on the ramp floor. To cause the scratches the ramp would have to rotate approximately 90 degrees about the left side locking system. This also supports the sequence of initiation occurring in the right side lock system of the ramp.

The laboratory analysis of the fracture surfaces at ramp station 33 support the direction of ramp tearing from right to left. The laboratory analysis did have some variance in the failure direction indicated, however, impact damage from the crash occurred to the fracture surfaces that would make the direction determination more difficult. The majority of the analysis confirmed the direction of failure as right to left.

b. Response to 4b: The evidence from the laboratory analysis does not lead to factual supportive evidence of the actual initiating cause within the right side locking system. It does, however, point in the direction of a "most probable" cause that supports the above failure progression, involving the numbers 1, 2 and 3 right side locking mechanisms. A sudden dumping of the load from #1, 2 and 3 locks on the BL 84 ramp hinge could cause a simultaneous compressive failure of the hinge and failure of the lower beam cap at RS 33. This is supported by the laboratory analysis of the BL 84 hinge. The remaining load carrying locks on the right side (4, 5, 7) failed in overload and the ramp was forced down from the right, tearing completely across at the RS 33 bulkhead.

Since the pressure door is attached to the ramp its motion was influenced by the ramp movement. Visual inspection of the recovered parts verify a downward right to left rotating of the pressure door. It is assumed that the pressure door struck the sloping torque deck area of the aircraft fuselage, causing the empennage flight control cables and hydraulic lines for systems #1 and #2 to separate. The laboratory failure analysis of these items does support this type of sequence. However the support is not conclusive.

c. Response to 4c: Concerning the aspect of material or part failure, the laboratory analysis does give evidence that fatigue was not a factor in any of the parts that were analyzed. The subject laboratory analysis does provide supportive evidence that indicates a stress-corrosion problem with the bellcranks. However, through personal knowledge and observation of the system this conclusion must be tempered by the following information.

A situation can exist where the hook tip does not engage the upper yoke shaft in the proper manner. A mis-rigged lock can result in the hook tip impinging on the bottom side of the yoke shaft during the locking sequence. The hook tip is now essentially set on a hair trigger unstable arrangement where it can either slip into the locked or the unlocked position depending on just where the hook tip has engaged the yoke shaft. When the hook tip does slip into either the locked or the unlocked condition, there is a dynamic shock release of the binding force that is transmitted into the bellcrank. This sudden shock impact force can be of sufficient magnitude to crack the bellcrank. This situation was verified by the cracking of three bellcranks during the accomplishment of TCTO 1768. Inspection of these cracked bellcranks revealed that they had cracked in an identical manner and in the same location as the bellcranks that were analyzed above.

If this situation occurs, and the bellcranks are not inspected, a cracked condition in the bellcrank would go unnoticed. In time the surfaces of the crack would then be exposed to corrosion. This corrosion and resulting discoloration of the cracked surfaces could easily be misinterpreted as stress-corrosion. In time, the evidence of the overload failure would be reduced due to the corrosion effects. There is enough other evidence to make the stress-corrosion documentation inconclusive. The ruling out of fatigue failures is conclusive.

3. In summary the above failure sequence was termed the "most probable" but there are other sequences that could have occurred. Since all of the critical component parts were not recovered, the exact initiating cause of the failure sequence will most likely remain in the hypothesis state.

"ENGINEERING ANALYSIS OF DATA FROM AF 68-218"

RELEASED BY

AIR FORCE INSPECTION AND SAFETY CENTER

NORTON AIR FORCE BASE, CALIFORNIA

The comments which follow are based on engineering analysis of data obtained from the Crash Data/Position Indicator Recorder (CDPIR) and the MADAR. The airplane was instrumented to acquire a portion of the C-5A Service Loads Recording Program (SLRP) parameters - no strain gage or gear loads data - but all the other parameters relating to aircraft motions, control surface positions, etc.

Appendix A, Items 43 and 44 provide very detailed time history plots of various parameters, status summaries of CDPIR parameters and MADAR messages, a time correlated narrative of significant events of the final flight, analysis of information relative to electrical wiring impacted by the rapid decompression events and various other data considered pertinent to this analysis.

Air Force 68-218 (C-5A LAC 0021) departed Tan Son Nhut Airport, Saigon, S. Viet Nam on 4 April 1975. The take-off gross weight was approximately 464,590 pounds with an estimated C.G. of 38.7% M.A.C. Fuel load was approximately 94,000 pounds and the estimated operating weight empty was 348,000 pounds. Take-off was from runway 07 with winds from 120° at 15 Knots.

The MADAR was placed in operation with a time entry of 04:55:13 with lift-off occurring at 05:01:26. All recorded data appeared normal at this time and recorded ground speed of 119 Knots correlates well with the Mach Number (0.19) converted speed of 126 Knots considering a 9.6 Knot headwind component.

After take-off, CDPIR voice and MADAR data gave indications of normal gear retraction, gear doors locked messages, flaps and slats retracted and completely normal flight progress until the rapid decompression (R.D.) took place at approximately 05:13:18 at which time significant responses were recorded for C.G. vertical acceleration (Nz_{CG}), C.G. lateral acceleration (Ny_{CG}), pitch acceleration (0), rudder position, and elevator position all of which indicated abrupt, abnormal inputs. The acceleration signals initially showed large amplitude, relatively high frequence (3 to 5 cps) responses which are interpreted as local structural responses rather than airplane motions. There was a rudder surface deflection of about six degrees which produced an airplane sideslip response of about 0.21g lateral acceleration at the C.G. The elevator input was an abrupt $\pm$ 1.5 degree down/up single cycle after which the elevator position data channel was lost. MADAR data indicated hydraulic pressure reductions below 1450 ($\pm$ 200) PSIG to the inboard elevator and rudder systems engaged by the pitch and yaw augmentation system at 05:15:33.

The vertical load factor trace (structural responses excluded) showed a response down to about 0.9g over an approximate 30 second time period followed by a positive response back to 1.15g with a slow drift back to 1.0g. This response correlates well with a flattening of the altitude trace from the prior climb trend and then showing a descent. Mach number also correlates well with these events with an increase of about 0.08 (0.60 Mach @ 23,800' to 0.68 Mach @ 22,000') which corresponds to an airspeed increase of approximately 60 Knots.

The loss of the pressure door, portions of the aft ramp and right side cargo door and center cargo door resulted in an approximate 8,000 pound weight reduction with an accompanying forward shift in C.G. of about 3.5% M.A.C. This produced a positive shift in the airspeed for trim while decreasing Mach number produced a negative shift in trim speed.

The flight crew recognized that engine power was the only means available to exercise control over the very delicate balance existing between pitch attitude, altitude and airspeed.

After the first few airspeed oscillations, the speed was fairly well stabilized between 250 and 260 Knots until gear extension. At this time, the airspeed decreased to about 220 Knots in spite of power application but gradually recovered to around 250 Knots (± 15 Knot oscillations) until aft main gear rotation when airspeed decayed to 211 Knots. At this point, application of power, beyond take-off fuel flow values, resulted in decreasing the rate of descent and an airspeed increase to 270 Knots.

The MADAR data for a period of 3.6 seconds prior to initial impact was lost due to power interruption at impact (data stored in the MADAR buffer was not recorded due to this power loss). At this point (3.6 seconds prior to impact) the airspeed was approximately 270 Knots and the altitude trend information available indicates a probable sink rate at initial touchdown on the order of 16 Ft/Sec, however, it must be emphasized that no data exists for approximately 3.6 seconds prior to touchdown and ground effect should have produced a reduction in sink rate prior to ground contact.

Analysis of main landing gear drop test data indicates that structural failure of the main landing gear could be expected at landing sink rates of between 11 and 16 fps for a landing weight of 450,000 pounds depending on the timing of the left aft and right aft gear contact and energy absorption stroking and on the soil condition at impact - large drag loads would result with deep penetration of the wheels in the soil.

Following the MADAR power interruption at or shortly after impact, the system cycled back on and provided an additional 2.28 seconds of data prior to complete loss of MADAR information. Very little information can be deduced from this final data group except to note again the 3 to 5 cps structural response indications appearing in the vertical, lateral, and pitch acceleration data channels. The last recorded Mach number was 0.41 which converts to an airspeed of 270 Knots. No data exists by which to derive airplane load factors or accelerations during either the first or second impact.

VISUAL OBSERVATIONS

The aircraft structure, recovered from the impact points and adjudged tobe pertinent to the accident, was cleaned and set up in Building 7216 at Clark AB in a manner similar to a comparable location on the aircraft. Members of the Technical Team examined this structure and documented their detailed physical observations in Appendix A, Item 57. The aircraft structure, recovered at sea, was set up at Kelley AB and examined by the Technical Team. These observations are documented in Appendix A, Item 58

These Items refer to numerous photographs for added details included as Appendix A, Item 56. All references to right and left side considered looking forward on the aircraft. The following is a summary of the Technical Team's observations.

PRESSURE DOOR FIXED OVERHEAD STRUCTURE (FUSELAGE STATION 2101.9)

The beam is structurally intact. The damage to the rollers, bath tub fittings and shims (T.O. 1C-5A-4-1, Figure No. 163, Index Nos. 104, 108, and 113) indicate that the upper support fingers of the pressure door came off of the rollers in a downward direction displaced to the right from a point looking forward. The severity of the damage increased progressively from the right to the left end of the beam.

CABLE PULLEYS ON AFT SIDE OF PRESSURE BULKHEAD (FUSELAGE STATION 2101.9)

The flight control cables for the rudder, elevator (2 sets) and pitch trim penetrate the torque deck 12 inches aft of the pressure bulkhead and are supported at that point by brackets (T.O. 1C-5A-4-5, Figure 58, Index Nos. 35, 36, and 37) running fore and aft with two idler pulleys. Damage to these brackets or structure immediately aft of the bracket, in the pitch trim cable location, indicates that excessive load was applied to the cables aft of the brackets in a left upward direction. The severity of the damage increased progressively from the right to the left side.

HYDRAULIC PLUMBING LINES AT PRESSURE DOOR UPPER SUPPORT BEAM

Ten lines (Hydraulic Systems No. 1 and No. 2) penetrate the pressure bulkhead on the left side. One of the lines was missing and all others were broken off 12 to 36 inches aft of the pressure bulkhead. (four lines (Hyd. Sys. No. 3) penetrate bulkhead on the right hand side. One line was missing and the other three were broken off about 24 inches aft of the pressure bulkhead during impact.)

TORQUE DECK INTERSECTION WITH PRESSURE BULKHEAD

The torque deck is spliced 24 inches aft of the pressure bulkhead and this section remained attached. The center portion is deformed upward about 8 inches over a total span of 11 feet 4 inches symmetrical about the aircraft centerline.

TORQUE DECK (T.O. 1C-5A-3, FIGURE 4-122)

Except for that portion of the torque deck discussed above, the most forward portion recovered from the crash site is at F.S. 2273 (14 feet, 5 inches aft of the pressure bulkhead) on the extreme right side, tapering to the extreme left side at F.S. 2361 (21 feet, 8 inches aft of the pressure bulkhead). Most of the torque deck structure aft of these stations has been accounted for at the crash site. Other than that section discussed in paragraph above, the only other piece of structure forward of these stations that was recovered was a section of the center beam (See Appendix A, Items 54 and 57) which was recovered from the ocean floor in the R.D. area.

AFT SIDE CARGO DOORS (4F61600-101A & 102A)

The right door had departed the aircraft by failing the hinges (T.O. 1C-5A-4-1, Figure 165, Index 30, 93, and 208), while over water and was recovered at sea. Except for approximately 15 feet of the aft end which was missing, the remainder of the door was in fair to good condition. The left door was recovered from the crash site. There is severe damage on the forward end of the door and the portion between 7 feet and 17 feet from the forward end is missing. The aft section is intact.

AFT CENTER CARGO DOOR

There were no pieces recovered at the crash site that could be identified as part of the center door. However, the left radius driver arm was recovered from the ocean.

AFT RAMP (T.O. 1C-5A-4-1, FIGURE 183)

The entire forward edge of the ramp floor, including various lengths of floor panels, was recovered from the crash site, along with both B.L. 84 hinges and various other pieces. The combination of pieces found indicate that the ramp failed through the forward edge of the winch well opening (Ramp Station 33) and was still attached to the airframe at the time of impact. Additional data on the ramp is covered in later discussion of aft ramp.

FIXED PRESSURE BULKHEAD (F.S. 2131)

A section of the right side 4 feet, 9 inches long was recovered from the crash site. It contained the pressure door upper hinge (T.O. 1C-5A-4-1, Figure 184). The upper hinge and actuators are in the unlocked position.

Most of the left pressure bulkhead was recovered from the crash site in three pieces. The center portion contained the pressure door upper hinge. Although the 4F54196-101A locking mechanism is in the locked position, the locking actuator is in the extended position, indicating that the mechanism was in the unlocked position prior to the impact.

NOTE: The balance of this section of the report covers portions of the airframe recovered at the crash site and in the ocean in the R.D. area.

RAMP LOCKS (T.O. 1C-5A-4-1, FIGURE 182)

Left Side - A section of fuselage side panel 7 feet, 6 inches forward of F.S. 2131 was recovered from the crash site. This portion includes ramp locks Nos. 4 through 7. The evidence on these locks plus those found on the mating parts attached to the ramp recovered at sea indicates that they were locked at the time of the R.D. and failed in a combination of tension and bending around the intersection of the ramp and fuselage structure. Further evidence of this rotation is indicated by scratches on the outer surface of the fuselage structure resulting from the scraping of button head screws, located along the outer edge of the ramp upper surface, around the corner of the interface plane. The portion of locks Nos. 1, 2, and 3 remaining on the recovered ramp indicate a similar failure mode to the others on the left side.

Right Side - Portions of No. 4 and No. 5 locks and the complete No.7 lock on the fuselage side were recovered at the crash site. The mating parts of the locks attached to the ramp indicate that locks Nos. 4, 5, 6, and 7 failed while locked due to an overload. Locks Nos. 2 and 3 exhibited evidence of wear. Neither of the components of lock No. 1 were recovered.

Miscellaneous Parts - Several miscellaneous parts were recovered from the crash site, some of which cannot be identified as to the side of the aircraft on which they were installed. The only significant piece is a portion of a push/pull rod and No 3 lock bellcrank where the rod end is adjusted to the full "In" position which would render the rod shorter than tolerances allow.

AFT RAMP AFT BULKHEAD

The overall appearance of the bulkhead is good with no evidence of structural failure. There is no evidence in the ramp/pressure door attaching hardware which would indicate that this system was contributory in the basic R.D. failure.

RAMP STRUCTURE

The ramp structure, recovered at sea, had separated completely just forward of Ramp Station 33. The most severe structural damage is in the right forward corner, forward of Ramp Station 95 and outboard of B.L.R. 28.

PRESSURE DOOR

The left one third of the pressure door was recovered from the ocean. The door had split along the B.L. 28 left beam with the beam also missing. The failure indicates that it was in a bending mode about the B.L. 28 left beam. The ramp/pressure door attaching hardware failures indicate that the two structures were intact at the time of the R.D.

LABORATORY ANALYSIS

The recovered structure and mechanical components of the aircraft where appropriate were subjected to laboratory analysis in order to determine: (1) the existence of traces of explosives, (2) properties of materials, (3) fatigue or overload failure mode, (4) stress corrosion, (5) tear pattern, etc. These laboratory analyses were conducted at the Metallurgical Laboratory at Kelley AFB, FBI Laboratory in Washington, D.C., Lockheed-Georgia Company and the Air Force Materials Laboratory at Wright-Patterson AFB, and are included in Appendix A. This section summarizes these laboratory findings.

The FBI Laboratory analysis of two sections of cargo floor structure and left upper pressure door hinge identified as having possible traces of explosives by the EOD section of Lackland AFB were completely negative as detailed in Appendix A, Item 59.

PRESSURE DOOR FIXED OVERHEAD STRUCTURE

The pressure door fixed overhead structure was intact except for impact damage, therefore analysis of components of this area was limited to the No. 5 roller bracket (Appendix A, Item 15) which indicated overload as the primary failure cause.

RAMP

The fuselage half of the ramp to fuselage hinge failed in compression at both left and right B.L. 84 hinge sections. The ramp from immediately aft of these hinges between Ramp Station 0 and 33 failed in tension (Appendix A, Items 5 and 6). This same beam between R.S. 33 and 54 and R.S. 54 and 75 failed in tension as detailed in Item 33, Sample 1,4, and 5.

Portions of the ramp floor structure forward of R.S. 33 recovered at the crash site were analyzed for mode of failure and direction of tear. The failure mode was predominantly tensile overload with some rubbing and bending. The direction of the tear is complex but was predominantly from the right to left as is detailed in Appendix A, Items 4, 17, 18, 19, and 20.

Portions of the forward edge of the ramp floor at R.S. 33 totaling 27 pieces were removed from the ramp, which was recovered at sea, and subjected to laboratory analysis to determine mode of failure and tear direction. The results of this analysis reveals that the failure was tensile overload in a direction from right to left as detailed in Appendix A, Item 26.

The right forward section of the ramp which was more extensively damaged was noted to have failed the fore and aft beams webs in tension, with the lower beam cap also failing in tension. Considerable compressive force was also exerted on the fore and aft beams and the left to right bulkheads resulting in buckling. especially of the honeycomb bulkheads prior to these bulkheads experiencing a failure in a fore and aft direction. Some insignificant foreign object damage was noted on the left aft side of the winch well. These observations are detailed in Appendix A, Item 33. Five sections of ramp external skin revealed damage as caused by impacting water or air as detailed in Appendix A, Item 34.

One section of ramp bulkhead was analyzed to determine the possibility of small arms fire type damage. The results were negative as detailed in Appendix A, Item 23.

LEFT LOCK SYSTEM

The number 7 hook was damaged by an overload pulling the yoke pin [illegible] the sides of the hook. The load path of the bellcrank is intact with some cracking, identified as stress corrosion, at the bottom lug as shown in Appendix A, Item 3. The number 7 yoke guide was missing one fastener as revealed in Appendix A, Item 14.

The number 6 bellcrank failed due to overload with some evidence of stress corrosion as detailed in Appendix A, Item 1. The number 6 saddle fitting suffered impact and foreign object damage as noted in Appendix A, Item 2.

The number 5 hook was damaged on the inboard side similar to number 7. The main load path of the bellcrank was intact with come evidence of stress corrosion similar to number 7 as detailed in Appendix A, Item 10. The number 5 saddle fitting was damaged by a foreign object which smeared blue paint in the radius type manner as detailed in Appendix A, Item 11.

The number 4 hook and bell crank were similar to number 7 and number 5 as shown in Appendix A, Item 13.

The tie rods between locks 4 and 5 failed in a compressive twisting manner as detailed in Appendix A, Item 12.

RIGHT LOCK SYSTEM

The number 7 hook was damaged by an overload pulling the yoke pin across the inboard side. The load path of the bellcrank was intact and the tie rod failed in compression as detailed in Item 16. The yoke found attached to the ramp was intact except for shearing of the upper pin at the small diameter on the outboard side as detailed in Appendix A, Item 31.

The number 6 floor bracket and yoke assembly were slightly corroded but structurally intact except for evidence of high load at the lower yoke pin shaft and a crack in the mono ball attached to this pin as detailed in Appendix A, Item 30. This high load was later determined to be wear as detailed in Appendix A, Item 47.

The number 5 floor bracket showed evidence of a high load pulling the yoke from the bracket as outlined in Appendix A, Item 28. The hook and bellcrank recovered at the crash site were intact except for the bellcrank arm fracture as detailed in Appendix A, Item 8.

The Number 4 floor bracket was similar to number 5, above, as detailed in Appendix A, Item 29. The bellcrank recovered at the crash site was intact except for the arm fracture and some stress corrosion in other areas as outlined in Appendix A, Item 7.

The number 3 floor bracket and yoke assembly were intact with no evidence of overload. The report erroneously accessed normal wear as shearing action. The details are shown in Appendix A, Items 27 and 47.

The number 2 floor bracket and yoke assembly were intact with no evidence of overload as detailed in Appendix A, Item 25.

MISCELLANEOUS LOCK HARDWARE

Two sections of bellcrank and push rod were recovered at the crash site and were identified as being from the No. 3 bellcrank either right or left. The failures were overload. It is noted that the rod end is adjusted to the shortest possible length with the threads bottomed out in the rod fitting. The details are outlined in Appendix A, Items 9, 24, and 47.

The laboratory analysis of two hydraulic lines taken from the left side at station 2101 were determined to have failed as a result of impact damage as detailed in Appendix A, Item 22.

Note that the AF Materials lab & Lockheed Ga lab reports are at varience with the Kelly AFB lab reports the Southwest Research Lab report with regard to the stress corrosion indications/findings as shown in Appendix A, Item-46 and 47 (Ref Appendix A, Item 62).

Three control cables removed from the tail section at the crash site were failed in tensile and torsional overloading as detailed in Appendix A, Item 21.

BURN FRAGMENTS

Portions of the right forward gear door and mating fuselage fairing were analyzed for combustibles. Hydraulic oil is indicated as the combustible as detailed in Appendix A, Item 32 and 48.

FAULT ANALYSIS

The fault analysis, prepared during the initial design phase of the C-5 and updated with each Engineering Change Proposal, is summarized in Appendix A, Item 46.

The fault analysis deals primarily with the resulting operation after a single fault either electrical, hydraulic, or mechanical. The faults are assumed to occur prior to any operation and to occur at various times in mid-cycle.

The results of this analysis indicate that no single fault can cause inadvertent operation of door system should the fault exist prior to the start of any operation.

In the event a single fault exists and the doors are commanded to operate, some operations beyond the commanded point will occur such as ramp lowering too far due to the inoperative condition of a ramp door limit switch.

The summary of the fault analysis continued beyond the normal first fault approach to cover multiple faults in regards to the ramp arming solenoid. This analysis reveals that even in the event of multiple faults such as the ramp hydraulically armed and operation of the ramp up and unlock solenoid either (electrically or manually) the ramp actuator and unlock actuator would be incapable of lifting and unlocking the ramp actuator and unlock actuator would be incapable of lifting and unlocking the ramp at 6.5 psi. (Appendix A, Item 37)

Evidence revealed by observations of recovered items indicates that the entire left ramp lock system was locked as were locks numbers 4 through 7 on the right side.

Therefore, it is concluded that single faults, combination of faults, or faults together with manual or electrical commands were not involved with the failure.

SABOTAGE OR SHELLING

The evidence from an evaluation of recovered items together with EOD Teams and FBI Laboratory analysis has not identified any evidence of sabotage, small arms ground fire, air burst, or onboard explosives.

Evaluation of the recovered ramp indicated that the bulkheads aft of the winch well were intact and suffered compressive damage on the initial water impact. Further water impact forced these bulkheads aft completely severing the bulkhead at R.S. 54 and folding the bulkhead at R.S. 75 in an aft direction. See Appendix A, Items 32, 35, 48 and 59.

CENTER DOOR

The center door is not considered to be the initiation point of the failure because the center door is outside the pressure vessel. Damage to the center door was the result of the cabin air entering this area as outlined in Appendix A, Item 42.

SIDE DOOR

The side doors are not considered to be the initiation point because evidence indicates that the side doors were locked to the fuselage bayonet latch at the time of failure as indicated tearing of the side door structure around the right bayonet latch and the left latch found in the locked condition.

PRESSURE DOOR LOWER HINGE

The pressure door lower hinge system is not considered to be the initiation point since:

(1) If the pressure door to ramp hinges had unlocked, the ramp would, under 6.5 psi cabin pressure deflect downward at the center. This, if the deflection was sufficient, would first release the B1 28.0 locks from the ramp and would give a pressure door failure pattern different to the one exhibited on 68-218. With this failure mode the ramp would most probably have stayed with the aircraft with only minor ramp damage.

(2) The lower hinge saddle fittings would offer an aft restraint in the event of unlocking of the lower hinge.

(3) The lower hinges are mechanically tied to the upper hinges such that unlocking the lower hinge necessitates locking of the upper hinge.

(4) The left upper hinge was intact and unlocked while the right upper hinge suffered crash damage.

PRESSURE DOOR FIXED OVERHEAD STRUCTURE

The beam structure that restrains the pressure door fingers at station 2101 is not considered to be the initiation point of the failure since the beam was recovered at the crash site relatively intact. The beam shows evidence of the pressure door fingers moving to the right and down off the roller assemblies.

LOCK SUPPORT STRUCTURE

The structure that supports the ramp locking system is not considered to be the initiation point of the failure. A section of the left side of the fuselage containing locks 4 through 7 and the lock actuator was recovered at the crash site. On the right side, portions of lock Nos. 3, 4, and 5, and the entire No. 7 lock was recovered at the crash site. Recovery of this amount of lock hardware indicates that the supporting structure was intact at ground impact.

RAMP STRUCTURE AND RAMP TO FUSELAGE HINGE

The ramp to fuselage hinges are not considered to be the initiation point of the failure since (1) both halves of the two outboard hinges were recovered at the crash site with portions of the fuselage seal and ramp beams attached, (2) the tear pattern of the ramp floor structure was from right to left.

WINCH WELL COVER

The winch well cover is not considered to be the initiation point of the failure. Should the winch cover have been left off at Tan Son Nhut, the aircraft pressure would have been limited to 2 psi due to the air leakage through the winch well through the floor structure and out the aft end of the ramp as outlined in Appendix A, Item 38. The winch recovered at sea did not show evidence of the winch cover collapsing onto the winch. Should the winch cover have failed structurally or have been blown off by an explosion and dumped cabin air into the winch well area, the bulkheads would have failed aft and forwards respectively and could not have suffered a compressive failure as was noted under laboratory analysis. See Appendix A, Item 39.

RAMP ACTUATION AND LOCKING SYSTEM

The complete ramp actuation and locking system is not considered to be the initiation cause of the failure. The Fault Analysis (Appendix A, Item 46) reveals that this system is incapable of lifting and unlocking the ramp at 6.5 psi. The left lock actuator was found locked. The evidence indicates that the left lock system remained locked and the ramp rotated 90° and twisted out of the left lock system. Locks Nos. 4 through 7 on the right side failed while locked under overload conditions.

The complete right lock system is not considered to be the initiation point of the failure because the evidence shows that locks 4 through 7 failed while locked under an overload condition.

The number 1 through 3 locks of the right lock system are considered to be the most probable initiation point of the failure for reasons outlined above and covered in the Aft Ramp Structural Failure Analysis as detailed below. The failure is considered to have occurred suddenly since there is no indication that "Pressure Door" unlock lights were on, or that any unusual noise caused by air escaping across the ramp seals, existed prior to the Rapid Decompression.

Aft Ramp Structural Failure Analysis

Examination of the aft ramp structural failure indicates a failure mode of vertical bending and shear at the R.B.L. 84 beam at approximately R.S. 33. The evidence supporting this failure mode is as follows:

(1) The R.B.L. 84 lower beam cap failed primarily in tension in a net section through the aft row of fasteners in the R.S. 33 splice.

(2) The R.B.L. 84 upper beam cap failed in combined tension and bending at approximately R.S. 19. The portion of the upper cap from R.S. 19 to R.S. 33 was deformed upward indicating rotation of the beam about R.S. 19 and the hinge at R.S. 00.0.

(3) The R.B.L. 84 corrugated web between R.S. 54 and R.S. 75 showed evidence of shear deformation and cracking diagonally. There was also evidence of additional damage due to water impact. A large portion of the web between R.S. 19 and 54 was missing.

(4) The lower member of the fuselage half of the R.B.L. 84 hinge fitting failed in compression, apparently due to a high vertical load at the hinge line. Since there was no evidence of fatigue in the R.B.L. 84 beam, the failure pattern described above can result only if the beam and hinge become overloaded. This overload could be caused by sudden loss of latch load transfer at the right forward end of the ramp.

Structural analysis of the ramp was made, Appendix A, Item 60, assuming that latches 1, 2, and 3 suddenly lost load carrying capability. In this case, the load carried by the transverse bulkheads at R.S. 33, 54, and 75 would have been picked up by the B.L. 84 beam and then distributed to the hinge at the forward end and to the transverse bulkheads at R.S. 95 and aft. Analysis of the R.B.L. 84 beam web at R.S. 33 indicates that this condition will result in failure of the web and, consequently, failure of the caps, followed by progressive failure of the remaining locks on the right side and the remaining hinges. Thus, the failure pattern of the ramp indicates that the right No. 1, 2, and 3 locks failed in some manner, either by unlocking or by structural failure of a lock component.

Examination of the right yokes No. 2 and No. 3 shows no evidence of high overload. Structural analysis of the bellcranks in an unlocked position shows that failure will occur at a load less than that required to yield the yoke components.

None of the components from right lock No. 1 was recovered; therefore, no assessment can be made of the condition of this lock. However, as discussed above, Lock No. 1 must have become unlocked to result in failure of the ramp.

FAILURE SEQUENCE

The failure sequence outlined herein is estimated to have occurred in an elapsed time of less than one second. An analysis of all available evidence indicates that the most probable initiation point of the failure involves locks No. 1, 2, and 3 of the right side of the ramp.

(1) The right side ramp locks 1, 2, and 3, due to a combination of rigging problems together with a sudden detachment of the tie rod between lock number 3 and lock number 4, suddenly dropped load. See Appendix A, Item 49 and 50.

(2) The load previously carried by the above locks was dynamically transferred through the ramp structure to the fuselage hinges and the remaining locks 4 through 7 of the right side lock system.

(3) This dynamically applied load, overloaded the R.B.L. 84 hinge, the ramp B.L. 84 beam webs and beam caps, and right lock number 4. This overload resulted in a simultaneous failure of the R.B.L. 84 beam and the locks sequentially from 4 through 7, which resulted in the ramp structure tearing from the right to the left at R.S. 33. See Appendix A. Item 51.

(4) As the lock number 7 failed on the right side the ramp lowered together with the attached pressure door and started to rotate about the left lock system. See Appendix A, Item 52.

(5) During the initial lowering of the ramp and pressure door, the fingers of the pressure door slipped to the right and down off the Sta. 2101 pressure bulkhead rollers allowing 6.5 psi cabin air to impact the sloping torque deck deflecting it upward symetrically about the aircraft center line. This escaping cabin air blew the side doors open and failed the center door. The center doors departed the aircraft. Subsequently, the right side cargo door departed the aircraft.

(6) When the six right side pressure door fingers cleared the rollers and passed through the light seal structure, the pressure door failed in bending and shear at L.B.L. 28 starting at the top due to the restraint of the remaining three fingers on the left side.

(7) The left 3 pressure door fingers slipped off the rollers causing the sloping torque deck to be impacted by the rotation of the remaining lift side portion of the pressure door, rupturing the torque deck, hydraulic systems Nos. 1 and 2 as well as all control cables and the lower portion of the wire runs immediately above the torque deck. The forces of escaping cabin air contributed to the upward motion of the torque deck structure and to failure of the control cables (See Appendix A, Item 52). The right side of the pressure door had dropped sufficiently to clear the No. 3 hydraulic system lines. See Appendix A, Item 53.

Tests were conducted (Ref Appendix A, Item 63) to determine the degradation of tension strength of a buckled tie rod. Failure occured at approximately 600 lbs. in two rods which were buckled similar to that experienced in operation. This failure load is well within loads which can be expected from misrigged conditions.

CONCLUSION

The following sub-systems of the aft cargo door complex did not contribute to the failure initiation.

1. Center Door
2. Side Doors
3. Pressure Door Upper Hinge
4. Pressure Door Lower Hinge
5. Upper Pressure Door Fixed Overhead Structure
6. Sloping Longeron
7. Ramp Structure
8. Ramp to Fuselage Hinge
9. Winch Well
10. Ramp Actuator and Ramp Lock Actuator
11. Left Side Ramp Lock System
12. Locks Number 4 through 7 of the Right Side Lock System

The most probable initiation point of the failure is right locks numbers 1, 2, and 3, and the tie rod interconnecting lock numbers 3 and 4.

The initiation of the failure in this area would occur under any one of the following circumstances:

Case I - An out of rig condition of locks 1, 2, and 3 or combination thereof resulting in yoke to hook interference such that during the last ramp closing operation a partial failure was induced in the tie rod between locks 3 and 4 that would result in separation at 6.5 psi due to an unlocking load from locks 1, 2, and 3. (Ref Appendix A, Item 63)

Case II - Out of rig condition on locks 1, 2, and 3 such that an unlocking force is created on the tie rod between locks 3 and 4 together with a sudden separation of this rod at 6.5 psi.

Case III - Out of rig condition of locks 1 and 2 with lock 3 in rig (or other combinations) such that a net unlocking force is created in the tie rod between lock 3 and 4 together with a sudden separation of this rod.

Case IV - An existing unlock condition on locks 1, 2, and 3 caused by: out of rig, out of rig resulting in mechanical failure of program links, etc., and the remaining two locks out of rig such that an unlocking force was created in the tie rod between locks 3 and 4 together with a sudden separation of this tie rod.

NOTE: Any reasonable out-of-rig condition of locks 1, 2, and 3 could not precipitate the failure assuming the tie rod was structurally intact and tie rod bolts properly installed. (See Appendix A, Item 55)

SUMMARY REPORT

OF

C-5A ACCIDENT

INVESTIGATION BOARD

SUMMARY REPORT OF C-5A ACCIDENT

Following the C-5A accident near Saigon, Vietnam on April 4, 1975, an investigation board was appointed to determine the cause of the accident. The facts as reconstructed during the investigation are as follows:

The aircraft departed Tan Son Nhut Airfield enroute to Clark Air Base at approximately 1600 hours local time. A rapid decompression and loss of the aft cargo ramp and pressure door occurred while passing FL 230. The numbers one and two hydraulic systems were lost immediately. The aircrew initiated a turn and started a shallow descent while the damage was being assessed. When the pilot applied back pressure to slow the rate of descent, he discovered that all pitch control was inoperative. It was subsequently found that the pitch trim and rudder were also inoperative. Faced with the loss of all empennage flight controls and using power and bank to control the rate of descent, the crew began an emergency return to Tan Son Nhut.

The aircraft was maneuvered onto a modified base leg but during the turn to line up with the runway the rate of descent increased rapidly. The pilot elected to roll out and crash land straight ahead. By applying full throttle he was able to raise the nose and partially arrest the rate of descent before impact. The throttles were retarded to idle just prior to the initial touchdown. The aircraft rolled and slid 1000 feet, became airborne, flew 2700 feet and again impacted the ground. The aircraft separated into four major sections: empennage, troop compartment, cockpit, and wing. One hundred fifty-five of the 330 passengers and crew on board were killed. The investigating board commended the crew's prompt evaluation of the situation and superb execution of the emergency return and crash landing which resulted in the survival of over half the personnel on board.

The investigation revealed that the failure of the aft ramp and subsequent rapid decompression resulted from the numbers one, two, and three locks on the right side of the ramp unlocking in flight. When the locks released, a dynamic overload was simultaneously exerted on the ramp and remaining right side locks. This caused the ramp and pressure door to separate from the aircraft. The pressure door struck the aft fuselage severing the pitch trim, rudder, and elevator cables.

The investigators were not able to conclusively determine the specific reason for unlocking of the ramp locks because a significant number of the key parts were not recovered. The system involved is a "gang locking system" where, because of the interaction between the individual locks through tie rods, an out-of-rig condition of any of the locking system components can affect other locking system components. Since the system is designed, and has been tested, to operate satisfactorily with one lock in the unlocked position, unlocking of a single lock would not cause this catastrophic result.

They believe that a combination of an out-of-rig condition and subsequent failure of a part such as a tie rod or bell-crank arm, while the aircraft was pressurized, resulted in an instantaneous dynamic overload condition on the ramp.

The accident board was able to determine that no structural failure was involved in the accident. It was conclusively shown that the ramp and pressure door were structurally sound and failed only as a result of the dynamic overload. The rapid decompression occurred when 65,800 cubic feet of air was displaced in less than one second.

During the investigation the accident board made recommendations designed to achieve the following:

An independent lock operation with elimination of interaction between individual locks; a revision of applicable technical orders and procedures to insure correct rigging; review of the system checks to insure that required checks of the system adequately verify correct rigging; examination of field level inspections and programmed depot maintenance to provide additional serviceability inspections of the loading systems; early rerouting of some cables and lines and further study/analysis to determine if more extensive changes are necessary.

The Air Force is presently reviewing the board's findings and recommendations to assess those actions necessary to prevent recurrence.

PRESS RELEASE

NEW YORK TIMES

USAF FINDINGS

CAUSE OF C-5 ACCIDENT

NEW YORK TIMES
Friday, June 13, 75

Mr. Witkin tells of the USAF findings on the cause of the C-5 accident near Saigon.

Open Latches Cited in Vietnam Air Crash Fatal to 155

By RICHARD WITKIN

Special to The New York Times

WASHINGTON, June 12—The unlocking of three of 14 latches on a rear-entry ramp caused the crash of a C-5A cargo plant carrying children out of Vietnam in April, the Air Force announced today.

A total of 155 persons were killed, including 98 of the 247 children on board the Lockheed plane, the largest in the world.

The investigating board said that, with tht three locks open, the tremendous pressure inside the plane exerted excessive force on the rest of the locks. The ramp they were holding in place broke loose, along with an adjacent pressure door.

These massive metal structures flew rearward as 65,800 cubic feet of air went out the now-open rear of the plane in less than a second. In doing so, they rammed into critical parts of the interior structure severing cables needed to control the plane.

The pilot started a slow descent from the plane's 23,000-foot altitude, heading back to Saigon's Tan Son Nhut Airport. But because of the damage to the controls, he had to crash-land in rice paddies short of the runway. The plane broke up and burned.

C-5A's Under Restrictions

There was speculation that the plane might have been sabotaged, but the crash investigators ruled this out.

The inquiry board made a number of recommendations for modification of the rear-entry locking system, for re-routing some of the vital cables and hydraulic and other lines, and for study of whether more extensive changes were needed.

Meantime, Air Force spokesmen said that the remaining 77 C-5's in the transport fleet would continue to be flown under restrictions imposed after the April crash.

The plane's rear entryways now must be kept locked, so that all loading and unloading must be done throughthe nose entries. And passengers have been barred from all C-5A flights for the time being.

The giant plane, nicknamed the Galaxy, has been a focus of controversy since its earliest days, when deficiencies in the wing structures and other problems led to large excess costs. The weakness in the wings threatened to cut the plane's lifetime to half, or even less, of what the design had called for.

Congress is currently considering new appropriations to beef up the wings and thereby prolong the plane's usefulness.

In commenting on the Saigon crash, the inquiry board said that it "could not conclusively determine the reason for the unlocking of the ramp locks because a significant number of parts were not recovered.

Looting Hampered Recovery

The recovery efforts, while highly productive, were hampered by the fact that much debris had fallen into the water (the plane was over the South China Sea when the entryway blew open) and looters at the crash scene had made off with some parts.

The pressure seal at the rear of the plan is made up essentially of two heavy structures which, when in place, form a reverse "L". The same two structures, when deployed downward, form the rampway over which trucks, tanks and other cargo can normally be loaded aboard the craft.

In the in-flight configuration, the "horizontal" part of the "L" sits at an angle of perhaps 25 degrees above horizontal, and the "vertical" part leans forward.

It is the "horizontal" part that has the 14 locks, seven on each side, to hold the total system in place. The three that came unlocked were the forward three on the right side of the plane.

The inquiry board said in a summary of its report:

"Although the board was not able to pinpoint the exact cause of the failure, it was able to trace the sequence close enough to ensure that subsequent actions will prevent a recurrence. Equally important, it was conclusively determined that there was no structural deficiency involved and that the ramp and pressure door failed only as a result of a dynamic overload."

Summary of Lawsuits

Filed Against

Lockheed

SUMMARY OF LAWSUITS FILED AGAINST LOCKHEED

1. Larry Reynolds, Robert Reynolds, Leslie Reynolds (children of Anne B. Reynolds, deceased) v. Lockheed, a corporation plus Does 1 through 50 - filed in Superior Court of California for County of Los Angeles on 17 April 1975.

2. Richard H. Jones, Administrator of Estate of Jo-An K. Pray, of Arlington, Virginia v. Lockheed, a California corporation - filed in U. S. District Court for District of Columbia - filed as a class action approximately 25 May 1975.

3. Marcella P. Kaufman, Administrator of the Estate of Marilynn P. Eichen v. Lockheed, a California corporation - filed in U. S. District Court for Southern District of Illinois, Springfield, Illinois - filed as a class action on 13 June 1975.

4. Patricia Dillenseger (passenger) as Administrator for Estate of Vivienne A. Clark v. Lockheed Aircraft Corporation - filed in U. S. District Court, Southern District of New York - filed as a class action on 2 July 1975

5. Garnett E. Bell, Andrea C. Bell (mother died in crash) v. Lockheed and Lockheed-Georgia - filed in U. S. District Court Central District of California on 8 July 1975.

6. American National Bank and Trust as Administrator of Estate of Vera Hollibaugh v. Lockheed Aircraft Corporation - filed in Circuit Court of Cook County, Illinois - filed as a class action on 30 July 1975.

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