NBSIR 75-686 (R)

Examination of Failed Pylon Components

T. Robert Shives

Mechanical Properties Section
Metallurgy Division
Institute for Materials Research
National Bureau of Standards
Washington, D. C. 20234

March 1975

Failure Analysis Report

Prepared for
Naval Air Test Center
Patuxent River, Maryland 20670

NBSIR 75–686

EXAMINATION OF FAILED PYLON COMPONENTS

T. Robert Shives

Mechanical Properties Section
Metallurgy Division
Institute for Materials Research
National Bureau of Standards
Washington, D. C. 20234

March 1975

Failure Analysis Report

Prepared for
Naval Air Test Center
Patuxent River, Maryland 20670

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

TABLE OF CONTENTS

FIGURES (continued)

SUMMARY

At the request of the Naval Air Test Center, Patuxent, Maryland, the NBS Mechanical Properties Section examined a number of components from failed aircraft pylons. It was found that fractured bolts and spar subassembly lugs had failed due to the initiation and propagation of fatigue cracks. The cracks had initiated in regions of mechanical damage or fretting corrosion damage, or where there was a rather abrupt change in cross section thickness. There was evidence that the systems had been subjected to vibrations which caused the cyclic loading necessary for fatigue cracking.

Examination of Failed Pylon Components

1. INTRODUCTION

1.1 Reference

Naval Air Test Center, Patuxent River, Maryland. This investigation was conducted at the request of Dr. Joseph G. Hoeg under Job Order No. P79 8426WS dated June 20, 1974.

1.2 Parts Submitted

Parts of four separate pylons made from an aluminum alloy were submitted for examination. The significant parts from each of the pylons are shown as received at NBS in figure 1. In addition, twelve unbroken cadmium plated steel bolts (shown in figure 2) that had been used in the pylons in the "normal" torque condition were submitted at a later date. Still later, eleven unbroken cadmium plated steel bolts (shown in figure 3) that had been used in the pylons at a new higher torque condition were submitted for examination.

1.3 Parts Examined

Although there are fractures, cracks, and regions of deformation and other mechanical damage in many of the aluminum alloy sheet metal components of all four pylons, this examination, with some exceptions, has been concentrated on the aluminum spar subassembly lugs from all four pylons, the two fractured bolts from pylon no. 3, and the two sets of unbroken bolts that were submitted.

2. PURPOSE

The Naval Air Test Center requested that the NBS Mechanical Properties Section characterize the fractures of the two submitted failed bolts from pylon no. 3 and the fractures of the failed spar subassembly lugs. In addition, it was requested that the intact lugs be examined for cracks and that the unbroken bolts be examined for general condition and cracks. A determination, if possible, of the sequence of events during the failure process was desired.

3. RESULTS OF EXAMINATIONS, ANALYSES, AND TESTS

3.1 Bolts

3.1.1 Fractured Bolts from Pylon No. 3

3.1.1.1 Visual and Macroscopic Examination

Fracture of the two failed cadmium plated steel bolts from pylon no. 3 occurred in the shank in each case and not in the threaded area. There was considerable mechanical damage - largely in the form of circumferential grooves - and what appeared to be fretting corrosion damage on the bolt shanks. The fracture cracks initiated in or adjacent to damaged areas. One view of each bolt shank is shown in figure 4. (The parts of the bolts not shown were lost at the time of failure and therefore were not available for examination.)

There was some deformation in the form of necking and bending near the fracture of the bolt shown in figure 4b. The change in the diameter of the bolt shank from 0.436 inch in the undeformed regions away from the fracture to 0.430 inch adjacent to the fracture gives an indication of the amount of necking.

There were also a number of secondary cracks in this same bolt in the vicinity of, and essentially parallel to, the fracture. Two of these cracks are indicated by the arrows on the scanning electron photomicrograph shown in figure 5, and others can be seen in this same figure.

3.1.1.2 Fractographic Examination

The fracture surfaces of the bolts shown in figure 4 appear in figure 6 - on the left is the bolt in figure 4a, and on the right is the bolt in figure 4b. Approximate locations of the crack origins are indicated by arrows in figure 6. These fracture surfaces were examined with the scanning electron microscope. The fracture cracks in both bolts appear to have propagated initially in fatigue. When the cross sections of the bolts had been reduced by the advancing fatigue cracks so that the applied load could no longer be sustained, the cracks propagated to fracture in ductile overload.

Representative scanning electron fractographs exhibiting fracture modes typical of the apparent fatigue portion of the fracture of the bolt shown in figure 4b appear in figure 7. A suggestion of fatigue striations appears in figure 7a. An area representative of the overload portions of the bolt fractures is shown in figure 8, where the primary fracture mode is dimpled rupture.

3.1.1.3 Metallographic Examination

A longitudinal section intersecting the fracture was prepared for metallographic examination from the bolt exhibiting secondary cracks (bolt shown in figures 4b and 5). An as-polished field showing the fracture profile in the fatigue portion of the fracture appears in figure 9. The fracture profile is relatively smooth. The material appears to be quite clean and relatively free of inclusions.

Part of the area shown in figure 9 appears at higher magnification in the etched condition in figure 10. (The specimen orientation is the same in both figures 9 and 10.) The microstructure consists primarily of tempered martensite. Several transverse cracks can be seen in the cadmium plating, and one crack (arrow) can be seen in the basis steel material. In figure 11, two more cracks in the basis steel are shown where there are no cracks in the cadmium plating. Indeed, the cadmium plating had substantially filled the cracks. The cracks shown in figure 11 are about 2 mm from the fracture.

The fracture profile in the overload portion of the fracture from the same bolt is shown in figure 12. The fracture is horizontal at the top of the figure. The rougher, more jagged appearance of the overload fracture profile - where the fracture mode is dimpled rupture - is contrasted with the relatively smooth appearance of the fracture profile in the fatigue portion of the fracture as shown in figures 9 and 10.

3.1.1.4 Chemical Analysis

A qualitative chemical analysis was made of the product of the fretting corrosion on the shanks of the two failed bolts and on the overload region of the fracture surface of the bolt shown in figure 4b. The analyses were made using a non-dispersive X-ray analyzer in conjunction with the scanning electron microscope.

The most strongly detected element in the fretting corrosion product was aluminum. The only element found in detectable quantities other than the aluminum and iron from the bolt was sulfur. The amount of sulfur was much less then the amount of aluminum. (The equipment employed in this analysis does not permit the determination of elements above ruthenium in the Periodic Table unless they are present in substantial amounts; hence the cadmium plating was not detected.)

On the overload region of the fracture surface, iron and silicon were the only elements detected in significant quantities.

3.1.1.5 Hardness Measurements

Rockwell C hardness measurements were made on a cross section through each of the fractured bolts. Five measurements were made on each bolt and the average hardness value for each was R_c 42. This corresponds approximately to an ultimate tensile strength of 194 ksi.

3.1.2 Unbroken Bolts Used at Normal Torque

3.1.2.1 Visual and Macroscopic Examination

The twelve unbroken bolts that had been used in the normal torque condition are shown as received at NBS in figures 2a, b, and c. They were in three groups of four each labeled as indicated in the legend of figure 2.

Each of the bolts had suffered mechanical damage and apparent fretting corrosion damage. Some of this damage can be seen in figure 2. The damage to the LQ-6 bolts and to two of the LQ-9 bolts was concentrated in a 1.9 inch length along the shank, starting at about 0.4 inch from the underside of the bolt head and extending to a location just short of the threaded region. For the other two LQ-9 bolts and the LQ-2 bolts, the damage extended essentially from the underside of the bolt head to just short of the threaded region. The damage adjacent to the bolt heads was primarily fretting corrosion. Most of the mechanical damage was circumferential in nature. In many cases there were areas where the cadmium plating was ruptured due to abrasion - and consequently was either missing or peeling away from the bolt. One example showing the absence of cadmium plating appears in figure 13, which is higher in magnification than figure 2.

3.1.2.2 Inspection for Cracks

All twelve of the unbroken bolts used at the normal torque were cleaned and then examined for cracks with a dye penetrant technique. No cracks were found.

3.1.3 Unbroken Bolts Used at Higher Torque

3.1.3.1 Visual and Macroscopic Examination

The eleven unbroken bolts that had been used in the higher torque condition are shown as received at NBS in figure 3. These bolts had suffered some circumferential mechanical damage, but in general, this damage was much less severe than that sustained by the unbroken bolts used in the normal torque condition.

3.1.3.2 Inspection for Cracks

The unbroken bolts used at the higher torque level were examined for cracks in the same way that the other unbroken bolts were examined. Evidence suggesting a crack in one of the bolts was detected, but when the bolt was sectioned through the apparent crack, it was found to be a mechanically produced gouge. Thus, as in the case of the unbroken bolts used in the normal torque condition, no cracks were found in the bolts used in the higher torque condition.

3.2 Spar Subassembly Lugs

3.2.1 Visual and Macroscopic Examination

Both the forward and aft lugs from pylons number 2 and 4 were received and examined. Only the aft lugs from pylons 1 and 3 were received. There were complete fractures in the aft lugs from pylons 3 and 4. These fracture surfaces are shown in figures 14 and 15, respectively. In both cases, the fracture cracks appear to have started (arrows A) at the edge of the flat area where the bolt head would seat. A secondary fatigue crack (arrow B) can also be seen in figure 14.

A large crack was also found in the forward lug from pylon no. 4 as shown in figure 16. This crack had traversed the entire distance between the hole and the outside of the lug on one side. This crack was opened by a saw-cut in the approximate location of the dotted line in figure 16. The exposed fracture surface is shown in figure 17. This crack initiated at the edge of the bolt hole at the bottom of the lug as indicated by the arrow in figure 17. The other spar subassembly lugs were examined macroscopically for cracks and none were found. The surfaces of many of the holes in the lugs exhibited evidence of mechanical and fretting corrosion damage. The surfaces of the two bolt holes in the forward lug from pylon no. 4 appeared to have suffered more damage than the surfaces of the holes in the other submitted lugs. Part of the surface of the bolt hole intersected by the fracture (hole on the right in figure 16) is shown in figure 18. This same lug was sectioned through the other bolt hole, and part of the surface of that hole is shown in figure 19. There appeared to be cracks in the surface (arrows, figure 19).

There was also some fretting corrosion damage on the bottom of some of the lugs where they were in contact with the aluminum alloy lower rib, and on the lower ribs both where they were in contact with the lugs and with the store. An example of the fretting damage on the bottom of a lug can be seen in figure 16 which shows part of the forward lug from pylon no. 4. A summary of mechanical and fretting damage on the hole surfaces, on the bottom of the lugs where contact was made with the lower rib, and in the areas under the bolt heads for all of the submitted lugs is as follows:

	Amount of Mechanical and Fretting Corrosion Damage		
	Holes	Bottom	Under Bolt Head
Pylon no. 1, aft lug	slight in one	slight	none, paint not damaged
Pylon no. 2, aft lug	none, paint not damaged	some	none, paint not damaged
fwd lug	slight	severe	insignificant
Pylon no. 3, aft lug	slight in one	slight	slight
Pylon no. 4, aft lug	some	some	some
fwd lug	severe	some	some

3.2.2 Fractographic Examination

The fracture surfaces of the three fractured lugs were examined with the scanning electron microscope. Examples of fractographs taken in the apparent fatigue portion of the fracture in the lug from pylon no. 3 are shown in figures 20 and 21. There is evidence of fatigue striations in each of these figures. A representative fractograph from the overload portion of one of the lug fractures from pylon no. 4 is shown in figure 22. The mode of fracture in the overload portion of the fractures appears to be dimpled rupture.

3.2.3 Metallographic Examination

An as-polished section intersecting the fatigue portion of the fracture in the failed lug from pylon no. 3 is shown in figure 23. Inclusions and second phase particles can be seen. Another field from this same section is shown in the etched condition in figure 24. It is evident that the relatively smooth fracture profile is transgranular and thus is consistent with fatigue cracking. The fracture profile in the overload portion of the fracture (figure 25) is much less smooth than that in the fatigue portion.

A section was taken through the intact hole in the forward lug from pylon no. 4 parallel to the longitudinal axis of the hole. This is the hole where apparent cracks could be seen in the hole surface (figure 19). When this section was polished, several cracks were revealed (figure 26). In some areas, they tend to follow forging flow lines.

3.2.4 Hardness Measurements

Rockwell B hardness measurements were made on the aft lugs from pylons 1 and 4. Five measurements were made for each lug resulting in the following hardness values:

Lug from pylon no. 1: Average R_B 90 1/2, range $\pm 1/2$

Lug from pylon no. 4: Average R_B 89 1/2, range ± 0

The acceptable hardness range for aluminum alloy 7075 in the T6 temper is R_B 85 to 95 (1).

4. DISCUSSION AND CONCLUSIONS

Both of the fractured bolts, the two completely fractured spar subassembly lugs, and the one partially fractured spar subassembly lug all failed due to the initiation and propagation of fatigue cracks. The fatigue cracks in the two failed bolts, both of which were from pylon no. 3, initiated in regions of the shank that had been damaged both mechanically and by fretting corrosion. The fatigue cracks in the lugs initiated either at a change in cross section thickness or at a mechanically damaged area.

There was a considerable amount of fretting corrosion damage on the spar subassembly lugs in some of the bolt holes, in areas where the bolt heads had seated, and in areas where the lugs had contacted the aluminum alloy lower ribs. Evidence of fretting damage was also found on the lower ribs both where these members contacted the lugs and where they contacted the store.

Fretting corrosion damage indicates relative oscillatory motion between two parts in contact. The relative motion resulting in fretting corrosion is usually very slight. Fretting damage frequently leads to the development of stress concentrators which increase the susceptibility of a part to fatigue cracking. Mechanical damage such as that found and changes in cross section area can also act as stress concentrators.

There were several cracks in the basis steel under the cadmium plating on one of the failed bolts. These cracks did not pass through the plating material; in fact, the plating material had filled some of the cracks in the steel indicating that the cracks were probably present before the plating was deposited. It is not clear how these cracks formed, but they could be detrimental in that they could act as stress concentrators. One of the failed bolts exhibited some necking, indicating that the yield strength of the material had been exceeded. There were a number of secondary cracks in the vicinity of the fracture in this same bolt.

In addition to the partial fatigue fracture at one bolt hole in the forward lug from pylon no. 4, there were a number of cracks in the vicinity of the other bolt hole. These cracks looked similar to those that can form from cavities that develop at the time of solidification (2). Such cracks can remain in the material through the forging process.

It was interesting to note that in the aft lug from pylon no. 1, the unmarred paint in the areas where the bolt heads would normally seat suggested that the bolt heads had not been seated. The bolt hole surfaces exhibited evidence that bolts had been in the holes. Moreover, the appearance of the lug surface that would have been in contact with the lower rib indicated that the lug had been in contact with the rib.

Nothing abnormal was noted in the hardness or microstructure of either the bolt or lug material. The limited chemical analysis on the fracture surface and of the fretting corrosion product on one of the bolt shanks revealed nothing unusual except for sulfur, which appeared to be present in small amounts. The significance of the sulfur is not clear. No fatigue cracks were found in any of the unbroken bolts used at either the normal torque or the high torque conditions. The shanks of the bolts used at both torque conditions exhibited some mechanical damage, but those used at the high torque condition exhibited less damage than those used at the normal torque. In addition to the mechanical damage, rather severe fretting corrosion damage was exhibited on the shanks of the bolts used at the normal torque condition. Since the length of service for the various bolts used under different conditions is not known, no definitive conclusion can be drawn regarding the effect of changing the torque on the life of the bolts and, subsequently, the integrity of the pylons.

There appears to be no clear pattern to the sequence of events resulting in the pylon failures. Complete fractures were found in two bolts from one pylon and in the aft spar subassembly lugs from two pylons, but there was a partial fracture in one of the forward lugs, and there were cracks in the vicinity of a bolt hole from the same forward lug. Failure of part of one lug would, of course, intensify the applied stress on the remaining parts of the system. Bolt failures would have the same effect. In the two cases where there were complete fractures on one side of a lug, the increased stress on the rest of the lug does not appear to have initiated cracking. In the case of the partial fracture, the cracks in the vicinity of the other bolt hole did not appear to be fatigue cracks.

It would appear that the fine scale fretting corrosion damage to the various components may be due to improper torquing of the bolts and subsequent vibration in service. The coarser circumferential damage to the bolts and the bolt hole surfaces may be due to improper tightening of the bolts at some point in time. Fatigue cracks initiated in the pylons in areas where stress concentrators had developed due to fretting corrosion damage or mechanical damage, or where there was a rather abrupt change in cross section area. The cyclic stressing necessary for the initiation and propagation of the fatigue cracks apparently came from the vibrations in the system in service.

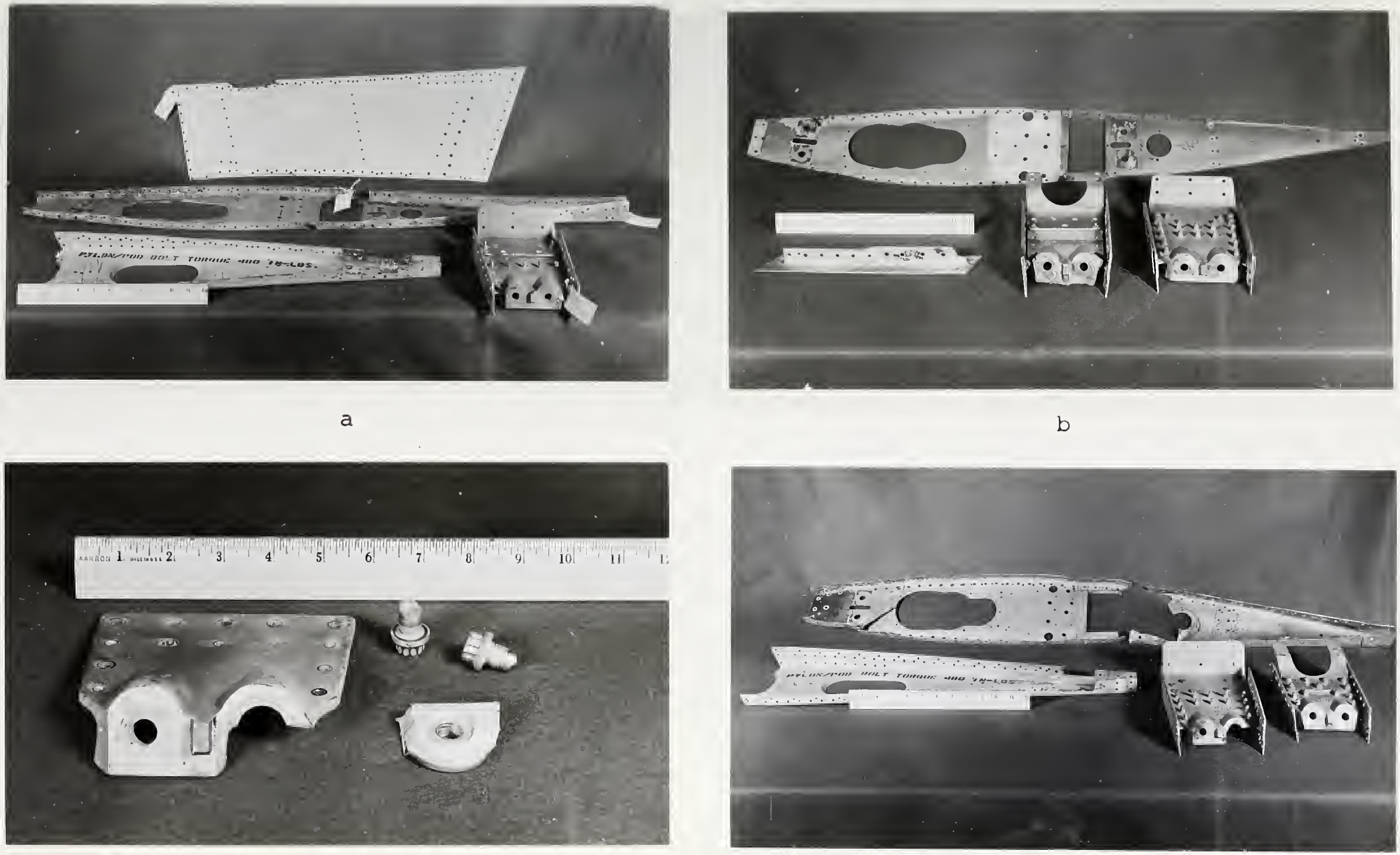
5. ACKNOWLEDGEMENT

Mr. L. C. Smith of the NBS Mechanical Properties Section performed the metallographic specimen preparation and the photographic work and assisted in other aspects of this investigation.

REFERENCES

1. Metals Handbook, American Society for Metals, 8th Edition, Volume 1, 1961.

2. Metals Handbook, American Society for Metals, 8th Edition, Volume 7, 1972.



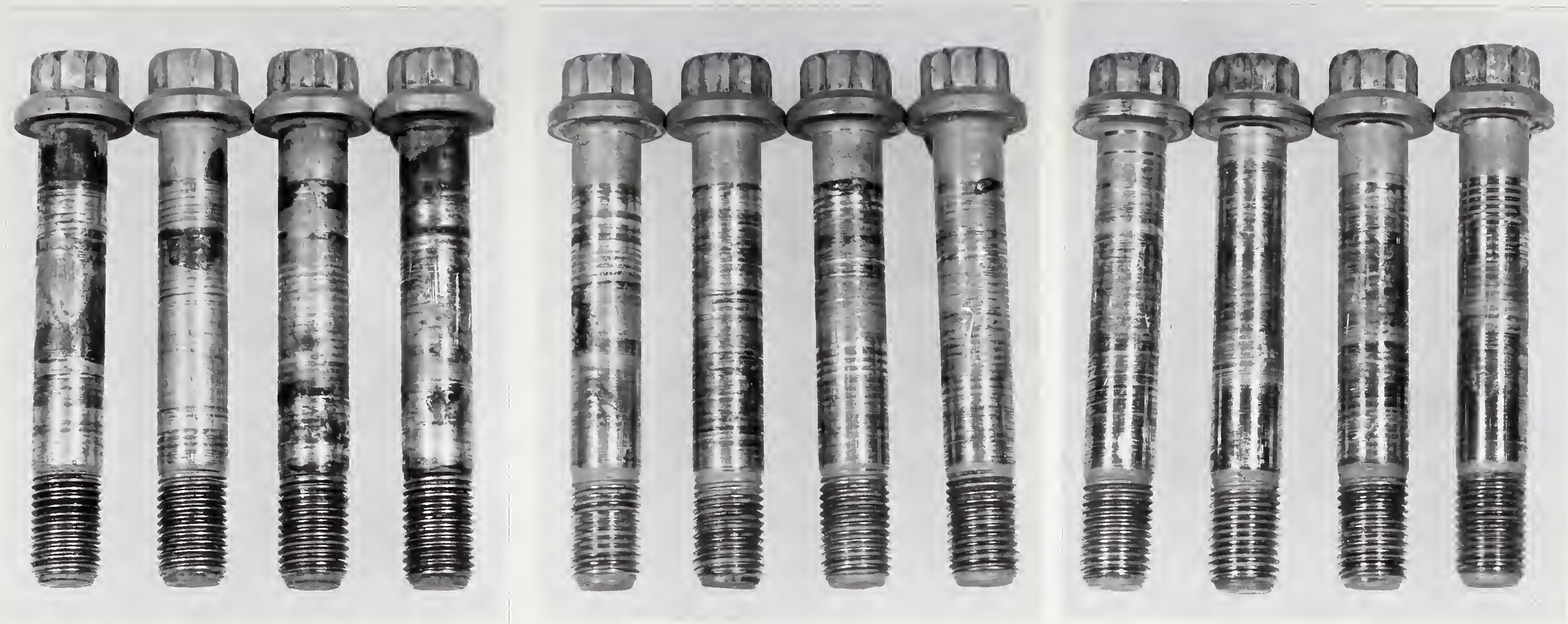
a

b

c

d

Figure 1. Significant pylon parts as received
a. Pylon no. 1, X 1/10
b. Pylon no. 2, X 1/10
c. Pylon no. 3, X 1/3
d. Pylon no. 4, X 1/10



a b c

Figure 2. Intact bolts used at the normal torque as received. X 1

a. Bolts labeled LQ-2

b. Bolts labeled LQ-6

c. Bolts labeled LQ-9

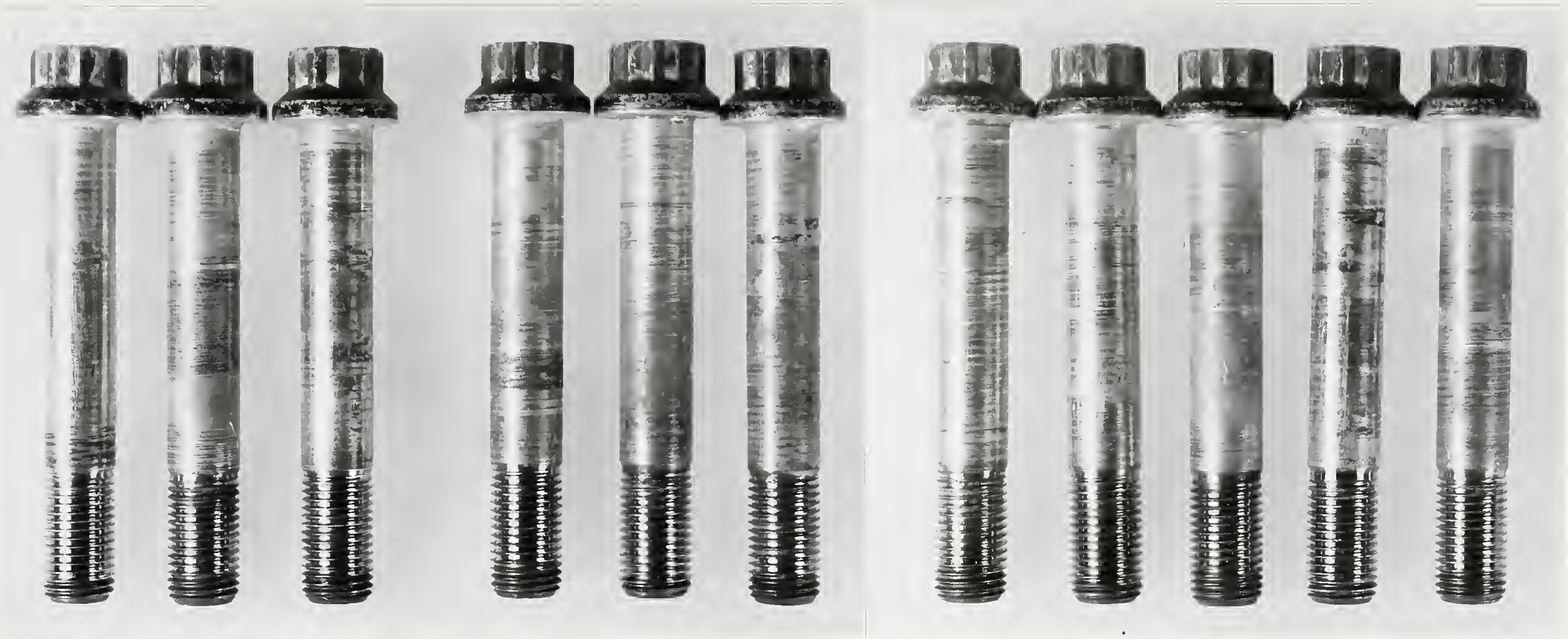
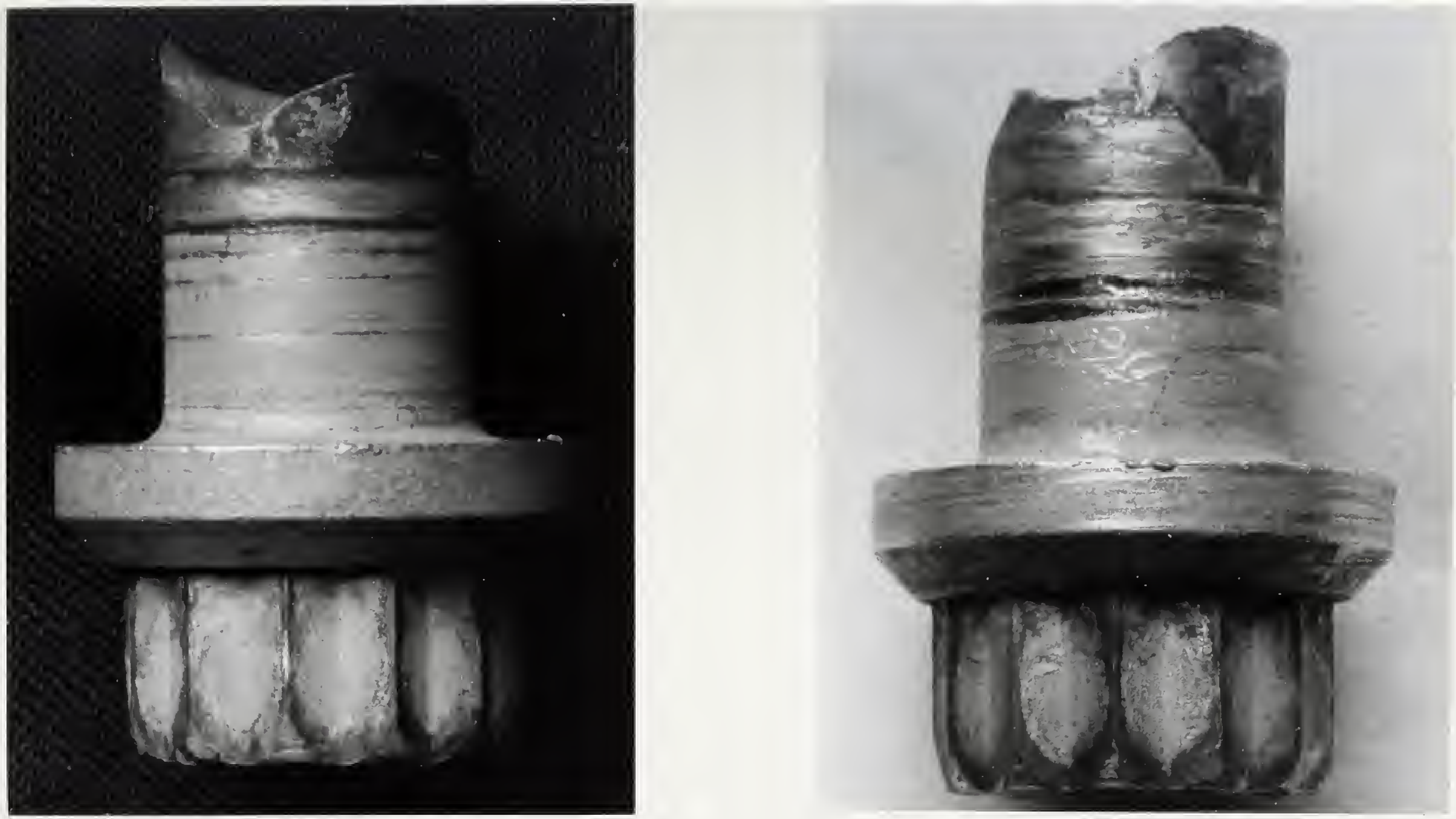


Figure 3. Intact bolts used at the new higher torque as received. The bolts were in three groups, but neither the bolts nor the groups were identified. X 1



a   b

Figure 4. Parts of the two fractured bolts from pylon no. 3. The circumferential mechanical and fretting damage can be seen. Deformation can be seen in the shank of the bolt shown in 4b. X 4

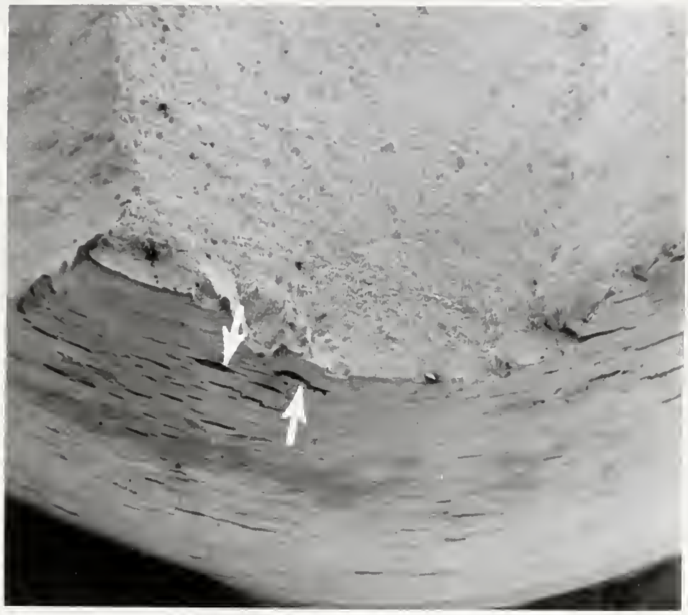


Figure 5. Scanning electron photomicrograph of bolt appearing in figure 4b. Several secondary cracks (arrows) appear in the shank surface, which is in the lower portion of the figure. Part of the fracture surface is shown in the upper portion of the figure. X 19

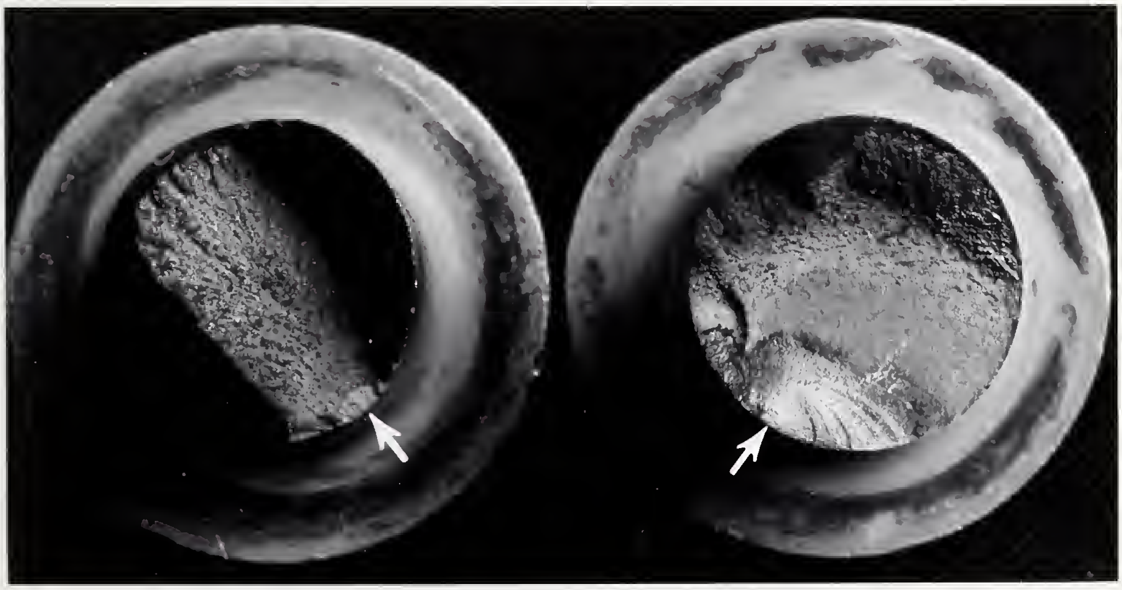
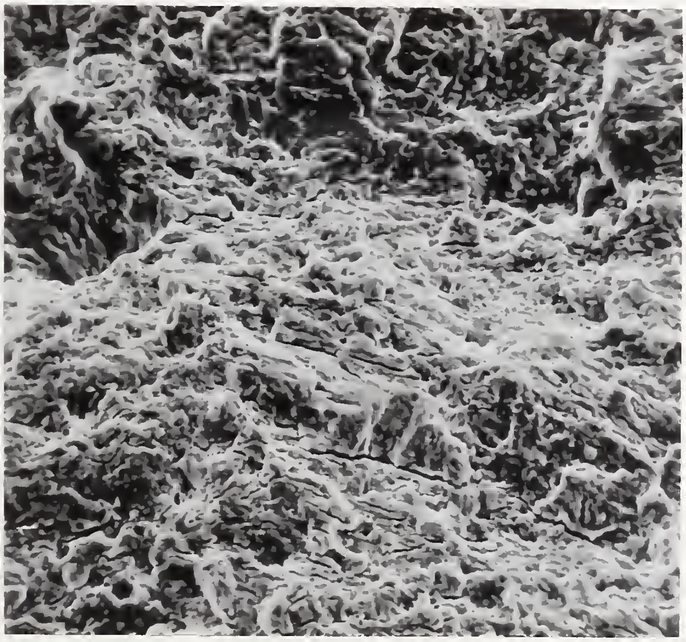


Figure 6. Fracture surfaces of the bolts shown in figure 4. The fracture surface on the left corresponds to the bolt shown in figure 4a. Arrows indicate the approximate locations of the crack origins. X 4

a



b

Figure 7. Scanning electron fractographs from the apparent fatigue portion of the fracture surface of the bolt shown in figure 4b. A suggestion of fatigue striations running from 1 o'clock to 7 o'clock appears in figure 7a.
a. X 500
b. X 1050

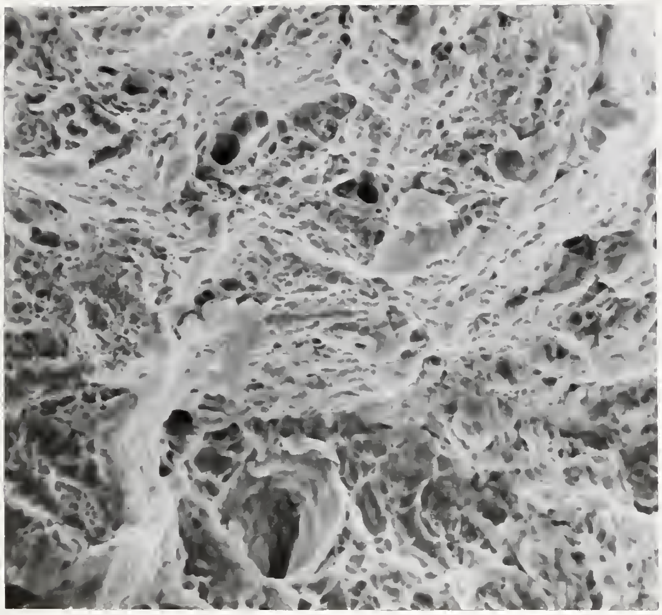


Figure 8. Scanning electron fractograph from the overload portion of the fracture of the bolt shown in figure 4b. The primary fracture mode is dimpled rupture. X 2000

Figure 9. As-polished longitudinal section from the bolt shown in figure 4b. The fracture profile in the fatigue portion of the fracture is horizontal at the top. The cadmium plating can be seen along the surface of the bolt shank vertically at the right. X 100

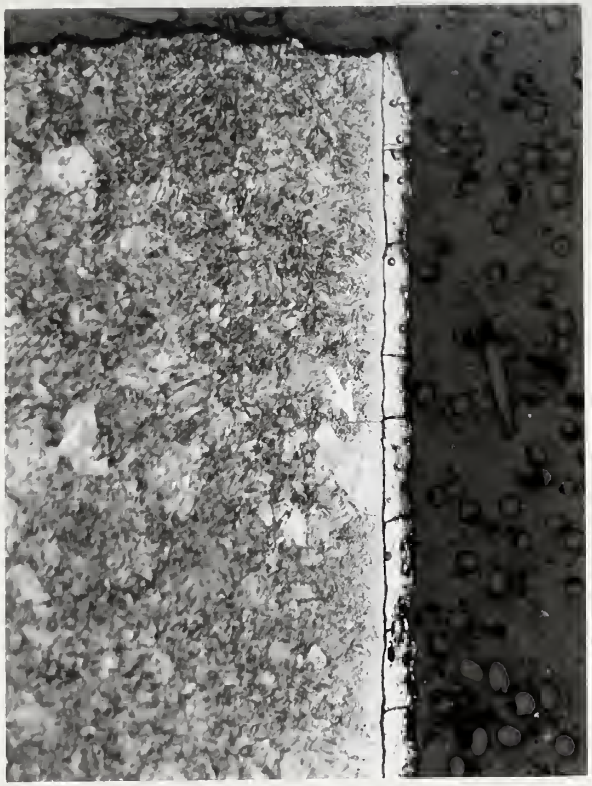


Figure 10. Part of the area shown in figure 9. The microstructure consists primarily of tempered martensite. The crack in the steel (arrow) is thought not to be associated with the crack in the cadmium plating. Several other cracks can be seen in the plating.
Etchant: 4% picral X 200

Figure 11. As-polished longitudinal section through the shank of the bolt shown in figure 4b exhibiting two cracks in the basis steel material that were essentially filled with cadmium plating. These cracks are about 2 mm from the fracture. X 200

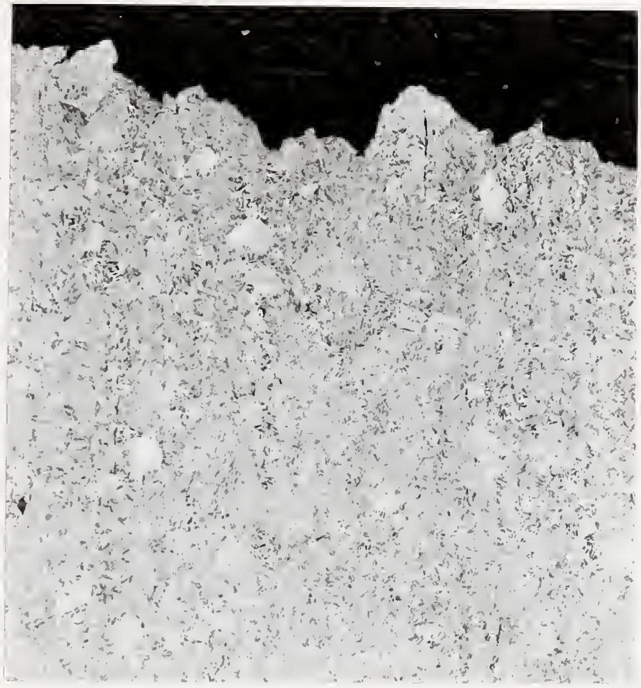


Figure 12. Etched longitudinal section from the bolt shown in figure 4b. The fracture profile in the overload portion of the fracture is horizontal at the top. Etchant: 4% picral X 100

Figure 13. Part of the shank of one of the unbroken bolts from the LQ-2 group showing the mechanical damage and an area where the cadmium plating is missing. X 16

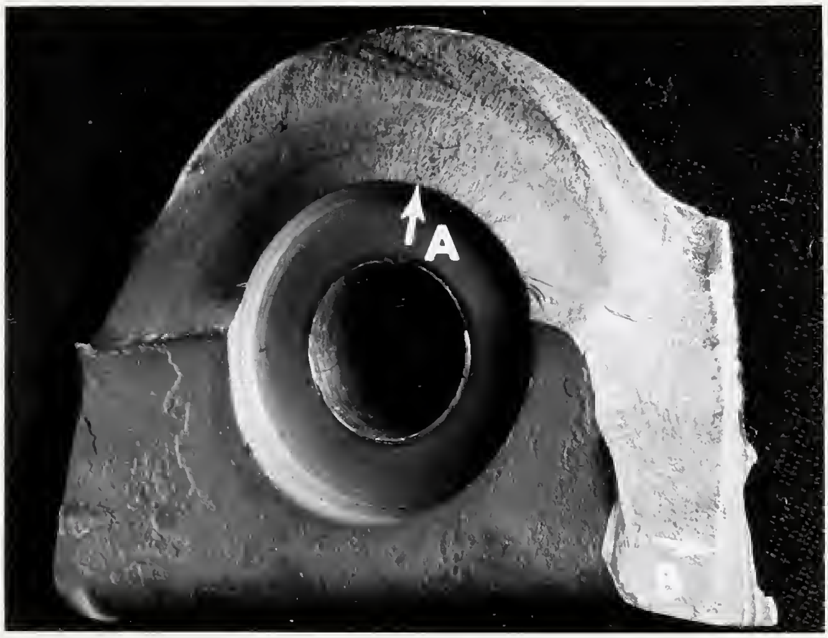


Figure 14. Separated piece from the aft spar subassembly lug from pylon no. 3 showing the fracture surface. Arrow A indicates the approximate location of the crack origin. Arrow B indicates a secondary fatigue crack. X 2

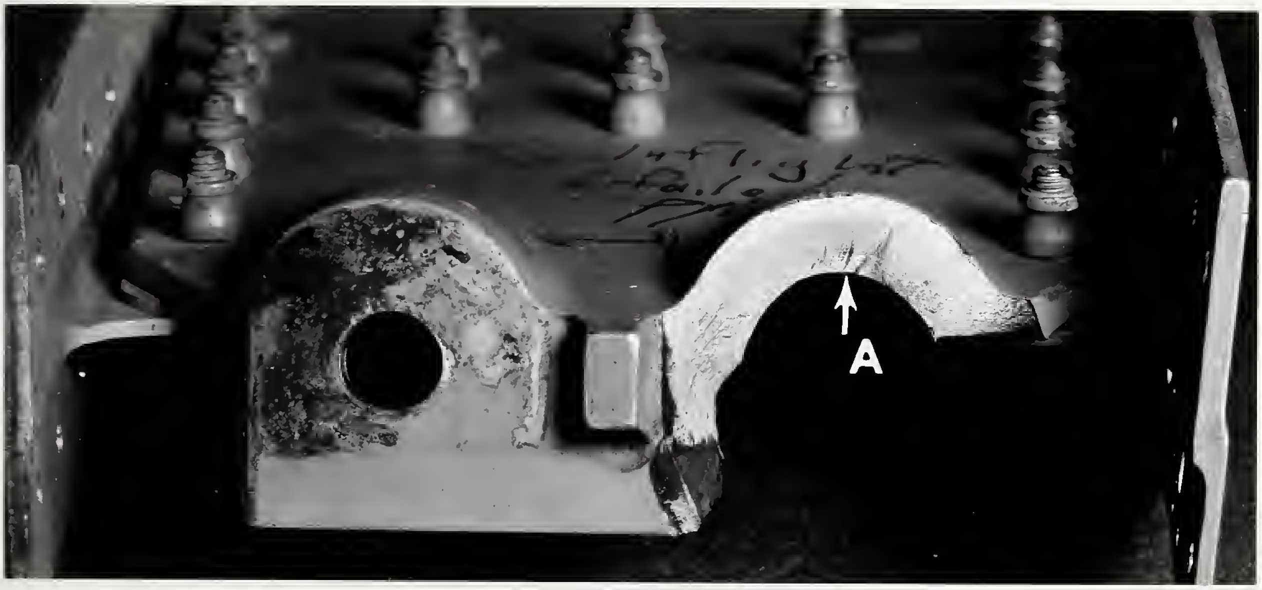


Figure 15. Aft spar subassembly lug from pylon no. 4 showing the fracture surface. Arrow A indicates the approximate location of the crack origin. X 1

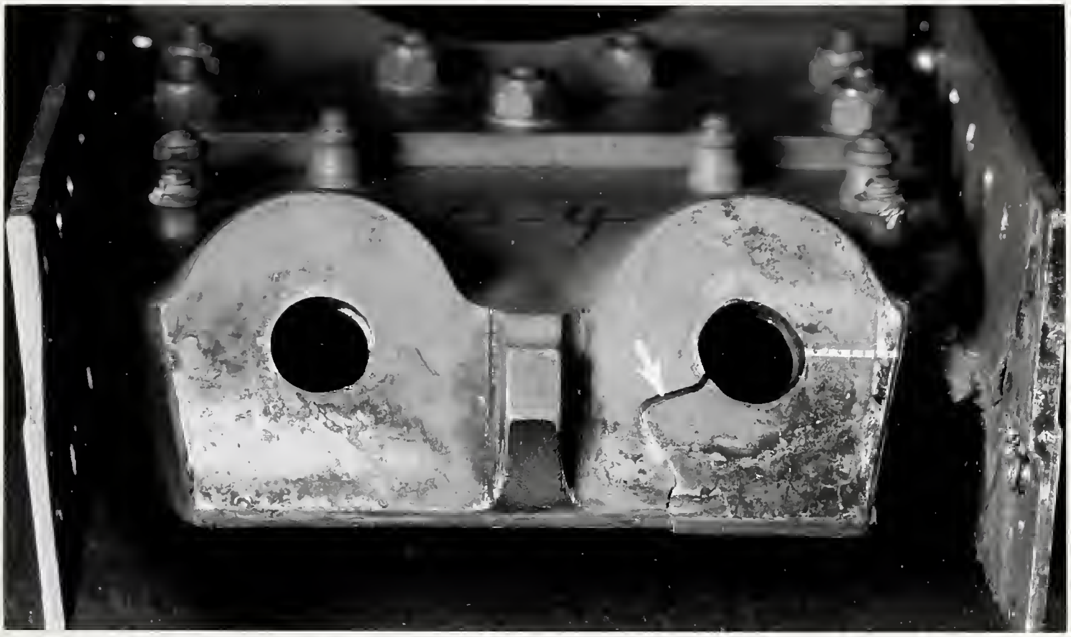


Figure 16. Forward spar subassembly lug from pylon no. 4. Arrow indicates crack. A saw-cut was made at the approximate location of the dotted line in order to expose the fracture surface. X 1

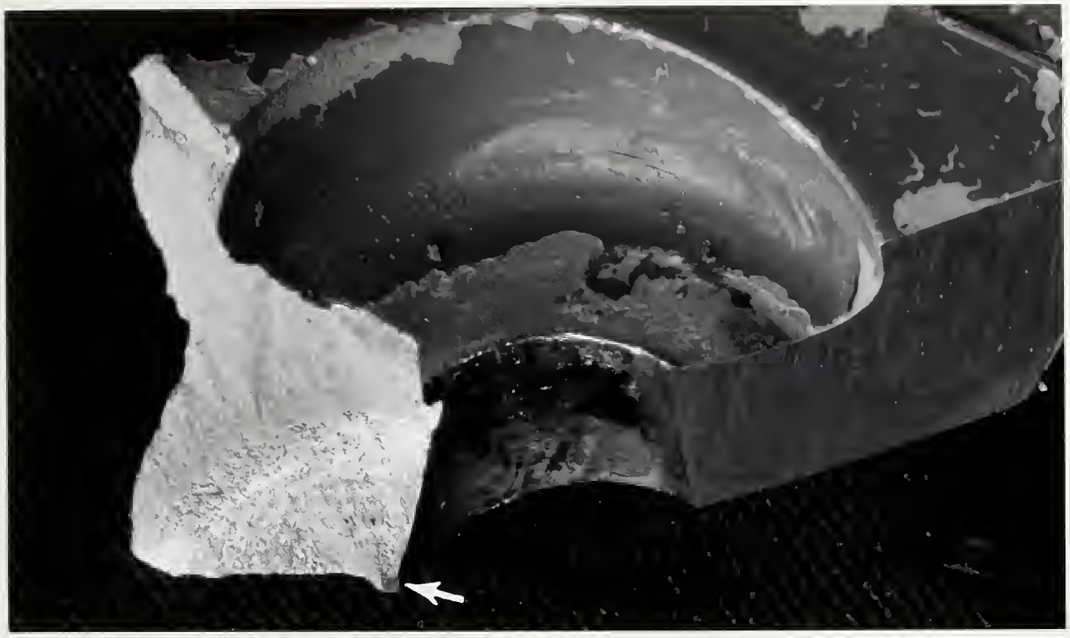


Figure 17. Part of the lug shown in figure 16 after being cut out. The fracture surface is at the left. The arrow indicates the approximate location of the point of crack initiation. X 4

Figure 18. The bolt hole surface of the part of the lug shown in figure 17 is in the center of the photograph. The fretted and mechanically damaged surface can be seen. Part of the fracture surface is at the far left. A saw-cut surface is at the right. X 8

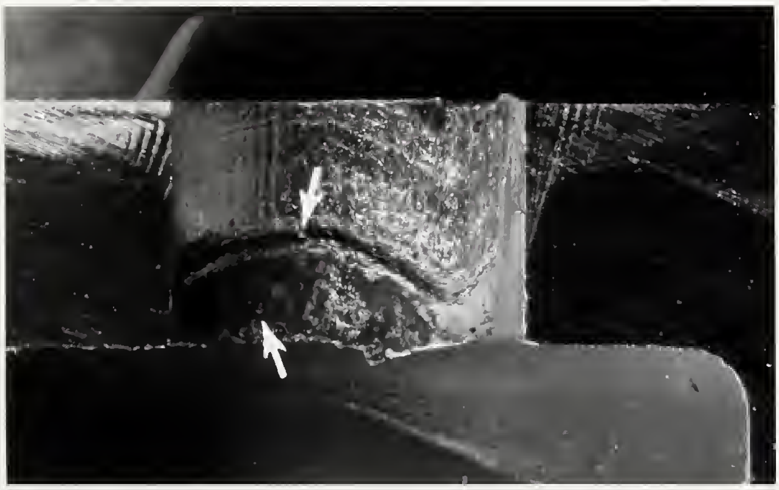


Figure 19. Part of the surface of the other bolt hole from the forward lug from pylon no. 4. This is the left bolt hole in figure 16. The damaged surface can be seen. Arrows indicate two apparent cracks. X 4

Figure 20. Scanning electron fractograph from the fatigue portion of the fracture through the aft spar subassembly lug from pylon no. 3. Fatigue striations are evident. X 470

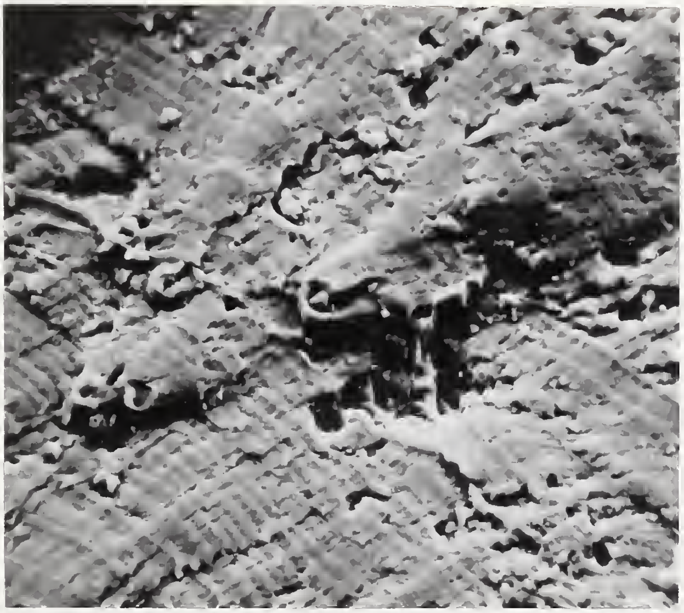


Figure 21. Scanning electron fractograph from the fatigue portion of the fracture through the aft spar subassembly lug from pylon no. 3. Fatigue striations are evident. This fractograph was taken in a different area than that shown in figure 20. X 540

Figure 22. Scanning electron fractograph from the overload portion of the fracture through the forward spar subassembly lug from pylon no. 4. X 440

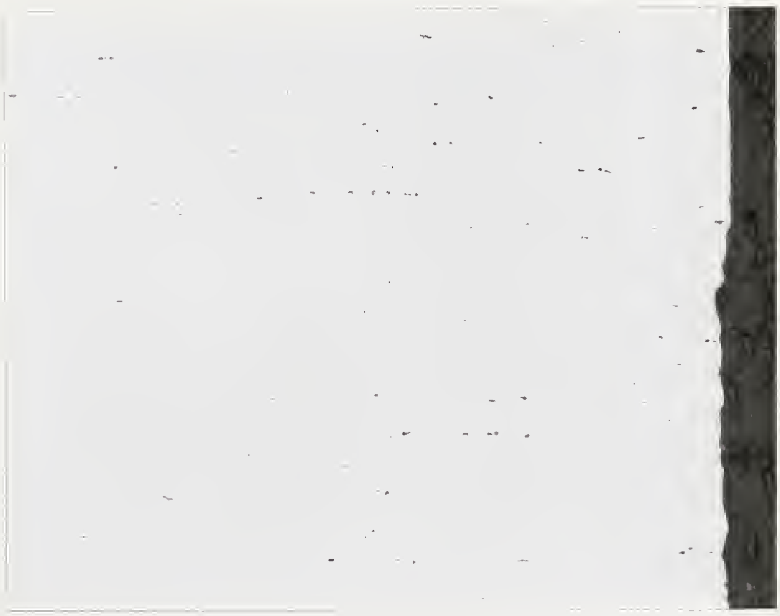


Figure 23. An as-polished section through the aft spar subassembly lug from pylon no. 3 intersecting the fatigue portion of the fracture. The fracture profile is vertical at the right. Second phase particles and inclusions can be seen. X 100

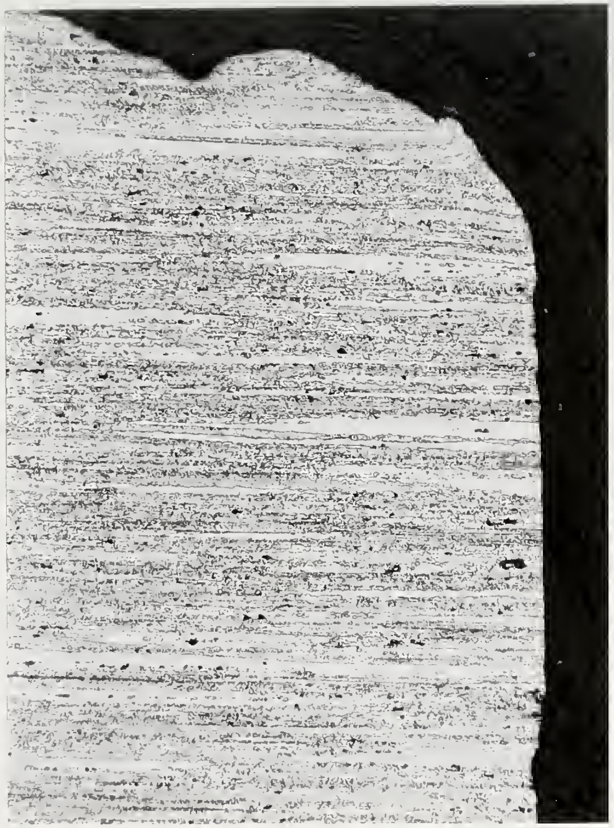


Figure 24. Etched section through the aft spar subassembly lug from pylon no. 3 showing the fracture profile in the fatigue portion of the fracture. The fracture profile is vertical at the right. Etchant: 10% NaOH X 100

Figure 25. Etched section through the aft spar subassembly lug from pylon no. 3 showing the fracture profile in the overload portion of the fracture. The fracture profile is vertical at the right. Etchant: 10% NaOH X 100

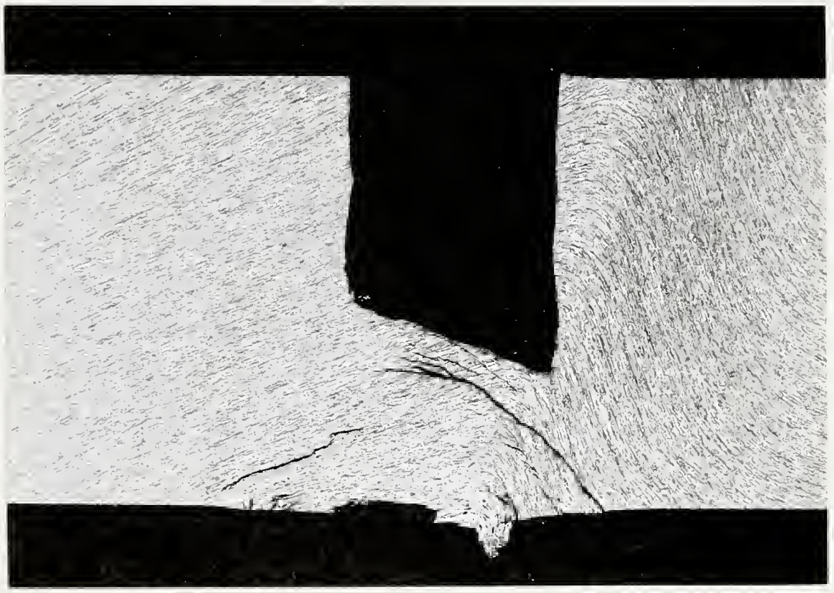


Figure 26. Etched section through the intact hole in the forward spar subassembly lug from pylon no. 4 revealing several cracks.
Etchant: 10% NaOH X 7

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 75-686	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

EXAMINATION OF FAILED PYLON COMPONENTS

5. Publication Date: March 1975

6. Performing Organization Code

7. AUTHOR(S): T. R. Shives

8. Performing Organ. Report No.: NBSIR 75-686

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.: 3120416

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Naval Air Test Center
Patuxent River, Maryland 20670

13. Type of Report & Period Covered: Failure Analysis Report

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

At the request of the Naval Air Test Center, Patuxent, Maryland, the NBS Mechanical Properties Section examined a number of components from failed aircraft pylons. It was found that fractured bolts and spar subassembly lugs had failed due to the initiation and propagation of fatigue cracks. The cracks had initiated in regions of mechanical damage or fretting corrosion damage, or where there was a rather abrupt change in cross section thickness. There was evidence that the systems had been subjected to vibrations which caused the cyclic loading necessary for fatigue cracking.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Fatigue; fracture; fretting corrosion; stress concentrator

18. AVAILABILITY

[ ] Unlimited

[XX] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT): UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE): UNCLASSIFIED

21. NO. OF PAGES: 31

22. Price

USCOMM-DC 29042-P74