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TEARDOWN REPORT
OF TWO TFE731-2-2B TURBOFAN ENGINES
SERIAL NUMBERS P-74264 AND P-74265

21-11090 **May 12, 2000**

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TEARDOWN REPORT
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SERIAL NUMBERS P-74264 AND P-74265

1. INTRODUCTION AND SUMMARY

1.1 Introduction

This report presents the findings of the teardown inspection conducted on two Honeywell Model TFE731-2-2B turbofan engines, Serial Numbers P-74264 and P-74265, at the Honeywell Product Safety and Integrity Investigation Laboratory in Phoenix, Arizona, on December 14 through 16, 1999.

The teardown inspection was conducted at the request of, and under the cognizance of, the National Transportation Safety Board (NTSB). The Federal Aviation Administration (FAA) Flight Standards District Office (FSDO) Representative also witnessed the teardown inspection.

1.2 Background

According to records, the engines, Serial Numbers P-74264 and P-74265, were installed in the right and left nacelles, respectively, of a Learjet 35 aircraft, Registration Number N47BA, Serial Number 35-060, operated by Sunjet Aviation. The aircraft crashed near Mina, South Dakota, on October 25, 1999.

The engines were delivered to the Honeywell Aerospace Product Safety and Integrity Investigation Laboratory in Phoenix, Arizona, where they were secured in a locked storage area until the teardown inspection commenced.

At the accident site, all of the engine components (power sections, fan sections, and loose controls/accessories) were placed in two shipping containers. Because of the nature and extent of damage, components were placed in a shipping container by location and/or proximity to each power section, as no traceability data was available. Near the conclusion of the teardown inspection, it was discovered, through matching of fracture surfaces/components, that the fan sections were matched to the wrong power sections. Therefore, in Sections 2.2 and 3.2, fan section components are mis-identified in the photos, but are identified correctly in the text. Components described in Section 4 are not traceable to either engine, and the photos merely identify which engine shipping container they were removed from.

Because all of the components from both engines were found within the biohazard area of the accident site, biohazard protection and precautions were used throughout the engine teardown and inspection procedures. The engine shipping containers were moved from the locked storage area to the designated decontamination area, where two Honeywell Associates were outfitted with full biohazard protection gear (Figure 1). The engine shipping containers were opened one at a time, and all components were removed and washed with high-pressure

water to remove exterior dirt and any possible biohazards. Every attempt was made to not remove evidence. All components were then decontaminated with a ten-percent bleach and water solution. The decontaminated components were then moved into the teardown area. During the teardown and inspection of both engines, all participants allowed into the investigation facility were outfitted with the appropriate biohazard protection gear.

1.3 Summary

The teardown and inspection of the engines disclosed that:

(a) The type and degree of damage observed on engine Serial Number P-74264 was indicative of engine rotation at the time of impact with the ground.

(b) The type and degree of damage observed on engine Serial Number P-74265 was indicative of engine rotation and operation at the time of impact with the ground.

(c) No pre-accident condition was found on either engine that would have interfered with normal operation.

2. FINDINGS OF TFE731-2-2B TURBOFAN ENGINE, SERIAL NUMBER P-74264

NOTES

All references to position are aft looking forward, unless otherwise noted.

All observations reported herein are based on visual examinations with the unaided eye, unless otherwise noted.

2.1 General

(a) The engine was received in a Honeywell engine shipping container (Figures 2 through 4). This engine serial number was determined from engine records; no engine data plate was recovered.

(b) The engine displayed evidence of major impact damage (Figures 3 through 6). All fan bypass structure and components were separated, and most of the controls and accessories were separated. The core engine was separated into two major segments; the power section, and the fan section (Figures 5 and 6).

(c) There was dirt and debris adhering to all surfaces of the engine and components, which was subsequently washed off during the decontamination process.

(d) There was no evidence of fire.

(e) No identifiable aircraft components were returned with the engine. None of the aircraft/engine mounts were returned with the engine.

(f) All plumbing tubes/fittings and wiring harnesses returned with the engine had sustained impact damage.

(g) Engine mount configuration and engine records were used to determine that this engine was installed in the right-hand position on the aircraft.

2.2 Fan Section

NOTE

The fan sections for both engines were placed in the shipping containers with the wrong power sections, and were subsequently photographed with the wrong engine serial number. In paragraph 2.2, the fan section and its' components are identified with the wrong serial number in the photos, but are identified correctly in the text.

(a) Fan spinner:

- Not returned with the engine.

(b) Fan spinner support:

- Not returned with the engine.

(c) Fan rotor assembly:

- Intact.
- Dirt and debris were washed off of the fan disk forward face during the decontamination process (Figure 7); however, dirt and debris lodged between it and the fan support housing was not removed (Figures 8 and 11).
- There were rotational score marks on the fan disk aft face (Figure 8), with corresponding rotational score marks on the fan support housing (Figure 11).

(d) Fan blades:

- Twenty-two blades were broken at or near the blade platform (Figures 7 and 9). All of the broken blade dovetails were retained in their respective slots in the fan rotor assembly (Figures 7 and 9).
- Eight blades were bent opposite to the direction of rotation (Figure 10).

(e) Fan support housing:

- Dirt and debris adhering to forward face (Figure 11).
- Fractured 360 degrees (Figure 11).
- There were rotational score marks on the forward face (Figure 11), with corresponding rotational score marks on the fan rotor disk and hub assembly (Figure 8).

(f) Fan shaft:

- Not disassembled.
- No. 1 fan shaft forward roller bearing:
  - Intact.
- No. 1 air/oil carbon seal:
  - Damaged by impact (Figure 12). No pre-impact wear or distress noted.
  - Seal and seal support were separated from the fan support housing and were wedged against the fan disk aft face (Figure 12).
- No. 2 fan shaft thrust ball bearing:
  - Not disassembled.

(g) Ring gear:

- Not disassembled.

(h) Pinion gearshaft:

- Not disassembled.
- Pinion gearshaft roller bearing:
  - Not disassembled.

(i) Planetary Gear Assembly:

- Planet carrier:
  - Not disassembled.
- Planetary gearshafts:
  - Not disassembled.
- Planetary gearshaft roller bearings:
  - Not disassembled.

(j) Fan bypass duct set:

- Not returned with the engine.

(k) PT2/TT2 probe:

- Not returned with the engine.

2.3 Low-Pressure (LP) Compressor Section

(a) Threaded tie shaft (tie bolt):

- Aft nut found to be unstretched (loose).
- Damage to first-stage LP compressor stub shaft would not allow the forward nut to be removed.
- Bent (Figure 13). Bend would not allow removal from the engine, so the tie bolt was cut with a power cutting tool (Figures 13 and 22).

(b) Engine support housing and No. 3 bearing housing (main mount):

- Sustained heavy impact damage (Figure 14).
- Major components (outer mount flange, inner support housing, and bearing housing) were separated at the struts. The outer mount flange was fractured, and the fragments were returned loose in the shipping container (Figure 14).
- The No. 3 bearing housing, No. 3 LP rotor thrust ball bearing, air/oil carbon seal and rotor, and the planetary drive coupling shaft were not disassembled.
- All cavities were packed with dirt and debris (before decontamination).

(c) First-stage LP compressor:

- Returned loose in the shipping container (Figure 3).
- Dirt and debris was packed between rotor blades (before decontamination).
- Eight rotor blades were bent in the direction of rotation (Figures 15 and 16).
- The leading-edge and trailing-edge of all of the rotor blades were damaged (Figures 15 through 20).
- There was a blade-tip rub on all of the rotor blades (Figure 19), in the area adjacent to the blade-tip shroud. The blade-tip shroud was not returned with the engine.
- There was a platform rub on the forward side of all of the rotor blades (Figure 20), in the area adjacent to the main mount. The fragment of the main mount adjacent to the rotor blades was not returned with the engine). There was a platform rub on the aft side of all of the rotor blades (Figure 18), in the area adjacent to the first-stage rotating shroud.
- The mount flange for the forward (stub) shaft was damaged (Figures 15 and 16), separating the stub shaft from the rotor. The stub shaft had sustained impact damage (Figure 21). The stub shaft aft Curvic coupling teeth were damaged (Figure 22).
- Part Number 3070440-8
- Serial Number 5-12112-327
- Lot Number L/N-7-534-R

(d) Second-stage LP compressor:

- Dirt and debris was packed between rotor blades (before decontamination).
- Nine rotor blades were displaced out of their dovetail slots (Figures 23 and 24). All of the rotor blades were bent opposite to the direction of rotation (Figures 23 and 24).
- The leading-edge and trailing-edge of all of the rotor blades were damaged (Figures 23 through 26).
- There was a blade-tip rub on all of the rotor blades, in the area adjacent to the blade-tip shroud. The blade-tip shroud was not returned with the engine.
- There was a platform rub on the forward side of all of the rotor blades (Figure 25), in the area adjacent to the first-stage rotating shroud. There was a platform rub on the aft side of all of the rotor blades (Figure 26), in the area adjacent to the second-stage rotating shroud.
- There were both rotational score marks and static impact marks on the forward face of the rotor disk (Figure 27), in the area adjacent to (and in the shape of) bolt heads that attach the stub shaft to the first-stage LP compressor rotor.

- The forward Curvic coupling teeth were damaged (Figure 27). The aft Curvic coupling teeth were heavily damaged with some blue discoloration (Figure 28).
- The first-stage (rotating) vane-tip shroud was damaged (Figure 29).

(e) Third-stage LP compressor:

- Dirt and debris was packed between rotor blades (before decontamination).
- All of the rotor blades were bent opposite to the direction of rotation (Figures 31 and 32).
- The leading-edge and trailing-edge of all of the rotor blades were damaged (Figures 31 through 33).
- There was a blade-tip rub on all of the rotor blades, in the area adjacent to the blade-tip shroud. The blade-tip shroud was not returned with the engine.
- There was a platform rub on the forward side of all of the rotor blades (Figure 33), in the area adjacent to the second-stage rotating shroud. There was a platform rub on the aft side of all of the rotor blades (Figure 34), in the area adjacent to the third-stage rotating shroud.
- A 200-degree section of the forward Curvic coupling flange was broken off, and the remaining coupling teeth were damaged (Figure 35). The aft Curvic coupling teeth were damaged (Figure 37).
- The second-stage (rotating) vane-tip shroud was damaged (Figure 30).

(f) Fourth-stage LP compressor:

- Dirt and debris was packed between rotor blades (before decontamination).
- Twenty-seven rotor blades were intentionally displaced (Figures 37 and 38), while removing the assembly, which was wedged in place.
- The leading-edge and trailing-edge of some of the rotor blades were damaged (Figures 37 through 40).
- There was a platform rub on the forward side of all of the rotor blades (Figure 39), in the area adjacent to the third-stage rotating shroud. There was a platform rub on the aft side of all of the rotor blades (Figure 40), with corresponding rotational score marks on the fourth-stage stator inner housing (Figure 41).
- There was a blade-tip rub on all of the rotor blades, with corresponding rotational score marks on the blade-tip shroud (Figure 41).
- There were rotational score marks on the aft face of the rotor disk (Figure 42), with corresponding rotational score marks on the No. 4 bearing housing (Figures 43 and 46).

- The aft shaft was fractured (Figure 44) and separated from the forward flange/coupling (Figure 42). The outside diameter (OD) of the aft shaft displayed rotational score marks (Figures 44 and 45), with corresponding rotational score marks on the inside diameter (ID) of the HP shaft (Figures 43 and 46).
- The forward (large) Curvic coupling teeth were damaged, however, the damage was made worse while removing the assembly, which was wedged in place (Figure 47). The aft (small) Curvic coupling teeth were damaged (Figure 48).
- The third-stage (rotating) vane-tip shroud was damaged (Figure 30).

(g) First-stage LP compressor stator:

- No stator vanes were returned with the engine
- The outer vane retainer ring was damaged (Figure 29).
- The blade-tip shroud was not returned with the engine.

(h) Second-stage LP compressor stator:

- Several stator vanes were found loose (Figure 49). The remaining vanes were not returned with the engine
- The outer vane retainer ring was damaged (Figure 50).
- The blade-tip shroud was not returned with the engine.

(i) Third-stage LP compressor stator:

- Several stator vanes were found loose (Figure 49). The remaining vanes were not returned with the engine
- The outer vane retainer ring was damaged (Figure 50).
- The blade-tip shroud was damaged (Figure 50).

(j) Fourth-stage LP compressor stator:

- Dirt and debris was packed between the stator vanes (Figure 51).
- The leading-edge of some of the stator vanes were damaged.
- There were rotational score marks on the blade-tip shroud (Figure 41), with corresponding rub marks on the fourth-stage LP compressor rotor blades.

(k) LP compressor case:

- Sheet metal was buckled and torn (Figures 6 and 52).

2.4 High-Pressure (HP) Compressor Section

(a) HP compressor impeller:

- Dirt and debris was packed between impeller blades (before decontamination).
- All of the impeller blades were bent opposite to the direction of rotation (Figures 53 through 57). Some of the impeller blades were broken at the blade platform (Figures 53 through 57).
- The shroud-line edge of all the impeller blades was heavily rubbed (Figures 53 through 57), with corresponding rotational score marks on the HP impeller shroud parent metal (Figure 56).
- The leading-edge of all of the impeller blades was pitted and nicked.
- The forward face of the impeller rotor displayed heavy rotationally score marks and a large burr (Figure 57), with corresponding rotational score marks on the compressor interstage diffuser (housing) (Figure 58). The forward face of the impeller ID bore displayed rotationally score marks (Figure 57), with corresponding rotational score marks on the compressor interstage housing (Figure 58).
- There were rotational score marks on the aft surfaces of the impeller disk (Figure 59), with corresponding rotational score marks on the forward face of the HP compressor diffuser.
- The impeller disk was bent (dished) from impact forces.
- The Curvic coupling teeth were damaged (Figure 60).

(b) HP impeller shroud:

- The shroud contour displayed rotational score marks, in the parent metal, with corresponding rub marks on the shroud-line edge of all the impeller blades (Figures 53 through 57).
- The shroud was crushed from impact forces, and all of the abradable coating had separated from the parent metal.

(c) HP compressor diffuser:

- There were rotational score marks on the forward face of the diffuser, with corresponding rotational score marks on the aft face of the HP compressor impeller (Figure 59).
- All of the diffuser vanes were separated (axially displaced) from the sheet-metal housing.
- The leading edge of all of the diffuser vanes was damaged.

(d) Compressor interstage diffuser (housing):

- Both the forward mount flange (Figure 51) and the aft mount flange (Figure 58) were damaged.
- The compressor housing displayed compression wrinkles and torn sheet metal (Figure 58).
- The compressor housing displayed rotationally score marks in two locations (Figure 58), with corresponding rotational score marks on the HP compressor impeller rotor (Figure 57).
- The tower shaft bearing support was separated from the housing (Figure 58).

(e) Deswirl vanes:

- Not disassembled.

(f) Beveled spur (tower) shaft:

- Shaft bent (Figure 58).
- Tower shaft thrust ball bearing:
  - Not disassembled.
- Tower shaft roller bearing:
  - Not disassembled.

(g) HP shouldered shaft:

- The forward ID of the HP shaft displayed rotational score marks (Figures 43 and 46), with corresponding rotational score marks on the fourth-stage LP compressor aft shaft OD (Figures 44 and 45). This rotational damage to the HP shaft ID prevented the removal of the retainer nut with normal tooling. The retainer nut was subsequently cut with a pneumatic cutting tool (Figure 61).
- The aft ID of the HP shaft displayed rotational score marks (Figure 63), with corresponding rotational score marks on the OD of the LP shaft and seal assembly (Figure 64).
- The HP shaft was broken (Figures 58 and 62). Fracture surfaces of the HP shaft were damaged (impacted) during the teardown sequence.
- No. 4 HP rotor forward roller bearing:
  - Housing partially crushed (Figures 43, 46, and 51).
  - Housing displayed rotational score marks (Figure 43 and 46), with corresponding rotational score marks on the aft face of the fourth-stage LP compressor rotor disk (Figure 42).

- Bearing not disassembled.
- Air/oil carbon seal destroyed during removal of HP shaft retainer nut (Figure 46).
- Post-impact oil staining (of dirt) was noted.
- No pre-impact wear or distress was noted.
- Air/oil seal rotor cut during removal of HP shaft retainer nut (Figure 61).

- No. 5 HP rotor aft ball bearing:
  - Bearing not disassembled.
  - Air/oil carbon seal and seal rotor not disassembled.
  - No pre-impact wear or distress was noted.

2.5 Combustion Section

(a) Fuel manifold assembly:

- One hose assembly was broken (Figure 52).
- Six fuel nozzle housings were broken at the combustion chamber liner interface (Figure 65).
- The fuel nozzle tips and the fuel nozzle shrouds were not disassembled.

(b) Igniter plugs:

- Not disassembled.

(c) Outer transition liner:

- Not disassembled.
- The honeycomb seal was very heavily worn.

(d) Inner transition liner:

- Not disassembled.

(e) Combustion chamber liner:

- There was a white-colored substance on portions of the dome and the inner skirt of the combustion chamber liner (Figure 66).

(f) Combustion chamber case:

- Sheet metal displayed compression wrinkles through 360 degrees (Figures 6 and 52).
- There was debris between the combustion chamber case and the combustion chamber liner (Figure 66).

2.6 High-Pressure (HP) Turbine Section

(a) HP turbine rotor:

- The forward face of the rotor disk displayed many small impact marks (Figures 67 and73), in the area adjacent to the HP turbine center Curvic coupling (Figure 75).
- There was a platform rub on the aft side of all of the rotor blades (Figures 68 and 69), with corresponding rotational score marks on the forward face of the interstage transition duct (Figure 70).
- There was a blade-tip rub on all of the rotor blades (Figure 71), with corresponding rotational score marks on the segmented blade-tip shrouds (Figure 72).
- The forward Curvic coupling teeth were damaged (Figure 73). The aft Curvic coupling teeth were damaged (Figure 74).
- Part Number 3072732-2
- Serial Number 9-23315-1618
- Lot Number 0646

(b) HP turbine nozzle (stator):

- Not disassembled, however the trailing-edge of all of the stator vanes was undamaged (Figure 65).
- The aft face of the inner vane support was rotationally scored, with corresponding rotational score marks on the HP center Curvic coupling (Figures 76 and 77).

(c) HP turbine segmented blade-tip shrouds:

- There were rotational score marks on the shrouds (Figure 72), with corresponding rub indications on all of the HP turbine rotor blades (Figure 71).

(d) HP center Curvic coupling

- The aft face of the coupling displayed many small impact marks (Figure 75), in the area adjacent to the HP turbine rotor disk (Figure 67 and 73).
- The forward face of the coupling was rotationally scored, through 360 degrees (Figures 76 and 77), with corresponding rotational score marks on the aft face of the HP turbine stator inner vane support.
- The forward Curvic coupling teeth were undamaged (Figure 76). The aft Curvic coupling teeth were undamaged (Figure 75).
- The knife-edge seal displayed some (normal) wear (Figures 75 and 76).

(e) HP aft Curvic coupling:

- The Curvic coupling teeth were damaged (Figure 78).
- The knife-edge seal displayed some (normal) wear (Figure 78).

2.7 Low-Pressure (LP) Turbine Section

(a) N1 monopole:

- Displayed contact witness marks in the area adjacent to the tie bolt aft nut (center arrow in Figure 79).
- Displayed gouge marks (connecting arrows in Figure 79), with corresponding metal shavings on the N1 speed pickup gear retainer nut (Figure 80).
- Displayed contact witness marks on both ends of the pole piece (Figure 81), with corresponding contact witness marks on the N1 speed pickup gear teeth (Figure 82).
- The electrical lead was broken, and the electrical connector was not returned with the engine.

(b) No. 6 LP rotor aft roller bearing:

- Undamaged (Figure 85).
- Residual oil was present.
- Air/oil carbon seal housing was bent. Carbon seal element was chipped in the area adjacent to the bent housing (Figure 83).
- Air/oil seal rotor was undamaged (Figure 84).

(c) Thrust and exhaust nozzle:

- Outer support housing displayed compression wrinkles, through 360 degrees (Figure 86).
- Inner support housing displayed rotational score marks on the forward face (Figure 87), with corresponding marks on the third-stage LP turbine rotor blades (Figure 88).

(d) First-stage LP turbine rotor:

- There was a platform rub on the forward side of all of the rotor blades (Figure 89), with corresponding rotational score marks on the aft side of the first-stage LP turbine stator vane inner support (Figure 90).
- There was a platform rub on the aft side of all of the rotor blades (Figure 91), with corresponding rotational score marks on the forward side of the second-stage LP turbine stator vanes (Figure 92).
- There was a blade-tip rub on all of the rotor blades (Figure 93), with corresponding rotational score marks on the blade-tip shroud (Figure 94).
- The forward Curvic coupling teeth were damaged (Figure 95). The aft Curvic coupling teeth were damaged (Figure 96).

- Part Number 3072070-5
- Serial Number 960322907907
- Lot Number 97P218

(e) Second-stage LP turbine rotor:

- There was a platform rub on the forward side of all of the rotor blades (Figure 97), with corresponding rotational score marks on the aft side of the second-stage LP turbine stator vane inner support (Figure 98).
- There was a platform rub on the aft side of all of the rotor blades (Figure 99), with corresponding rotational score marks on the forward side of the third-stage LP turbine stator vanes (Figure 100).
- There was a blade-tip rub on all of the rotor blades (Figure 101), with corresponding rotational score marks on the blade-tip shroud (Figure 102).
- The forward Curvic coupling teeth were damaged (Figure 103). The aft Curvic coupling teeth were damaged (Figure 104).
- Part Number 3072013-5
- Serial Number 960322907915
- Lot Number 97P232

(f) Third-stage LP turbine rotor:

- All of the rotor blades were bent opposite to the direction of rotation (Figures 105 and 106).
- There was a platform rub on the forward side of all of the rotor blades (Figure 107), with corresponding rotational score marks on the aft side of the third-stage LP turbine stator vane inner support (Figure 108).
- There was a platform rub on the aft side of all of the rotor blades (Figure 89), with corresponding rotational score marks on the thrust and exhaust nozzle inner support housing (Figure 87).
- There was a blade-tip rub on all of the rotor blades (Figure 109), with corresponding rotational score marks on the blade-tip shroud (Figure 110).
- The knife-edged seal was undamaged.
- The Curvic coupling teeth were damaged (Figure 111).
- Part Number 3072068-1
- Serial Number 6-18040-1829
- Lot Number 7466

(g) Interstage transition duct:

- Fractured 270 degrees just forward of the first-stage LP turbine compressor vanes, and fractured 270 degrees just aft of the first-stage LP turbine compressor vanes (Figure 112).
- There were rotational score marks on the forward face of the inner structure (Figure 70), with a corresponding platform rub on the aft side of all of the HP turbine rotor blades (Figure 69).
- The (three) aft engine mounts were undamaged as received; however, the 9 o'clock mount was broken during the teardown.
- The Feltmetal seal displayed some (normal) wear.

(h) First-stage LP turbine stator:

- Some stator vanes were fractured in-line with the interstage transition duct fractures (Figures 90 and 112).
- There were rotational score marks on the aft side of the stator vane inner support (Figure 90), with a corresponding platform rub on the forward side of all of the first-stage turbine rotor blades (Figure 89).
- There were rotational score marks on the blade-tip shroud (Figure 94), with a corresponding blade-tip rub on all of the first-stage LP turbine rotor blades (Figure 93).

(i) Second-stage LP turbine stator:

- There were rotational score marks on the inboard leading-edge of the stator vanes (Figure 92), with a corresponding platform rub on the aft side of all of the first-stage turbine rotor blades (Figure 91).
- There were rotational score marks on the aft side of the stator vane inner support (Figure 98), with a corresponding platform rub on the forward side of all of the second-stage turbine rotor blades (Figure 97).
- There were rotational score marks on the blade-tip shroud (Figure 102), with a corresponding blade-tip rub on all of the second-stage LP turbine rotor blades (Figure 101).
- The honeycomb seal was undamaged (Figure 102).

(j) Third-stage LP turbine stator:

- There were rotational score marks on the inboard leading-edge of the stator vanes (Figure 100), with a corresponding platform rub on the aft side of all of the second-stage turbine rotor blades (Figure 99).
- There were rotational score marks on the aft side of the stator vane inner support (Figure 108), with a corresponding platform rub on the forward side of all of the third-stage turbine rotor blades (Figure 107).
- There were rotational score marks on the blade-tip shroud (Figure 110), with a corresponding blade-tip rub on all of the third-stage LP turbine rotor blades (Figure 109).
- The honeycomb seal was undamaged (Figures 108 and 110).

(k) Thermocouple harness assembly:

- One thermocouple probe was broken (Figure 113). The other nine probes appeared to be undamaged.
- The thermocouple harness was undamaged (Figure 112).
- The electrical lead was broken, and the electrical connector was not returned with the engine.

(l) LP turbine tie shaft:

- Undamaged (Figure 114).

(m) LP shaft and seal assembly:

- There were rotational score marks on the OD of the LP shaft and seal assembly (Figures 64 and 115), with corresponding rotational score marks on the aft ID of the HP shaft (Figure 63).
- The forward (small) Curvic coupling teeth were heavily damaged (Figure 115). The aft (large) Curvic coupling teeth were undamaged (Figure 116).
- The Feltmetal seal displayed some (normal) wear.

(n) LP rotating seal:

- The forward Curvic coupling teeth were damaged (Figure 117). The aft Curvic coupling teeth were damaged (Figure 118).
- The knife-edge seal displayed some (normal) wear.

2.8 Miscellaneous

(a) Surge bleed valve:

- Removed from engine Serial Number P-74264.
- Valve poppet was broken at the stem (Figure 119). Valve poppet was not returned with the engine.
- Cap damaged (Figure 120).
- Part Number 978812-4-1
- Serial number unknown.

(b) Air/oil cooler (top)

- Severe impact damage (Figure 121).
- Part Number 158600-XX[1]
- Serial number unknown.

(c) Air/oil cooler (left)

- Severe impact damage (Figure 122).
- Part Number 159900-XX[1]
- Serial number unknown.

(d) Air/oil cooler (right)

- Severe impact damage (Figure 122).
- Part Number 159910-XX[1]
- Serial number unknown.

[1] The basic part number for this component is known; however, the data plate was missing or unreadable and the dash number(s) are unknown.

3. FINDINGS OF TFE731-2-2B TURBOFAN ENGINE, SERIAL NUMBER P-74265

3.1 General

(a) The engine was received in a Honeywell engine shipping container (Figures 123 through 126). This engine serial number was determined from engine records; no engine data plate was recovered.

(b) The engine displayed evidence of major impact damage (Figures 124 through 128). All fan bypass structure and components were separated, and all of the controls and accessories were separated. The core engine was separated into two major segments; the power section, and the fan section (Figures 127 and 128).

(c) There was dirt and debris adhering to all surfaces of the engine and components, which was subsequently washed off during the decontamination process.

(d) There was evidence of post-impact fire on the aft portion of the power section (Figures 127 and 128).

(e) No identifiable aircraft components were returned with the engine with the exception of two aircraft/engine mounts (Figures 129 and 130).

(f) All plumbing tubes/fittings and wiring harnesses returned with the engine had sustained impact damage.

(h) Engine mount configuration and engine records were used to determine that this engine was installed in the left-hand position on the aircraft.

3.2 Fan Section

NOTE

The fan sections for both engines were placed in the shipping containers with the wrong power sections, and were subsequently photographed with the wrong engine serial number. In paragraph 3.2, the fan section and its' components are identified with the wrong serial number in the photos, but are identified correctly in the text.

(a) Fan spinner:

- Two fragments returned loose (Figure 131).
- One fragment found lodged in the front of the fan shaft (Figure 132).

(b) Fan spinner support:

- Not returned with the engine.

(c) Fan rotor assembly:

- Dirt and debris were washed off of the fan disk forward face during the decontamination process (Figures 133 and 135); however, dirt, debris, and sheet-metal fragments lodged between it and the fan support housing was not (Figures 134 and 137).
- There were rotational score marks on the fan disk aft face (Figure 134), with corresponding rotational score marks on the fan support housing (Figure 137).
- Some of the fan blade (dovetail) retaining slots were bent (Figure 133).

(d) Fan blades:

- Three blade fragments, broken just outboard of the midspan damper, were retained within their dovetail slots, and were bent opposite to the direction of rotation (Figures 133 through 135).
- Thirteen blade fragments, broken at or near the blade platform, were retained within their dovetail slots, however several of these fragments were displaced during the decontamination process (Figures 133 through 135).
- Fifteen blade fragments were returned loose (Figure 136). Loose blade fragments with the dovetail feature intact were displaced from this engine's fan rotor assembly (no blades were displaced from the other engine's fan rotor assembly). Loose blade fragments with no dovetail features (broken at or above the blade platform) could not be traced to a specific engine or a specific fan rotor assembly (Figure 136).

(e) Fan support housing:

- Dirt and debris adhering to forward face (Figure 137).
- Fractured 360 degrees (Figure 137).
- There were rotational score marks on the forward face (Figure 137), with corresponding rotational score marks on the fan rotor disk and hub assembly (Figure 134).

(f) Fan shaft:

- Not disassembled.
- No. 1 fan shaft forward roller bearing:
  - Not Disassembled.
- No. 1 air/oil carbon seal:
  - Damaged by impact (Figure 138). No pre-impact wear or distress noted.
- No. 2 fan shaft thrust ball bearing:
  - Not disassembled.

(g) Ring gear:

- Not disassembled.

(h) Pinion gearshaft:

- Not disassembled.
- Pinion gearshaft roller bearing:
  - Not disassembled.

(i) Planetary Gear Assembly:

- Planet carrier:
  - Not disassembled (Figure 139).
- Planetary gearshafts:
  - Not disassembled.
- Planetary gearshaft roller bearings:
  - Not disassembled.

(j) Fan bypass duct set:

- Not returned with the engine.

(k) PT2/TT2 probe:

- Not returned with the engine.

3.3 Low-Pressure (LP) Compressor Section

(a) Threaded tie shaft (tie bolt):

- Aft nut removed with standard tooling, but stretch was less than specification requirement.
- Forward nut found to be unstretched (loose).
- Bent (Figure 140). Bend would not allow removal from the engine, so the tie bolt was cut with a power cutting tool.
- Damage to LP turbine tie shaft and LP shaft and seal assembly would not allow the shaft to be removed (Figure 140).

(b) Engine support housing and No. 3 bearing housing (main mount):

- Sustained heavy impact damage (Figures 139 and 141).
- Major components (outer mount flange, inner support housing) were separated at the struts. The outer mount flange was fractured, and the fragments were returned loose in the shipping container (Figure 141).
- All cavities were packed with dirt and debris (before decontamination).
- No. 3 bearing:
  - Housing separated from main mount (Figure 142).
  - No. 3 LP rotor thrust ball bearing undamaged (Figure 143).
  - Air/oil carbon seal damaged by impact (Figure 142). No pre-impact wear or distress noted.
  - Air/oil seal rotor was not returned with the engine.
- Planetary drive coupling shaft was broken (Figure 144).

(c) First-stage LP compressor:

- Dirt and debris was packed between rotor blades (before decontamination).
- Six rotor blades were displaced out of their dovetail slots (Figure 145 and 146).
- Six rotor blades were broken at or near the blade platform (Figures 145 and 146).
- Nineteen rotor blades were bent opposite to the direction of rotation (Figures 145 through 148).
- The leading-edge (Figures 145 and 147) and trailing-edge (Figures 146 and 148) of all 19 of the retained/unbroken rotor blades were damaged.
- There was a blade-tip rub, and rub indications on the pressure-side, of all 19 of the retained/unbroken rotor blades (Figure 147), in the area adjacent to the blade-tip shroud. The blade-tip shroud was not returned with the engine.
- There was a platform rub on the forward side of all of the rotor blades (Figure 147), with corresponding rotational score marks on the main mount (Figure 139). There was a platform rub on the aft side of all of the rotor blades (Figure 148), with corresponding rotational score marks on the first-stage rotating shroud (Figure 150).
- The mount flange for the forward (stub) shaft was damaged (Figures 145 through 149), separating the stub shaft from the rotor. The stub shaft had sustained impact damage (Figure 151). The stub shaft aft Curvic coupling teeth were damaged (Figure 152).

(d) Second-stage LP compressor:

- The second- and third-stage LP compressor rotors were lodged together (Figures 155, 156, and 159), and were not forced apart during the teardown.
- Dirt and debris was packed between rotor blades (before decontamination).
- Five rotor blades were displaced out of their dovetail slots (Figures 153 and 154).
- Twenty-two rotor blades were broken at or near the blade platform (Figure 153).
- Twelve rotor blades were bent opposite to the direction of rotation (Figures 153 and 155).
- The leading-edge and trailing-edge of all 12 of the retained/unbroken rotor blades were damaged (Figures 153 and 155).
- There was a blade-tip rub, and rub indications on the pressure-side, on all 12 of the retained/unbroken rotor blades, with corresponding rotational score marks on the blade-tip shroud (Figure 150).
- There was a platform rub on the forward side of all of the rotor blades (Figures 154 and 156), with corresponding rotational score marks on the first-stage rotating shroud (Figure 150). The aft rotor blade platform was not accessible.
- The rotor disk was fractured (Figures 153, 154, and 156).
- The forward Curvic coupling teeth were damaged (Figure 156). The aft Curvic coupling teeth were damaged.
- The first-stage (rotating) vane-tip shroud was damaged (Figure 150).

(e) Third-stage LP compressor:

- The second- and third-stage LP compressor rotors were wedged together (Figures 155, 156, and 159) and were not forced apart during the teardown.
- Dirt and debris was packed between rotor blades (before decontamination).
- Seven rotor blades were displaced out of their dovetail slots (Figure 157).
- Twenty rotor blades were broken at or near the blade platform (Figures 157 and 158).
- Twelve rotor blades were bent opposite to the direction of rotation (Figures 157 and 159).
- The leading-edge and trailing-edge of all 12 of the retained/unbroken rotor blades were damaged (Figure 159).
- There was a blade-tip rub, and rub indications on the pressure-side, on all 12 of the retained/unbroken rotor blades, with corresponding rotational score marks on the blade-tip shroud (Figure 159).

- There was a platform rub on the aft side of all of the rotor blades (Figure 158), with corresponding rotational score marks on the third-stage rotating shroud (Figure 150). The forward rotor blade platform was not accessible.
- The rotor disk was fractured (Figure 158).
- The forward Curvic coupling teeth were damaged (Figure 156). The aft Curvic coupling teeth were damaged (Figure 160).
- The second-stage (rotating) vane-tip shroud was trapped between the second- and third-stage LP compressor rotors, and was damaged.

(f) Fourth-stage LP compressor:

- Dirt and debris was packed between rotor blades (before decontamination).
- Thirty-one rotor blades were displaced out of their dovetail slots (Figures 161 and 162).
- Eleven rotor blades were bent opposite to the direction of rotation (Figures 161 through 163).
- The leading-edge and trailing-edge of all 11 of the retained rotor blades were damaged (Figure 163).
- There was a blade-tip rub, and rub indications on the pressure-side, on all 11 of the retained rotor blades (Figure 163), with corresponding rotational score marks on the blade-tip shroud.
- There was a platform rub on the forward side of all of the rotor blades (Figure 163), with corresponding rotation score marks on the third-stage rotating shroud (Figure 150). There was a platform rub on the aft side of all of the rotor blades (Figure 164), with corresponding rotational score marks on the fourth-stage stator inner housing (Figure 172).
- There were rotational score marks on the aft face of the rotor disk (Figure 165), with corresponding rotational score marks on the No. 4 bearing housing (Figure 166).
- The aft shaft mount flange was damaged (Figure 167) and separated from the forward flange/coupling (Figure 161). The OD of the aft shaft displayed rotational score marks (Figures 167 and 168), with corresponding rotational score marks on the ID of the HP shaft (Figure 166).
- The forward (large) Curvic coupling teeth were damaged (Figure 169). The aft (small) Curvic coupling teeth were damaged (Figure 170).
- The third-stage (rotating) vane-tip shroud was damaged (Figure 150).

(g) First-stage LP compressor stator:

- No stator vanes were returned with the engine
- The blade-tip shroud was not returned with the engine.

(h) Second-stage LP compressor stator:

- Several stator vanes were found loose (Figure 171). The remaining vanes were not returned with the engine.
- The blade-tip shroud was damaged (Figure 150).

(i) Third-stage LP compressor stator:

- Several stator vanes were found loose (Figure 171). The remaining vanes were not returned with the engine.
- The outer vane retainer ring was damaged (Figure 150).
- The blade-tip shroud was damaged (Figure 150).

(j) Fourth-stage LP compressor stator:

- Dirt and debris was packed between the stator vanes (Figure 172).
- Approximately 50 percent of the stator vanes were displaced from the vane support structure (Figure 172).
- The leading-edge of some of the stator vanes was damaged.
- There were rotational score marks on the blade-tip shroud, with corresponding rotational score marks on the fourth-stage LP compressor rotor blades.

(k) LP compressor case:

- Sheet metal was buckled and torn (Figure 172). There were sections of sheet metal missing, exposing the LP compressor rotors (Figure 128).

3.4 High-Pressure (HP) Compressor Section

(a) HP compressor impeller:

- Dirt and debris was packed between impeller blades (before decontamination).
- All of the impeller blades were bent opposite to the direction of rotation (Figures 173 and 174). The leading-edge corner of four impeller blades was broken (Figure 173), and the leading-edge of fifteen impeller blades was nicked and pitted (Figure 174).
- The shroud-line edge of all the impeller blades was heavily rubbed (Figures 173 and 174), with corresponding rotational score marks on the HP impeller shroud (Figures 175 and 176).
- There were rotational score marks on the forward face, forward disk ID (Figure 177, and forward bore ID of the impeller rotor, with corresponding rotational score marks on the compressor interstage diffuser (housing) (Figure 179).

- There were rotational score marks on the aft surfaces of the impeller disk (Figure 180), with corresponding rotational score marks on the forward face of the HP compressor diffuser.
- The Curvic coupling teeth were damaged (Figure 181).

(b) HP impeller shroud:

- The shroud contour displayed rotational score marks, through 360 degrees (Figures 175 and 176), with corresponding rub marks on the shroud-line edge of all the impeller blades (Figures 173 and 174).
- The forward (throat) area of the shroud was distorted and cracked (Figures 175 and 176).

(c) HP compressor diffuser:

- There were rotational score marks on the forward face of the diffuser, with corresponding rotational score marks on the aft face of the HP compressor impeller (Figure 180).
- The diffuser vanes were not disassembled.

(d) Compressor interstage diffuser (housing):

- Both the forward mount flange (Figure 179) and the aft mount flange were damaged.
- The compressor housing displayed rotational score marks in three locations (Figure 179), with corresponding rotational score marks on the HP compressor impeller rotor (Figures 177 and 178).
- The tower shaft bearing support was damaged.

(e) Deswirl vanes:

- Not disassembled.

(f) Beveled spur (tower) shaft:

- Not disassembled.
- Tower shaft thrust ball bearing:
  - Not disassembled.
- Tower shaft roller bearing:
  - Not disassembled.

(g) HP shouldered shaft:

- The forward ID of the HP shaft displayed rotational score marks (Figure 166), with corresponding rotational score marks on the fourth-stage LP compressor aft shaft OD (Figures 167 and 168).
- The aft ID of the HP shaft displayed rotational score marks (Figure 179), with corresponding rotational score marks on the OD of the LP shaft and seal assembly (Figure 182).
- The HP shaft was broken (Figures 179, 183, and 185). One fragment of the HP shaft displayed a spiral-shaped fracture (Figure 183 and 184).
- No. 4 HP rotor forward roller bearing:
  - Housing displayed rotational score marks (Figure 166), with corresponding rotational score marks on the aft face of the fourth-stage LP compressor rotor disk (Figure 165).
  - Bearing not disassembled.
  - Air/oil carbon seal destroyed (Figure 166). No pre-impact wear or distress noted.
  - Air/oil seal rotor not disassembled.
- No. 5 HP rotor aft ball bearing:
  - Bearing not disassembled (Figure 179).
  - Air/oil carbon seal and seal rotor not disassembled.

3.5 Combustion Section

(a) Fuel manifold assembly:

- Eleven hose assemblies were broken (Figures 128 and 186). All of the hose assemblies displayed evidence of post-impact fire (Figures 128 and 186).
- All 14 fuel nozzle housings were broken or deformed at the combustion chamber liner interface (Figure 187).
- The fuel nozzle tips and the fuel nozzle shrouds were not disassembled.

(b) Igniter plugs:

- Not disassembled.

(c) Outer transition liner:

- Not disassembled.
- The honeycomb seal was very heavily worn.

(d) Inner transition liner:

- Not disassembled.

(e) Combustion chamber liner:

- There was debris on the dome of the combustion chamber liner, and between the combustion chamber liner and the combustion chamber case (Figures 186 and 188).
- The combustion chamber liner dome and outer skirt were bent and buckled at the 6 o'clock position (Figure 189)

(f) Combustion chamber case:

- Sheet metal buckled and dented (Figure 127).
- The forward mount flange was fractured, through 180 degrees.
- There was debris between the combustion chamber case and the combustion chamber liner (Figures 186 and 188).

3.6 High-Pressure (HP) Turbine Section

(a) HP turbine rotor:

- There was a platform rub on the aft side of all of the rotor blades (Figures 190 and 191), with corresponding rotational score marks on the forward face of the interstage transition duct (Figure 192).
- There was a heavy blade-tip rub, with metal roll-over, on all of the rotor blades (Figure 193), with corresponding rotational score marks on the segmented blade-tip shrouds (Figure 194).
- There were compressor-shroud metal-spray deposits adhering to the suction side of all of the rotor blades (Figure 195). The trailing-edge of all of the rotor blades was battered and broken (Figure 196).
- The forward Curvic coupling teeth were damaged (Figure 197). The aft Curvic coupling teeth were damaged (Figure 198).
- Part Number 3072730-3
- Serial Number 9-23315-1664
- Lot Number 0846

(b) HP turbine nozzle (stator):

- Not disassembled, however the trailing-edge of all of the stator vanes was undamaged (Figure 189).
- There were compressor-shroud metal-spray deposits adhering to the suction side of the vanes (Figure 199).

(c) HP turbine segmented blade-tip shrouds:

- There were rotational score marks on the shrouds (Figure 194), with corresponding rub indications on all of the HP turbine rotor blades (Figure 193).

(d) HP center Curvic coupling

- The seal plate was separated from the coupling (Figure 200).
- The forward Curvic coupling teeth were undamaged (Figure 201). The aft Curvic coupling teeth were undamaged (Figure 202).
- The knife-edge seal was worn (Figure 202).

(e) HP aft Curvic coupling:

- The coupling could not be removed from the aft fragment of the broken HP shaft (Figure 203).
- The Curvic coupling teeth were damaged (Figure 204).
- The knife-edge seal was worn.

3.7 Low-Pressure (LP) Turbine Section

(a) N1 monopole:

- Displayed gouge marks (Figure 205), with corresponding metal shavings on the N1 speed pickup gear retainer nut (Figure 206).
- Displayed contact witness marks on both ends of the pole piece (Figure 207), with corresponding contact witness marks on the N1 speed pickup gear teeth (Figure 208).
- The electrical lead was broken (Figure 127), and the electrical connector was not returned with the engine.

(b) No. 6 LP rotor aft roller bearing:

- Undamaged (Figure 209).
- Residual oil was present.
- Air/oil carbon seal was undamaged (Figure 211).
- Air/oil seal rotor was undamaged (Figure 210.

(c) Thrust and exhaust nozzle:

- Aft mount flange, connected to the aircraft tailpipe, was cut with a power cutting tool to facilitate the teardown (Figure 212).
- Inner support housing displayed rotational score marks on the forward face (Figure 213), with corresponding marks on the third-stage LP turbine rotor blades (Figure 214).

(d) First-stage LP turbine rotor:

- There was a platform rub on the forward side of all of the rotor blades (Figure 215), with corresponding rotational score marks on the aft side of the first-stage LP turbine stator vanes and the inner vane support (Figure 216).
- There was a platform rub on the aft side of all of the rotor blades (Figure 217), with corresponding rotational score marks on the forward side of the second-stage LP turbine stator vanes (Figure 218).
- There were rotational score marks on the aft side of the rotor blade winglets (Figure 217), with corresponding rotational score marks on the forward outboard area of the second-stage LP turbine stator outer vane support (Figure 218).
- There was a blade-tip rub on all of the rotor blades (Figure 219), with corresponding rotational score marks on the blade-tip shroud (Figure 220).
- Both the leading-edge (Figures 215 and 219), and the trailing-edge (Figure 217) of the rotor blades were battered.
- There were compressor-shroud metal-spray deposits adhering to the suction side of the rotor blades (Figures 215 and 217).
- The forward Curvic coupling teeth were damaged (Figure 221). The aft Curvic coupling teeth were damaged (Figure 222).
- Part Number 3073070-5
- Serial Number 6-03229-1675
- Lot Number 5680

(e) Second-stage LP turbine rotor:

- Fifty two rotor blades were broken at the rotor blade winglet (Figure 223).
- There was a platform rub on the forward side of all of the rotor blades (Figure 223), with corresponding rotational score marks on the aft side of the second-stage LP turbine stator vane inner support (Figure 224).
- There was a platform rub on the aft side of all of the rotor blades (Figure 225), with corresponding rotational score marks on the forward side of the third-stage LP turbine stator vanes (Figure 226).
- There were rotational score marks on the forward side of all 32 of the unbroken rotor blade winglets (Figure 223), with corresponding rotational score marks on the trailing-edge of the second-stage LP turbine stator vanes (Figure 224).
- There were rotational score marks on the aft side of all 32 of the unbroken rotor blade winglets (Figure 225), with corresponding rotational score marks on the forward outboard area of the third-stage LP turbine stator vanes (Figure 226).
- There was a blade-tip rub on all 32 of the unbroken rotor blades (Figure 227), with corresponding rotational score marks on the blade-tip shroud (Figure 228).
- Both the leading-edge (Figures 223 and 227), and the trailing-edge (Figure 225) of the rotor blades were battered.
- The forward Curvic coupling teeth were damaged (Figure 229). The aft Curvic coupling teeth were damaged (Figure 230).
- Part Number 3072013-5
- Serial Number 5-18040-5315
- Lot Number 6768R

(f) Third-stage LP turbine rotor:

- Twelve rotor blades were broken at the rotor blade winglet, and one rotor blade was broken at the blade midspan (Figures 231 and 232). All of the rotor blades were bent opposite to the direction of rotation (Figures 231 through 233).
- There was a platform rub on the forward side of all of the rotor blades (Figure 233), with corresponding rotational score marks on the aft side of the third-stage LP turbine stator vane inner support (Figure 234).
- There was a platform rub on the aft side of all of the rotor blades (Figure 214), with corresponding rotational score marks on the thrust and exhaust nozzle inner support housing (Figures 211 and 212).

- There was a blade-tip rub on all 67 of the unbroken rotor blades (Figure 235), with corresponding rotational score marks on the blade-tip shroud (Figure 236).
- The leading-edge of the rotor blades was battered (Figures 231 and 233).
- There were compressor-shroud metal-spray deposits adhering to the suction side of the rotor blades (Figures 214 and 232).
- The knife-edged seal was heavily worn (Figure 233).
- The Curvic coupling teeth were damaged (Figure 237).
- Part Number 3072068-3
- Serial Number 960322902021
- Lot Number 9723151293

(g) Interstage transition duct:

- Fractured 360 degrees just aft of the first-stage LP turbine compressor vanes (Figure 238 and 239).
- There were rotational score marks on the forward face of the inner structure (Figure 192), with a corresponding platform rub on the aft side of all of the HP turbine rotor blades (Figure 191).
- The 3 o'clock aft engine mount was broken (Figure 239). The 9 o'clock and the 12 o'clock aft engine mounts were undamaged.
- The honeycomb seal was heavily worn (Figure 240).

(h) First-stage LP turbine stator:

- There were rotational score marks on the aft side of the stator vanes and the stator vane inner support (Figure 216), with a corresponding platform rub on the forward side of all of the first-stage turbine rotor blades (Figure 215).
- The trailing-edge of the stator vanes was battered (Figure 216).
- There were rotational score marks on the blade-tip shroud (Figure 220), with a corresponding blade-tip rub on all of the first-stage LP turbine rotor blades (Figure 219).

(i) Second-stage LP turbine stator:

- There were rotational score marks on the inboard leading-edge of the stator vanes (Figure 218), with a corresponding platform rub on the aft side of all of the first-stage turbine rotor blades (Figure 217).
- There were rotational score marks on the forward face of the stator vane outer support (Figure 218), with corresponding rotational score marks on the aft side of all of the first-stage turbine rotor blade winglets (Figure 217).
- There were rotational score marks on the aft side of the stator vane inner support (Figure 224), with a corresponding platform rub on the forward side of all of the second-stage turbine rotor blades (Figure 223).
- There were rotational score marks on the outboard trailing-edge of all of the stator vanes (Figure 224), with corresponding rotational score marks on the forward side of 32 second-stage turbine rotor blade winglets (Figure 223).
- The trailing-edge of the stator vanes was pitted and rough.
- There were compressor-shroud metal-spray deposits adhering to the suction side of the stator vanes (Figure 224).
- There were rotational score marks on the blade-tip shroud (Figure 228), with a corresponding blade-tip rub on all of the second-stage LP turbine rotor blades (Figure 227). A 90-degree section of the blade-tip shroud was fractured (Figure 241).
- The honeycomb seal was worn, with four deep grooves (Figures 218 and 241).

(j) Third-stage LP turbine stator:

- There were rotational score marks on the inboard leading-edge of all of the stator vanes (Figure 226), with a corresponding platform rub on the aft side of all of the second-stage turbine rotor blades (Figure 225).
- There were rotational score marks on the outboard leading-edge of all of the stator vanes (Figure 226), with corresponding rotational score marks on the forward side of 67 third-stage turbine rotor blade winglets (Figure 225).
- There were rotational score marks on the aft side of the stator vane inner support (Figure 234), with a corresponding platform rub on the forward side of all of the third-stage turbine rotor blades (Figure 233).
- Both the leading-edge and the trailing-edge of the stator vanes were pitted and rough.
- There were compressor-shroud metal-spray deposits adhering to both the pressure-side (Figure 226), and the suction side (Figures 234 and 242) of the stator vanes.

- There were rotational score marks on the blade-tip shroud (Figure 236), with a corresponding blade-tip rub on 67 third-stage LP turbine rotor blades (Figure 235).
- The honeycomb seal was worn with deep grooved; however, the seal was damaged during the teardown (Figures 234 and 236).

(k) Thermocouple harness assembly:

- The thermocouple probes were undamaged.
- The thermocouple harness was undamaged.
- The electrical lead and the electrical connector were undamaged.

(l) LP turbine tie shaft:

- The shaft was broken (Figures 140 and 243).
- The forward fragment could not be removed from the LP shaft and seal assembly (Figure 243).

(m) LP shaft and seal assembly:

- There were rotational score marks on the OD of the LP shaft and seal assembly (Figures 182, 245, and 246), with corresponding rotational score marks on the aft ID of the HP shaft (Figures 166, 183).
- The forward (small) Curvic coupling teeth were smeared (Figure 244). The aft (large) Curvic coupling teeth were undamaged (Figure 243).
- The Feltmetal seal was worn.

(n) LP rotating seal:

- The forward Curvic coupling teeth were damaged (Figure 247). The aft Curvic coupling teeth were damaged (Figure 248).
- The knife-edge seal displayed some (normal) wear.

3.8 Miscellaneous

(a) Surge bleed valve:

- Returned loose in box with engine S/N P-74264. Engine Serial Number incorrect in Figures 249 and 250.
- Valve found partially open. Sheet-metal fragment blocking valve movement (Figures 249 and 250).
- Cap damaged.
- Part Number 978812-5
- Serial Number P-1918C

(b) Air/oil cooler (top)

- Sustained impact damage.
- Damaged in the area adjacent to the LP compressor rotor blades (Figures 251 and 252).
- Part Number 158600-XX[1]
- Serial number unknown.

(c) Air/oil cooler (left)

- Sustained impact damage.
- Damaged in the area adjacent to the LP compressor rotor blades, with axial (static) score marks over the rotational marks (Figure 253).
- Part Number 159900-XX[1]
- Serial number unknown.

(d) Air/oil cooler (right)

- Sustained impact damage.
- Damaged in the area adjacent to the LP compressor rotor blades, with axial (static) score marks over the rotational marks (Figure 254).
- Part Number 159910-XX[1]
- Serial number unknown.

4. COMPONENTS THAT WERE RETURNED LOOSE

At the accident site, all of the engine components (power sections, fan sections, and loose controls/accessories) were placed in two shipping containers. Because of the nature and extent of damage, components were placed in a shipping container by location and/or proximity to each power section, as no traceability data was available. Components described in Section 4 are not traceable to either engine, and the photos merely identify which engine shipping container they were removed from.

4.1 Inlet and Bypass Section

Component Name	Shipped With P-74264	Shipped With P-74265
Fan Inlet Housing	• No sheet metal was returned. • Fan blade containment ring was distorted (egg-shaped) (Figure 255).	• Several small, unidentifiable bits of sheet metal were returned. • Fan blade containment ring was fractured, and the fragments were stretched and distorted (Figure 256)
Compressor Inlet Stator	• No vanes were returned. • Inner vane retainer ring was not returned. • One small fragment of the outer vane retainer ring was damaged (Figure 257).	• No vanes were returned. • Fragments of the inner vane retainer ring and the outer vane retainer ring were damaged (Figure 258).
Fan Bypass Stator	• No vanes were returned. • Inner vane retainer ring was not returned. • One small fragment of the outer vane retainer ring was damaged (Figure 257).	• No vanes were returned. • Inner vane retainer ring was not returned. • Two fragments of the outer vane retainer ring were damaged (Figure 258).

4.2 Gearbox Section

Component Name	Shipped With P-74264	Shipped With P-74265
Fuel Pump Drive Shaft	• Slightly bent.	• None.
Accessory Gearbox Drive Shaft	• Bent (Figure 259). • Splines intact.	• Bent (Figure 260). • Splines intact.
Accessory Drive Gearbox	• Housing fractured. • Only fragments of housing returned (Figure 261). • Only a few of the gears returned (Figure 261). • P/N 3070003-XX[1] • S/N unknown	• Housing fractured. • Only fragments of housing returned (Figure 262). • Only a few of the gears returned (Figure 262). • P/N 3070003-XX[1] • S/N unknown
Transfer Gearbox	• Drive shaft intact (Figure 263). • Impact damage to N2 monopole. • P/N 3070093-12 • S/N P-359	• Drive shaft intact (Figure 264). • Impact damage to N2 monopole. • P/N 3070093-12 • S/N P-562

4.3 Fuel Section

Component Name	Shipped With P-74264	Shipped With P-74265
Flow Divider and Drain	• Fittings bent (Figure 265). • P/N 394396-XX[1] • S/N unknown	• Adjustment features separated (Figure 266). • P/N 394396-1-1 • S/N P-1076
Fuel Pump	• Broken just forward of aft mount flange. • Mount flange was the only fragment returned (Figure 267) • P/N 3070850-XX[1] • S/N unknown	• Broken in the plane of rotation of LP impeller (Figure 268). • LP impeller separated. • Honeywell P/N 3070850-XX[1] • Vickers P/N 623138 • S/N MX285879
Fuel Control	• Slight external impact damage (Figures 267 and 269). • Drive shaft intact. • Pointer indicated 120 degrees. • P/N 3070800-21 • S/N A3466PTC	• Forward mount flange damaged (Figure 270). • Drive shaft broken (Figure 270). • Pointer indicated 120 degrees. • Electrical connector broken (Figure 271). • P3 limiter separated (Figure 272). • P/N 3070800-8 • S/N A5650T
Fuel/Oil Cooler	• Control valve separated from heat exchanger (Figure 273). • Heat exchanger dented. • P/N 158610-8 • S/N unknown	• Sustained impact damage. • Heat exchanger dented (Figure 274). • P/N 158610-XX[1] • S/N unknown

4.4 Oil Section

Component Name	Shipped With P-74264	Shipped With P-74265
Oil Filter	• Filter element crushed (Figure 275). • Filter housing cap damaged.	• Filter element crushed (Figure 276). • Filter housing cap damaged.
Oil Tank	• Crushed. • Most external sheet metal not returned. • Internal tubes damaged (Figure 277). • Glass in liquid level gage broken.	• Crushed. • Most external sheet metal not returned. • Internal tubes damaged (Figure 278). • Glass in liquid level gage broken.
Oil Lube and Scavenge Pump	• Mount flange damaged (Figure 279). • Drive shaft broken. • P/N 3071949-XX[1] • S/N unknown	• Mount flange damaged (Figure 280). • Drive shaft broken. • P/N 3071949-11 • S/N 5-14057-364
Oil Temperature Control Valve	• Inlet fitting broken (Figure 281). • P/N 158465-3 • S/N 96-188	• External impact damage (Figure 282). • P/N 158465-3 • S/N 72-3770

4.5 Electrical Section

Component Name	Shipped With P-74264	Shipped With P-74265
Ignition Unit	• Output electrical connectors broken (Figure 283). • Body of unit not returned. • Ignition leads damaged (Figure 283). • P/N unknown • S/N unknown	• Not returned.
Solenoid Controller Valve	• Solenoids separated from valve body (Figure 284). • Valve body damaged. • P/N unknown • S/N unknown	• Not returned.
Electronic Engine Control (EEC)	• Housing damaged (Figures 285 and 287). • Specific gravity set at JET B. • P/N 2101142-44 • S/N 116-947	• Housing severely damaged exposing internal components (Figures 286 and 288). • Specific gravity set at JET B. • P/N 2101142-1 • S/N 21-1365

5. ANALYSIS AND CONCLUSIONS

5.1 Analysis

On engine Serial Number P-74264, engine rotation at the time of impact was evidenced by the following:

(a) Rotational score marks on the fan rotor disk and hub assembly, with corresponding rotational score marks on the fan support housing.

(b) Fan rotor blades bent opposite to the direction of rotation.

(c) All stages of LP compressor rotor blades bent opposite to the direction of rotation.

(d) Blade-tip rub on all stages of LP compressor rotor blades, with corresponding rotational score marks on the blade-tip shrouds.

(e) Platform rub on all stages of LP compressor rotor blades, with corresponding rotational score marks on the rotating shrouds.

(f) Smeared Curvic coupling teeth on the second-stage LP compressor, with corresponding damage to the Curvic coupling teeth on the third-stage LP compressor.

(g) Smeared Curvic coupling teeth on the fourth-stage LP compressor aft shaft, with corresponding damage to the Curvic coupling teeth on the LP turbine shaft and seal assembly.

(h) Rotational score marks on the OD of the fourth-stage LP compressor aft shaft and the LP turbine shaft and seal assembly, with corresponding rotational score marks on the ID of the HP shaft.

(i) Rotational score marks on the fourth-stage LP compressor rotor disk, with corresponding rotational score marks on the No. 4 bearing housing.

(j) HP compressor impeller blades bent opposite to the direction of rotation.

(k) Rotational score marks on the shroud-line edge of the HP compressor impeller blades, with corresponding rotational score marks on the impeller shroud contour.

(l) Rotational score marks on the HP compressor impeller rotor, with corresponding rotational score marks on the compressor interstage diffuser (housing), and on the HP compressor diffuser.

(m) Impact marks on the forward face of the HP turbine rotor, with corresponding impact marks on the HP turbine center Curvic coupling.

(n) Platform rub on the HP turbine rotor blades, with corresponding rotational score marks on the interstage transition liner.

(o) Blade-tip rub on the HP turbine rotor blades, with corresponding rotational score marks on the segmented blade-tip shrouds.

(p) Rotational score marks on the HP turbine center Curvic coupling, with corresponding rotational score marks on the HP turbine nozzle (stator) inner vane support.

(q) Gouges on the N1 monopole, with corresponding metal shaving on the N1 speed pickup gear retainer nut.

(r) Contact witness marks on the N1 monopole, with corresponding contact witness marks on the N1 speed pickup gear.

(s) Platform rub on all stages of LP turbine rotor blades, with corresponding rotational score marks on the LP turbine stators.

(t) Blade-tip rub on all stages of LP turbine rotor blades, with corresponding rotational score marks on the blade-tip shrouds.

On engine Serial Number P-74265, engine rotation at the time of impact was evidenced by the following:

(a) Rotational score marks on the fan rotor disk and hub assembly, with corresponding rotational score marks on the fan support housing.

(b) Fan rotor blades bent opposite to the direction of rotation.

(c) All stages of LP compressor rotor blades bent opposite to the direction of rotation.

(d) Blade-tip rub on all stages of LP compressor rotor blades, with corresponding rotational score marks on the blade-tip shrouds.

(e) Platform rub on all stages of LP compressor rotor blades, with corresponding rotational score marks on the rotating shrouds.

(f) Smeared Curvic coupling teeth on the fourth-stage LP compressor aft shaft, with corresponding damage to the Curvic coupling teeth on the LP turbine shaft and seal assembly.

(g) Rotational score marks on the OD of the fourth-stage LP compressor aft shaft and the LP turbine shaft and seal assembly, with corresponding rotational score marks on the ID of the HP shaft.

(h) Rotational score marks on the fourth-stage LP compressor rotor disk, with corresponding rotational score marks on the No. 4 bearing housing.

(i) HP compressor impeller blades bent opposite to the direction of rotation.

(j) Rotational score marks on the shroud-line edge of the HP compressor impeller blades, with corresponding rotational score marks on the impeller shroud contour.

(k) Rotational score marks on the HP compressor impeller rotor, with corresponding rotational score marks on the compressor interstage diffuser (housing), and on the HP compressor diffuser.

(l) Spiral-shaped fracture line on the HP shouldered shaft.

(m) Platform rub on the HP turbine rotor blades, with corresponding rotational score marks on the interstage transition liner.

(n) Blade-tip rub on the HP turbine rotor blades, with corresponding rotational score marks on the segmented blade-tip shrouds.

(o) Gouges on the N1 monopole, with corresponding metal shaving on the N1 speed pickup gear retainer nut.

(p) Contact witness marks on the N1 monopole, with corresponding contact witness marks on the N1 speed pickup gear.

(q) Platform rub on all stages of LP turbine rotor blades, with corresponding rotational score marks on the LP turbine stators.

(r) Blade-tip rub on all stages of LP turbine rotor blades, with corresponding rotational score marks on the blade-tip shrouds.

(s) Rotational score marks on the second-stage LP turbine rotor blade winglets, with corresponding rotational score marks on the second- and third-stage LP turbine stator vanes.

On engine Serial Number P-74265, engine operation at the time of impact was evidenced by the following:

(a) Compressor-shroud metal-spray deposits adhering to the HP turbine rotor blades, and the HP turbine stator vanes.

(b) Compressor-shroud metal-spray deposits adhering to the first- and third-stage LP turbine rotor blades, and the second- and third-stage LP turbine stator vanes.

5.2 Conclusion

The teardown and inspection of the engines disclosed that:

(a) The type and degree of damage observed on engine Serial Number P-74264 was indicative of engine rotation at the time of impact with the ground.

(b) The type and degree of damage observed on engine Serial Number P-74265 was indicative of engine rotation and operation at the time of impact with the ground.

(c) No pre-accident condition was found on either engine that would have interfered with normal operation.

Figure 1. (Photo No. 34-28) Biohazard Protection.

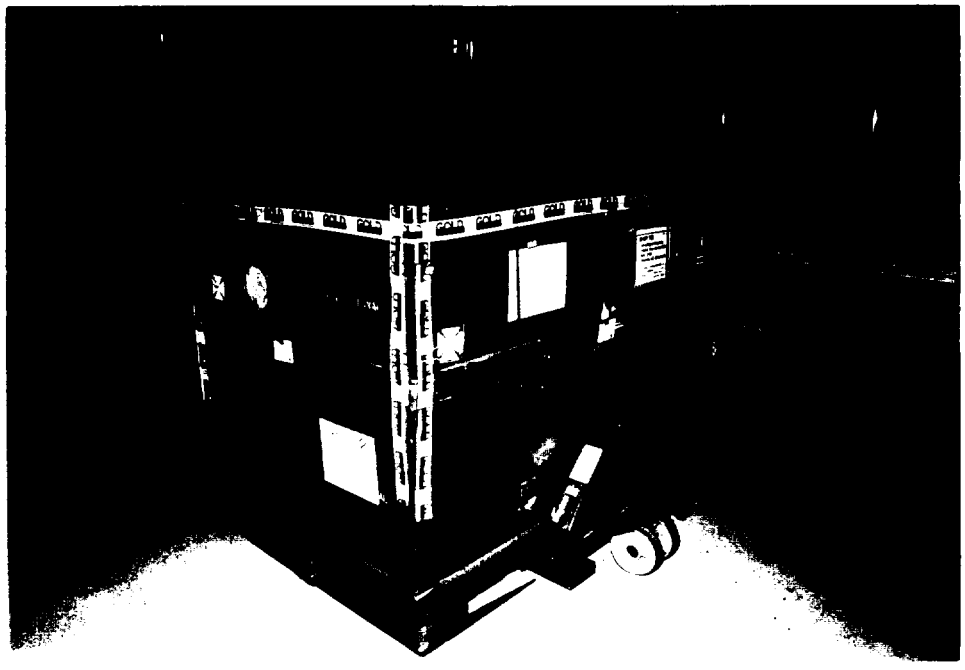


Figure 2. (Photo No. 34-2) Shipping Container.

Figure 3. (Photo No. 34-14) Engine S/N P-74264, as Received.

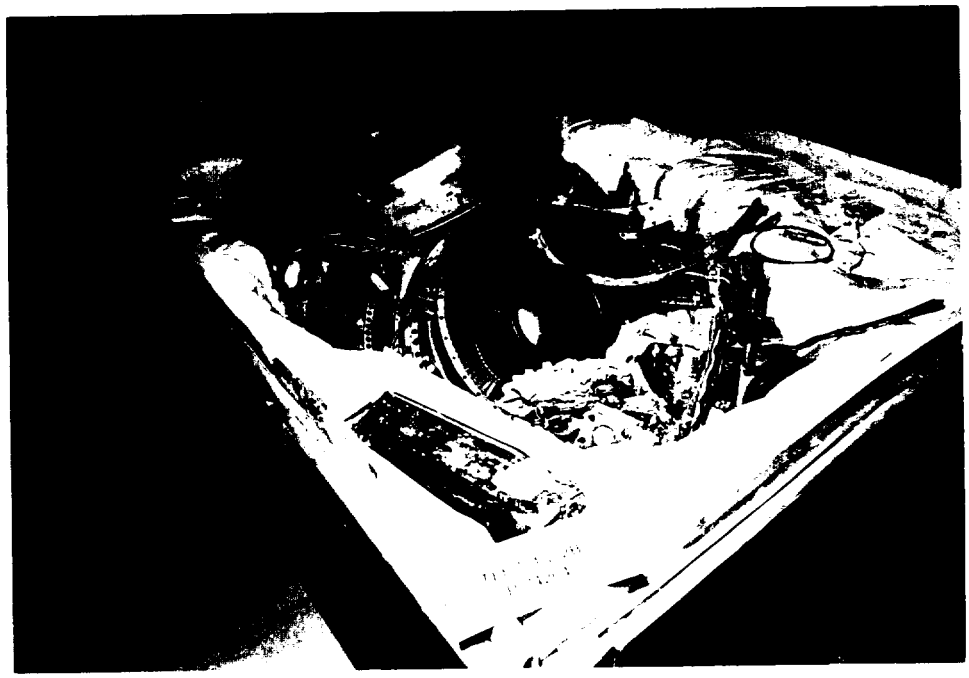


Figure 4. (Photo No. 34-16) Engine S/N P-74264, as Received.

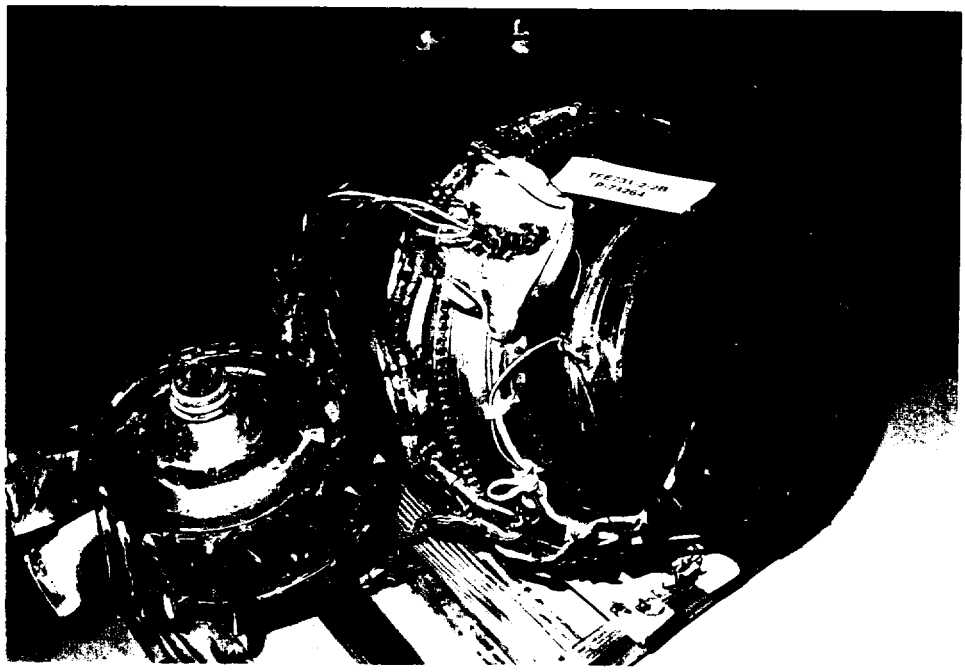


Figure 5. (Photo No. 29-4) Engine S/N P-74264, After Decontamination.

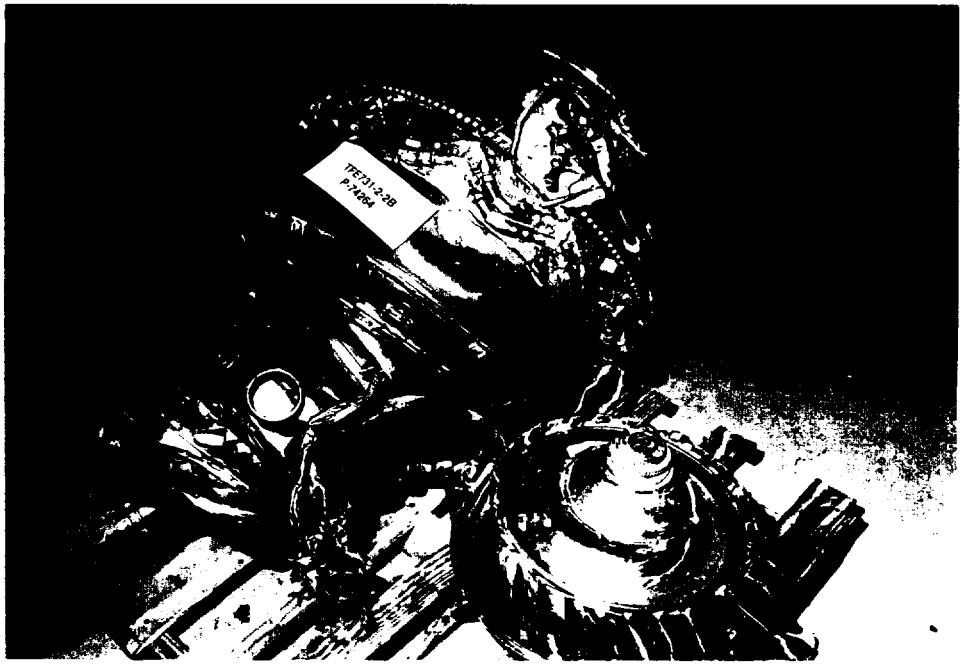


Figure 6. (Photo No. 29-5) Engine S/N P-74264, After Decontamination.

Figure 7. (Photo No. 40-32) Fan Rotor Hub, and Damaged Fan Blades.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

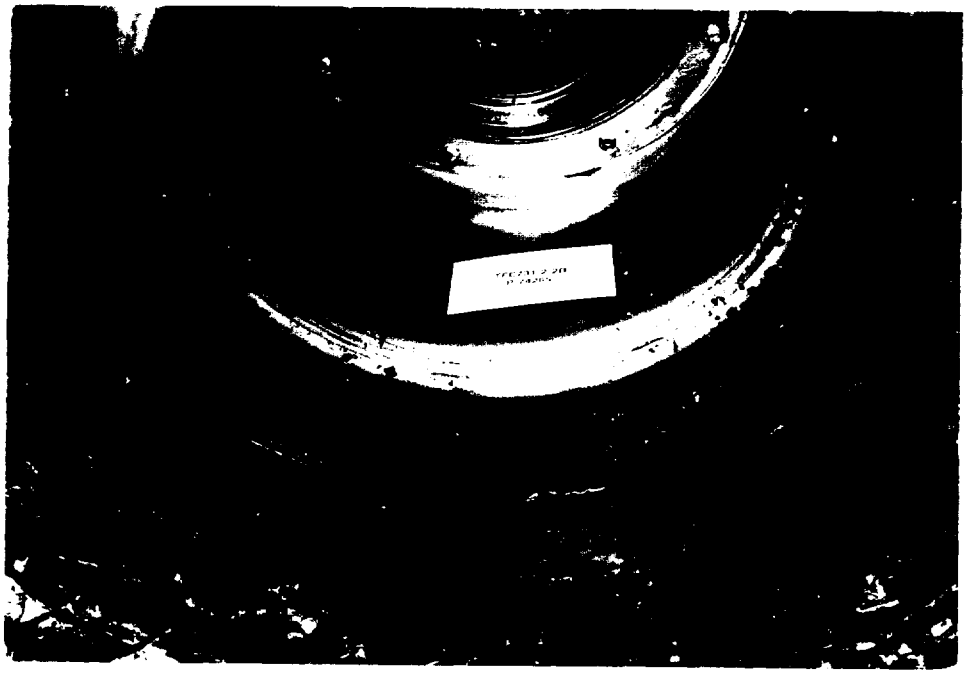


Figure 8. (Photo No. 40-24) Dirt and debris, and Score Marks on the Fan Rotor Hub.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

Figure 9. (Photo No. 40-31) Broken Fan Blades.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

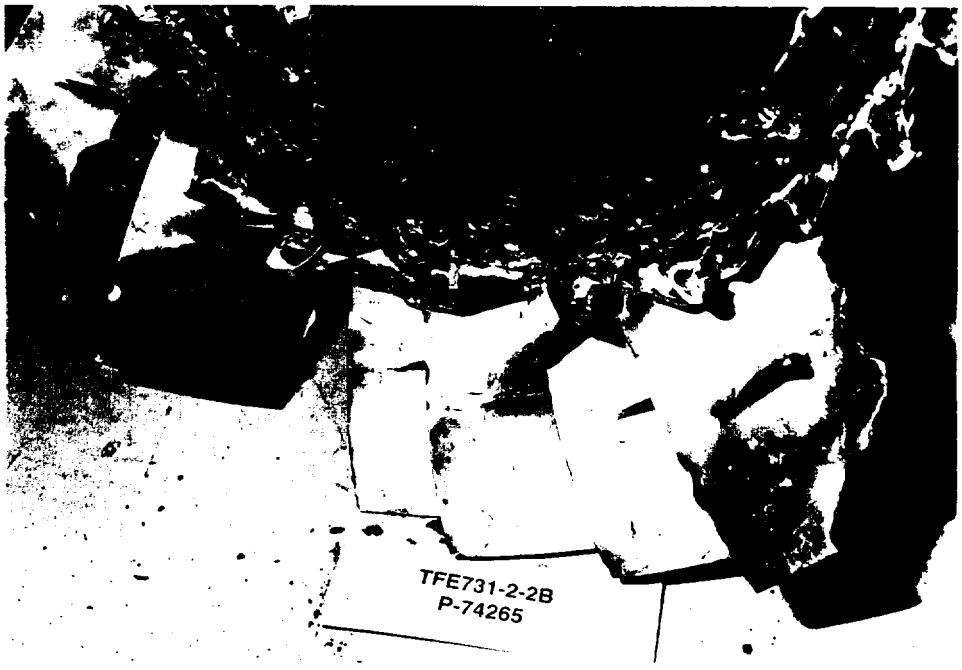


Figure 10. (Photo No. 40-29) Bent Fan Blades.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

Figure 11. (Photo No. 40-20) Fractured Fan Support Housing.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

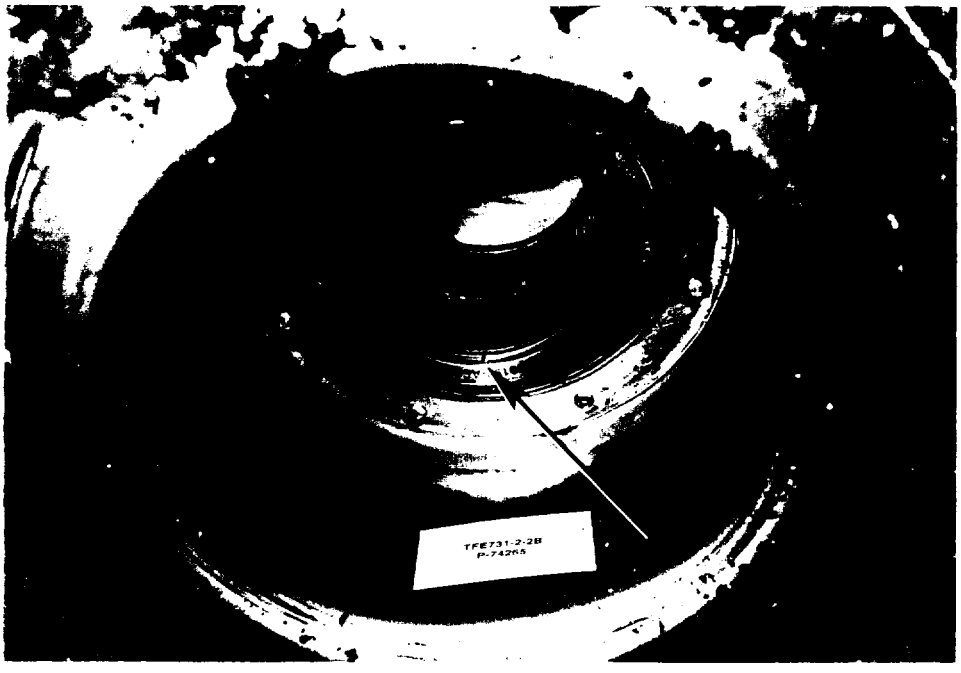


Figure 12. (Photo No. 40-23) Damaged No. 1 Carbon Seal.
(Part of Engine S/N P-74264 - S/N P-74265 on Placard in Photo is in Error.)

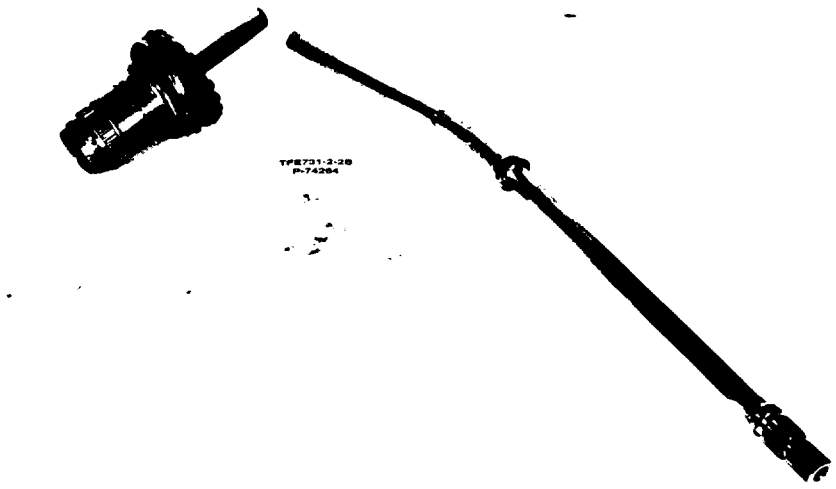


Figure 13. (Photo No. 36-21) Damaged Tie Bolt.

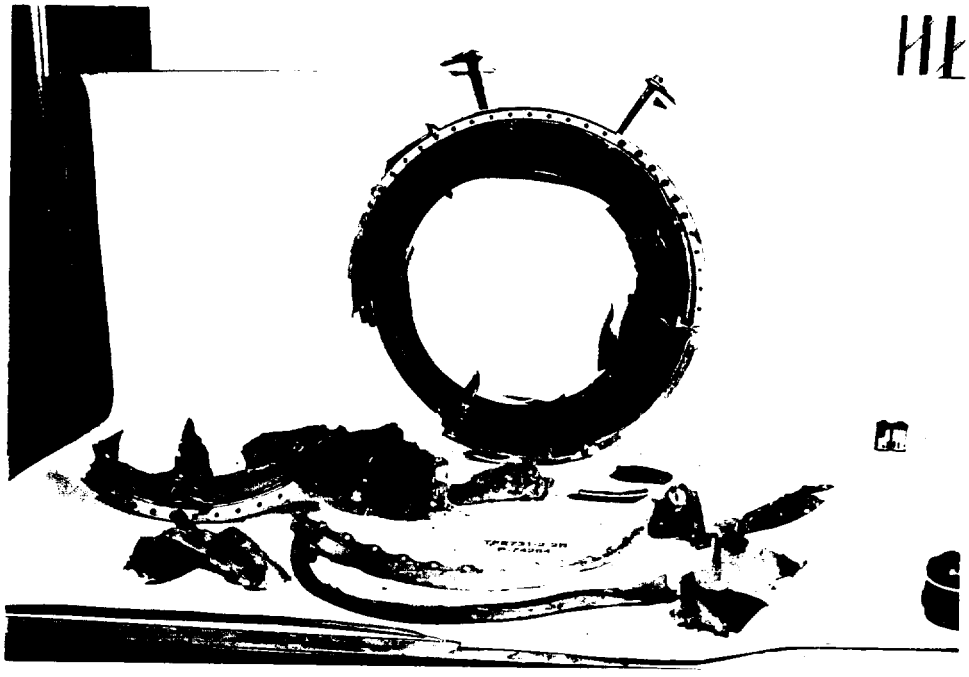


Figure 14. (Photo No. 28-15) Damaged Main Mount.

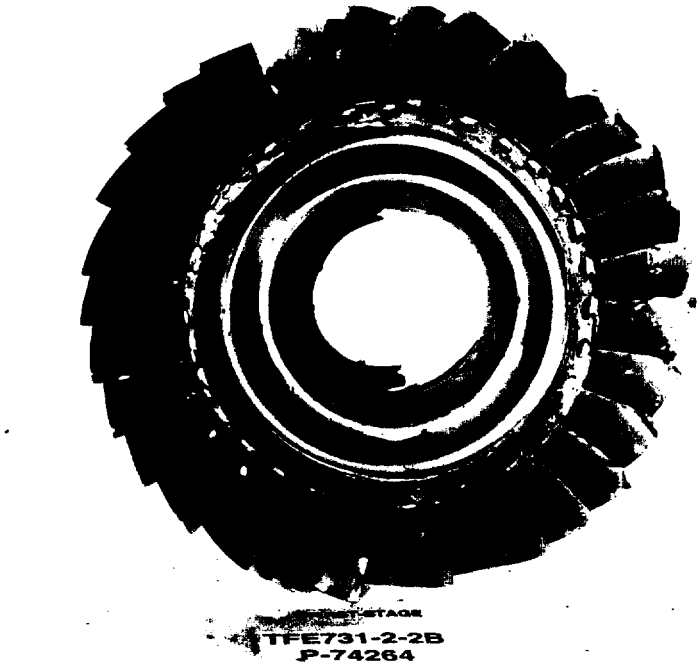


Figure 15. (Photo No. 32-26) Damaged First-Stage LP Compressor.

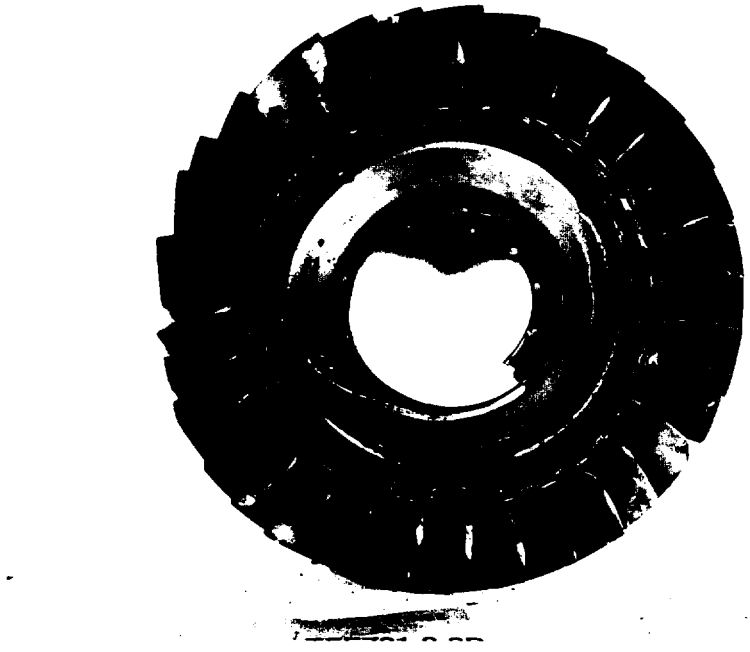


Figure 16. (Photo No. 32-27) Damaged First-Stage LP Compressor.

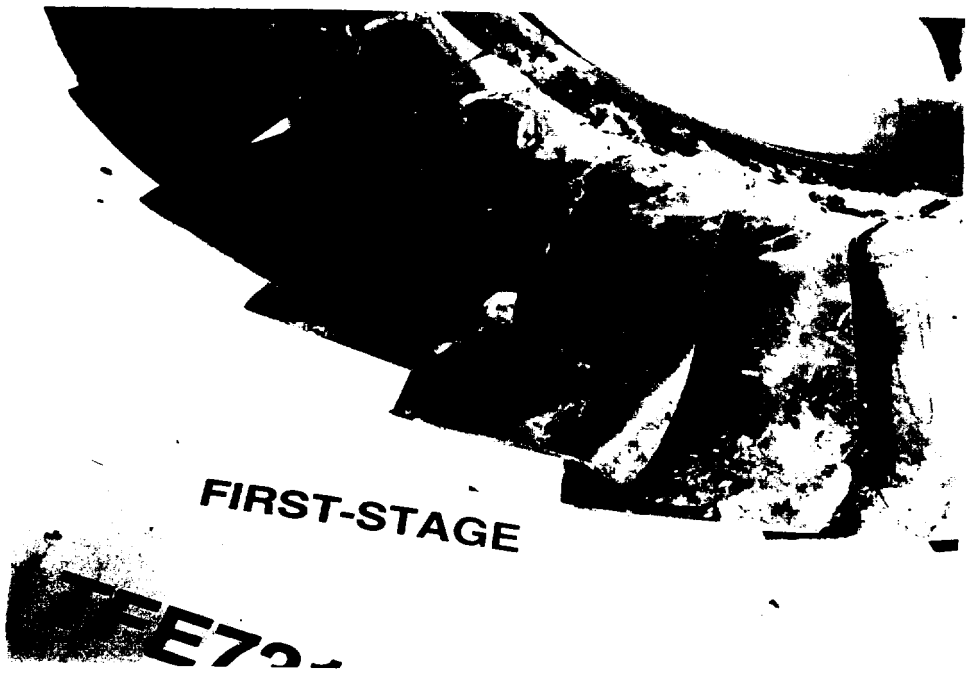


Figure 17. (Photo No. 32-29) Damaged First-Stage LP Compressor Rotor Blades.

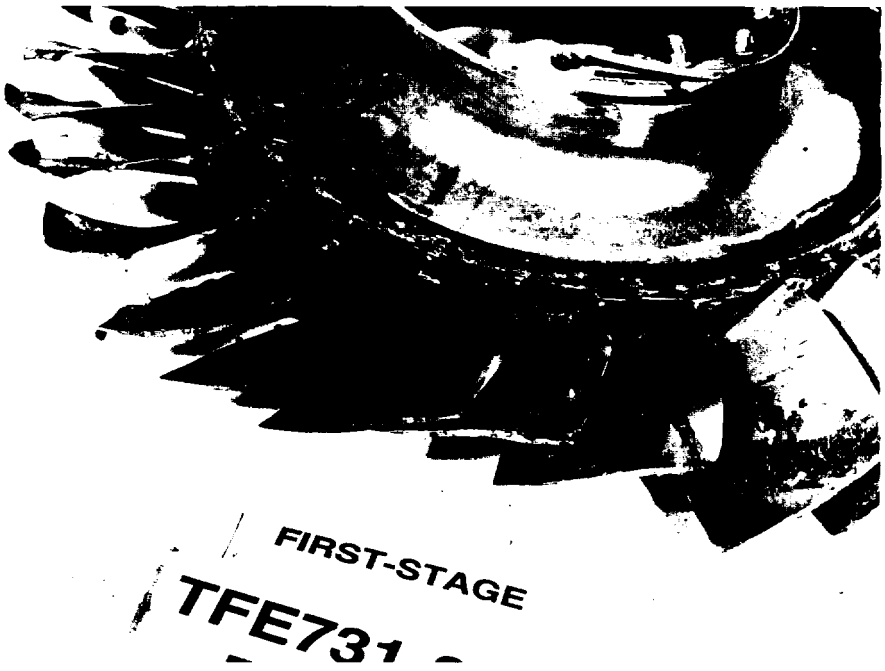


Figure 18. (Photo No. 32-28) Damaged First-Stage LP Compressor Rotor Blades.

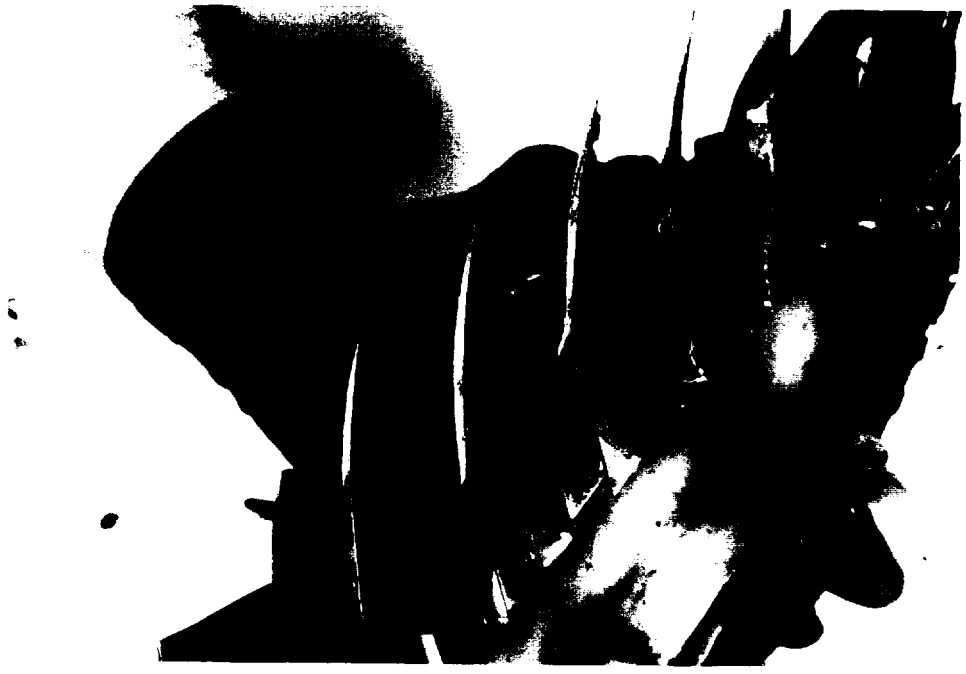


Figure 19. (Photo No. 32-31) Rub Marks on the First-Stage LP Compressor Rotor Blades.

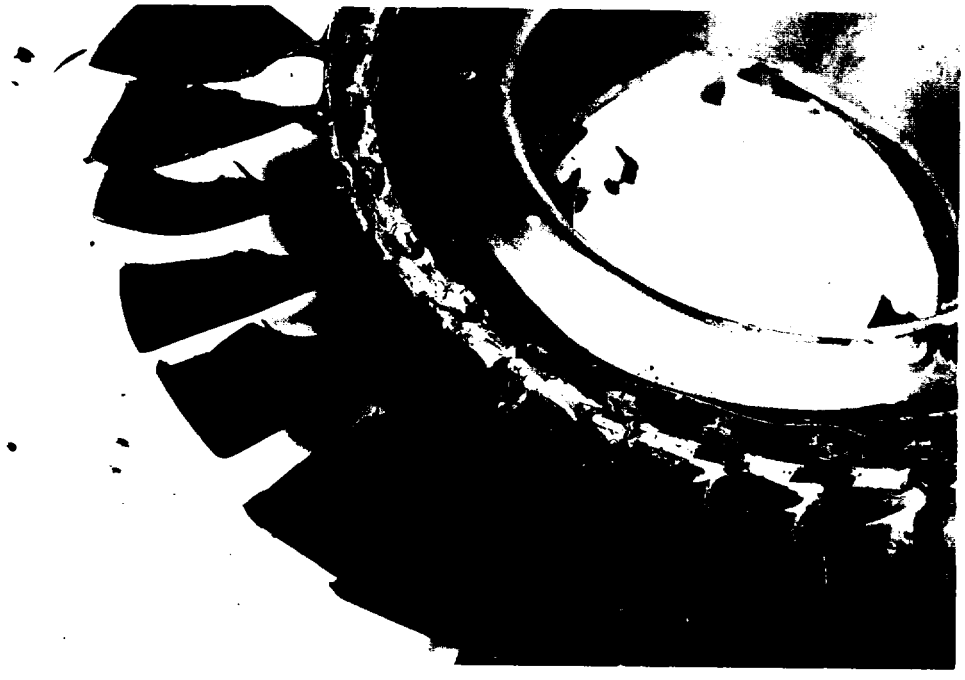


Figure 20. (Photo No. 32-30) Platform Rub on the First-Stage Compressor Rotor Blades.

Figure 21. (Photo No. 36-23) Damaged Stub Shaft.

Figure 22. (Photo No. 36-22) Damaged Curvic Coupling and Cut Tie Bolt.

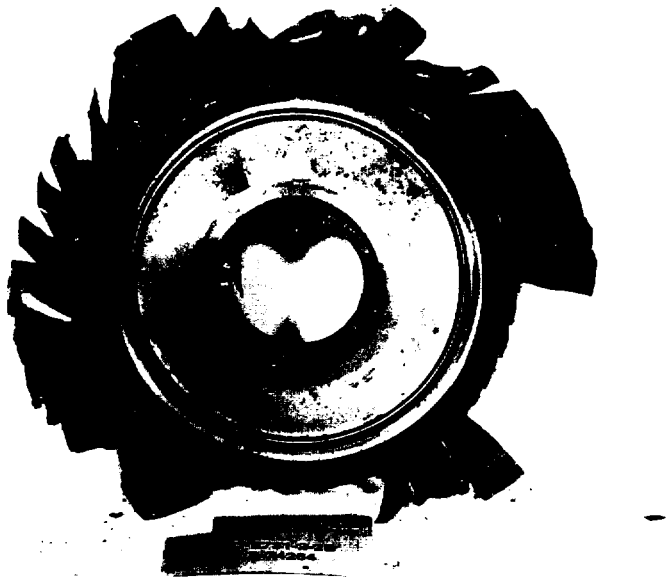


Figure 23. (Photo No. 36-24) Damaged Second-Stage LP Compressor.

Figure 24. (Photo No. 36-25) Damaged Second-Stage LP Compressor.

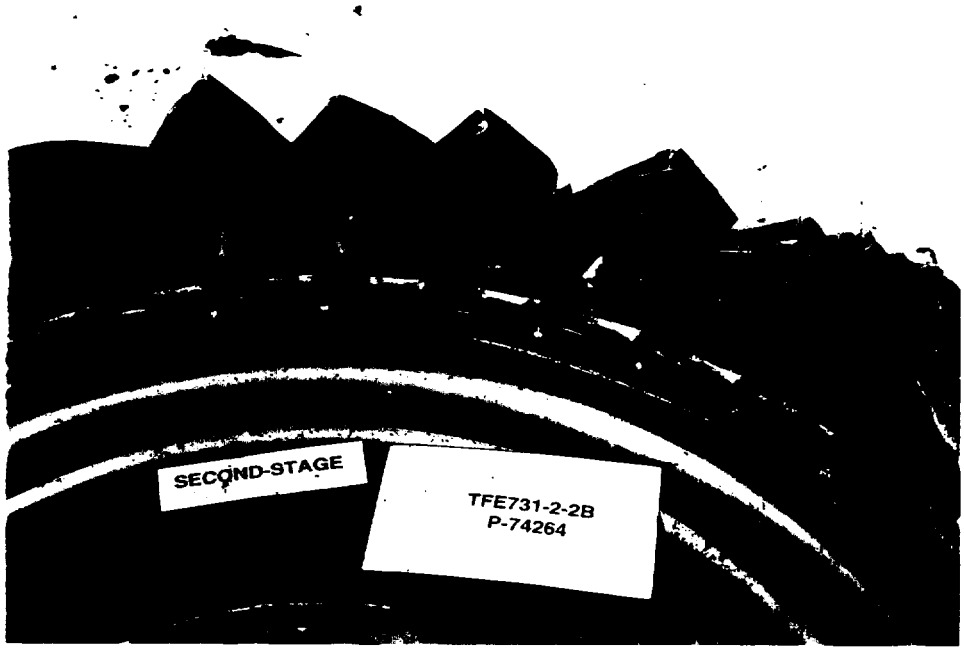


Figure 25. (Photo No. 36-30) Damaged Second-Stage LP Compressor Rotor Blades, with Platform Rub.

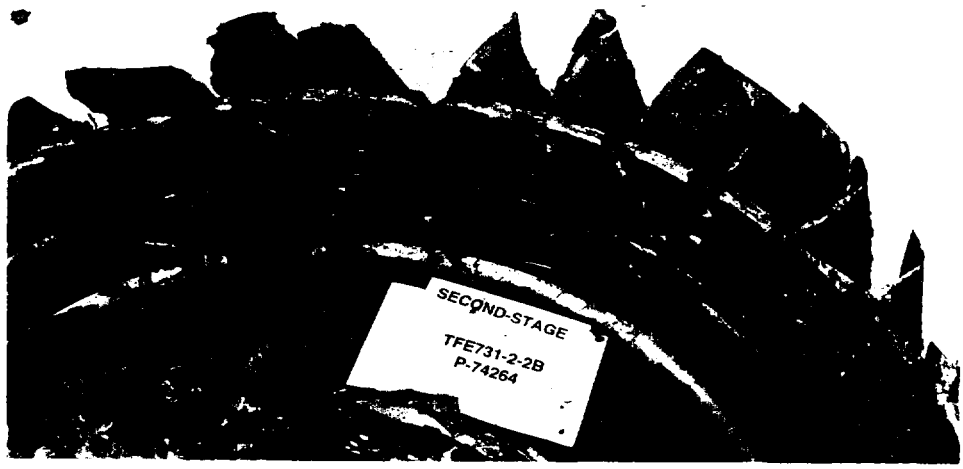


Figure 26. (Photo No. 36-27) Damaged Second-Stage LP Compressor Rotor Blades, with Platform Rub.

Figure 27. (Photo No. 36-28) Damaged Forward Curvic Coupling and Impact Marks.

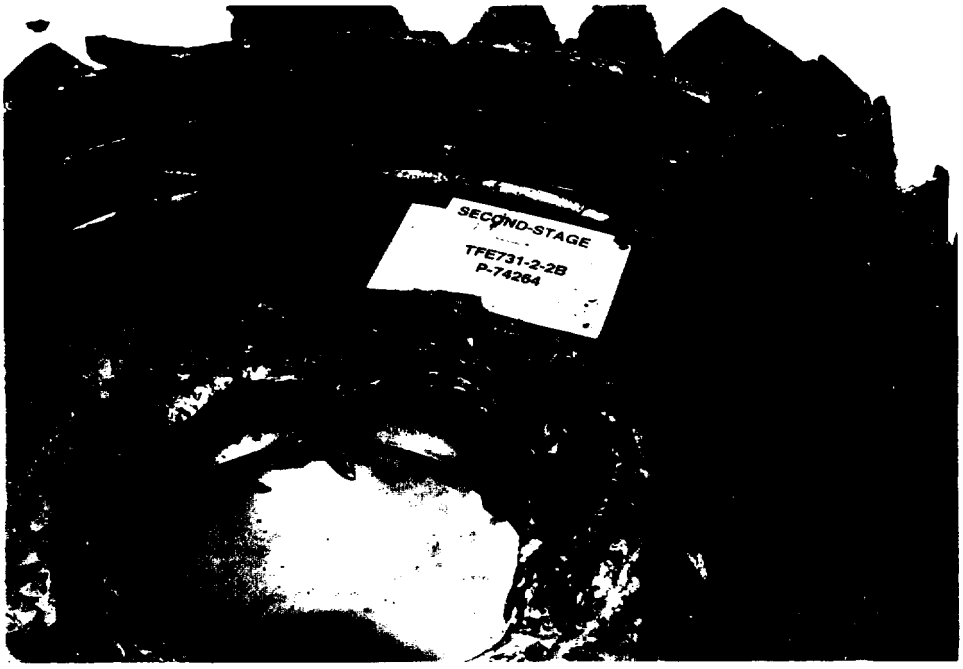


Figure 28. (Photo No. 36-26) Damaged Aft Curvic Coupling.

Figure 29. (Photo No. 32-25) Damaged First-Stage LP Compressor Vane-Tip Shroud, and Damaged First-Stage LP Compressor Stator Vane Retainer Ring.

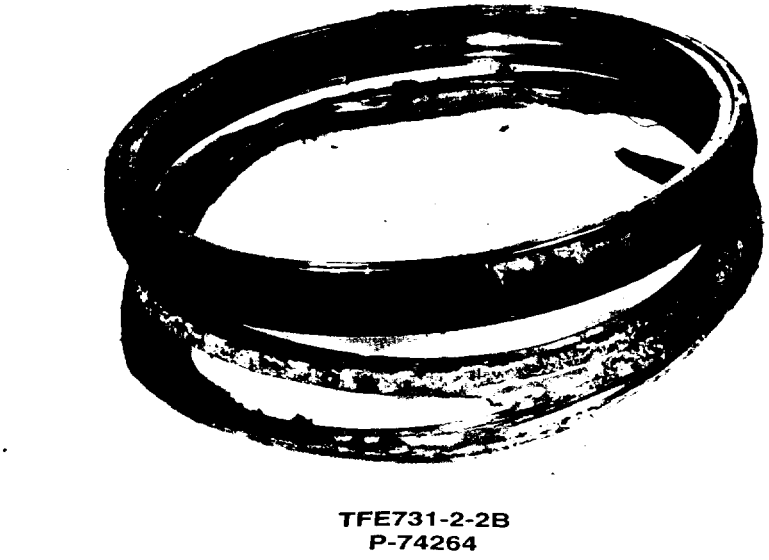


Figure 30. (Photo No. 33-9) Damaged Second- and Third-Stage LP Compressor Vane Tip Shrouds.

Figure 31. (Photo No. 36-31) Damaged Third-Stage LP Compressor.

Figure 32. (Photo No. 36-32) Damaged Third-Stage LP Compressor.

Figure 33. (Photo No. 33-6) Platform Rub, and Damaged Third-Stage Compressor Blades.

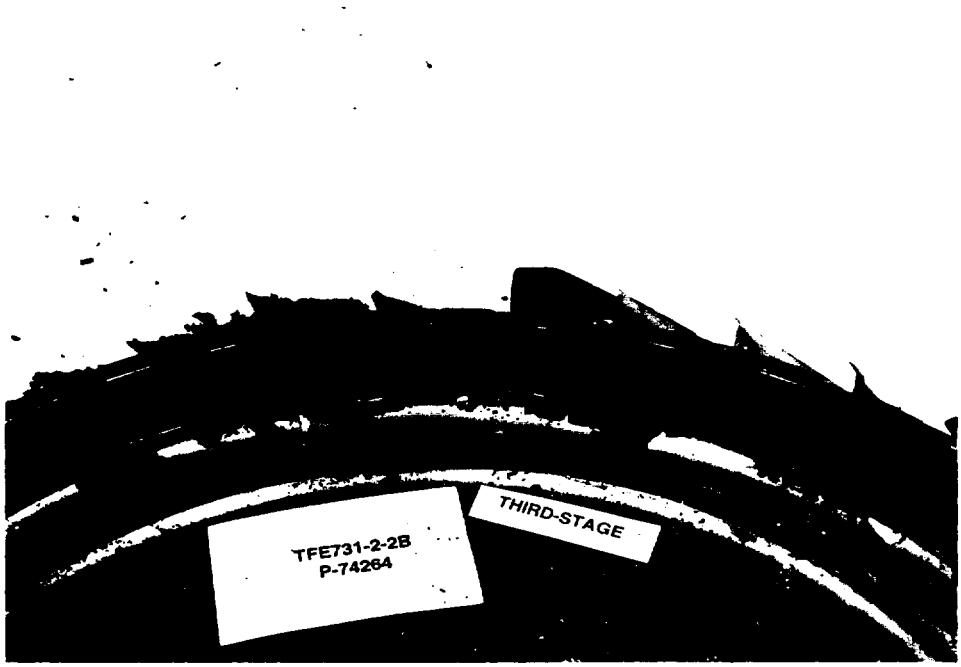


Figure 34. (Photo No. 36-25) Platform Rub on the Third-Stage LP Compressor Blades.

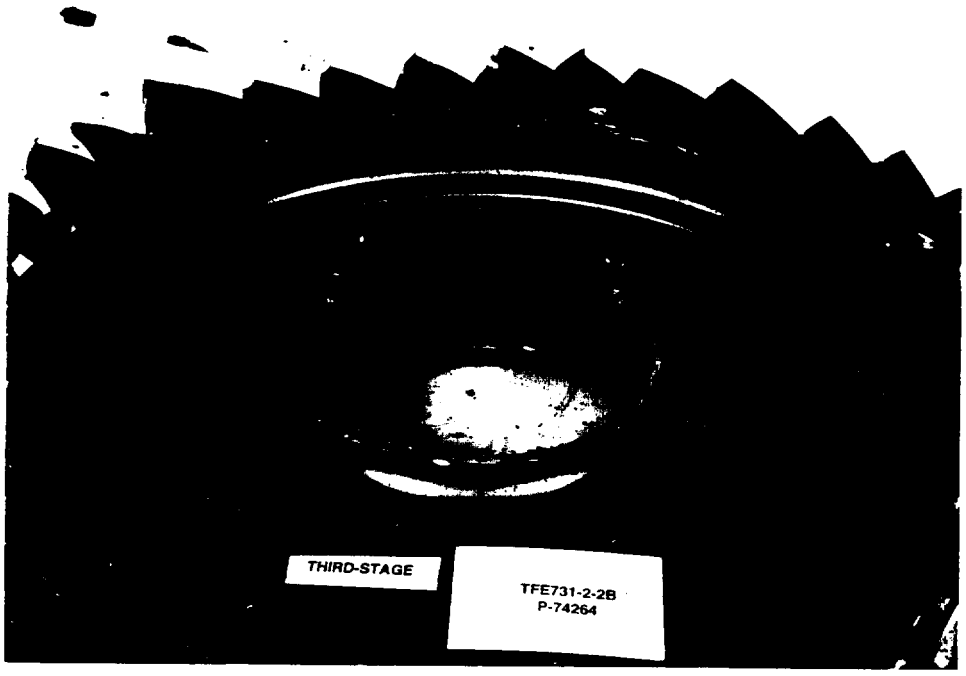


Figure 35. (Photo No. 36-36) Damaged Curvic Coupling.

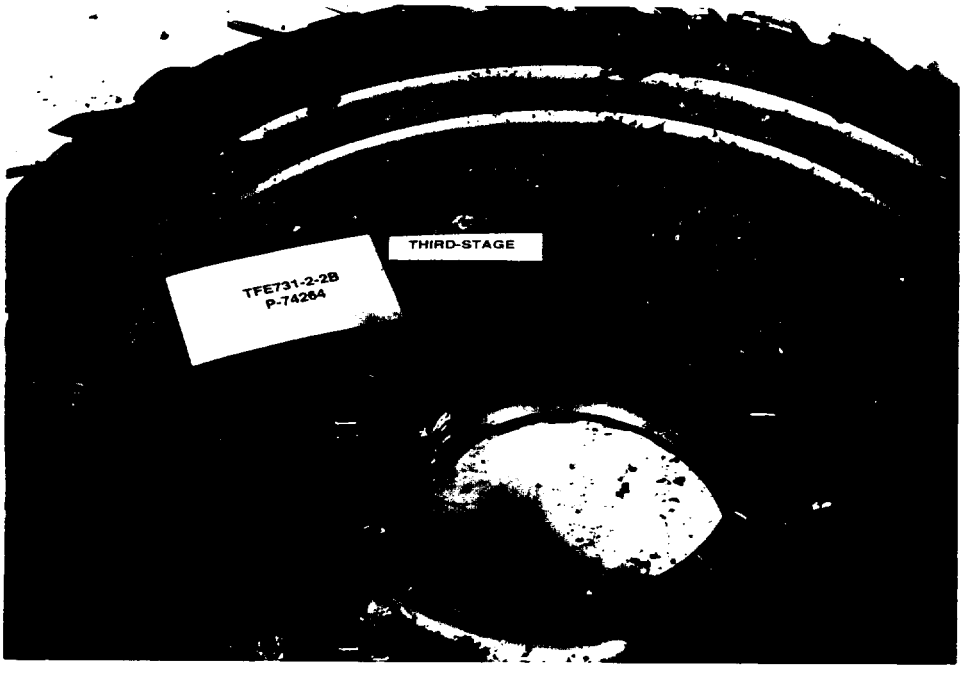


Figure 36. (Photo No. 36-33) Damaged Curvic Coupling.

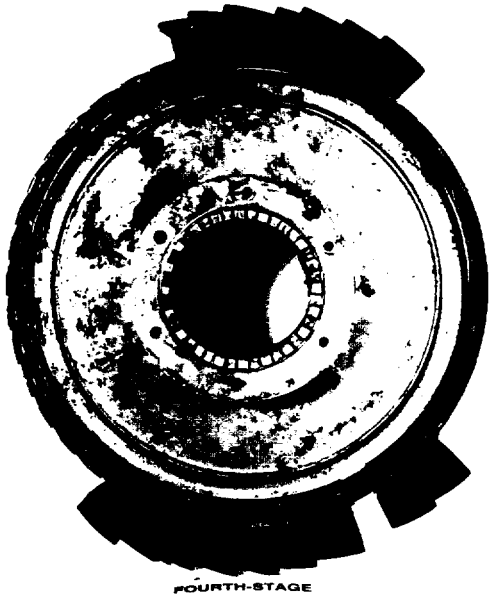


Figure 37. (Photo No. 33-16) Damaged Fourth-Stage LP Compressor.

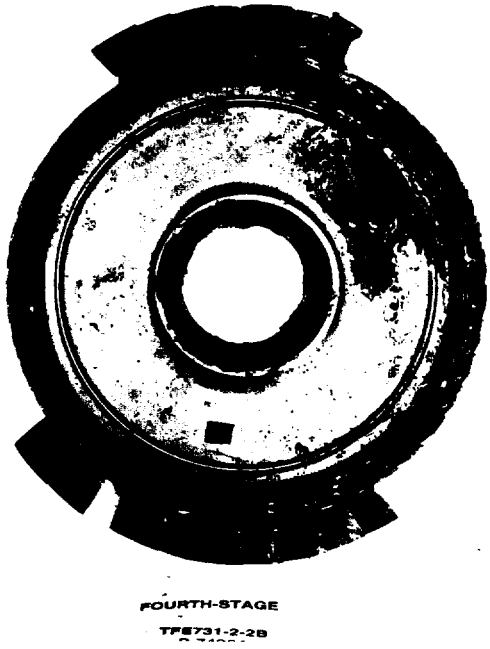


Figure 38. (Photo No. 33-17) Damaged Fourth-Stage LP Compressor.

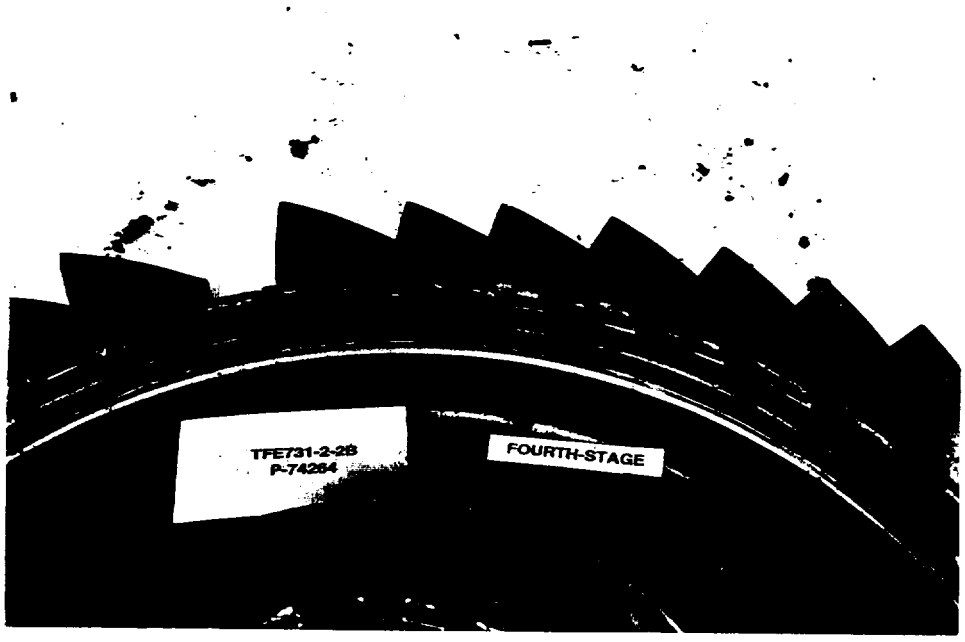


Figure 39. (Photo No. 33-21) Platform Rub on the Fourth-Stage LP Compressor Blades.

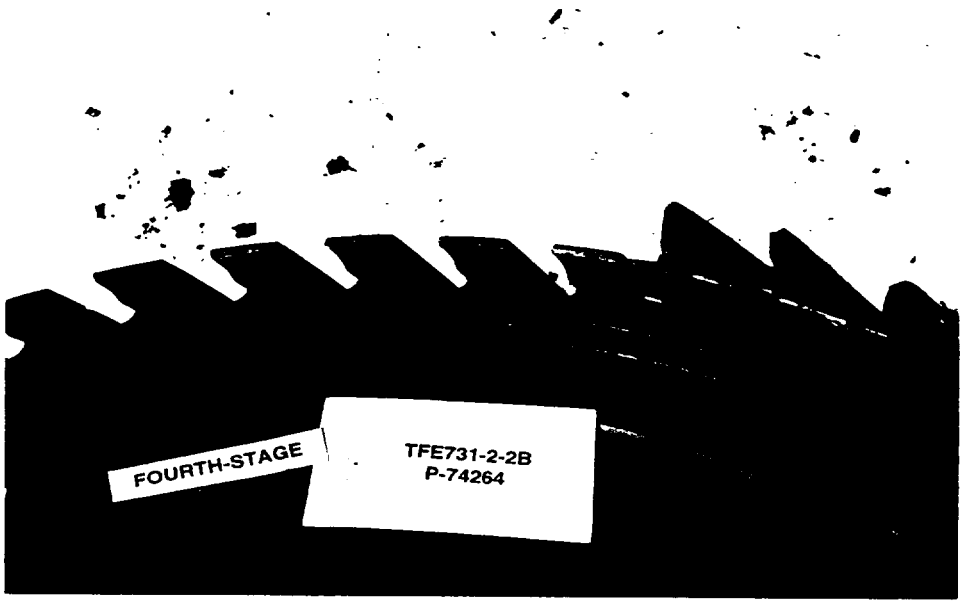


Figure 40. (Photo No. 33-19) Platform Rub on the Fourth-Stage LP Compressor Blades.

Figure 41. (Photo No. 33-34) Score Marks on the Fourth-Stage Blade-Tip Shroud and the Stator Inner Housing.

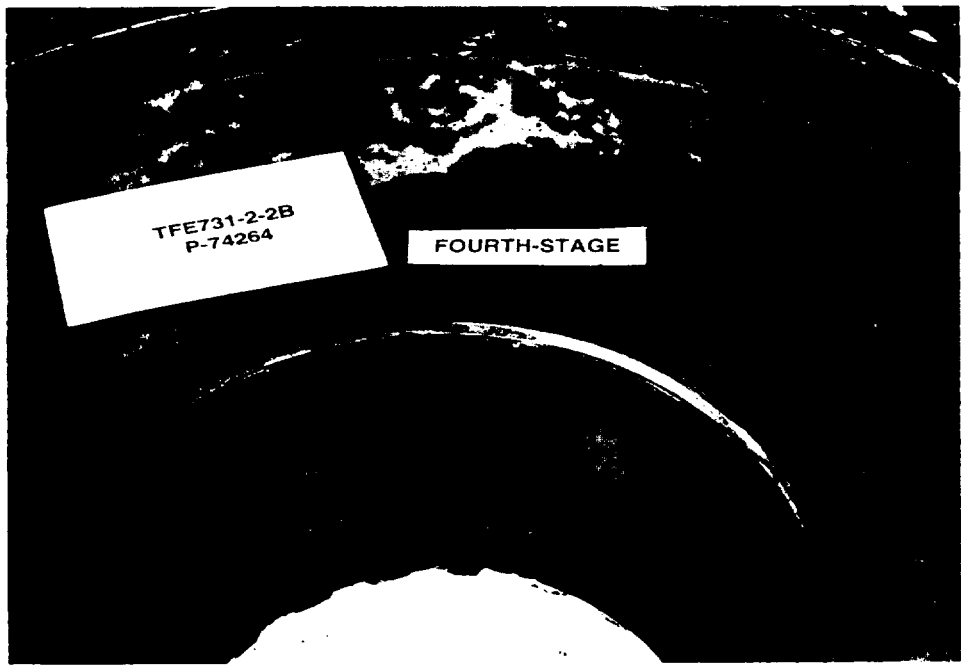


Figure 42. (Photo No. 33-18) Scored Fourth-Stage LP Compressor Disk.

Figure 43. (Photo No. 33-14) Scored No. 4 Bearing Housing, Scored HP Shaft, and Damaged Fourth-Stage Stator Vanes.

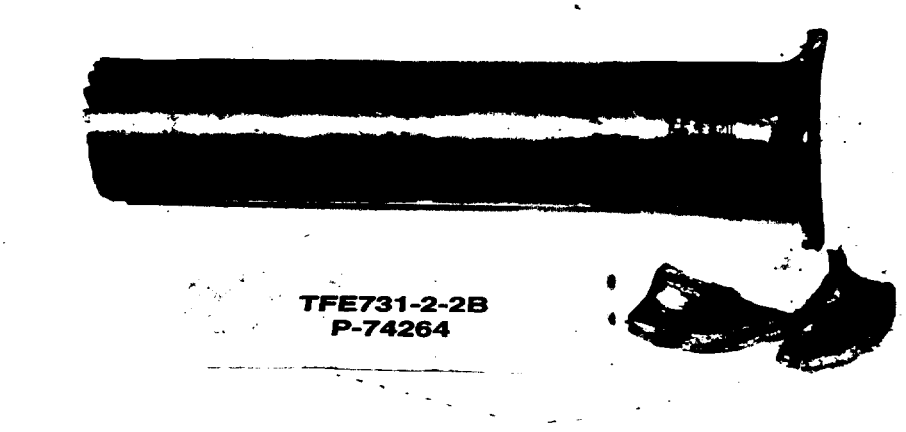


Figure 44. (Photo No. 37-2) Fractured Shaft.

Figure 45. (Photo No. 36-20) Scored Shaft.

Figure 46. (Photo No. 33-32) Scored Bearing Housing, and Scored HP Shaft.

Figure 47. (Photo No. 33-20) Damaged Curvic Coupling.

Figure 48. (Photo No. 36-19) Damaged Curvic Coupling.

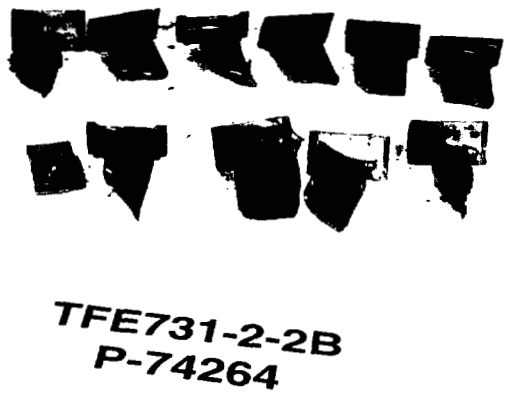


Figure 49. (Photo No. 28-20) Loose/Damaged Second- and Third-Stage LP Compressor Stator Vanes.

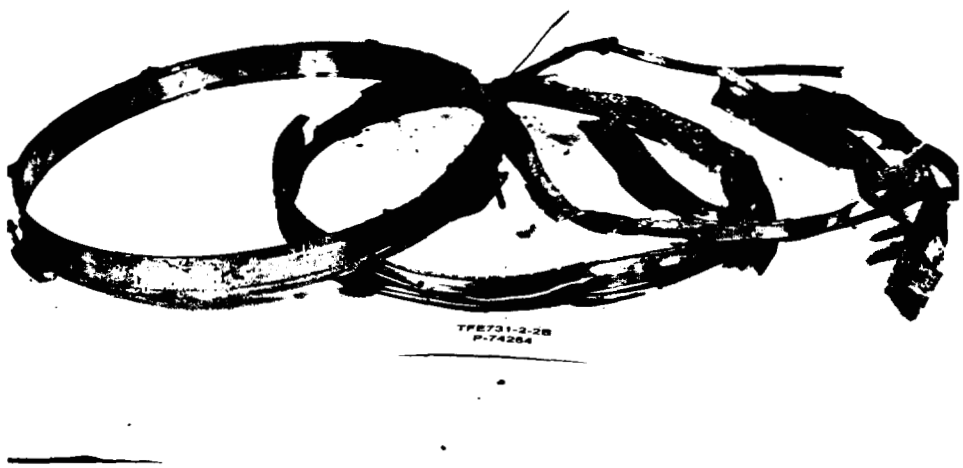


Figure 50. (Photo No. 33-11) Damaged LP Compressor Stator Vane Retainer Rings.

Figure 51. (Photo No. 33-31) Damaged Fourth-Stage LP Compressor Stator Vanes.

Figure 52. (Photo No. 29-6) Damaged LP Compressor Case.

Figure 53. (Photo No. 42-16) Damaged HP Compressor Impeller Blades.

Figure 54. (Photo No. 42-17) Damaged HP Compressor Impeller Blades.

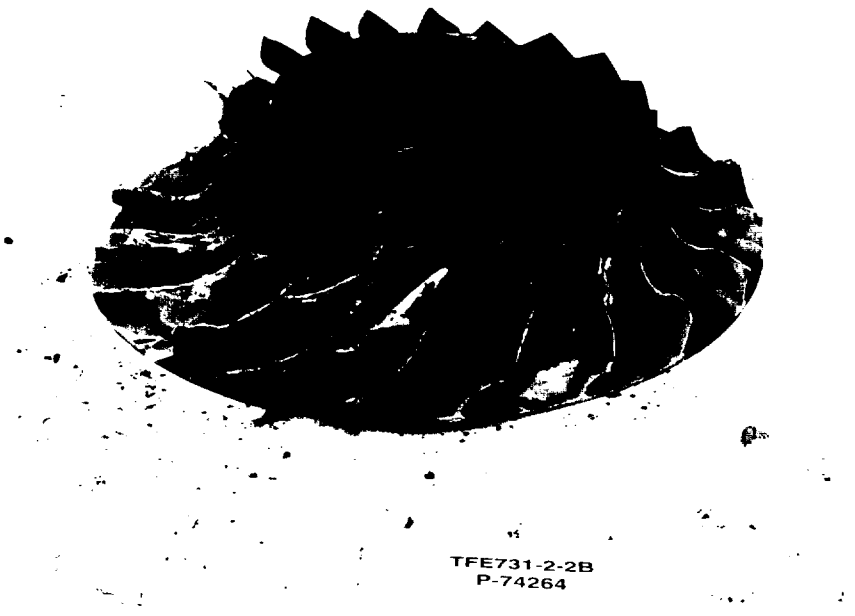


Figure 55. (Photo No. 42-18) Damaged HP Compressor Impeller Blades.

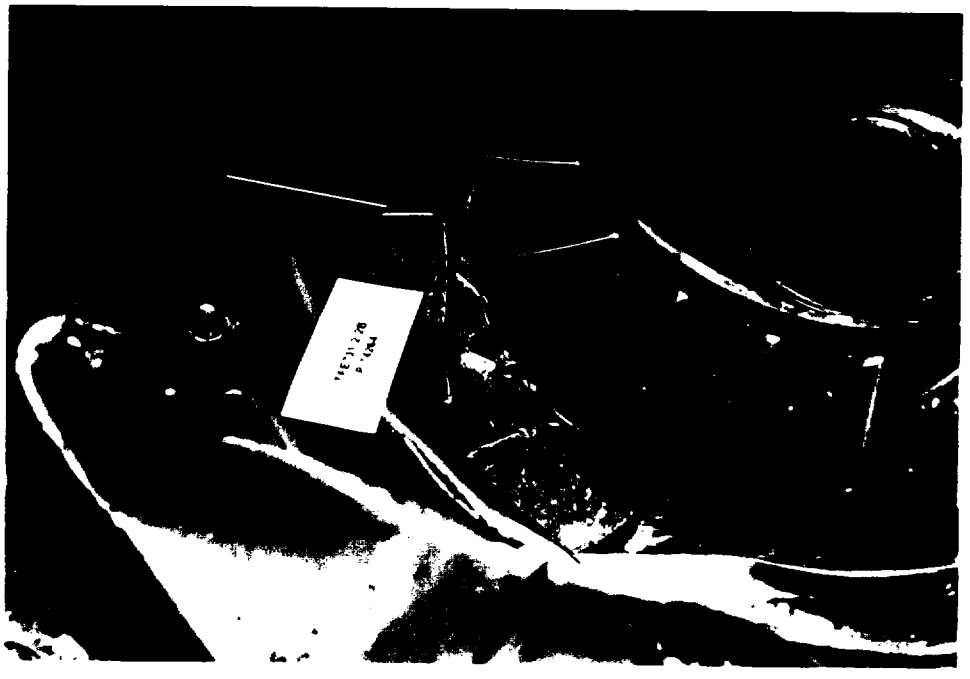


Figure 56. (Photo No. 37-31) Bent HP Compressor Impeller Blades, and Damaged Impeller Shroud.

Figure 57. (Photo No. 42-19) Scored HP Compressor Rotor.

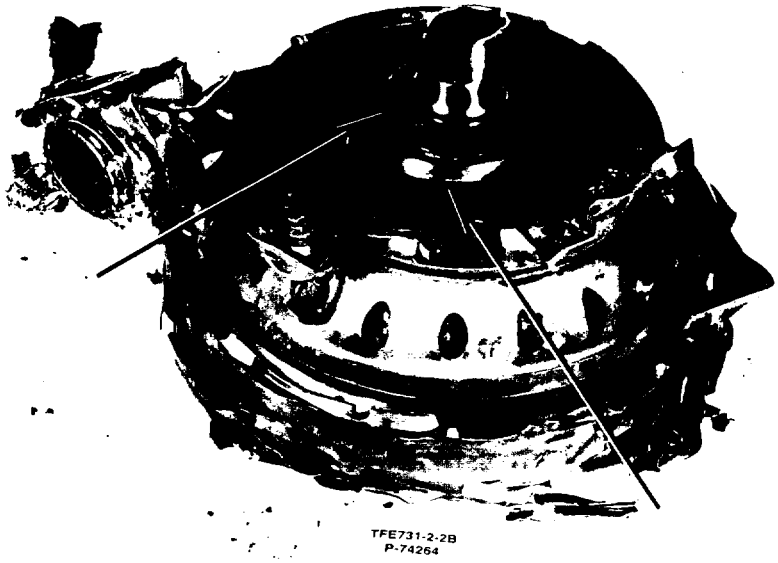


Figure 58. (Photo No. 33-36) Damaged Compressor Housing with Score Marks, and Broken HP Shaft.

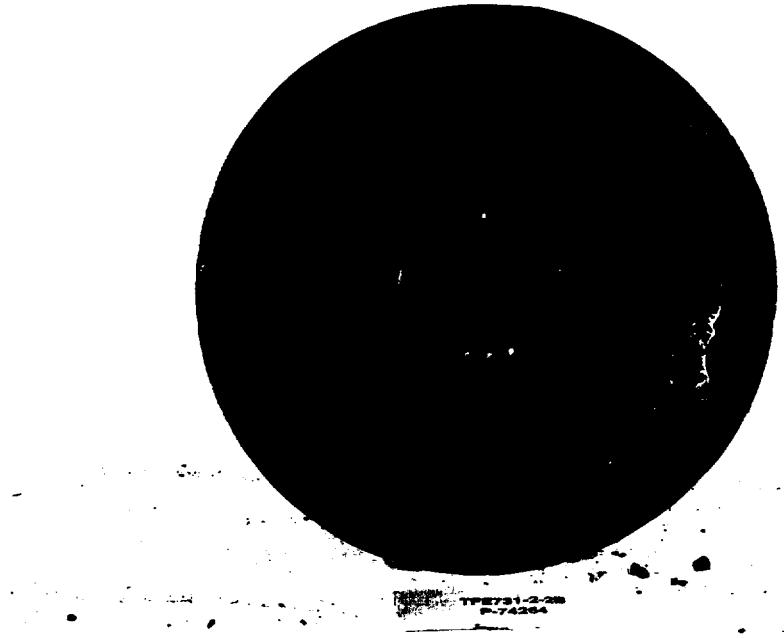
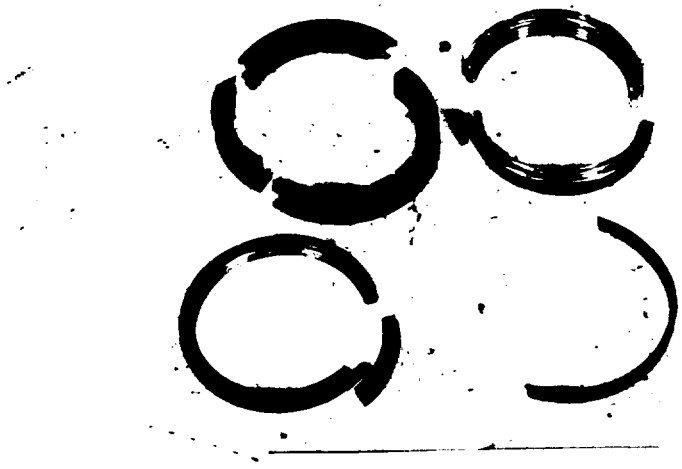


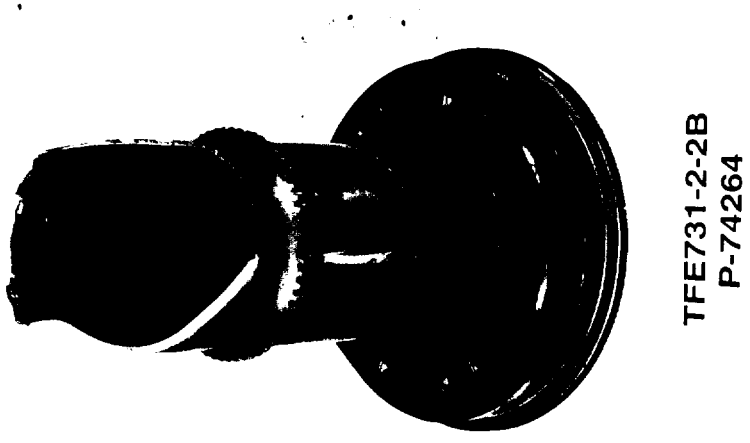
Figure 59. (Photo No. 42-20) Scored Impeller Backface.

Figure 60. (Photo No. 42-21) Damaged Curvic Coupling.



TFE731-2-2B
P-74264

Figure 61. (Photo No. 37-25) Cut HP Shaft Retainer and Seal Rotor.



TFE731-2-2B
P-74264

Figure 62. (Photo No. 31-19) Broken HP Shaft.

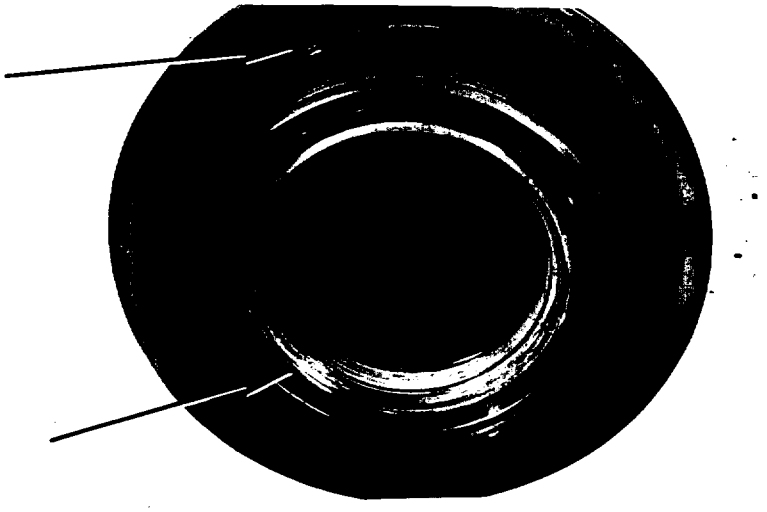


Figure 63. (Photo No. 31-21) Scored HP Shaft (With Burr).

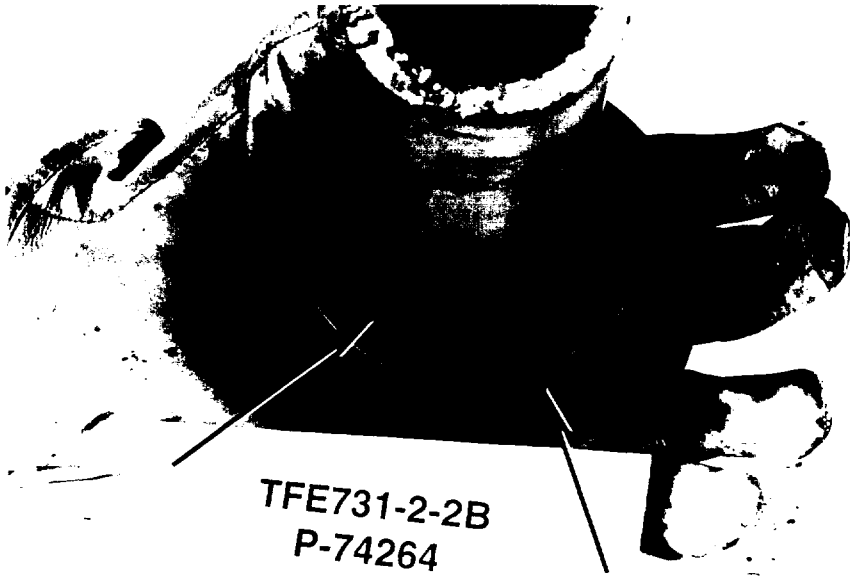


Figure 64. (Photo No. 31-18) Scored LP Shaft and Seal Assembly.

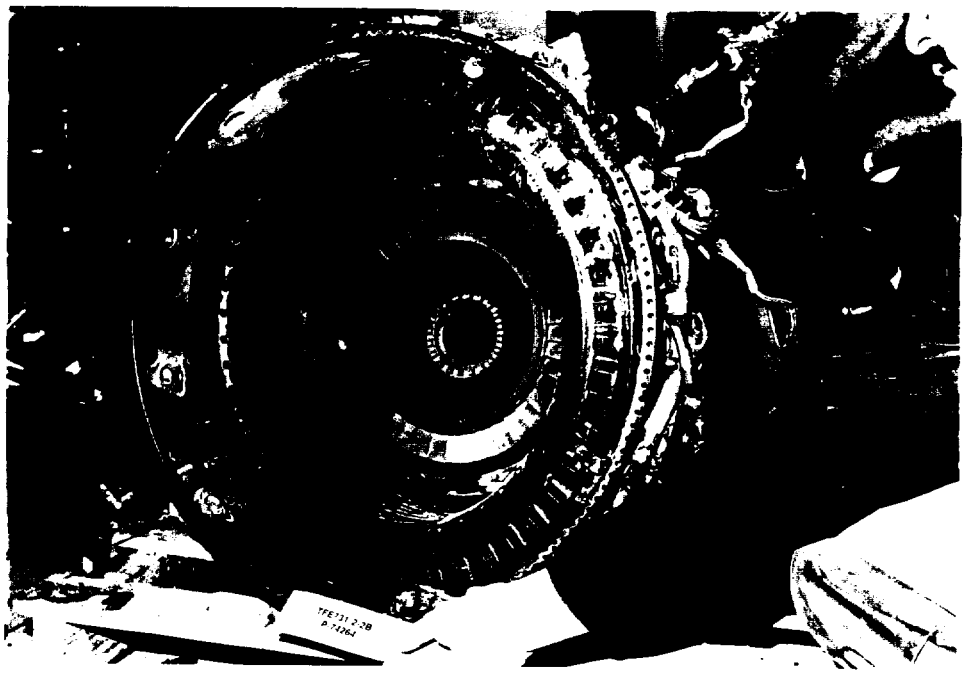


Figure 65. (Photo No. 29-29) Broken Fuel Nozzle Housings, and HP Turbine Nozzle.

Figure 66. (Photo No. 29-28) White Substance on the Combustion Chamber Liner, and Debris on the Combustion Chamber Case.

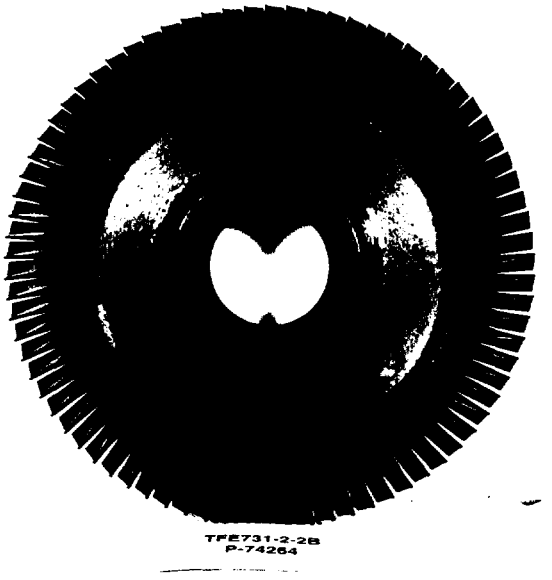


Figure 67. (Photo No. 36-5) HP Turbine Rotor.

Figure 68. (Photo No. 36-6) HP Turbine Rotor.

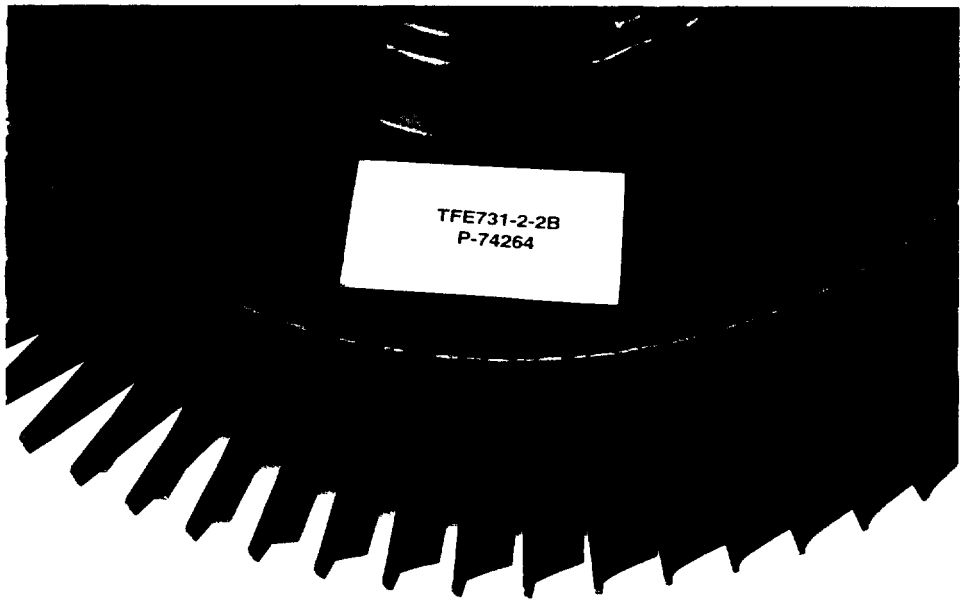


Figure 69. (Photo No. 36-9) Platform Rub on the HP Turbine Rotor Blades.

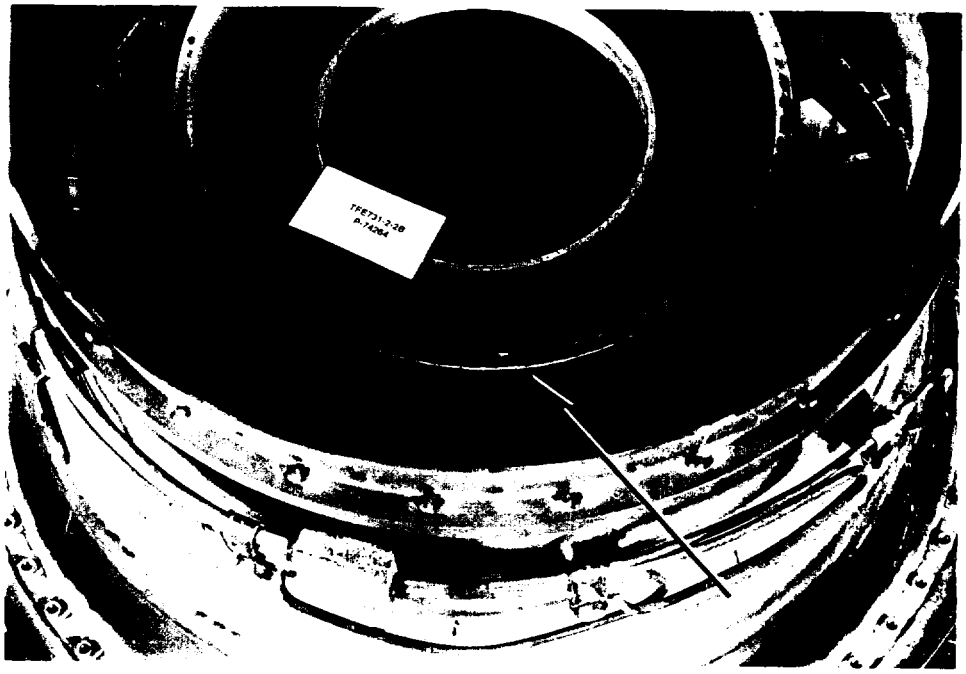


Figure 70. (Photo No. 36-3) Scored Interstage Transition Duct.

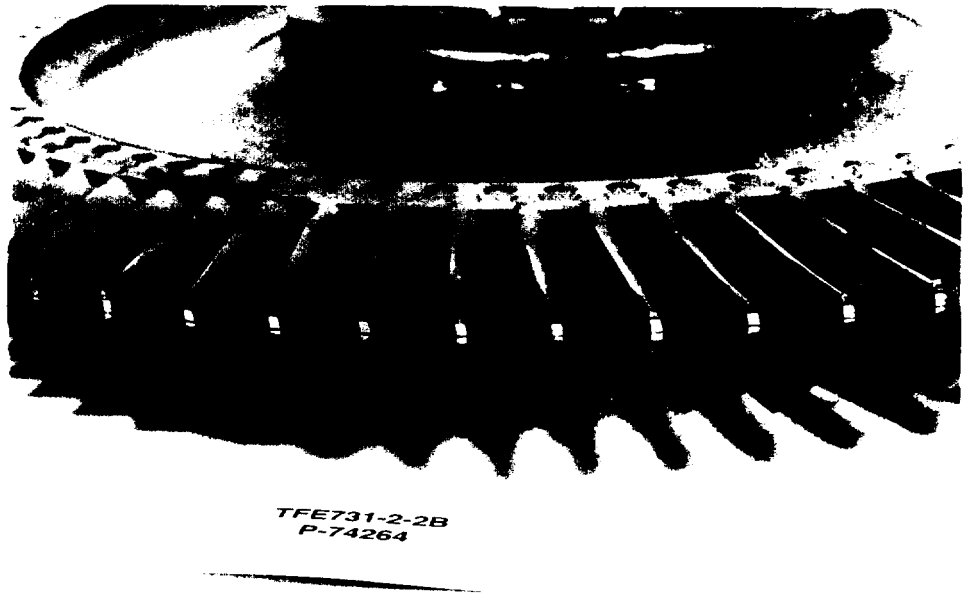


Figure 71. (Photo No. 36-11) Blade-Tip Rub on the HP Turbine Rotor Blades.

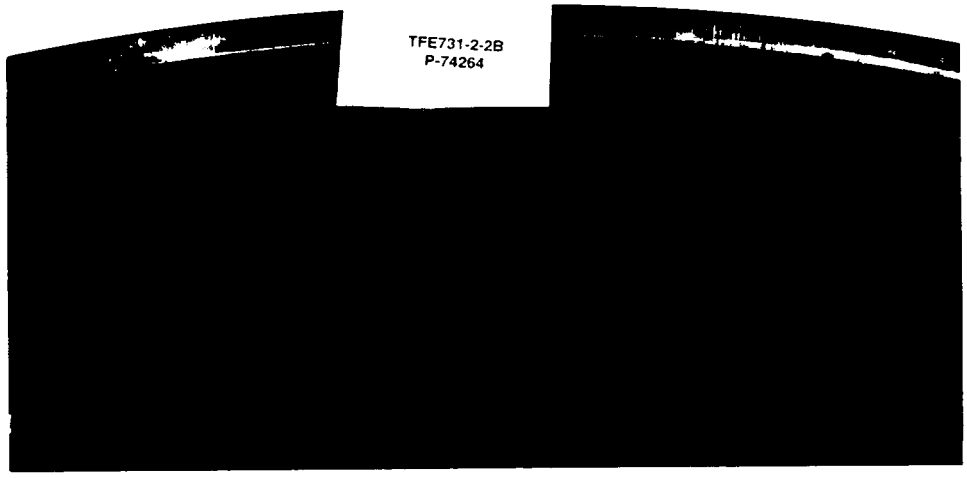


Figure 72. (Photo No. 29-36) Scored Blade-Tip Shrouds.

Figure 73. (Photo No. 36-10) Impact Marks on the HP Turbine Rotor Disk, and Damaged Forward Curvic Coupling.

Figure 74. (Photo No. 36-8) Damaged Aft Curvic Coupling.

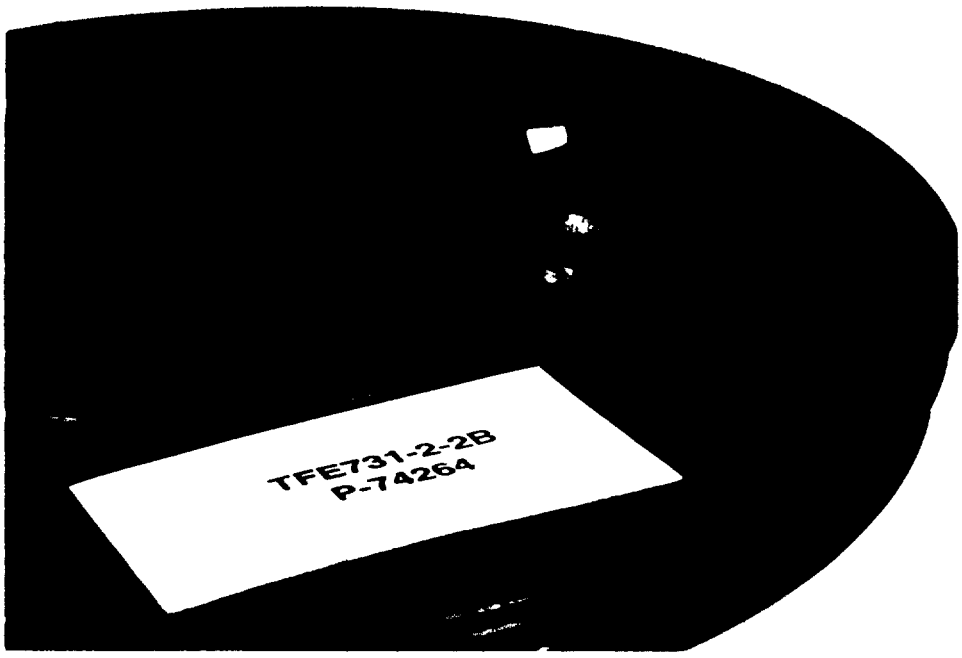


Figure 75. (Photo No. 36-14) Impact Marks on the HP Center Curvic Coupling.

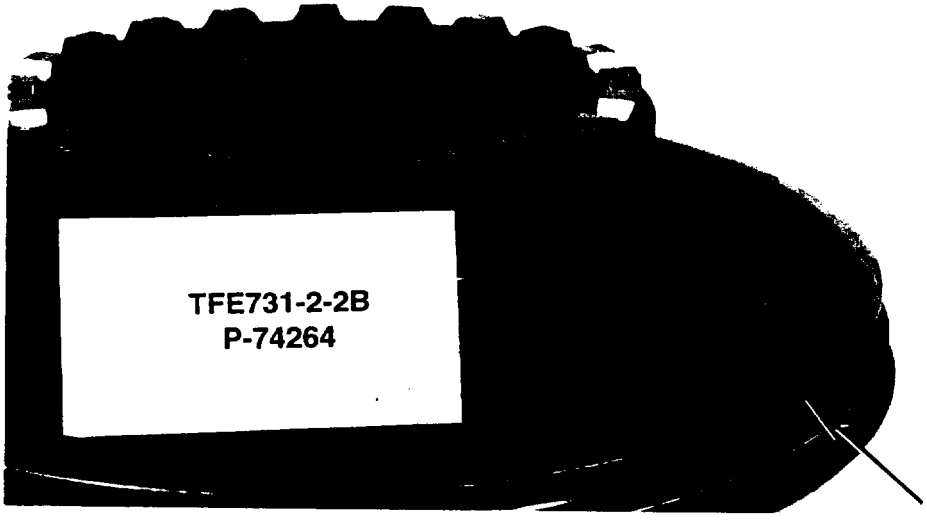


Figure 76. (Photo No. 36-16) Scored HP Center Curvic Coupling.

Figure 77. (Photo No. 36-15) Scored HP Center Curvic Coupling.

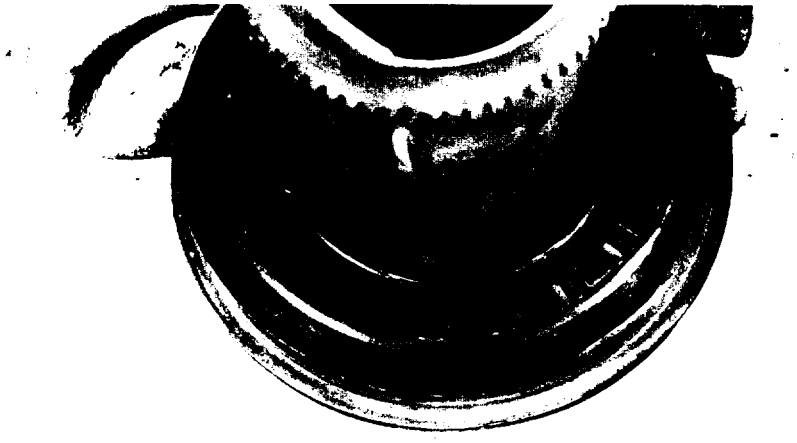


Figure 78. (Photo No. 31-20) Damaged Teeth on the HP Aft Curvic Coupling.

Figure 79. (Photo No. 29-19) Contact Marks on the N1 Monopole.

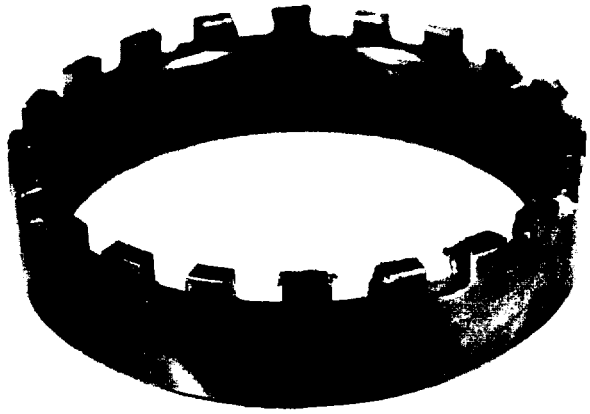


Figure 80. (Photo No. 29-9) Metal Shavings on the Retainer Nut.

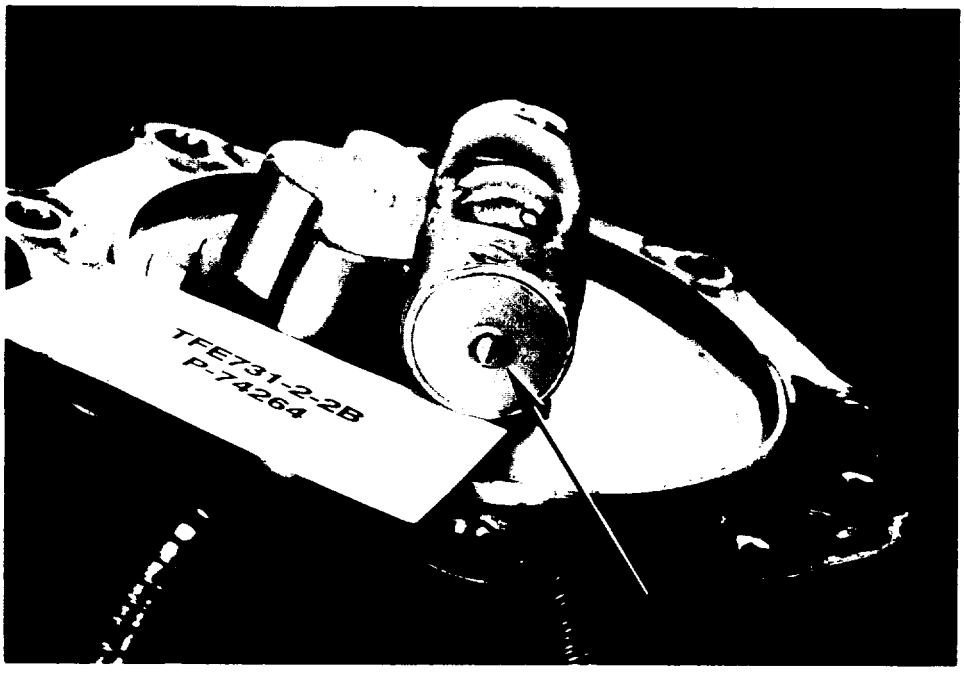


Figure 81. (Photo No. 29-20) Contact Mark on the N1 Monopole.

Figure 82. (Photo No. 29-10) Contact Mark on the N1 Speed Pickup Gear.

Figure 83. (Photo No. 29-15) Chipped No. 6 Air/Oil Carbon Seal.

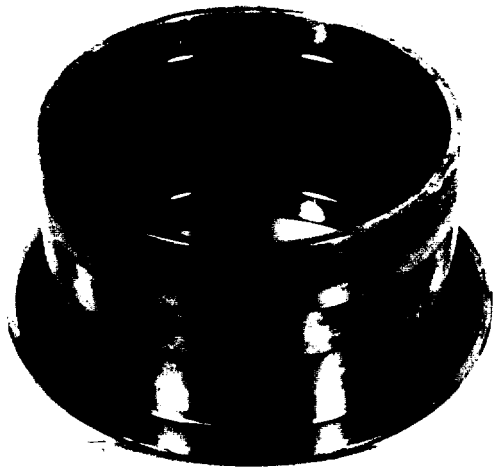


Figure 84. (Photo No. 29-22) No. 6 Air/Oil Seal Rotor.

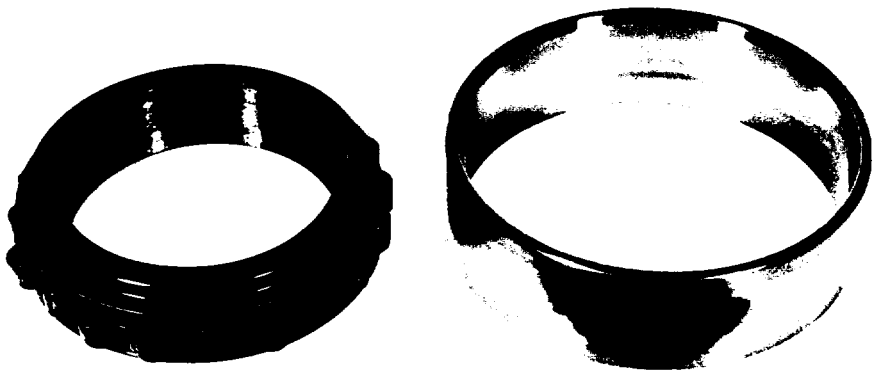


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Figure 85. (Photo No. 29-14) No. 6 LP Rotor Aft Roller Bearing.

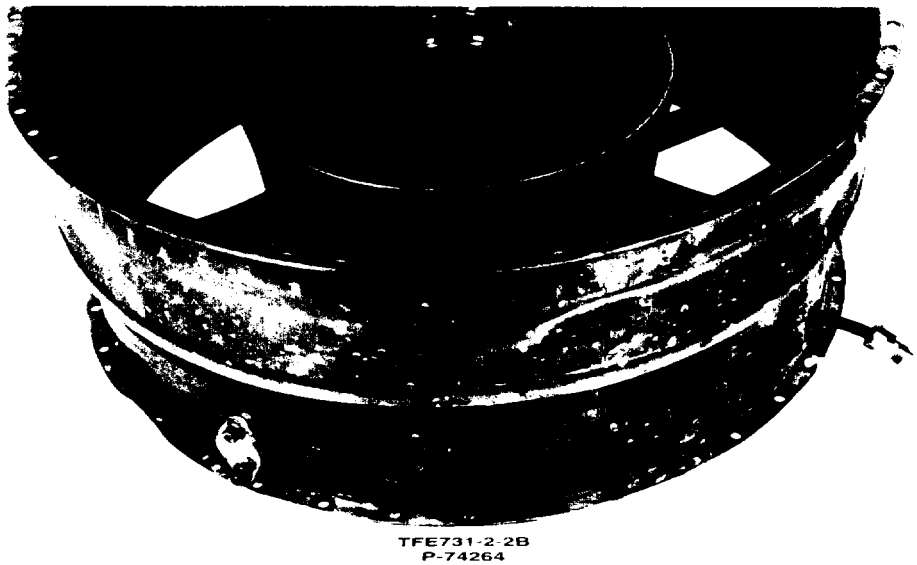

Figure 86. (Photo No. 29-17) Wrinkled Thrust and Exhaust Nozzle.

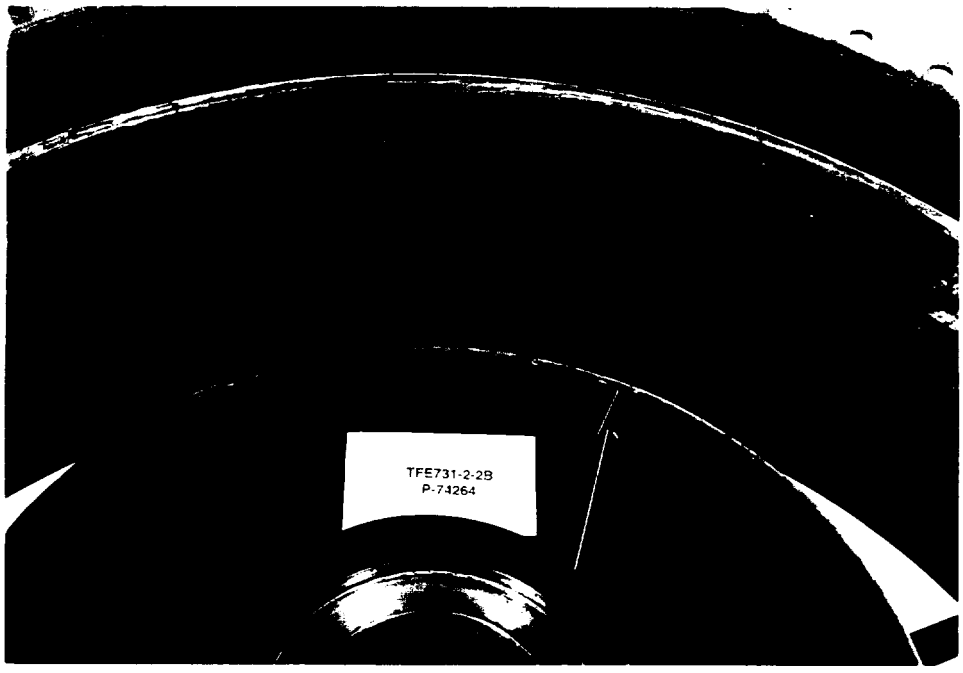

Figure 87. (Photo No. 33-22) Scored Thrust and Exhaust Nozzle.

Figure 88. (Photo No. 37-24) Platform Rub on the Third-Stage LP Turbine Rotor Blades.

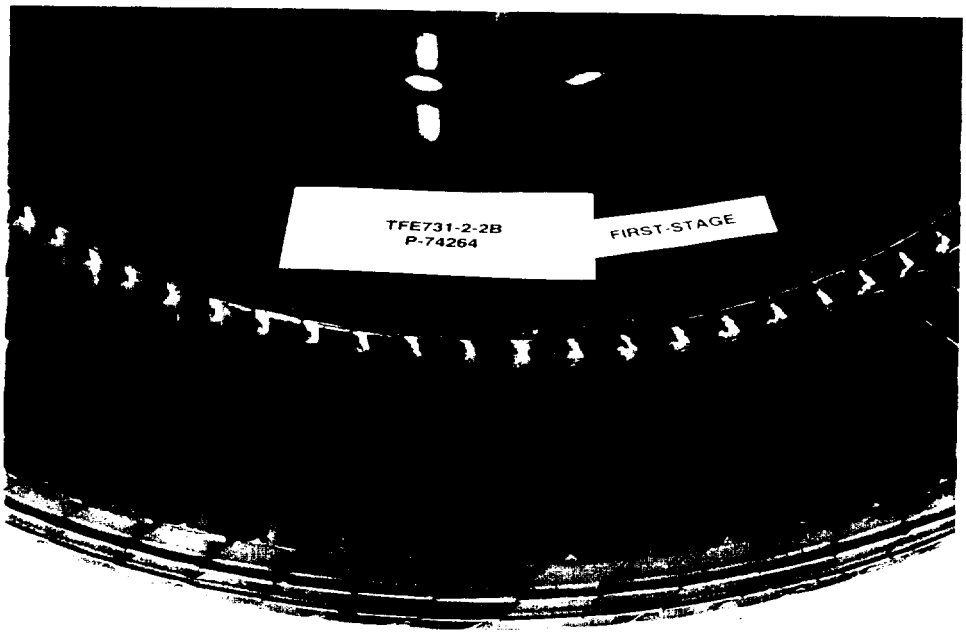

Figure 89. (Photo No. 37-5) Platform Rub on the First-Stage LP Turbine Rotor Blades.

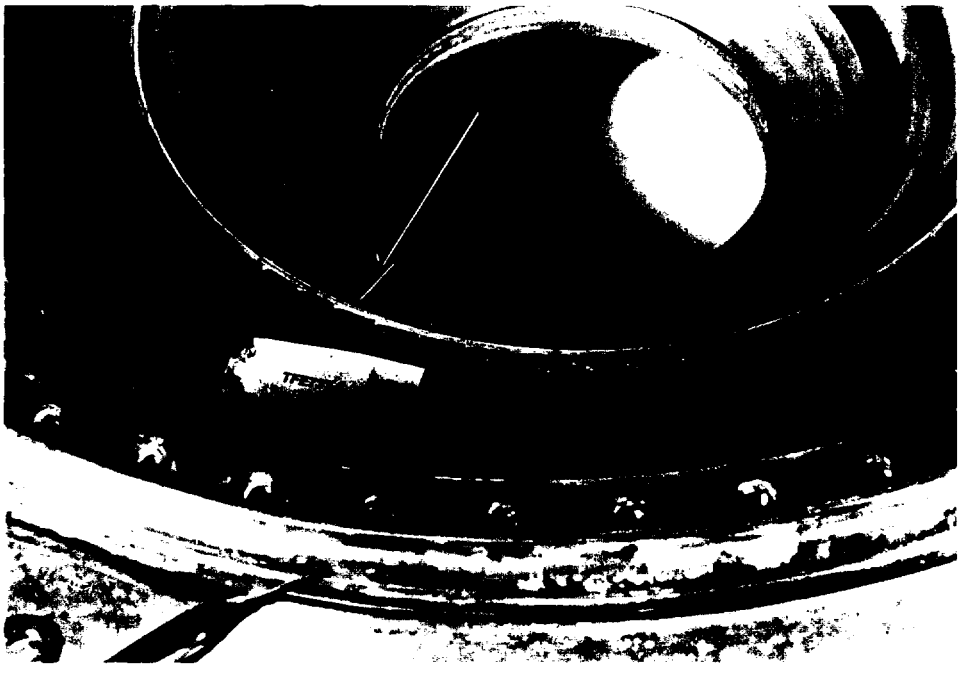

Figure 90. (Photo No. 29-30) Scored First-Stage LP Turbine Stator Vane Support.

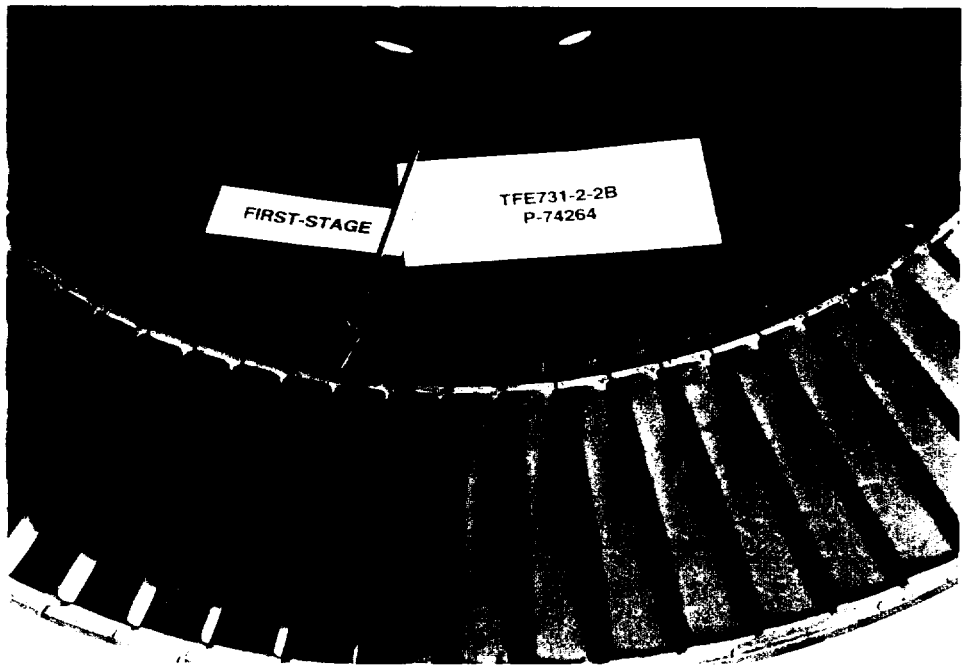

Figure 91. (Photo No. 37-8) Platform Rub on the First-Stage LP Turbine Rotor Blades.

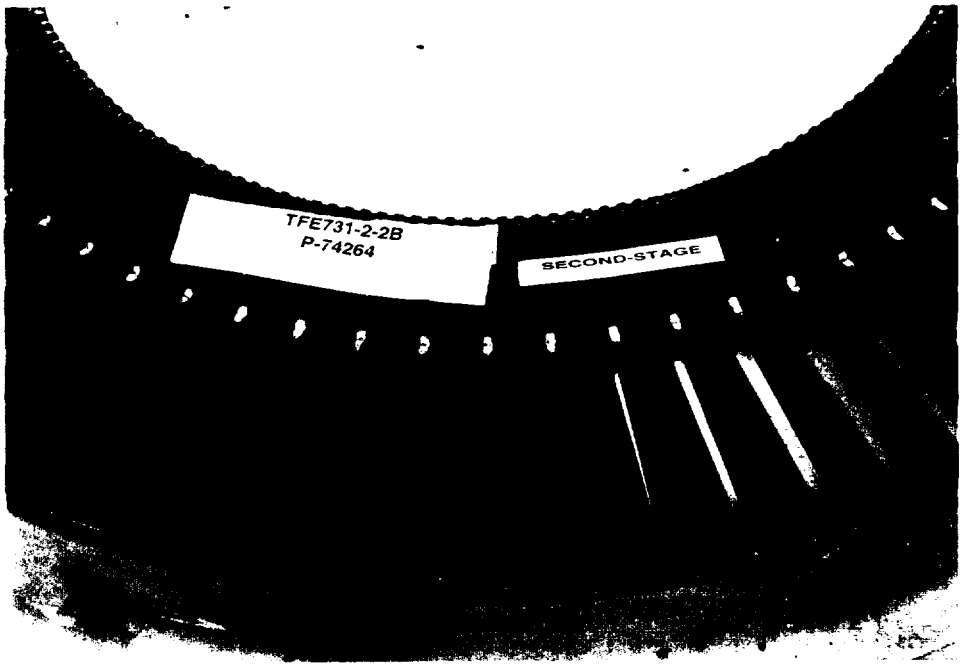

Figure 92. (Photo No. 31-4) Scored Second-Stage LP turbine Stator Vanes.

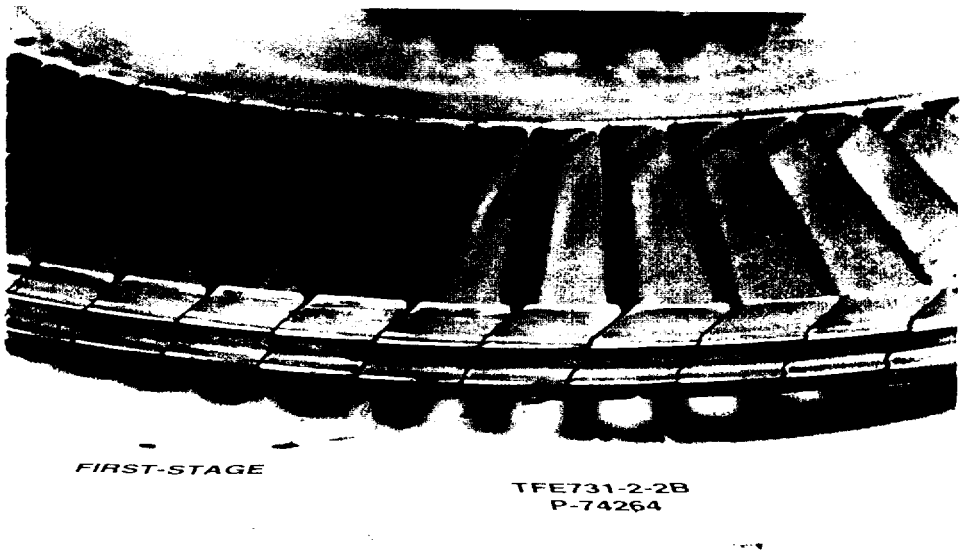

Figure 93. (Photo No. 37-9) Blade-Tip Rub on the First-Stage LP Turbine Rotor Blades.

Figure 94. (Photo No. 29-32) Scored Blade-Tip Shroud.

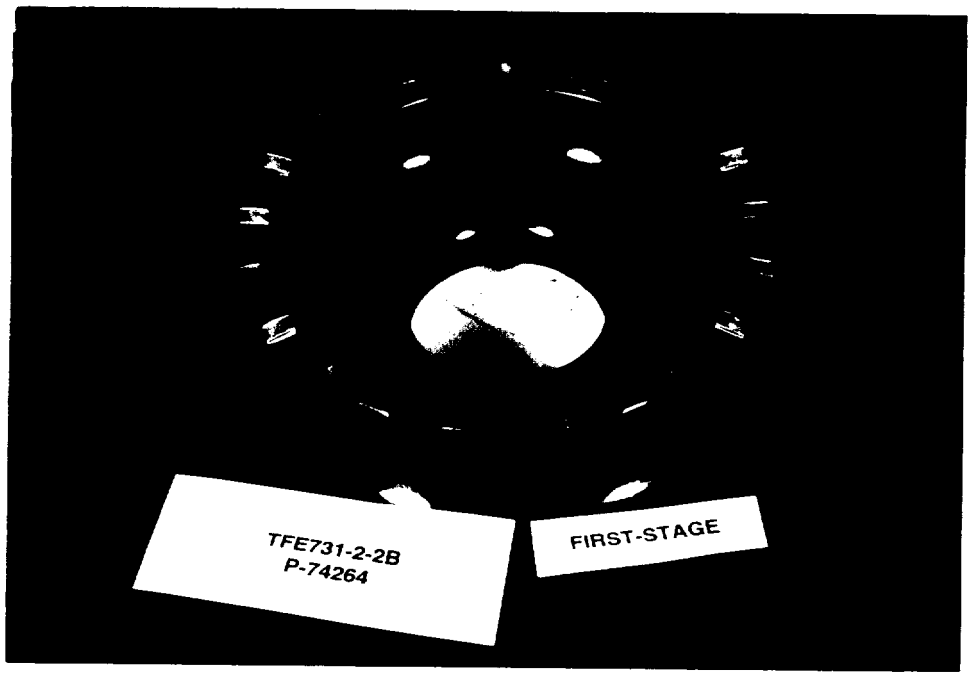

Figure 95. (Photo No. 37-6) Damaged Forward Curvic Coupling Teeth.

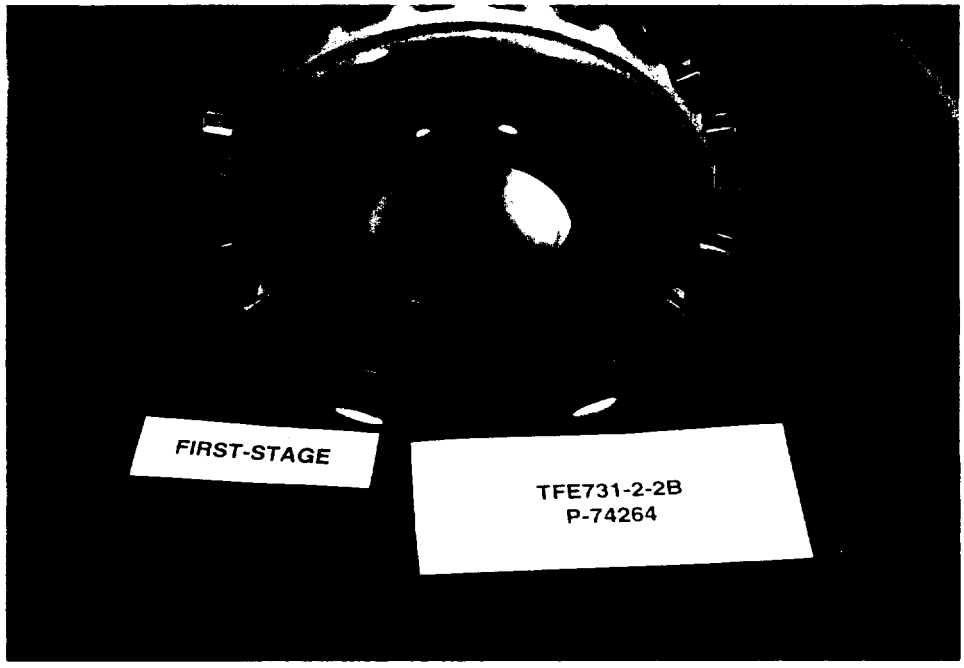

Figure 96. (Photo No. 37-7) Damaged Aft Curvic Coupling Teeth.

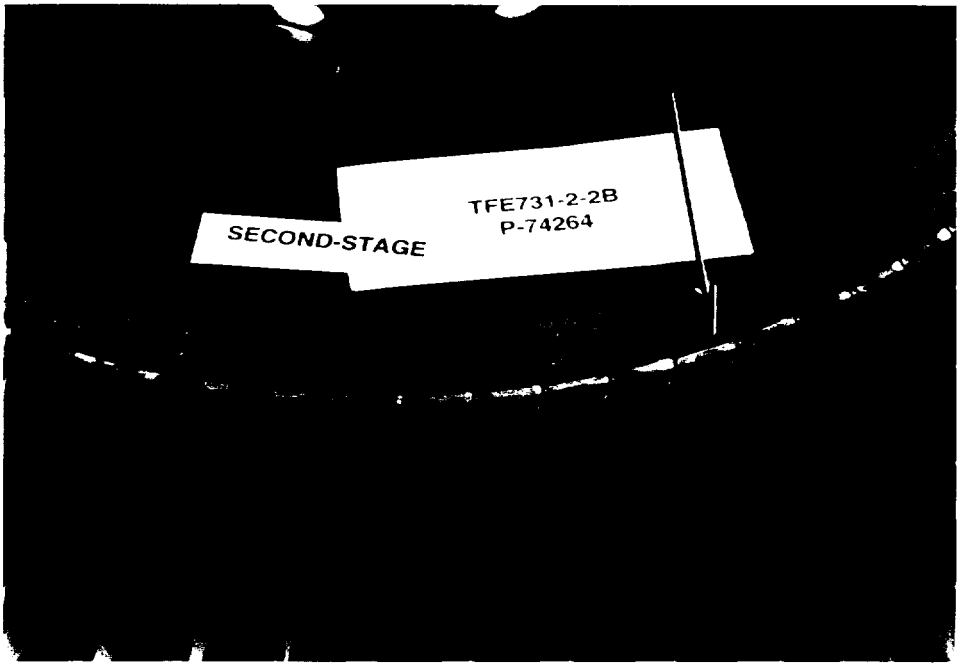

Figure 97. (Photo No. 37-13) Platform Rub on the Second-Stage LP Turbine Rotor Blades.

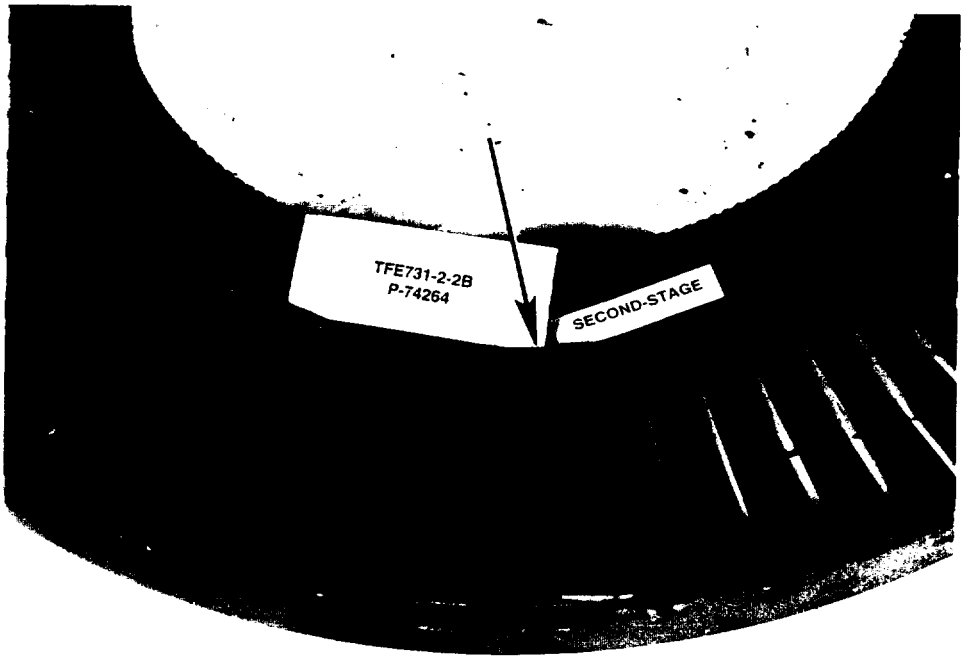

Figure 98. (Photo No. 37-36) Scored Second-Stage LP Turbine Stator Vane Support.

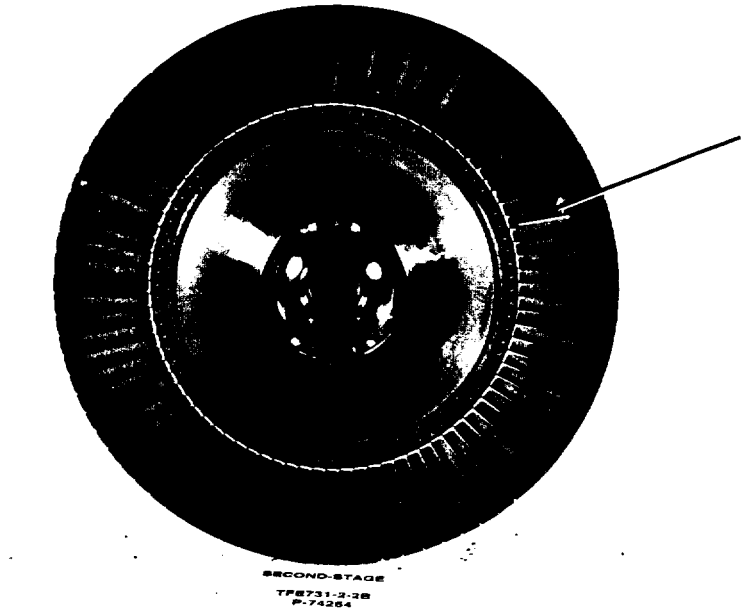

Figure 99. (Photo No. 37-10) Platform Rub on the Second-Stage LP Turbine Rotor Blades.

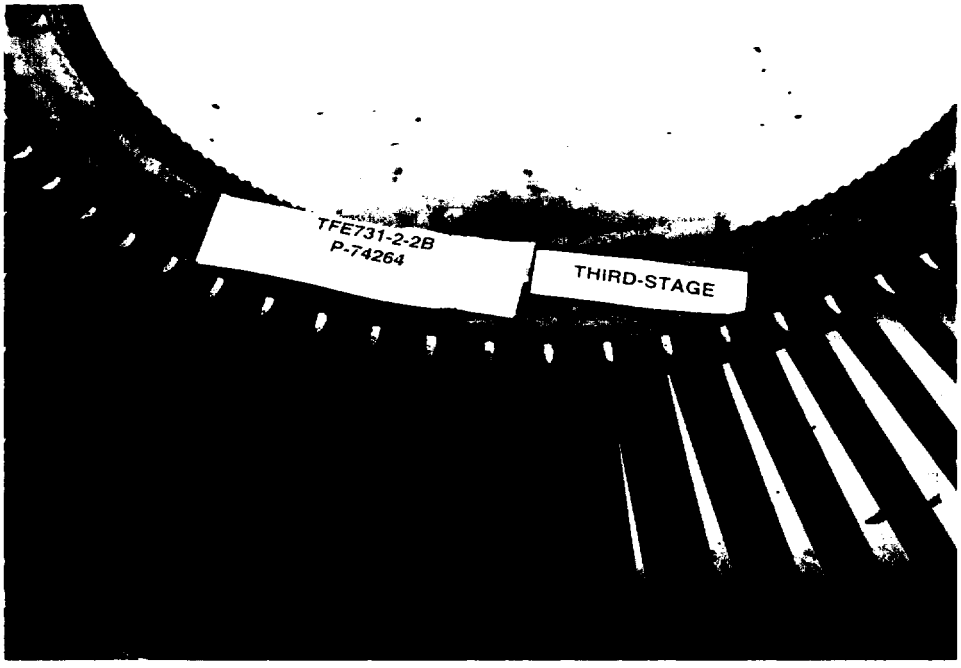

Figure 100. (Photo No. 31-8) Scored Third-Stage LP Turbine Stator Vanes.

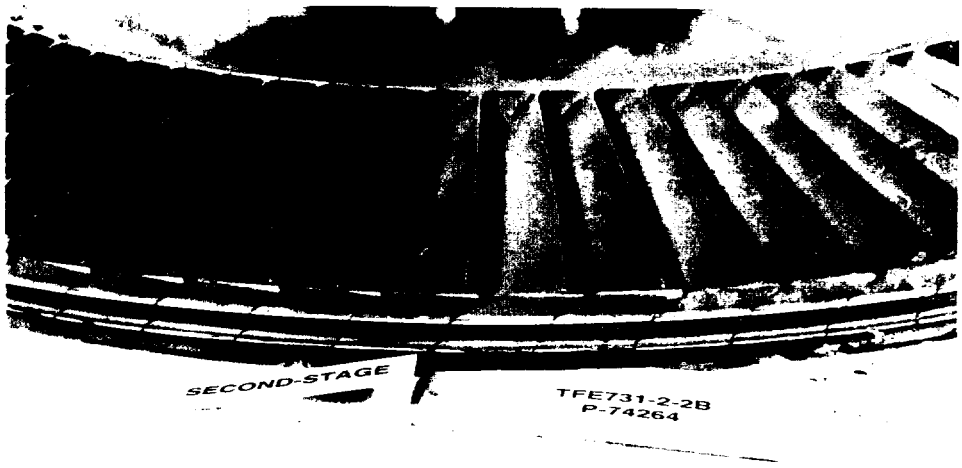

Figure 101. (Photo No. 37-16) Blade-Tip Rub on the Second-Stage LP Turbine Rotor Blades.

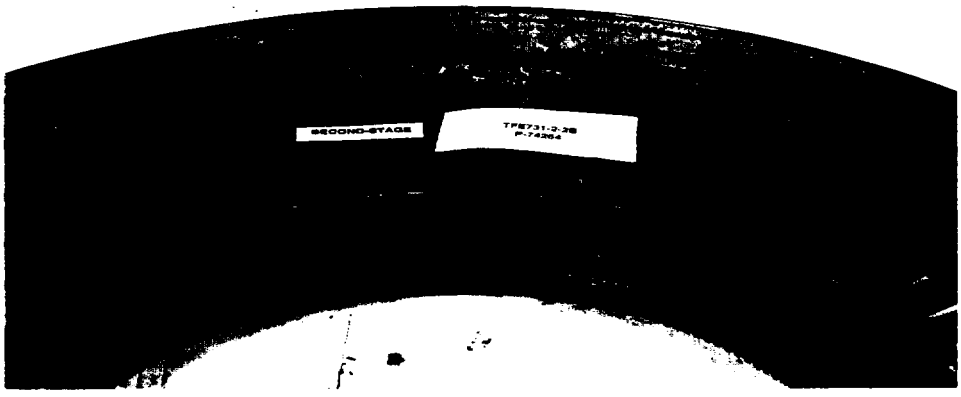

Figure 102. (Photo No. 37-37) Scored Blade-Tip Shroud.

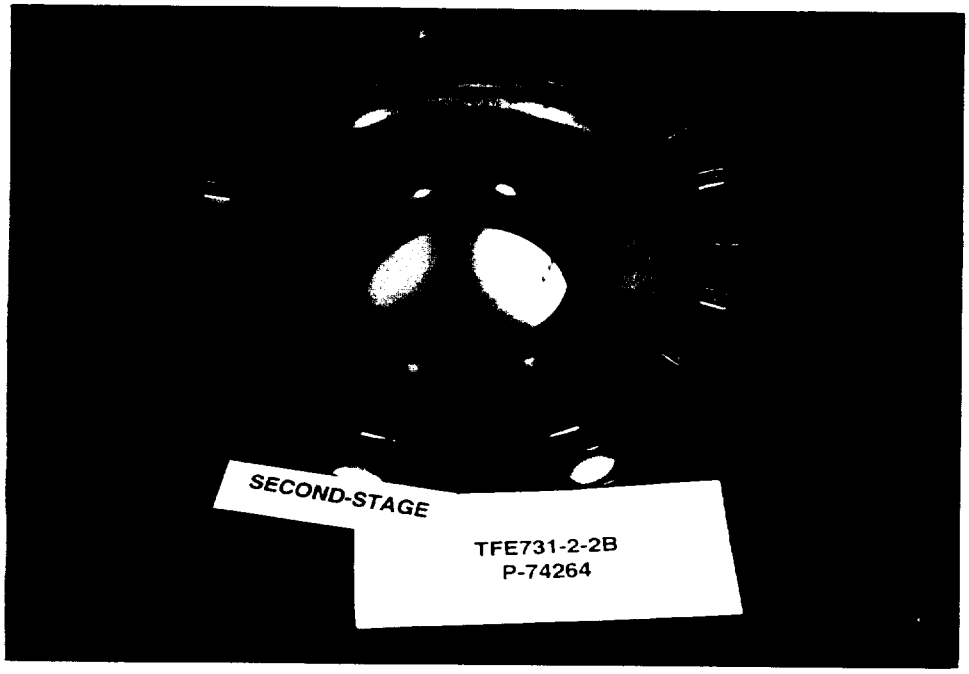

Figure 103. (Photo No. 37-12) Damaged Forward Curvic Coupling Teeth.

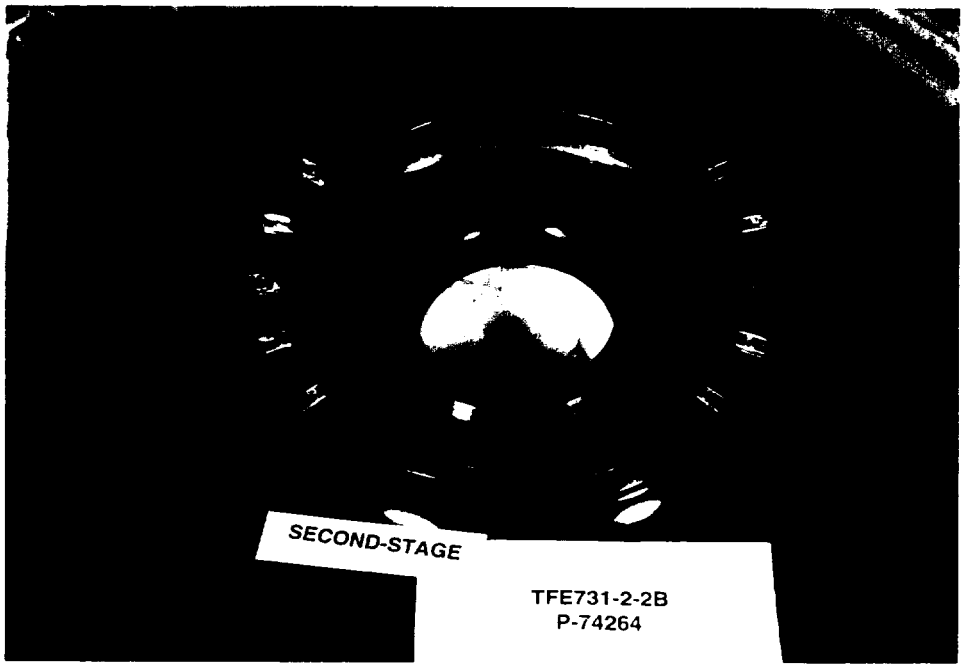

Figure 104. (Photo No. 37-15) Damaged Aft Curvic Coupling Teeth.

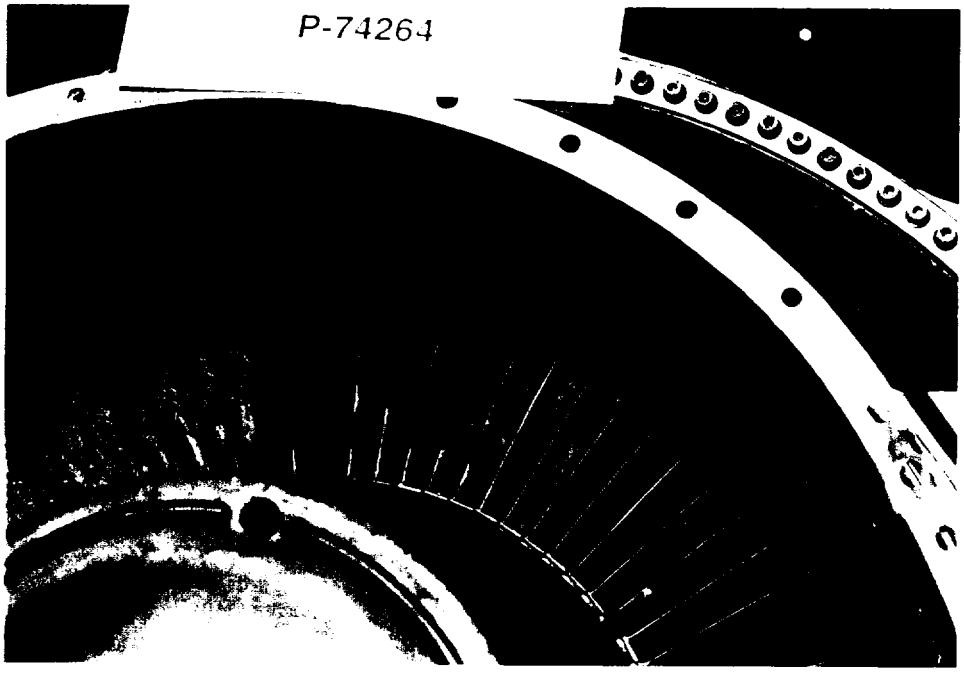

Figure 105. (Photo No. 32-34) Bent Third-Stage LP Turbine Rotor Blades.

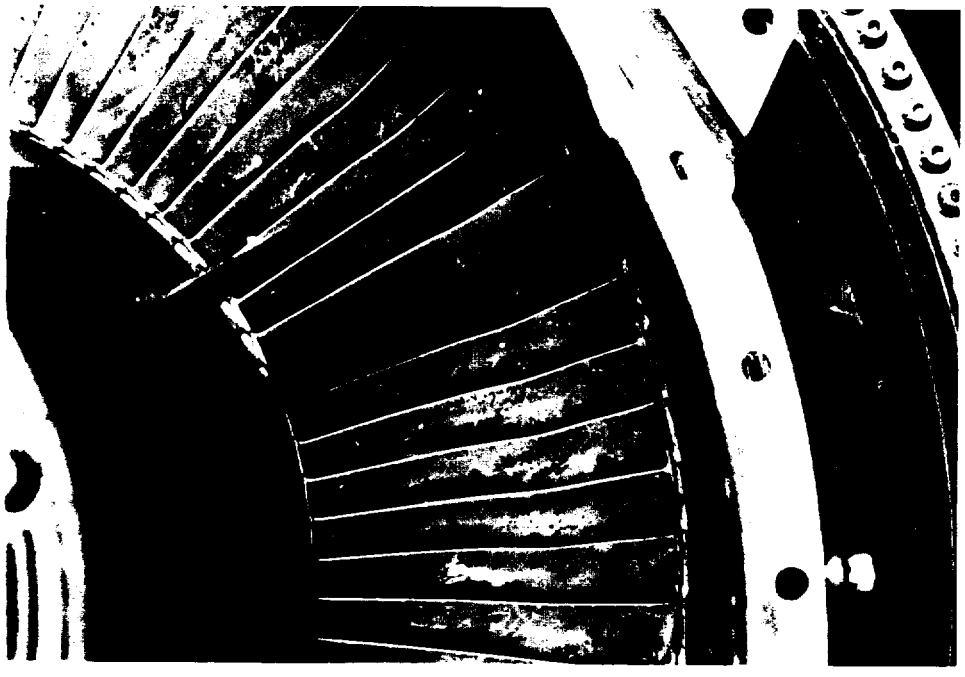

Figure 106. (Photo No. 32-35) Bent Third-Stage LP Turbine Rotor Blades.

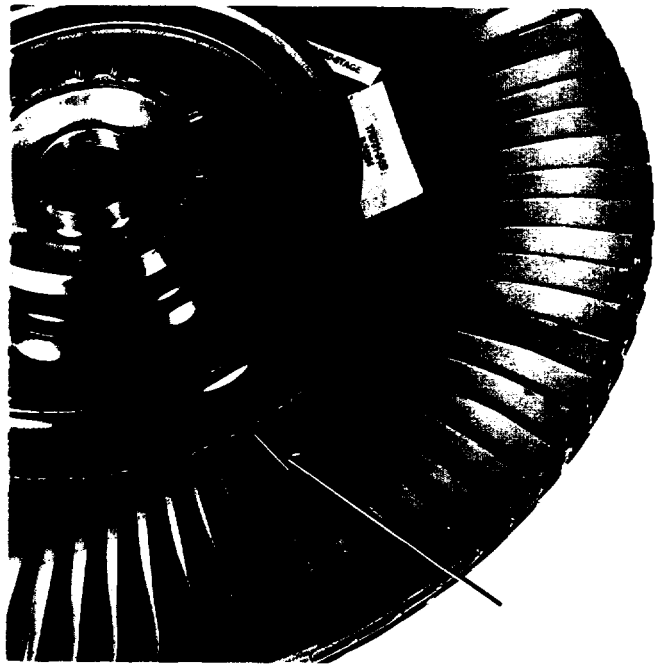

Figure 107. (Photo No. 37-23) Platform Rub on the Third-Stage Turbine Rotor Blades.

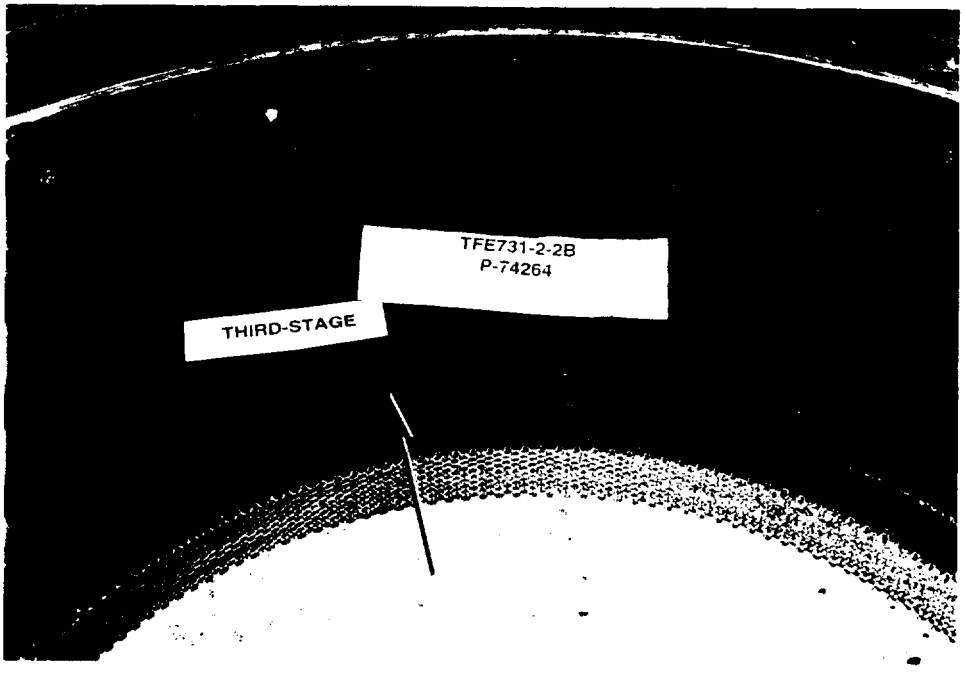

Figure 108. (Photo No. 31-10) Scored Third-Stage LP Turbine Stator Vane Support.

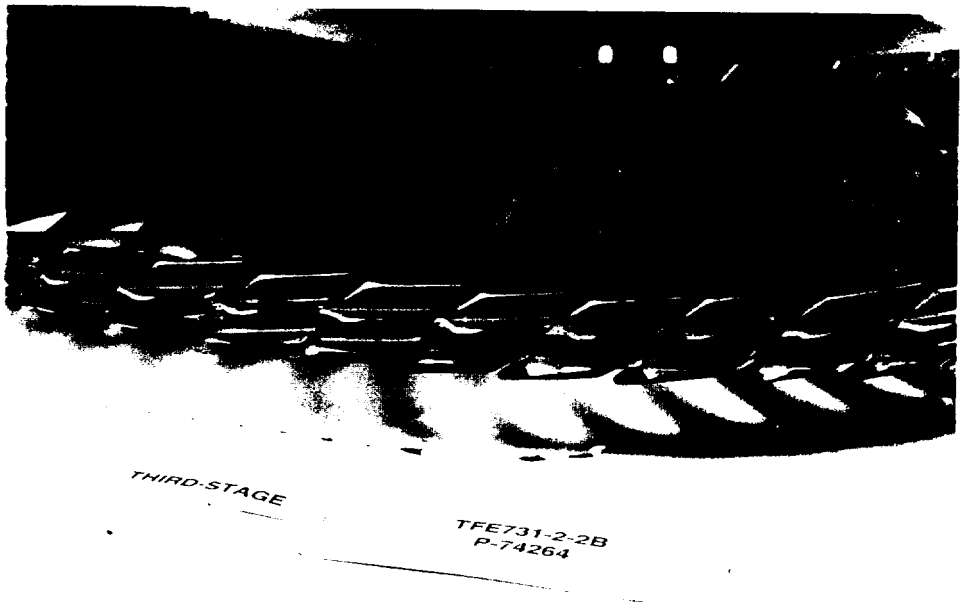

Figure 109. (Photo No. 37-21) Blade-Tip Rub on the Third-Stage LP Turbine Rotor Blades.

Figure 110. (Photo No. 31-9) Scored Blade-Tip Shroud.

Figure 111. (Photo No. 37-22) Damaged Curvic Coupling Teeth.

Figure 112. (Photo No. 29-34) Fractured Interstage Transition Duct.

Figure 113. (Photo No. 29-36) Broken Thermocouple.

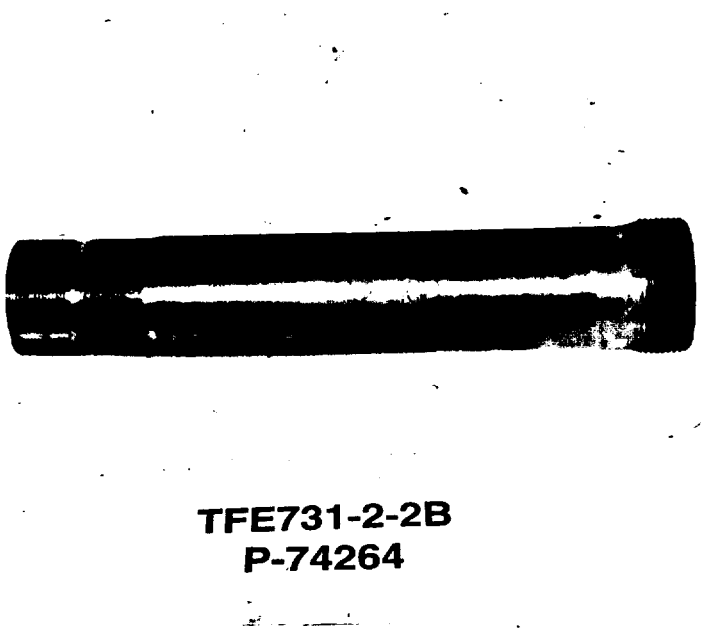

Figure 114. (Photo No. 31-22) LP Turbine Tie Shaft.

Figure 115. (Photo No. 31-15) Damaged Curvic Coupling and Score Marks on the LP Shaft and Seal Assembly.

Figure 116. (Photo No. 31-17) Curvic Coupling.

Figure 117. (Photo No. 31-14) LP Turbine Rotating Seal, Forward View.

Figure 118. (Photo No. 31-13) LP Turbine Rotating Seal, Aft View.

Figure 119. (Photo No. 33-8) Damaged Surge Bleed Valve.

Figure 120. (Photo No. 33-7) Damaged Surge Bleed Valve.

Figure 121. (Photo No. 32-20) Damaged Top Air/Oil Cooler.

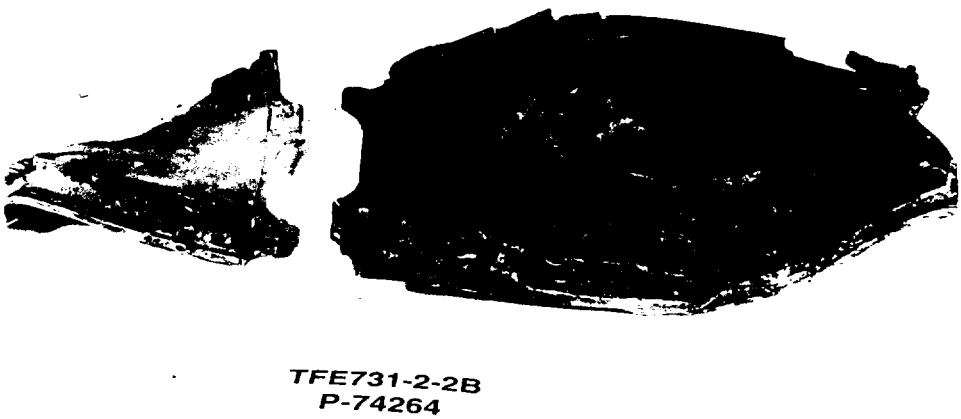

Figure 122. (Photo No. 32-18) Damaged Air/Oil Coolers.

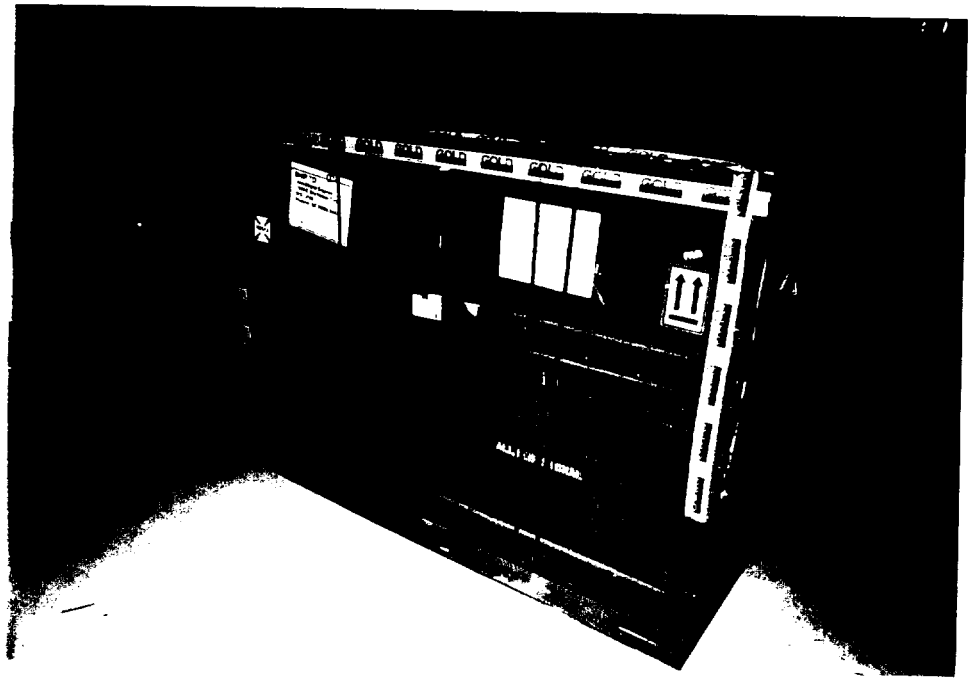

Figure 123. (Photo No. 35-9) Shipping Container.

Figure 124. (Photo No. 43-2) Engine S/N P-74265, as Received.

Figure 125. (Photo No. 43-1) Engine S/N P-74265, as Received.

Figure 126. (Photo No. 43-4) Engine S/N P-74265, as Received.

Figure 127. (Photo No. 41-3) Engine S/N P-74265, After Decontamination.

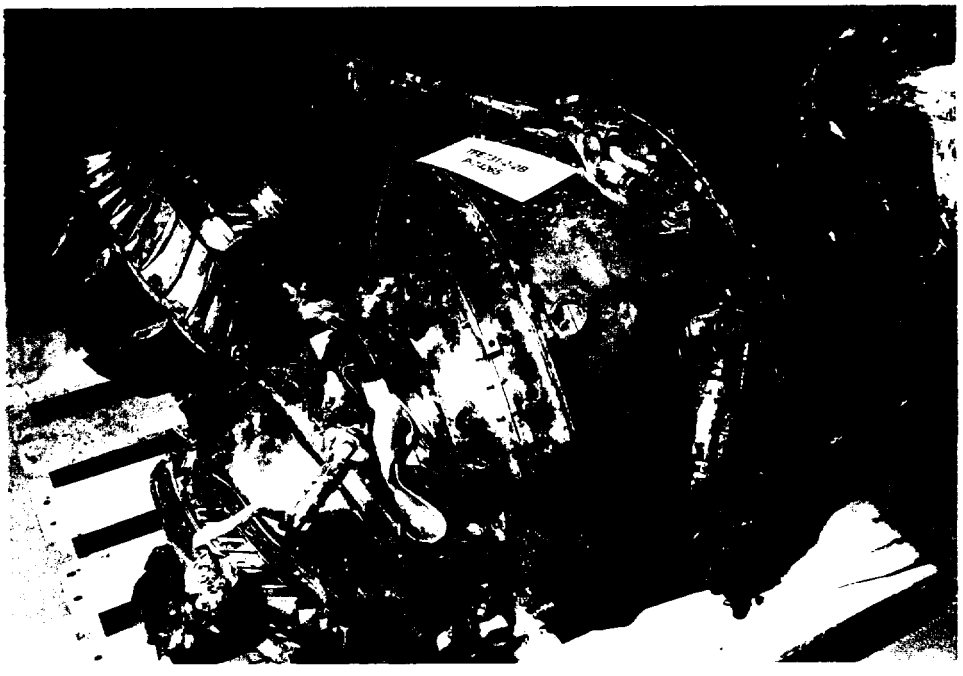

Figure 128. (Photo No. 41-4) Engine S/N P-74265, After Decontamination.

Figure 129. (Photo No. 42-14) Aircraft/Engine Mount.

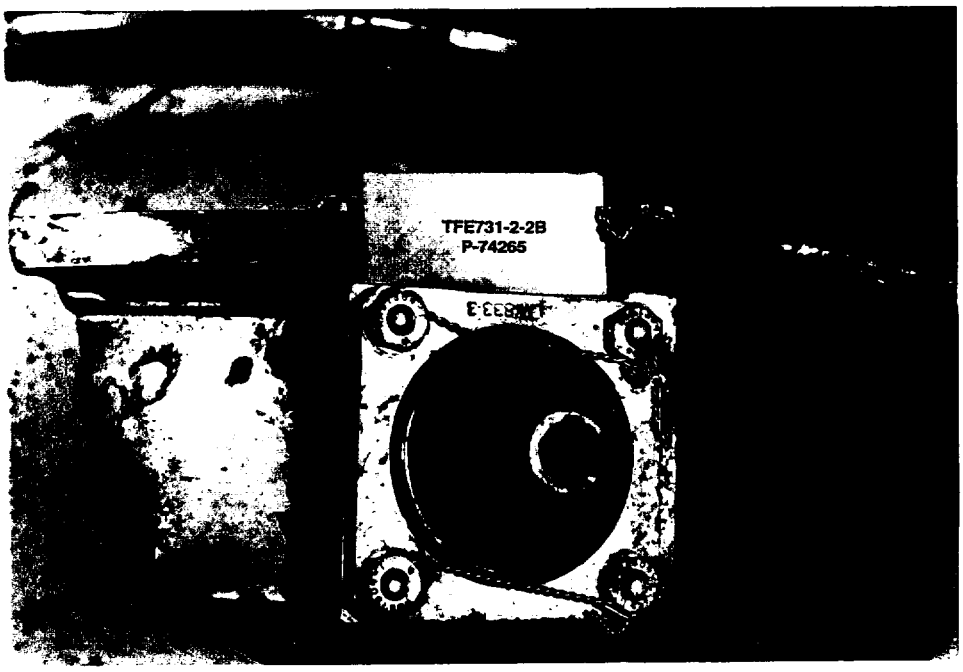

Figure 130. (Photo No. 42-13) Aircraft/Engine Mount.

Figure 131. (Photo No. 28-11) Fan Spinner Fragments.

Figure 132. (Photo No. 32-37) Fan Spinner Fragment Lodged in Fan Shaft. (Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

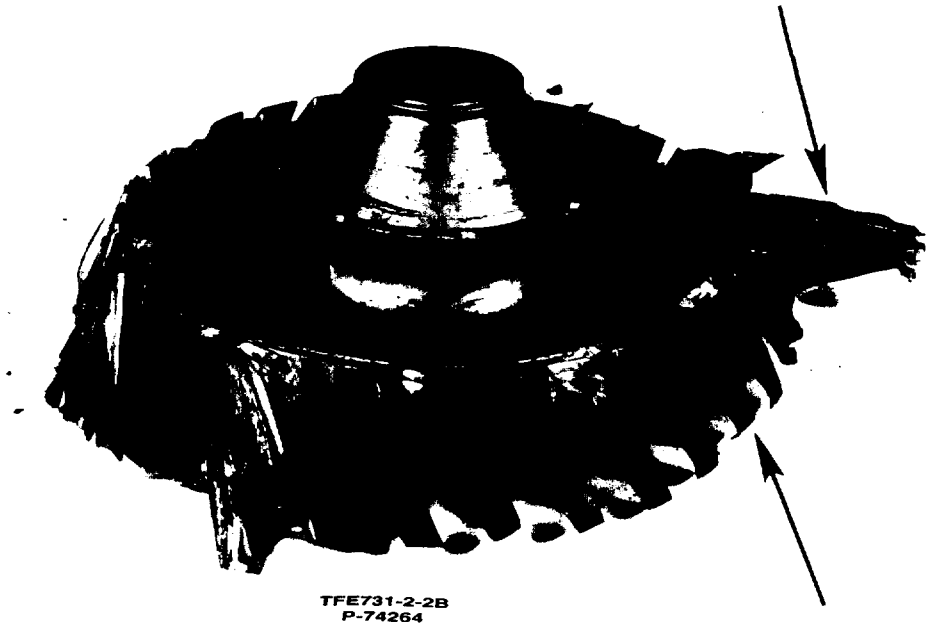

Figure 133. (Photo No. 33-26) Damaged Fan Disk Dovetails, and Damaged Fan Blades. (Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

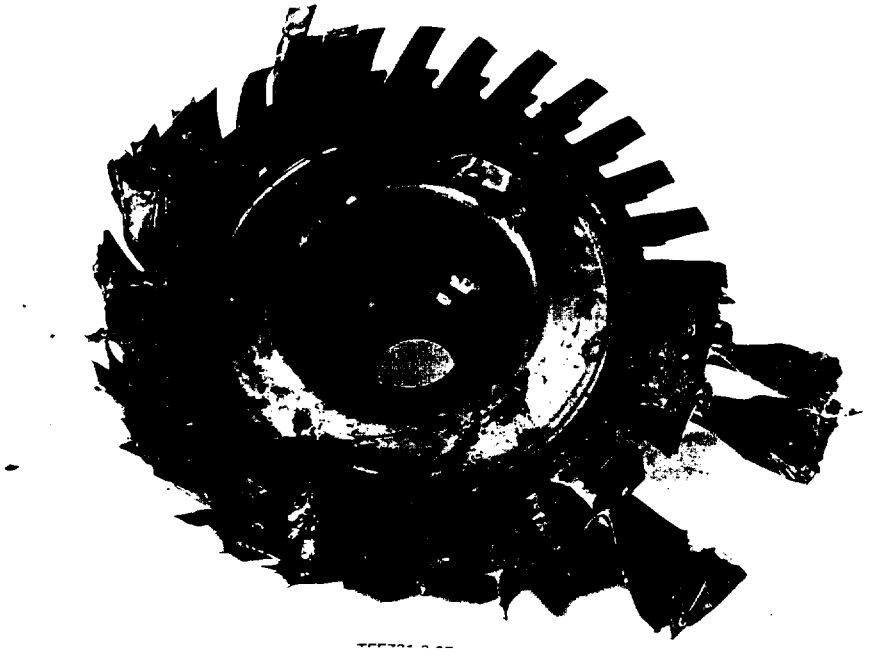

Figure 134. (Photo No. 33-25) Damaged Fan Disk Dovetails, and Damaged Fan Blades. (Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

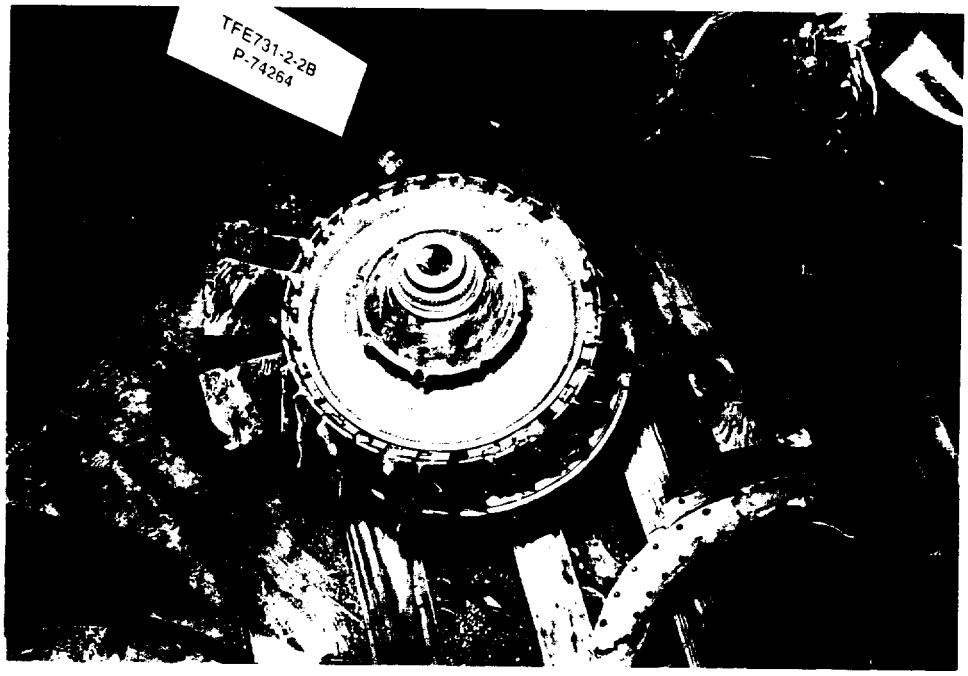

Figure 135. (Photo No. 30-5) Bent and Broken Fan Blades.
(Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

Figure 136. (Photo No. 32-17) Fan Blade Fragments.
(Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

Figure 137. (Photo No. 33-28) Fractured Fan Support Housing.
(Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

Figure 138. (Photo No. 33-29) Damaged No. 1 Carbon Seal.
(Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

Figure 139. (Photo No. 33-30) Planetary Gear Assembly, and Main Mount Fragment with Score Marks.
(Part of Engine S/N P-74265 - S/N P-74264 On Placard In Photo Is In Error.)

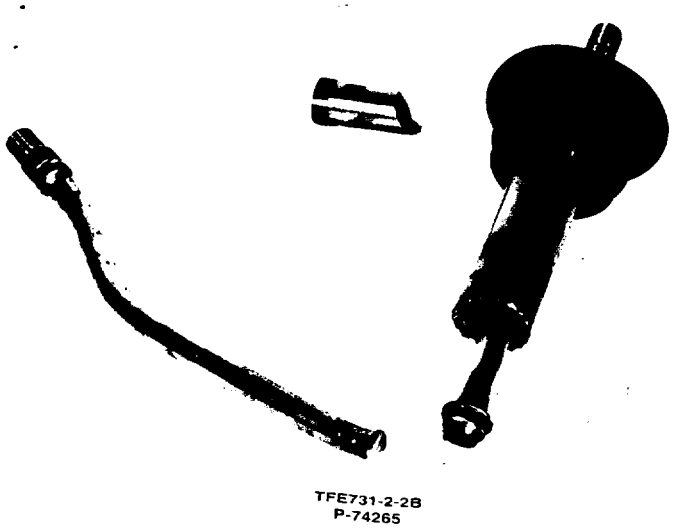

Figure 140. (Photo No. 45-29) Damaged Tie Bolt, Broken LP Turbine Tie Shaft, and LP Shaft and Seal.

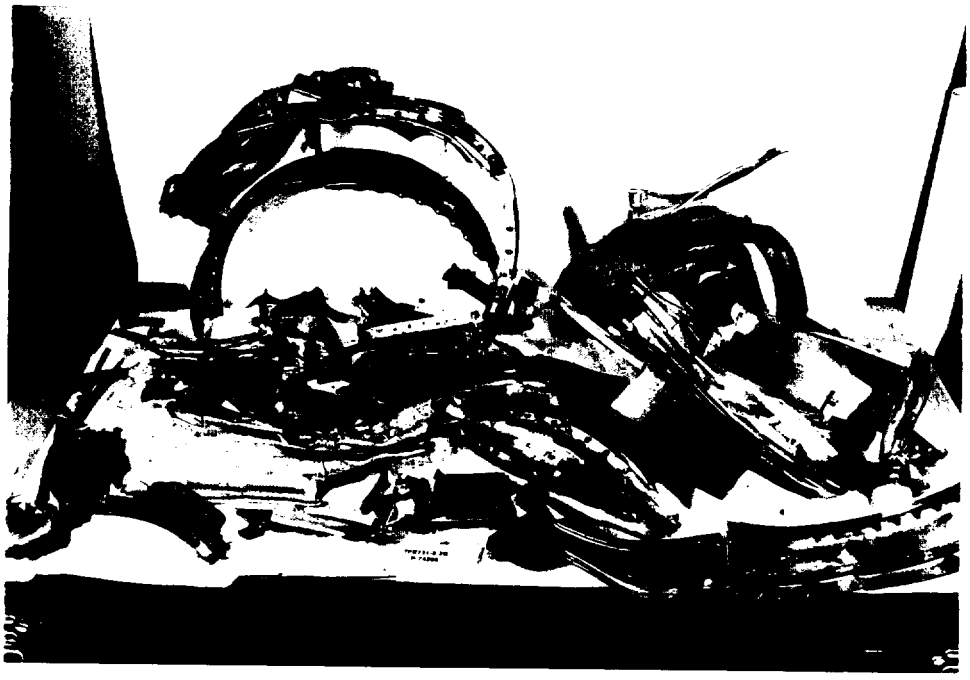

Figure 141. (Photo No. 42-12) Damaged Main Mount.

Figure 142. (Photo No. 38-19) Damaged No. 3 Bearing Housing, and Damaged No. 3 Carbon Seal.

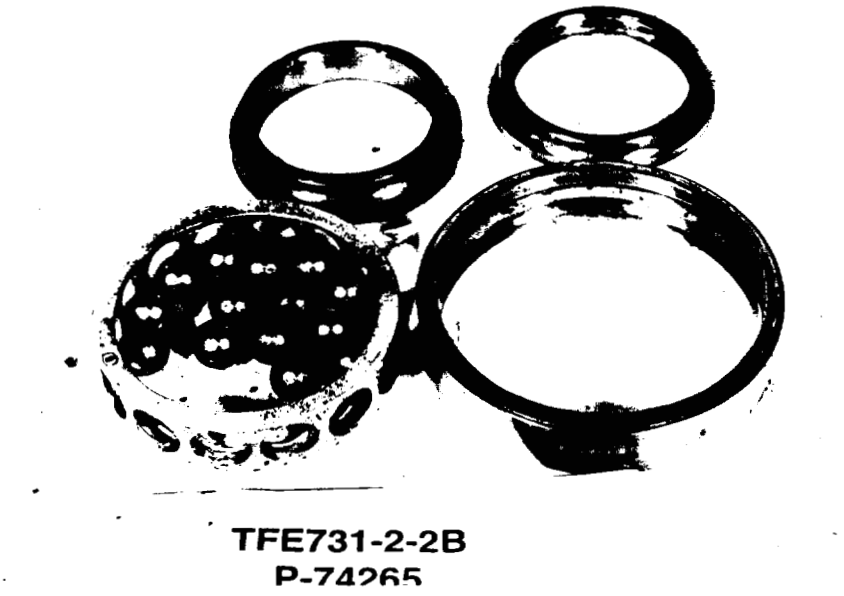

Figure 143. (Photo No. 38-16) No. 3 Bearing.

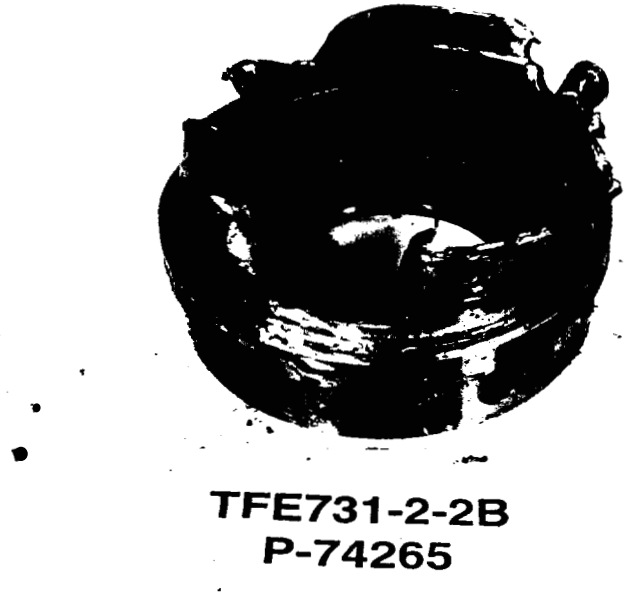

Figure 144. (Photo No. 38-17) Broken Planetary Drive Coupling Shaft.

Figure 145. (Photo No. 41-11) Damaged First-Stage LP Compressor.

Figure 146. (Photo No. 41-12) Damaged First-Stage LP Compressor.

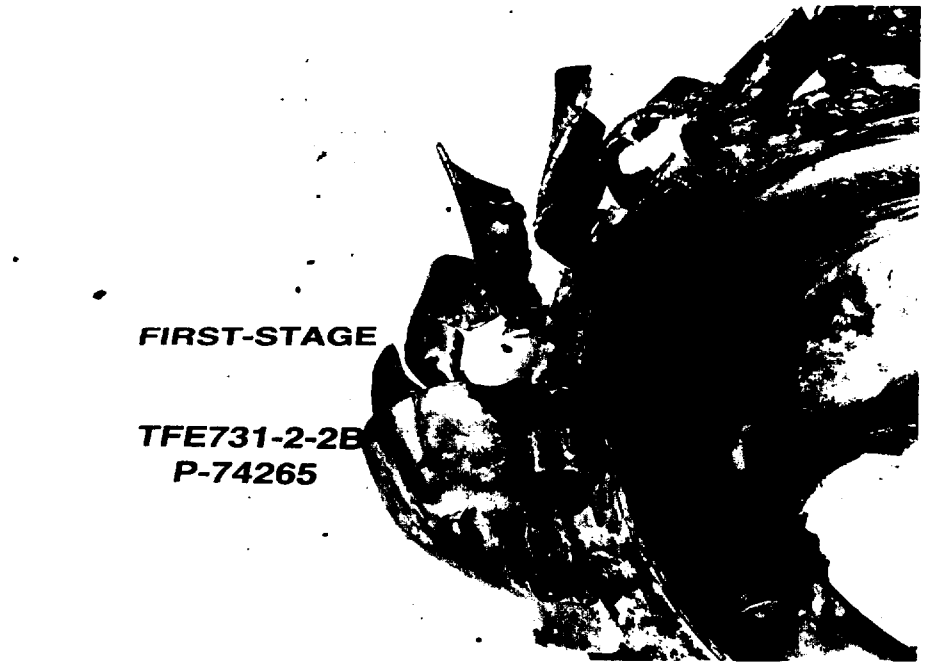

Figure 147. (Photo No. 41-14) Damaged First-Stage LP Compressor Rotor Blades.

Figure 148. (Photo No. 41-13) Damaged First-Stage LP Compressor Rotor Blades.

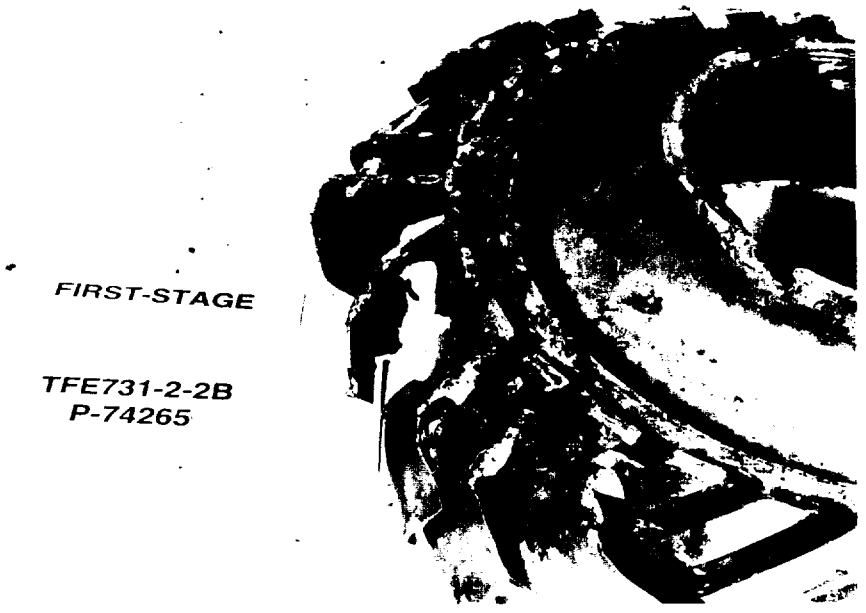

Figure 149. (Photo No. 41-15) Damaged First-Stage LP Compressor Rotor Blades.

Figure 150. (Photo No. 41-32) Damaged First- and Third-Stage LP Compressor Vane-Tip Shrouds, Damaged Second- and Third-Stage Blade-Tip Shrouds, and Damaged Third-Stage LP Compressor Vane Retainer Ring.

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Figure 151. (Photo No. 45-28) Damaged Stub Shaft.

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Figure 152. (Photo No. 45-27) Damaged Curvic Coupling.

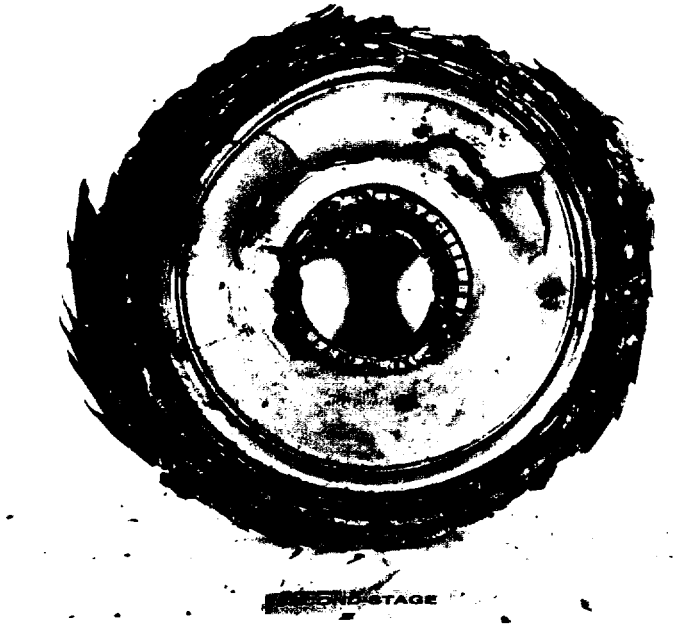

Figure 153. (Photo No. 41-16) Damaged Second-Stage LP Compressor.

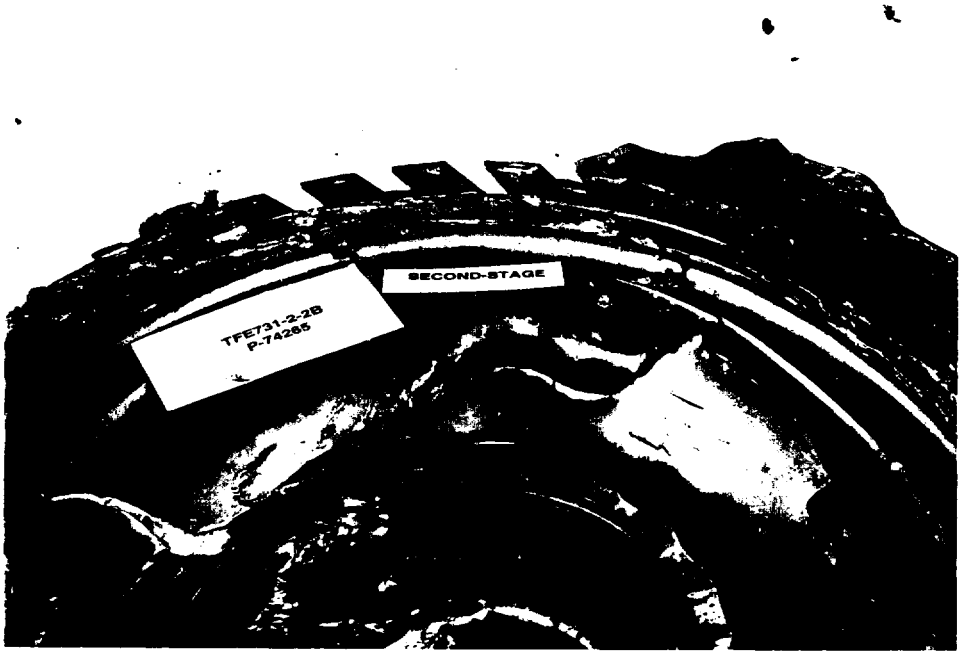

Figure 154. (Photo No. 41-22) Platform Rub on the Second-Stage LP Compressor Rotor Blades, and Fractured Rotor Disk.

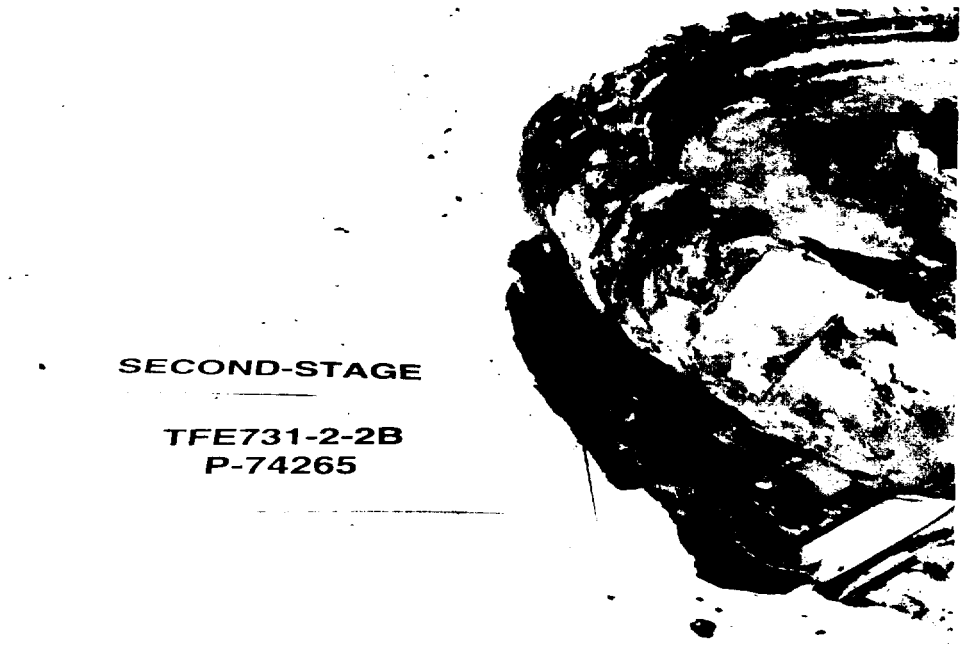

Figure 155. (Photo No. 41-23) Damaged Second- and Third-Stage LP Compressor Blades.

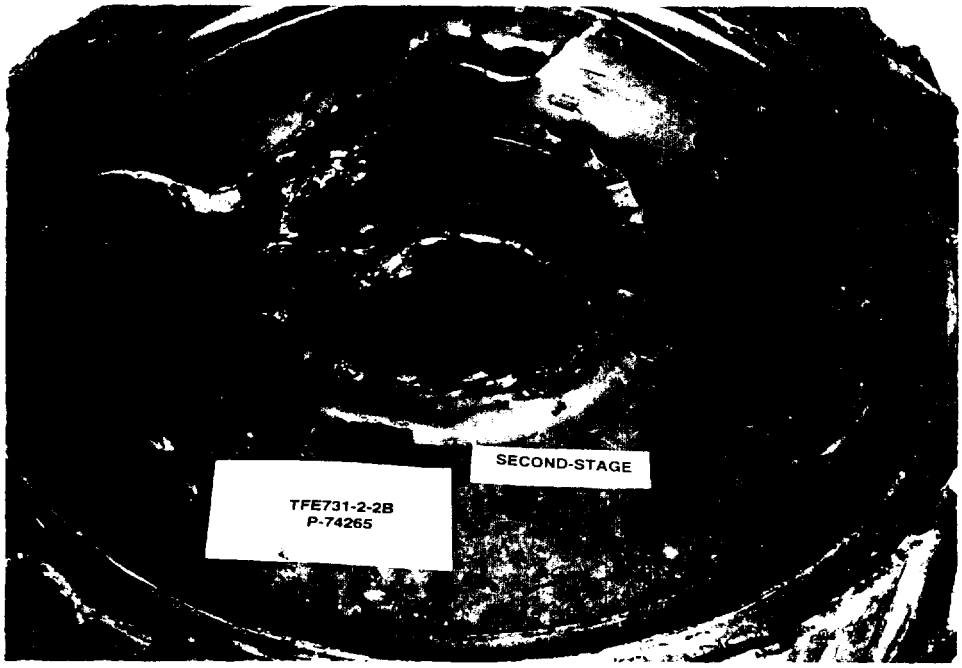

Figure 156. (Photo No. 41-21) Damaged Second- and Third-Stage Curvic Coupling.

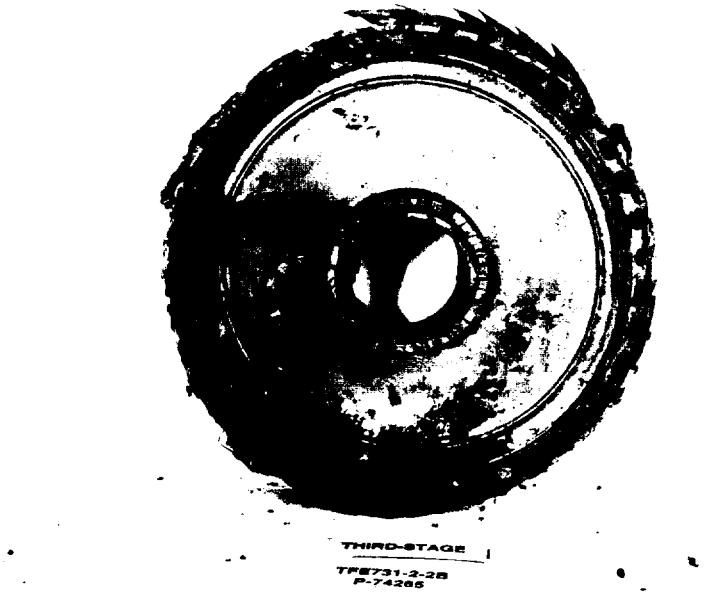

Figure 157. (Photo No. 41-17) Damaged Third-Stage LP Compressor Rotor.

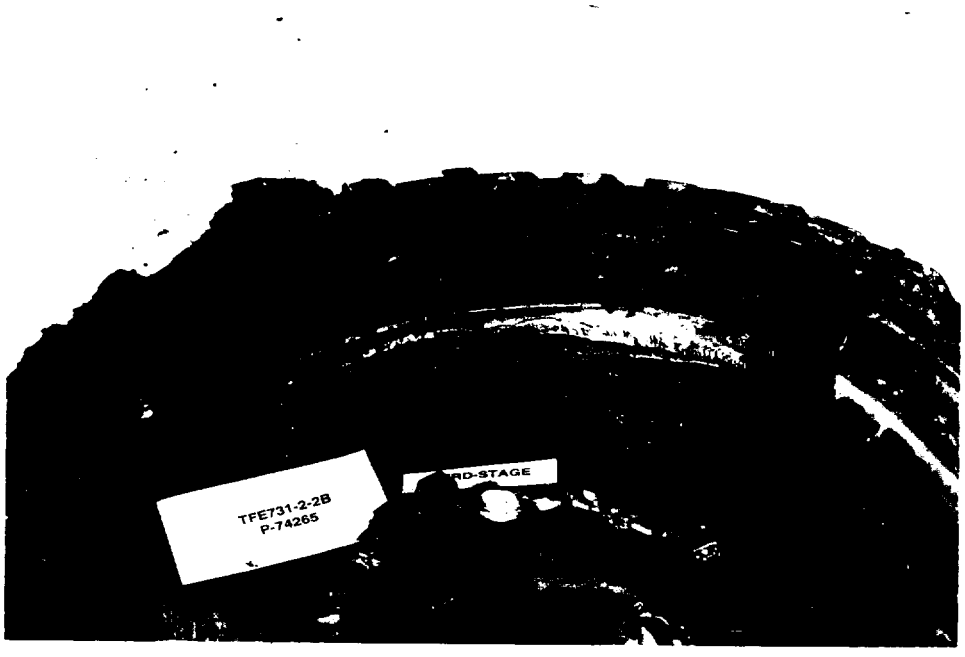

Figure 158. (Photo No. 41-19) Platform Rub on the Third-Stage LP Compressor Rotor Blades, and Fractured Rotor Disk.

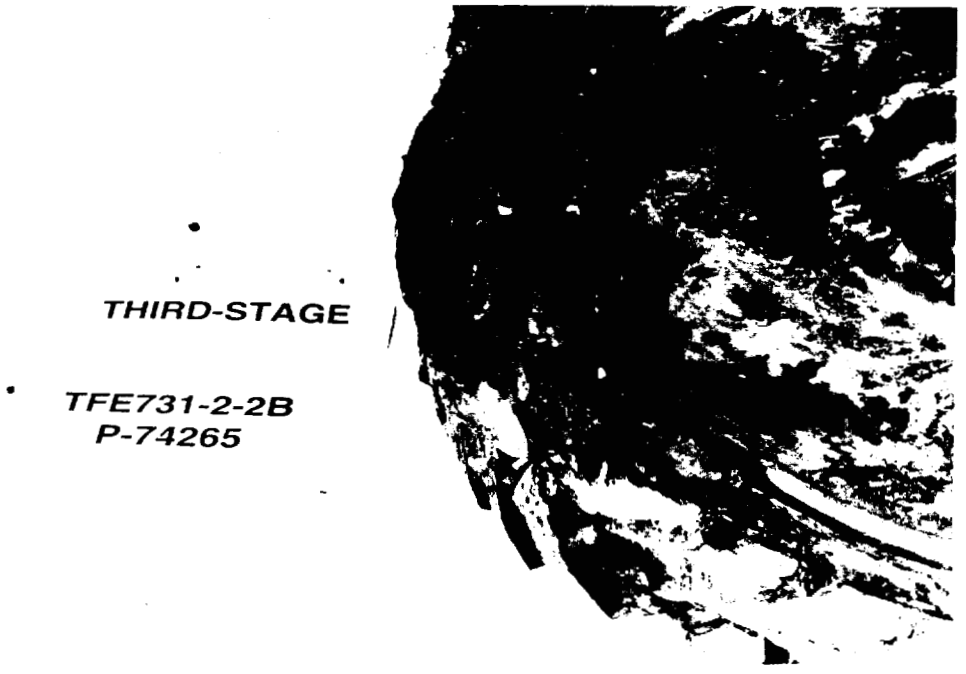

Figure 159. (Photo No. 41-20) Damaged Second- and Third-Stage LP Compressor Rotor Blades.

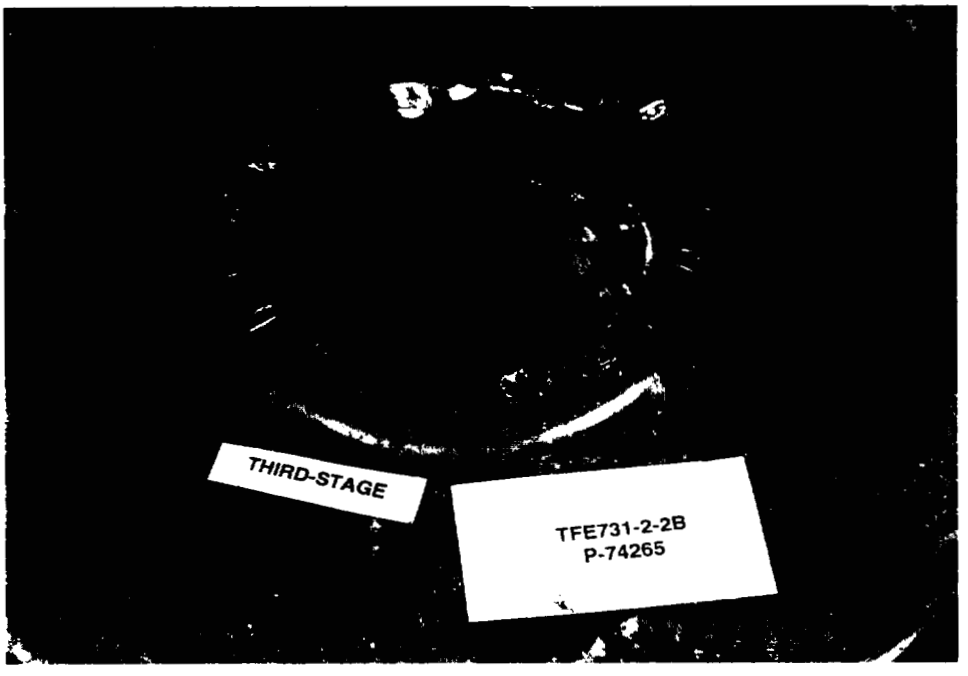

Figure 160. (Photo No. 41-18) Damaged Third-Stage Curvic Coupling.

Figure 161. (Photo No. 41-24) Damaged Fourth-Stage LP Compressor.

Figure 162. (Photo No. 41-27) Damaged Fourth-Stage LP Compressor.

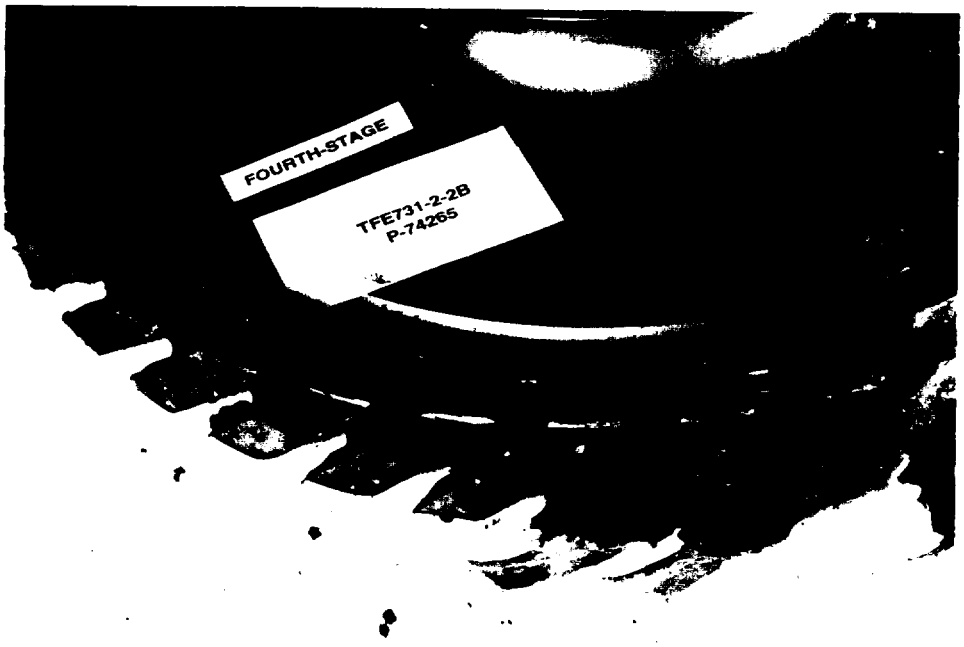

Figure 163. (Photo No. 41-28) Platform Rub on the Fourth-Stage LP Compressor Rotor Blades.

Figure 164. (Photo No. 41-30) Platform Rub on the Fourth-Stage LP Compressor Rotor Blades.

Figure 165. (Photo No. 41-29) Scored Fourth-Stage LP Compressor Disk.

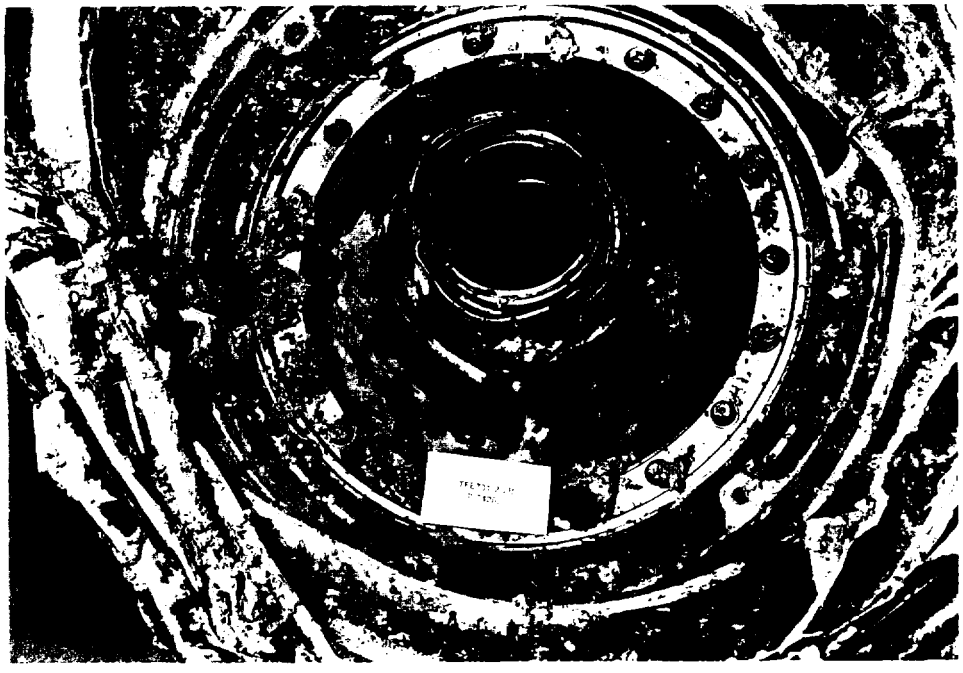

Figure 166. (Photo No. 42-3) Scored No. 4 Bearing Housing, and Scored HP Shaft.

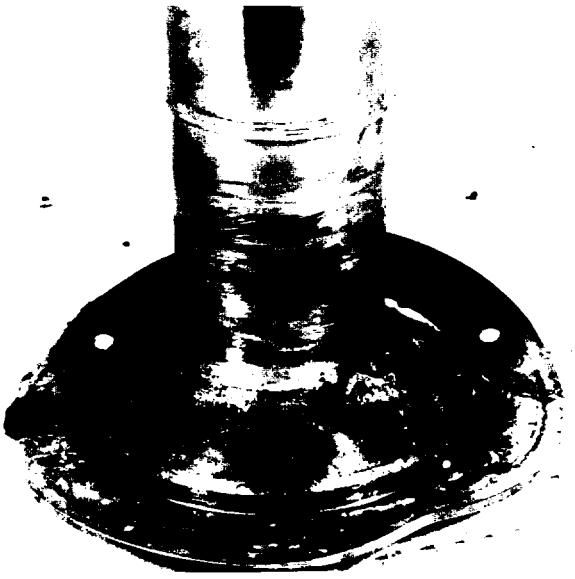

Figure 167. (Photo No. 41-35) Scored Shaft with Damaged Flange.

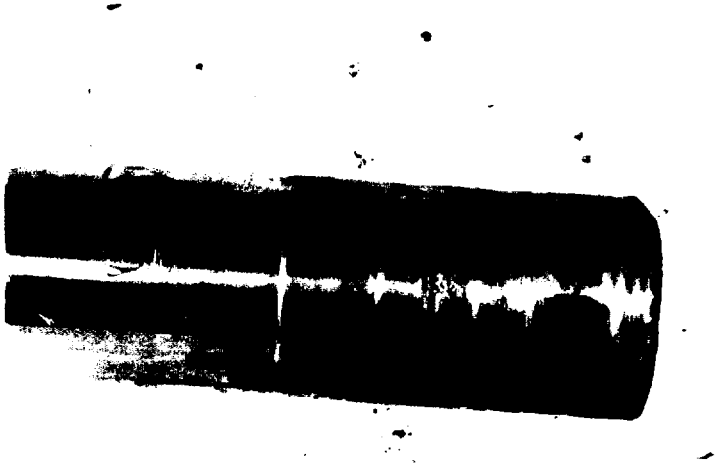

Figure 168. (Photo No. 41-36) Scored Shaft.

Figure 169. (Photo No. 41-33) Damaged Curvic Coupling.

Figure 170. (Photo No. 41-34) Damaged Curvic Coupling.

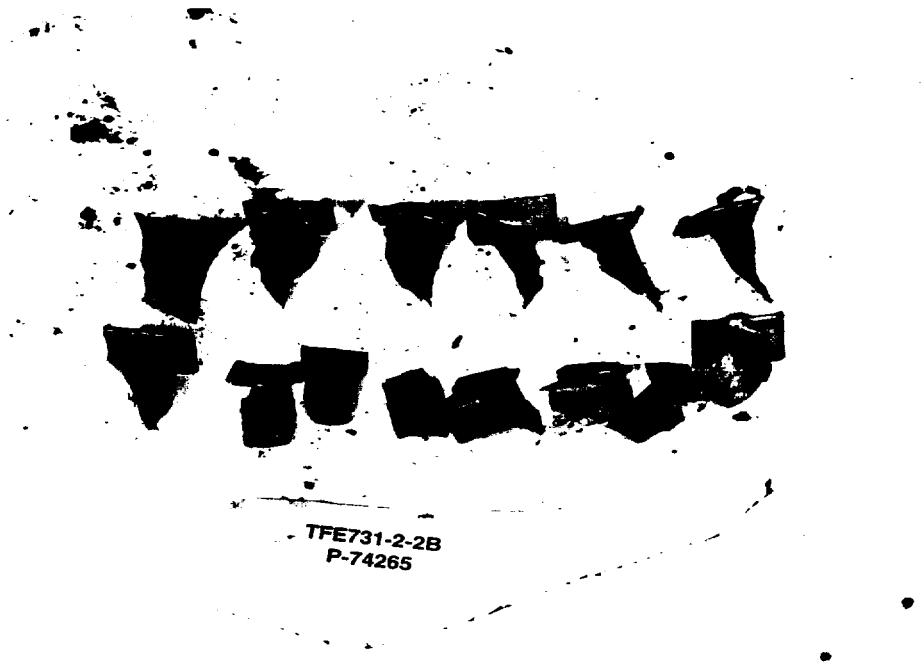

Figure 171. (Photo No. 40-22) Loose/Damaged Second- and Third-Stage LP Compressor Stator Vanes.

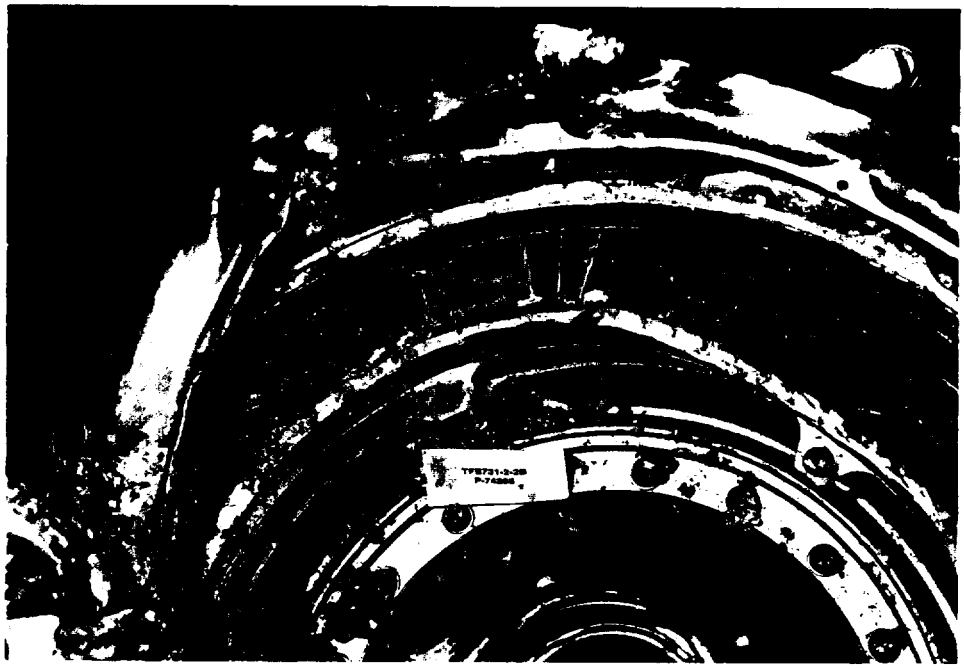

Figure 172. (Photo No. 42-4) Damaged Fourth-Stage LP Compressor Stator, with Scored Inner Vane Support.

Figure 173. (Photo No. 44-12) Damaged HP Compressor Impeller Blades.

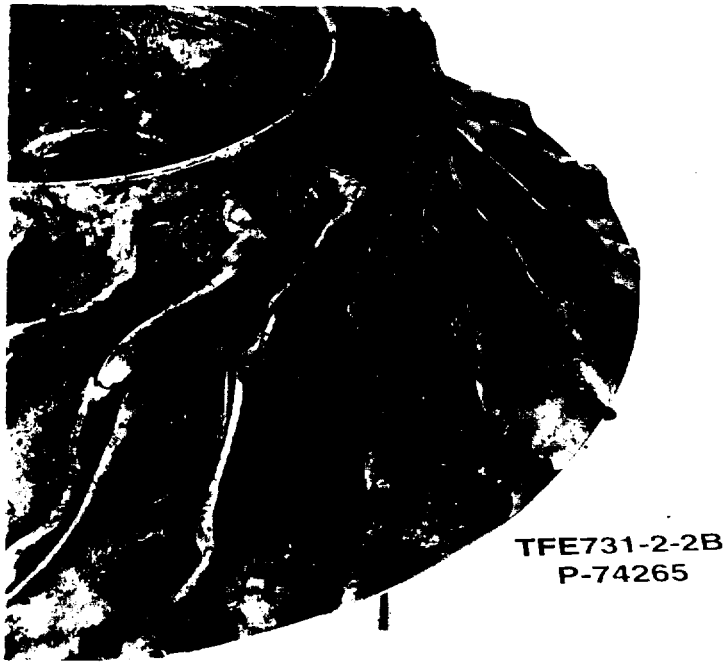

Figure 174. (Photo No. 44-13) Damaged HP Compressor Impeller Blades.

Figure 175. (Photo No. 44-4) Scored HP Impeller Shroud.

Figure 176. (Photo No. 44-5) Scored HP Impeller Shroud.

Figure 177. (Photo No. 44-11) Scored HP Compressor Impeller Rotor.

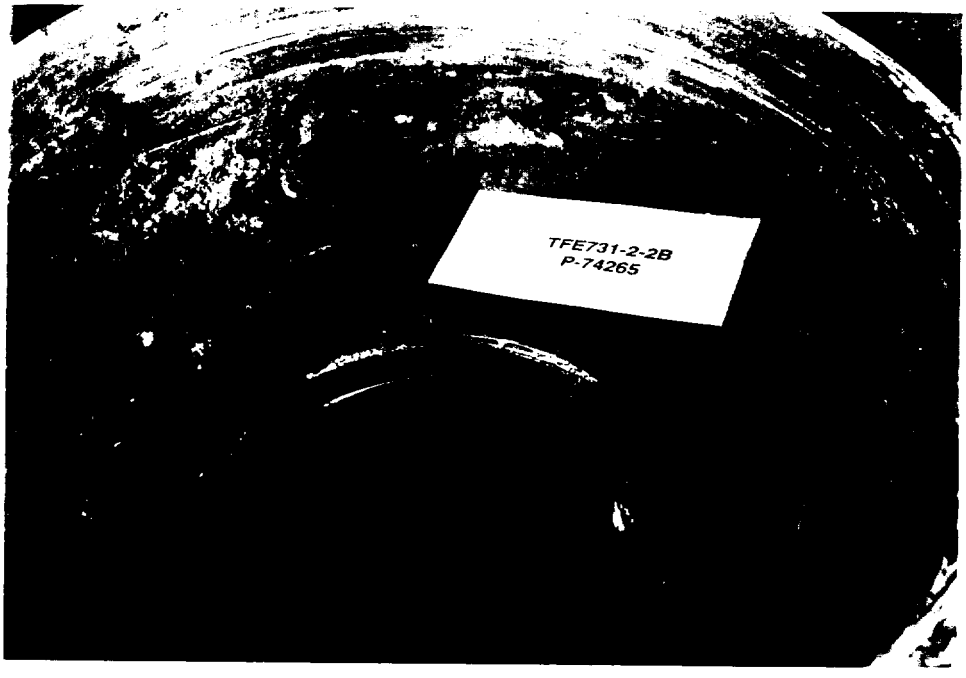

Figure 178. (Photo No. 44-10) Scored HP Compressor Impeller Rotor.

Figure 179. (Photo No. 45-36) Damaged Compressor Housing, with Score Marks, and Broken HP Shaft.

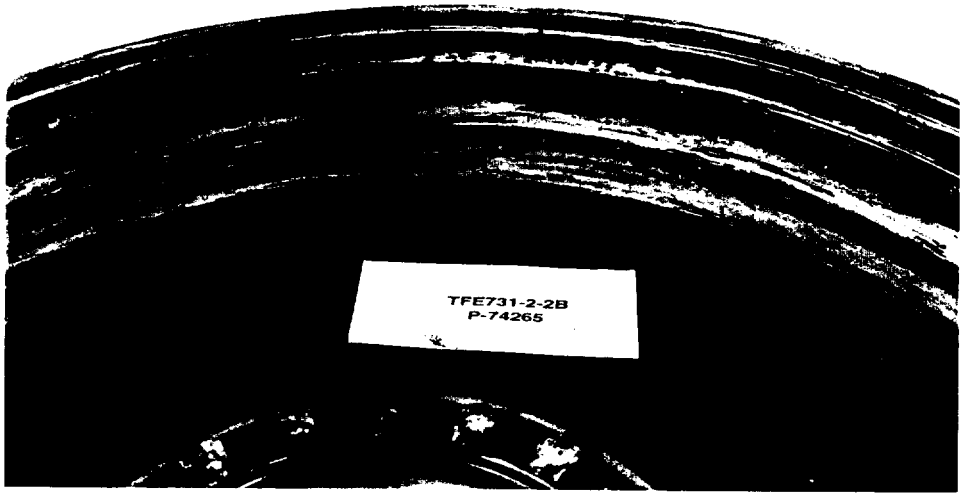

Figure 180. (Photo No. 44-9) Scored HP Compressor Impeller Backface.

Figure 181. (Photo No. 44-8) Damaged Curvic Coupling.

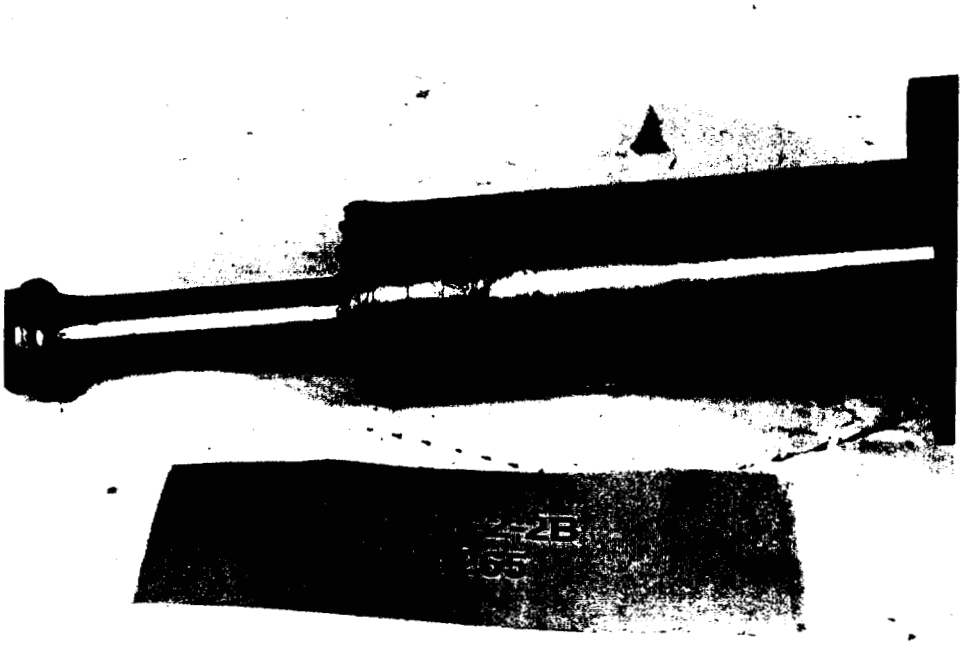

Figure 182. (Photo No. 45-32) Scored LP Shaft and Seal.

Figure 183. (Photo No. 44-18) HP Shaft Fragment, with Score Marks.

Figure 184. (Photo No. 44-16) HP Shaft Fragment.

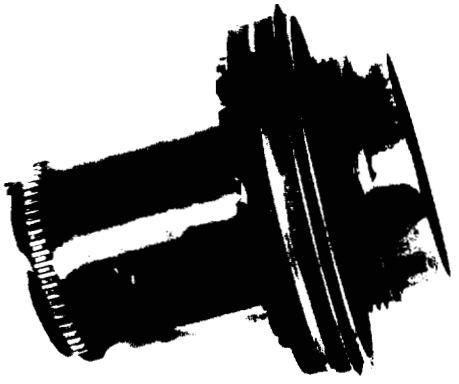

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Figure 185. (Photo No. 38-5) HP Shaft Fragment, and HP Aft Curvic Coupling.

Figure 186. (Photo No. 40-35) Damage to the Combustion Section.

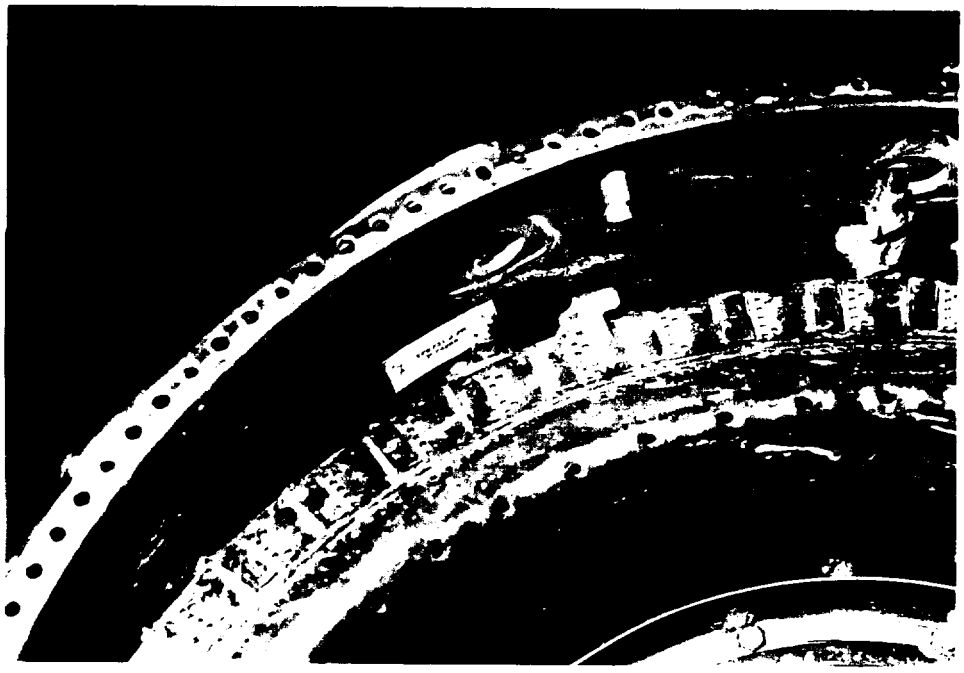

Figure 187. (Photo No. 40-36) Broken Fuel Nozzle Housing.

Figure 188. (Photo No. 38-7) Debris on the Combustion Chamber Dome.

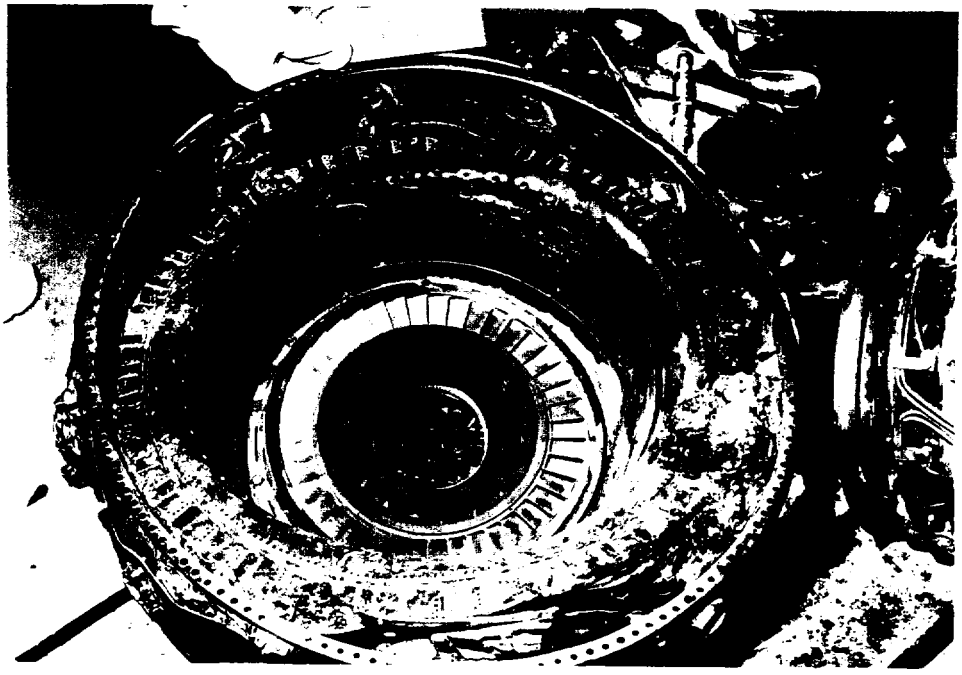

Figure 189. (Photo No. 38-6) Damaged Combustion Chamber.

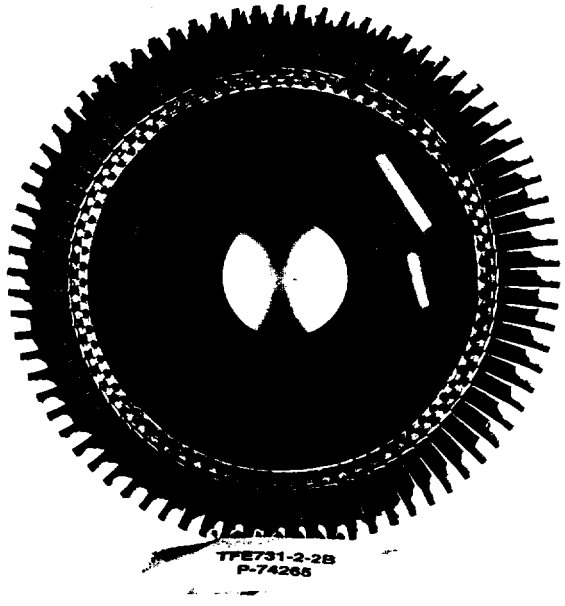

Figure 190. (Photo No. 44-20) HP Turbine.

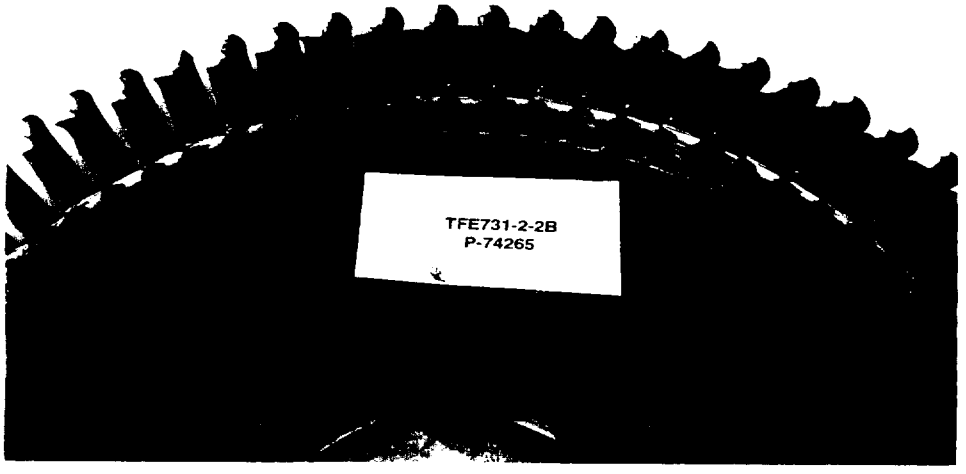

Figure 191. (Photo No. 44-24) Platform Rub on the HP Turbine Rotor Blades.

Figure 192. (Photo No. 39-10) Scored Interstage Transition Duct.

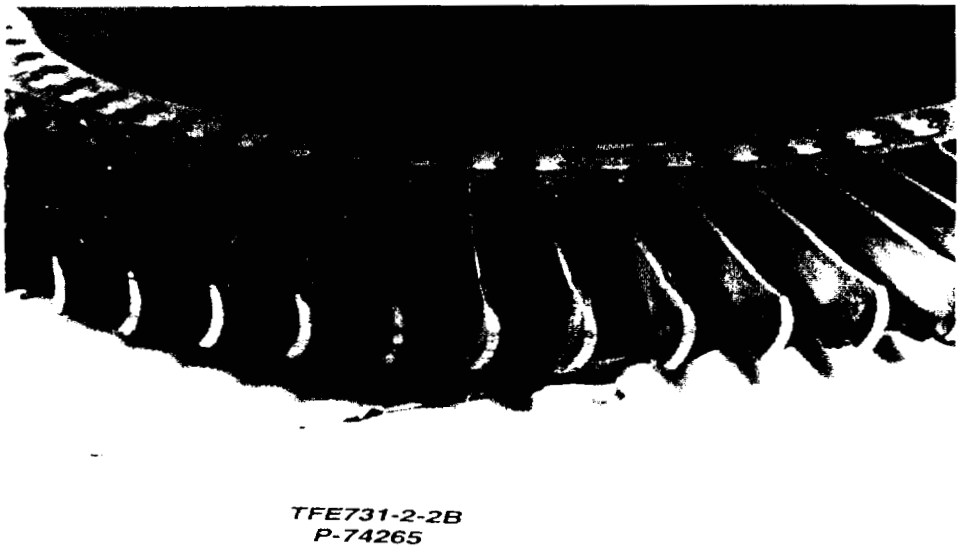

Figure 193. (Photo No. 44-29) Blade-Tip Rub on the HP Turbine Rotor Blades.

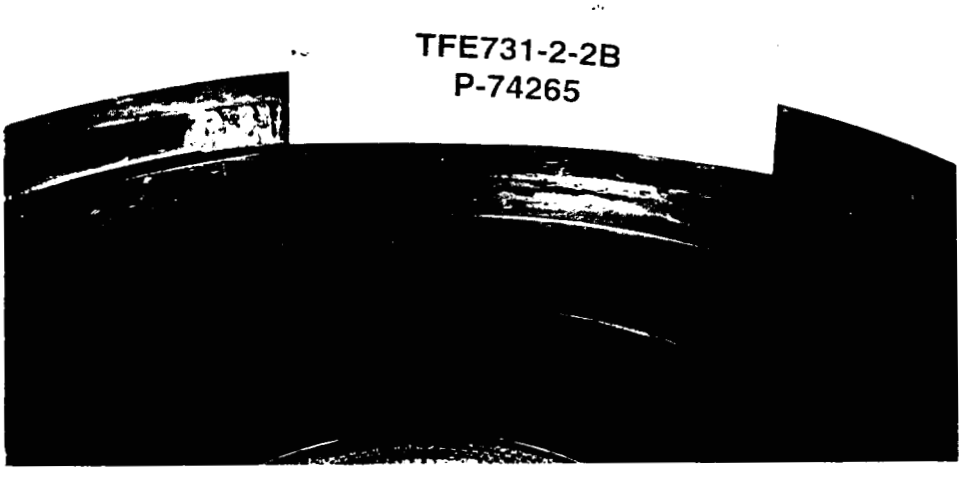

Figure 194. (Photo No. 39-11) Scored Blade-Tip Shrouds.

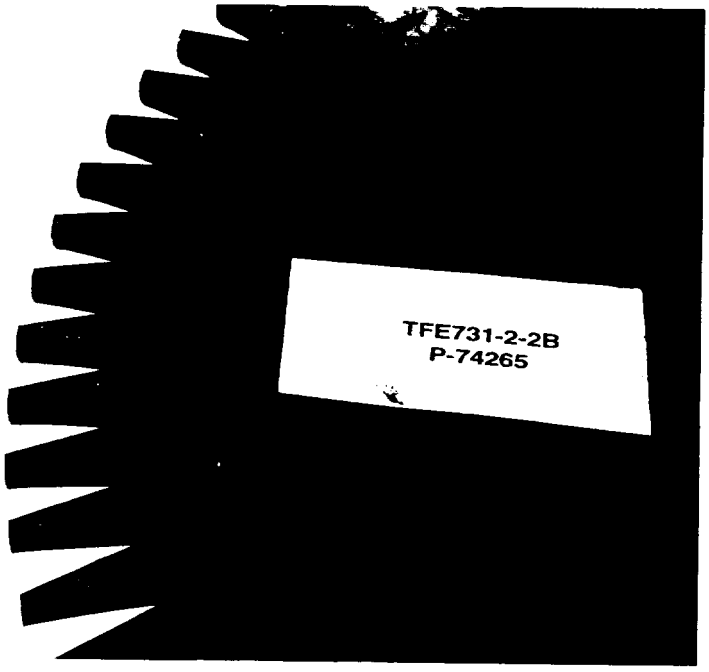

Figure 195. (Photo No. 44-28) Metal-Spray Deposits on the HP Turbine Rotor Blades.

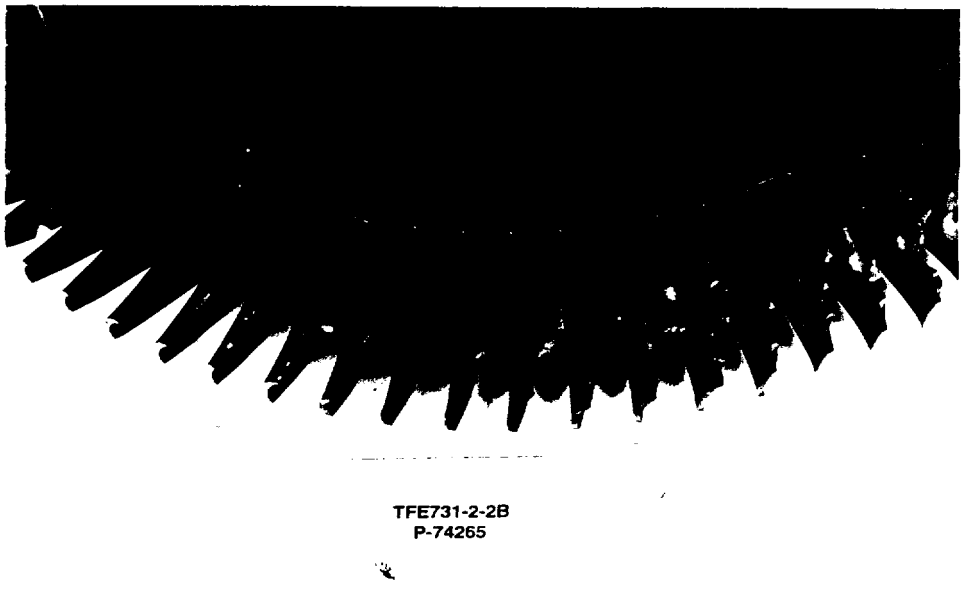

Figure 196. (Photo No. 44-25) Battered HP Turbine Rotor Blades.

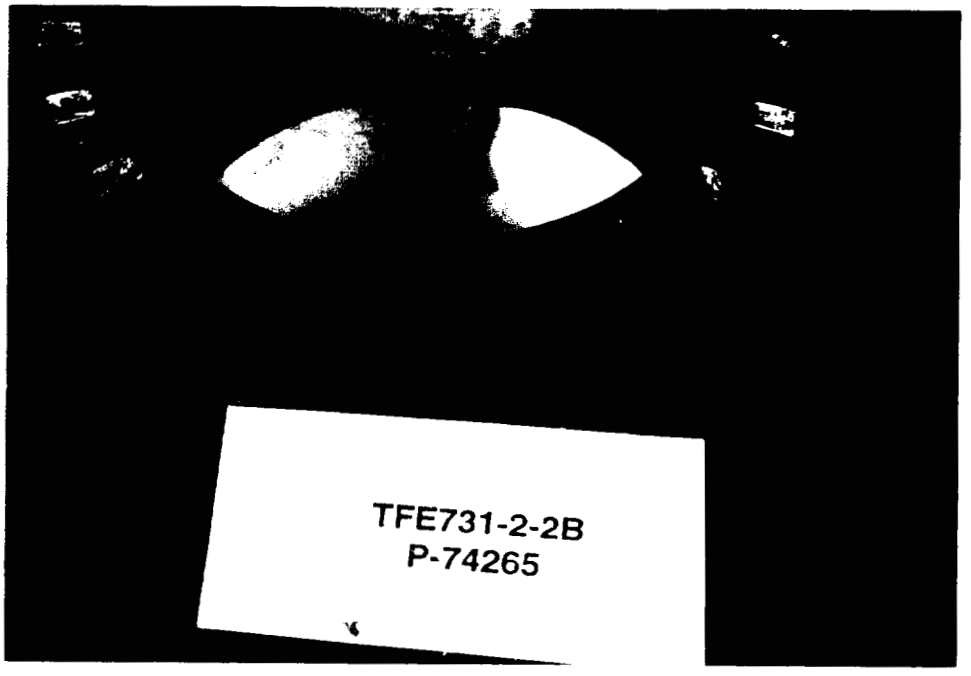

Figure 197. (Photo No. 44-26) Damaged Forward Curvic Coupling.

Figure 198. (Photo No. 44-21) Damaged Aft Curvic Coupling.

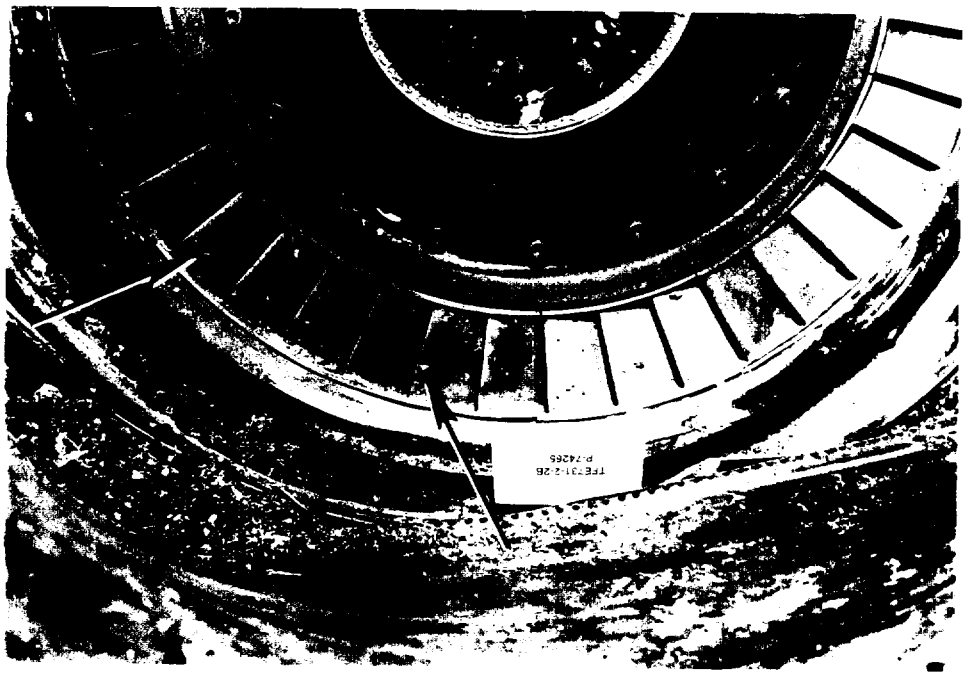

Figure 199. (Photo No. 40-33) Metal-Spray Deposits on the HP Turbine Stator Vanes.

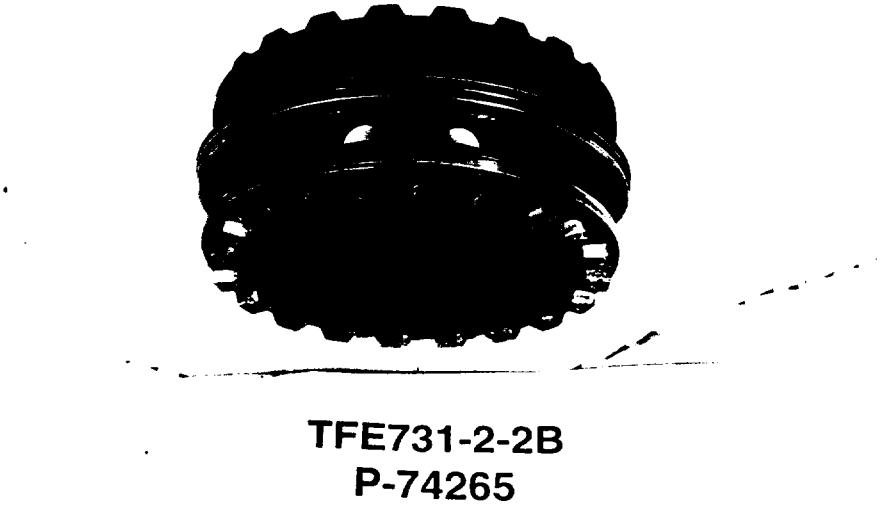

Figure 200. (Photo No. 45-26) HP Center Curvic Coupling.

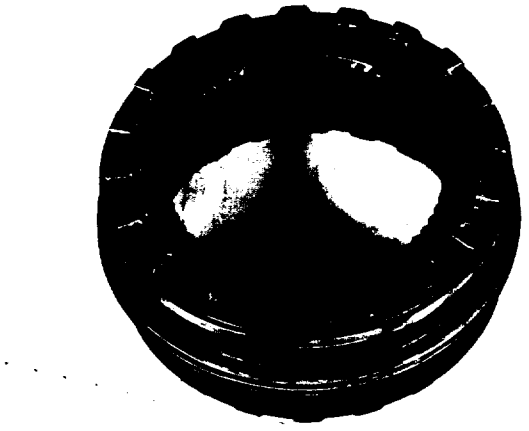

Figure 201. (Photo No. 45-24) Damaged Forward Curvic Coupling.

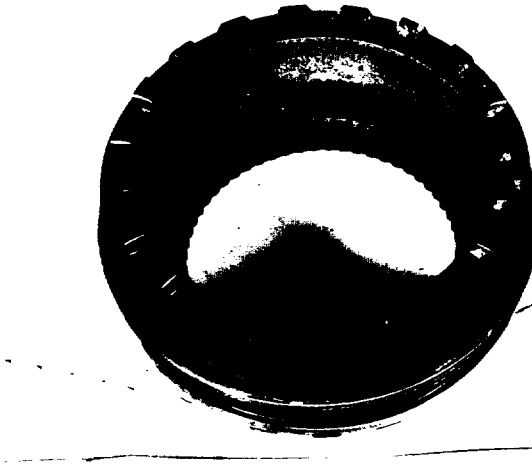

Figure 202. (Photo No. 45-25) Damaged Aft Curvic Coupling.

Figure 203. (Photo No. 38-4) HP Aft Curvic Coupling and Broken HP Shaft.

Figure 204. (Photo No. 38-3) Damaged Teeth on the HP Aft Curvic Coupling.

Figure 205. (Photo No. 38-9) Contact Marks on the N1 Monopole.

Figure 206. (Photo No. 38-14) Metal Shavings on the Retainer Nut.

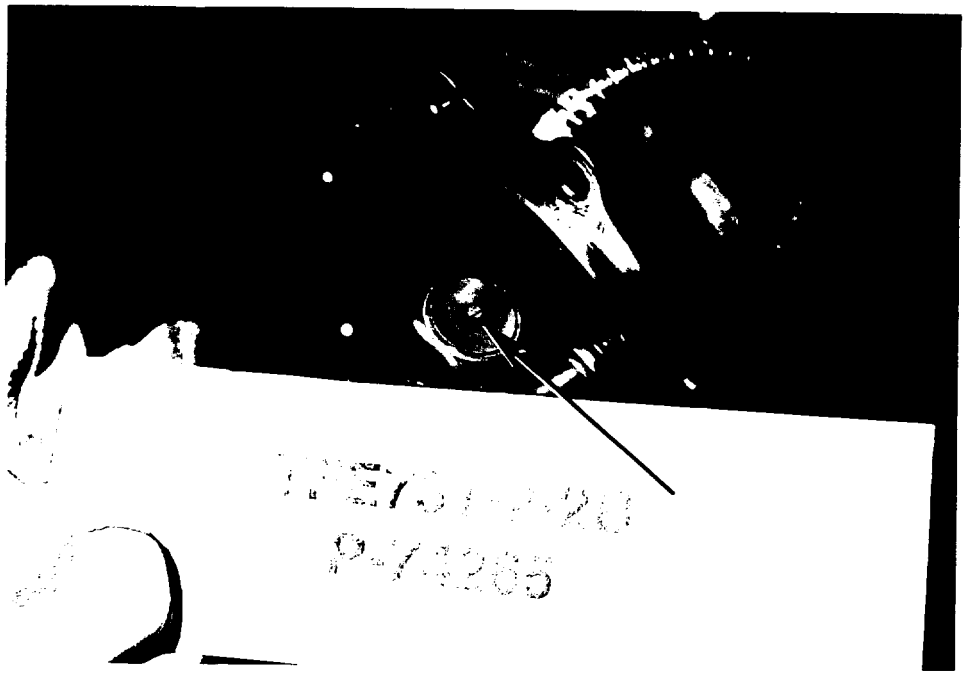

Figure 207. (Photo No. 38-11) Contact Marks on the N1 Monopole.

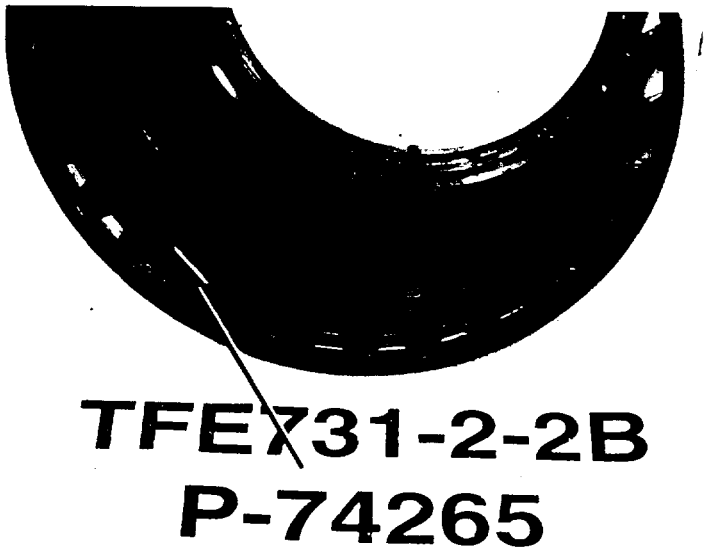

Figure 208. (Photo No. 38-12) Contact Mark on the N1 Speed Pickup Gear.

Figure 209. (Photo No. 39-8) No. 6 LP Rotor Aft Roller Bearing.

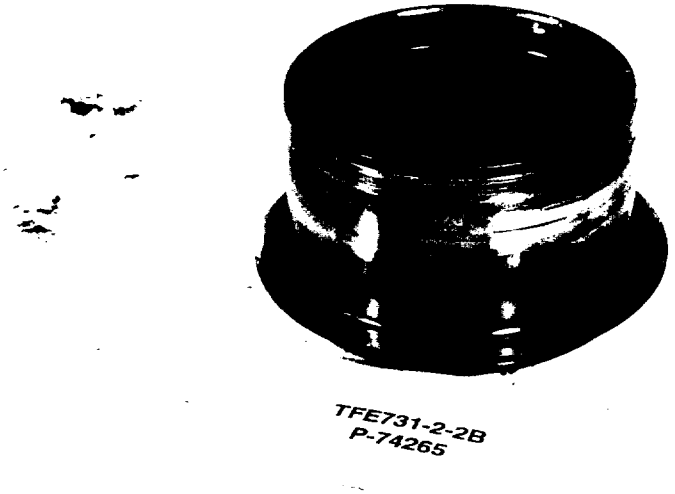

Figure 210. (Photo No. 39-9) No. 6 Air/Oil Seal Rotor.

Figure 211. (Photo No. 42-27) No. 6 Air/Oil Carbon Seal, and Scored Thrust and Exhaust Nozzle.

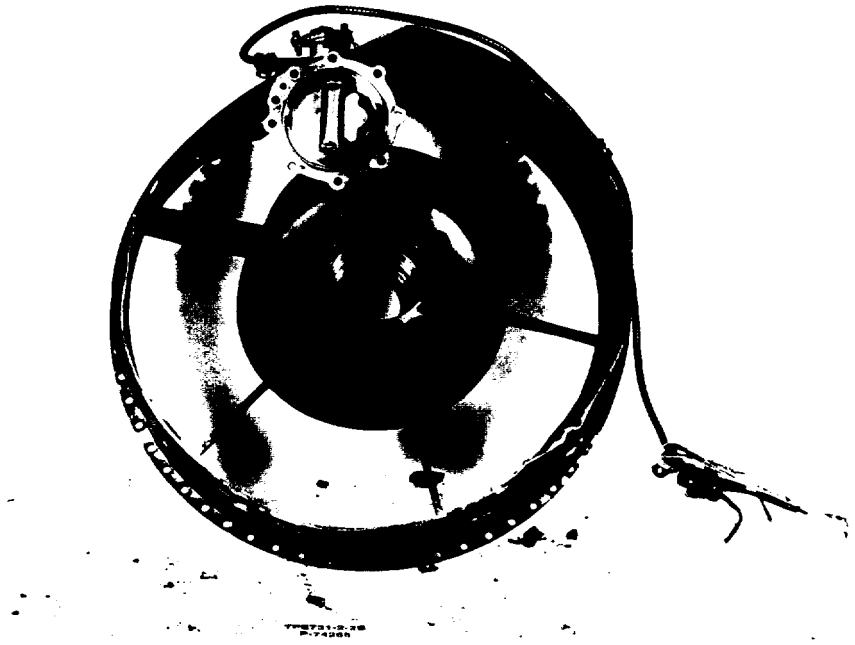

Figure 212. (Photo No. 42-23) Thrust and Exhaust Nozzle with Aft Mount Flange Removed.

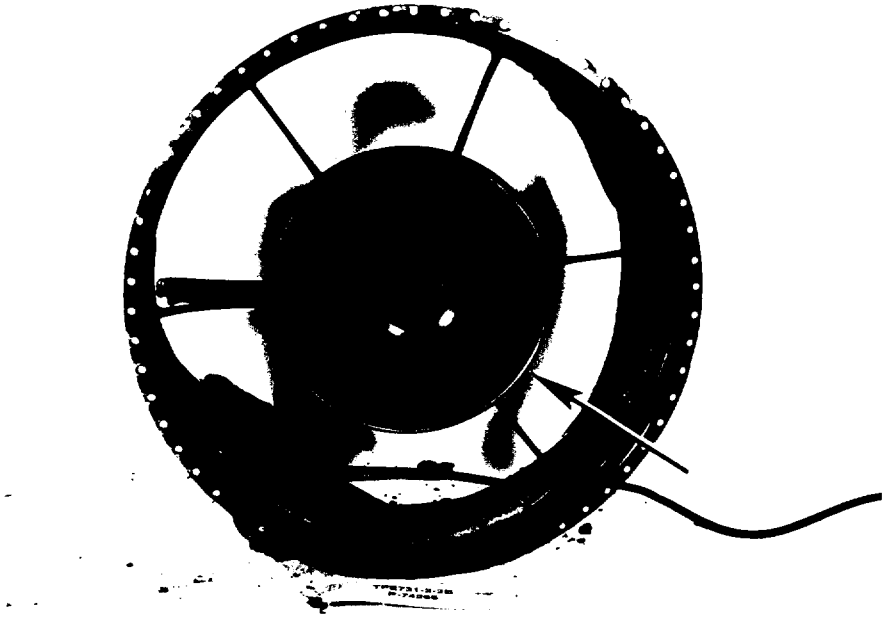

Figure 213. (Photo No. 42-26) Scored Thrust and Exhaust Nozzle.

Figure 214. (Photo No. 42-30) Platform Rub on the Third-Stage LP Turbine Rotor Blades.

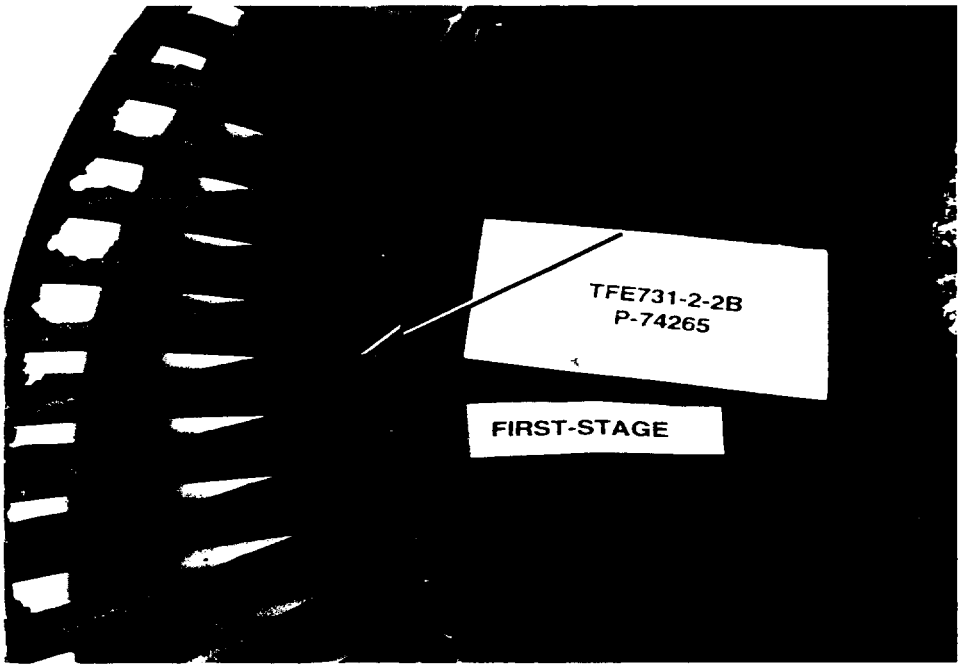

Figure 215. (Photo No. 44-33) Platform Rub on the First-Stage LP Turbine Rotor Blades.

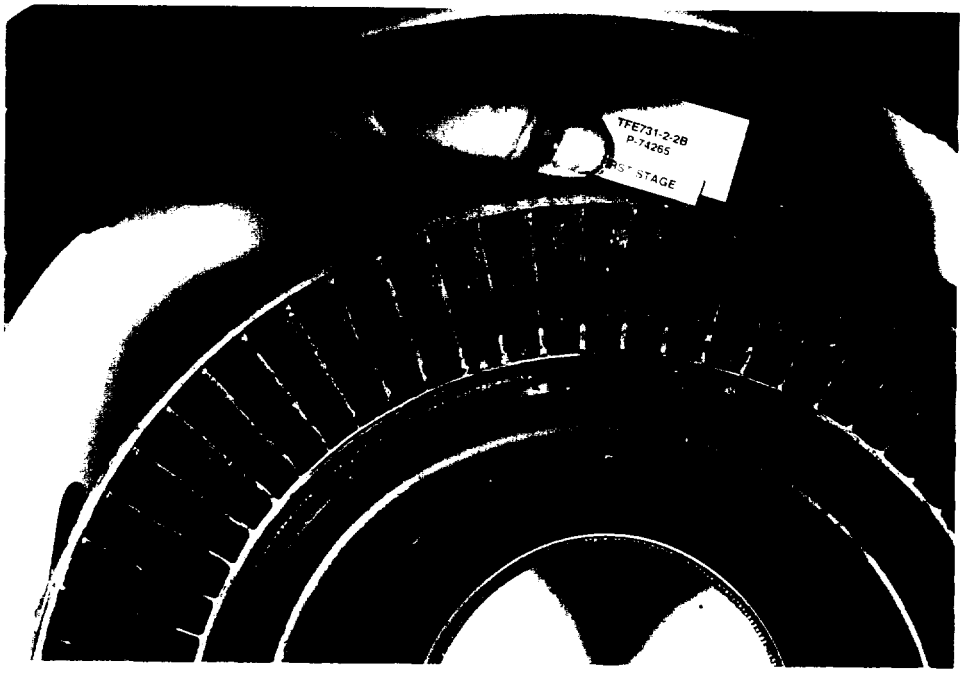

Figure 216. (Photo No. 39-13) Scored First-Stage LP Turbine Stator Vanes and Inner Vane Support.

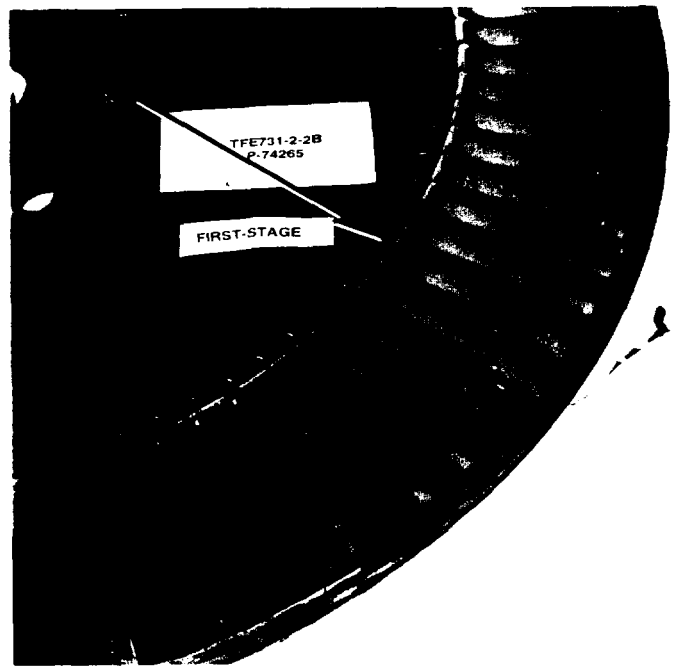

Figure 217. (Photo No. 44-36) Platform Rub on the First-Stage LP turbine Rotor Blades.

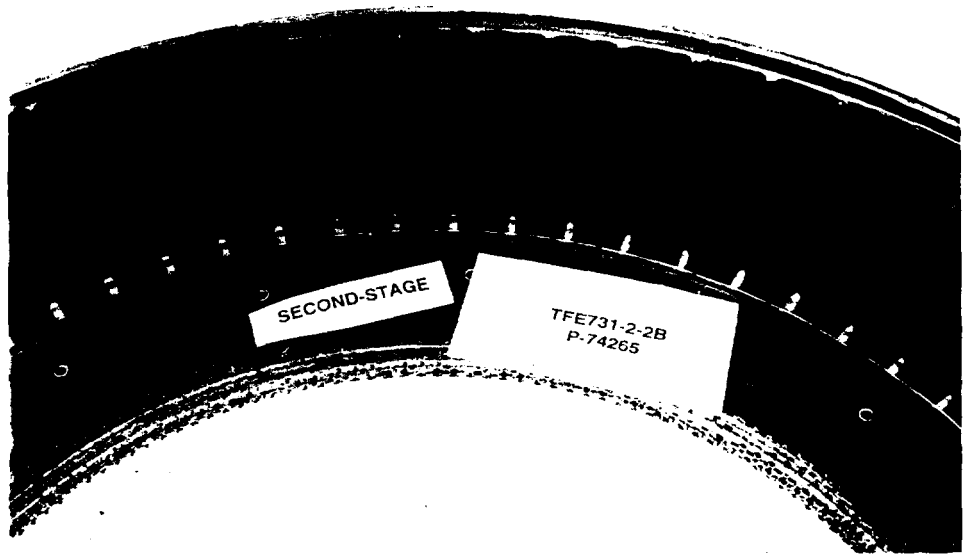

Figure 218. (Photo No. 45-14) Scored Second-Stage LP Turbine Stator Vanes and Outer Vane Support.

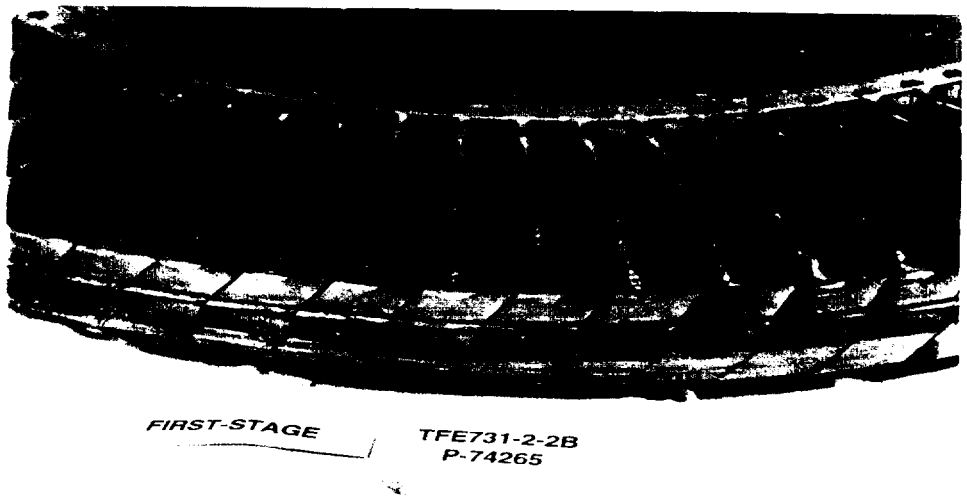

Figure 219. (Photo No. 44-34) Blade-Tip Rub on the First-Stage LP Turbine Rotor Blades.

Figure 220. (Photo No. 39-15) Scored Blade-Tip Shroud.

Figure 221. (Photo No. 44-32) Damaged Forward Curvic Coupling Teeth.

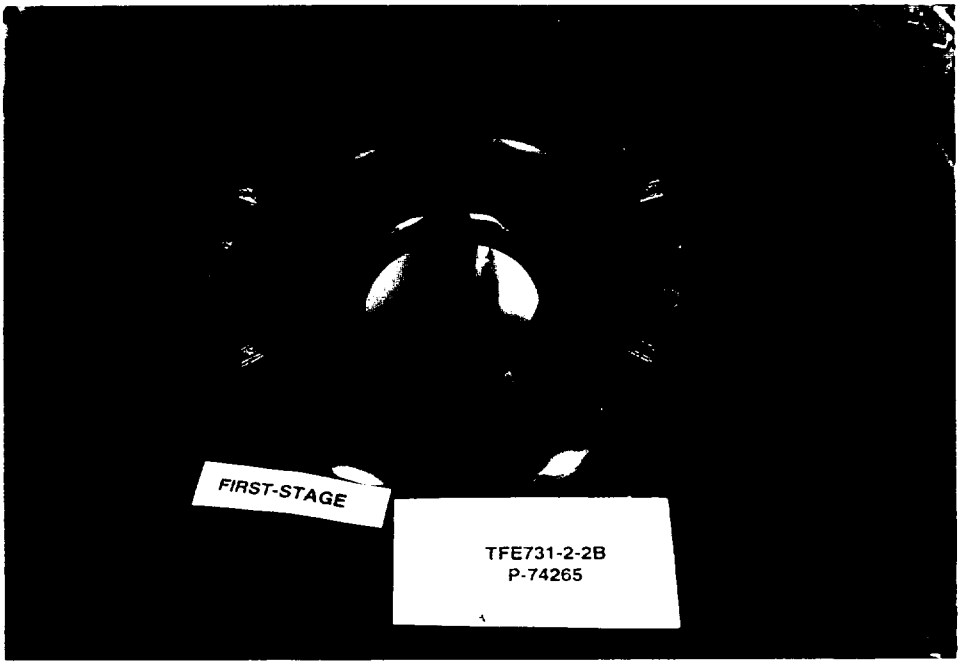

Figure 222. (Photo No. 44-35) Damaged Aft Curvic Coupling Teeth.

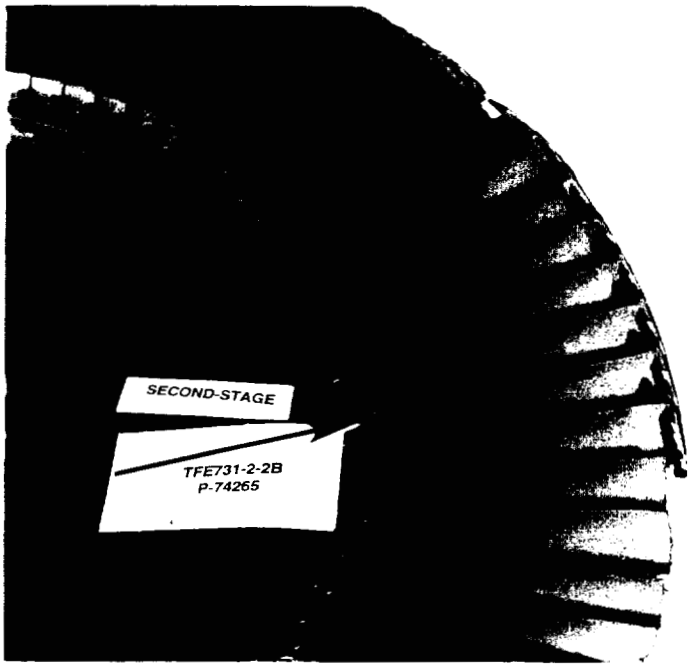

Figure 223. (Photo No. 45-8) Damaged Second-Stage LP Turbine Rotor Blades.

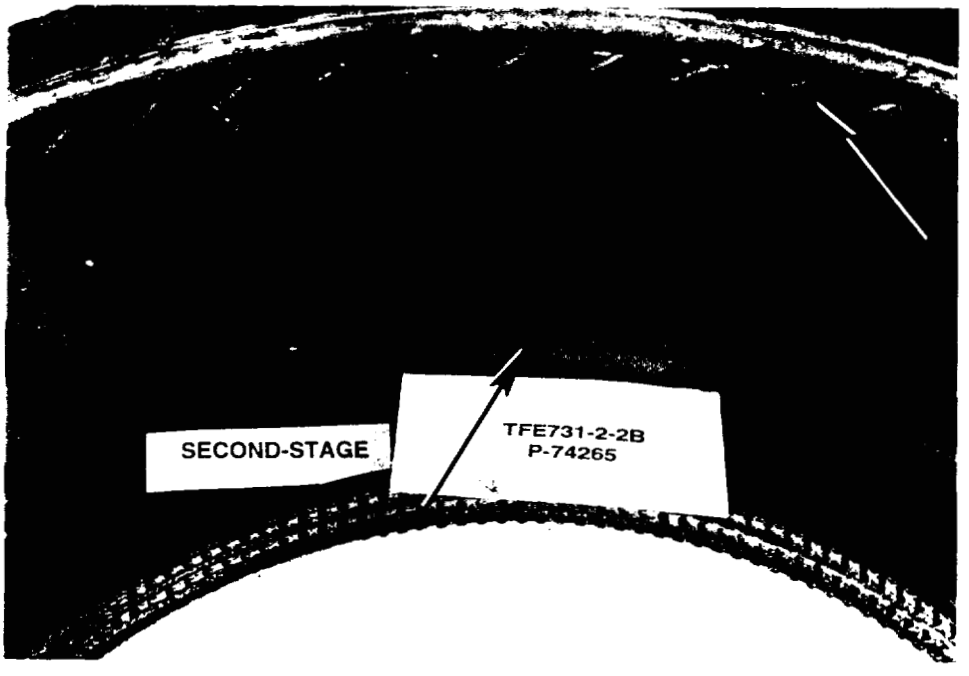

Figure 224. (Photo No. 45-19) Damaged Second-Stage LP Turbine Stator Vanes.

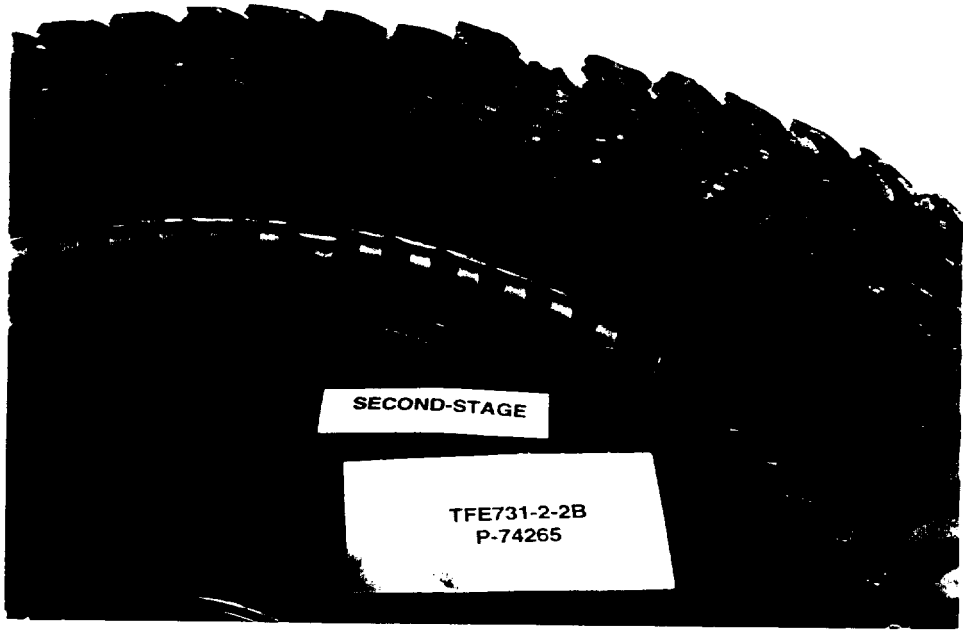

Figure 225. (Photo No. 45-6) Damaged Second-Stage LP Turbine Rotor Blades.

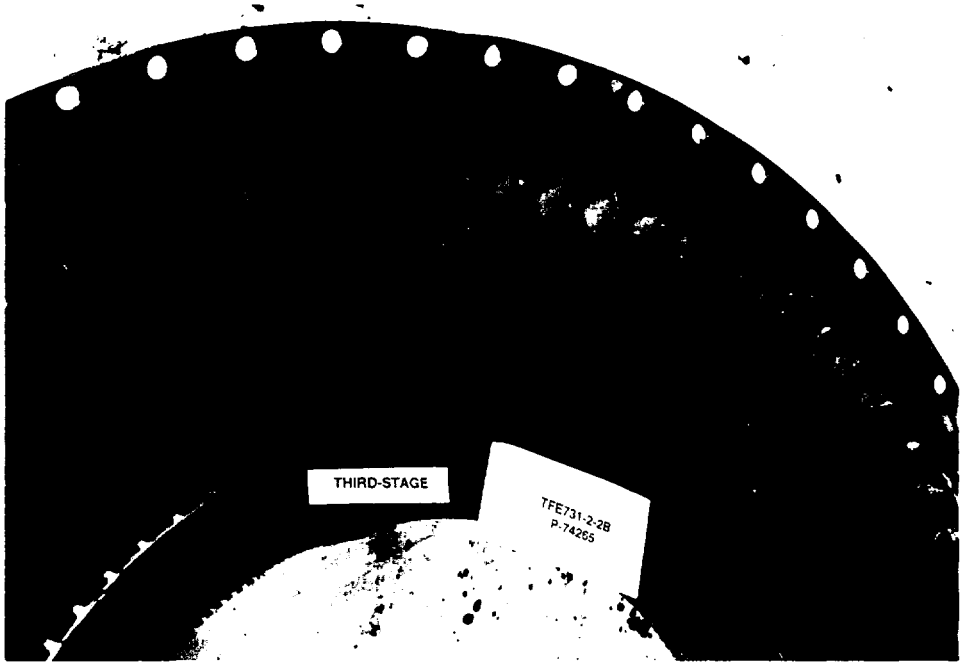

Figure 226. (Photo No. 39-2) Damaged Third-Stage LP Turbine Stator Vanes.

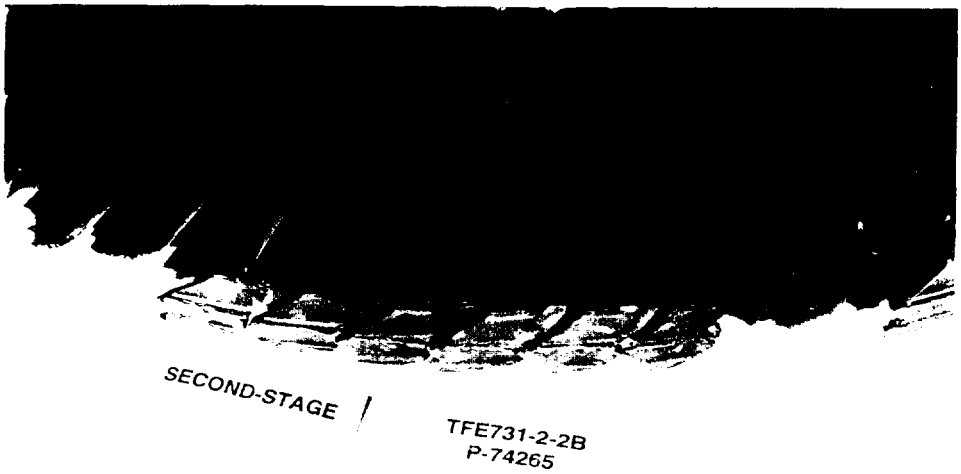

Figure 227. (Photo No. 45-10) Blade-Tip Rub on the Second-Stage Turbine Rotor Blades.

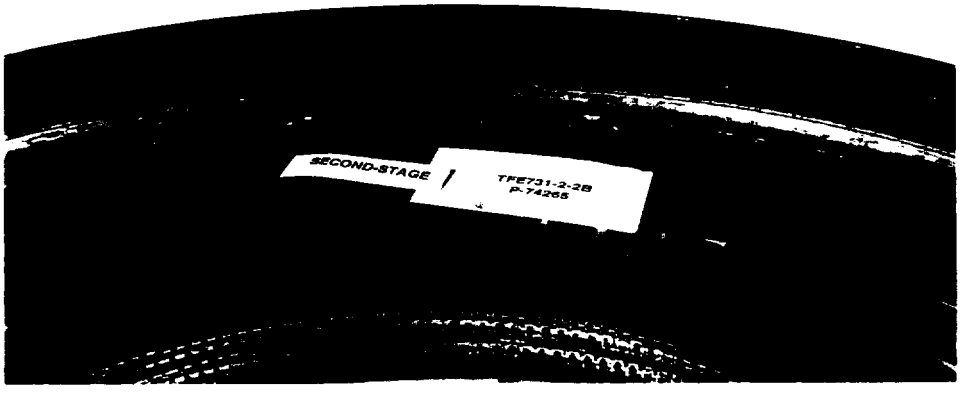

Figure 228. (Photo No. 45-16) Scored Blade-Tip Shroud.

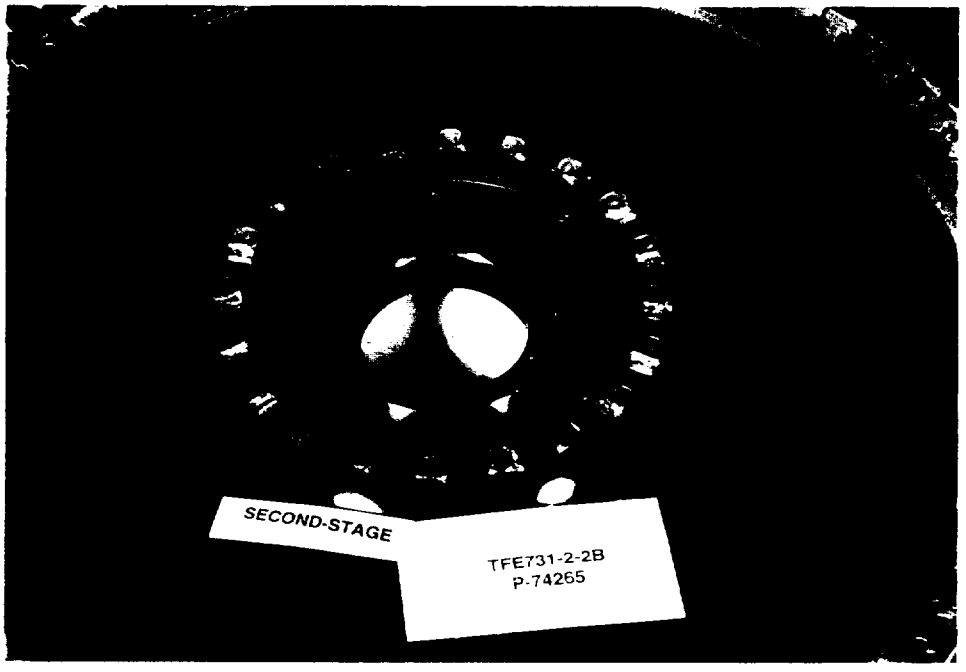

Figure 229. (Photo No. 45-7) Damaged Forward Curvic Coupling.

Figure 230. (Photo No. 45-5) Damaged Aft Curvic Coupling.

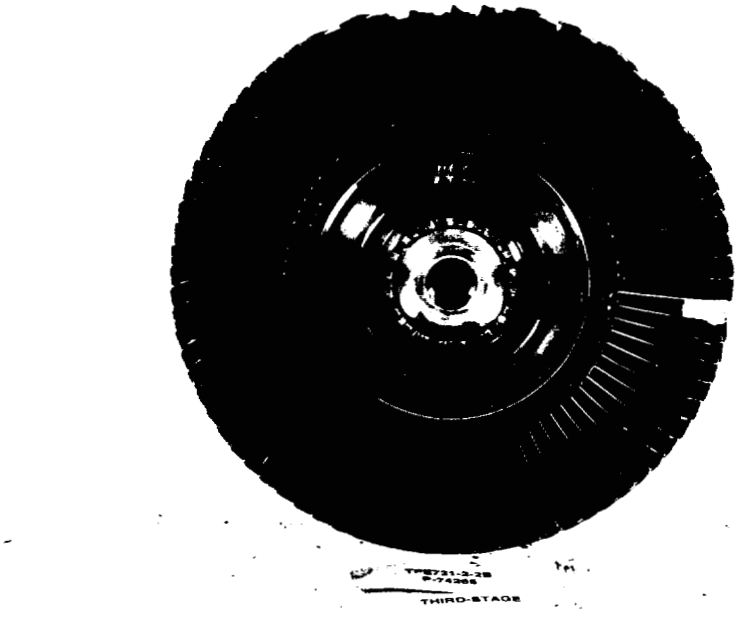

Figure 231. (Photo No. 42-33) Damaged Third-Stage LP Turbine Rotor Blades.

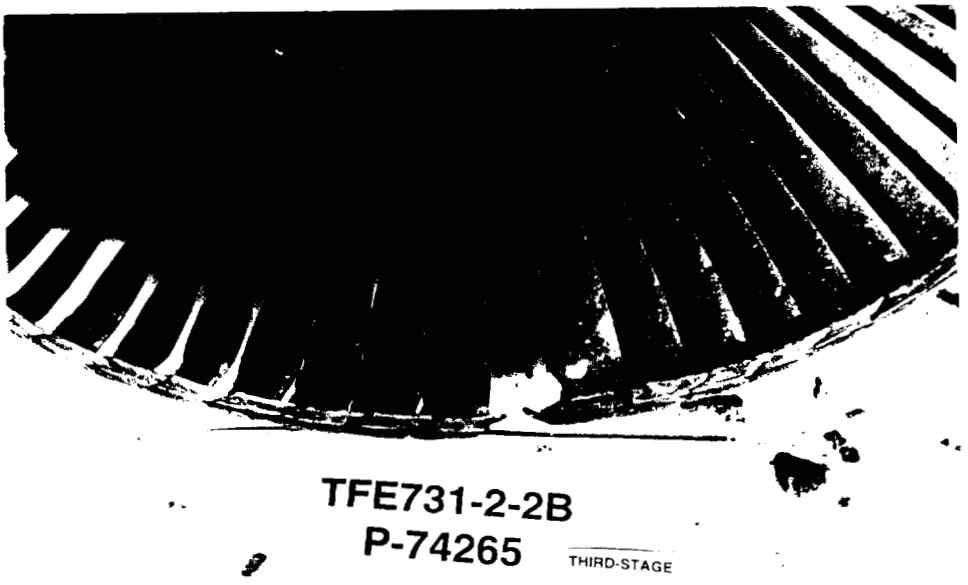

Figure 232. (Photo No. 42-28) Broken Third-Stage LP Turbine Rotor Blades.

Figure 233. (Photo No. 42-31) Damaged Third-Stage LP Turbine Rotor Blades.

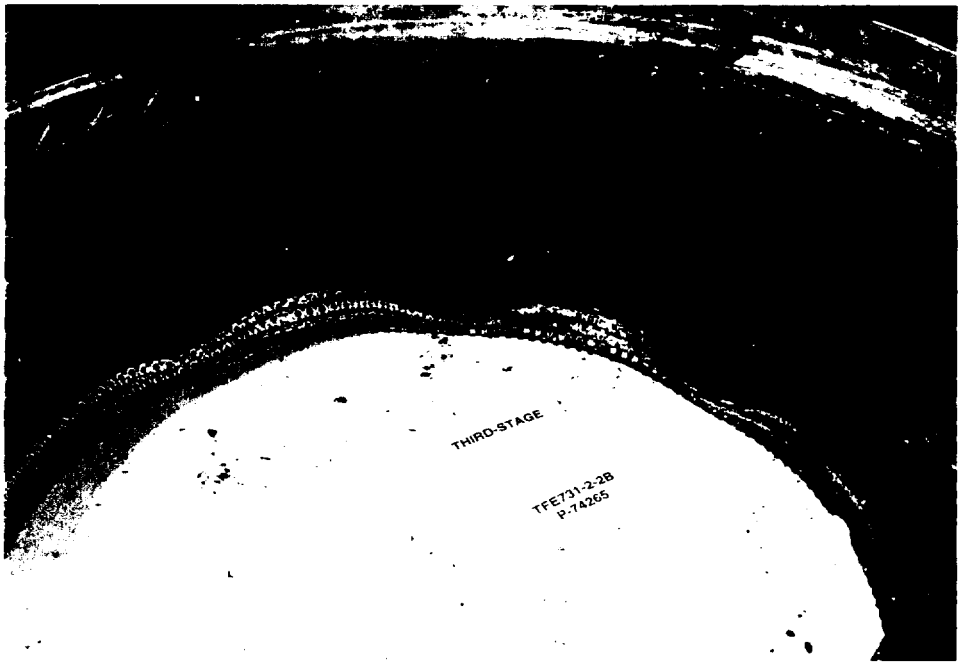

Figure 234. (Photo No. 39-5) Scored Third-Stage LP Turbine Stator Vane Inner Support.

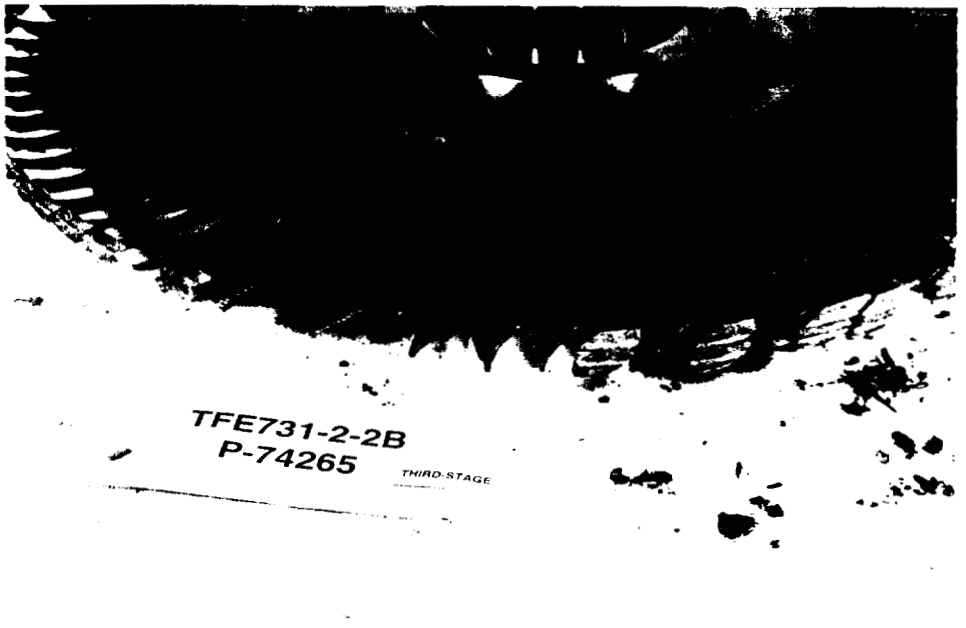

Figure 235. (Photo No. 42-29) Blade-Tip Rub on the Third-Stage Turbine Rotor Blades.

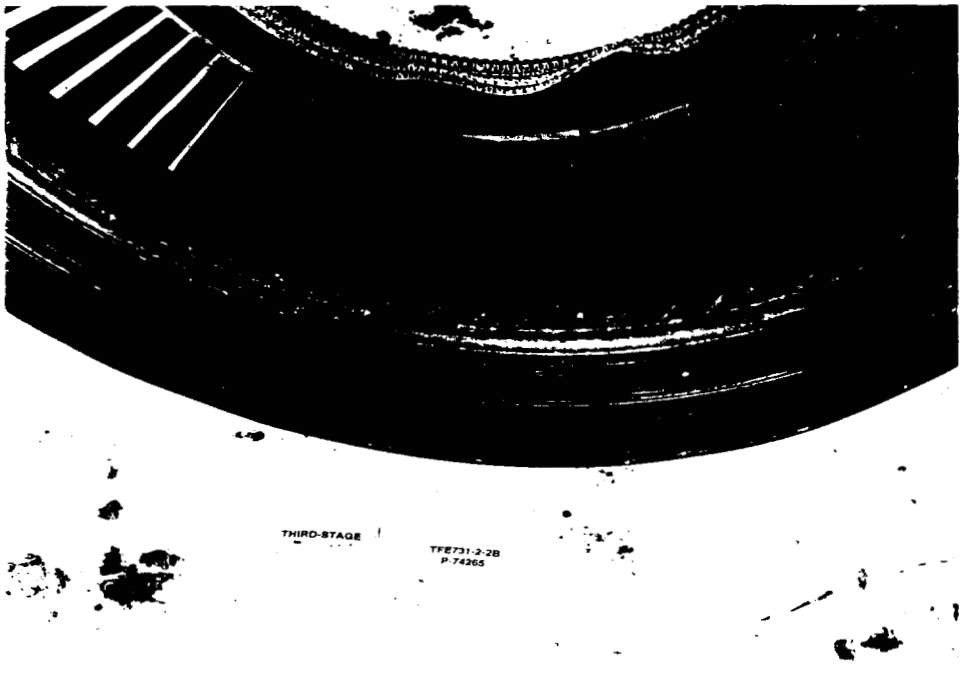

Figure 236. (Photo No. 39-6) Scored Blade-Tip Shroud.

Figure 237. (Photo No. 42-32) Damaged Curvic Coupling Teeth.

Figure 238. (Photo No. 42-6) Fractured Interstage Transition Duct.

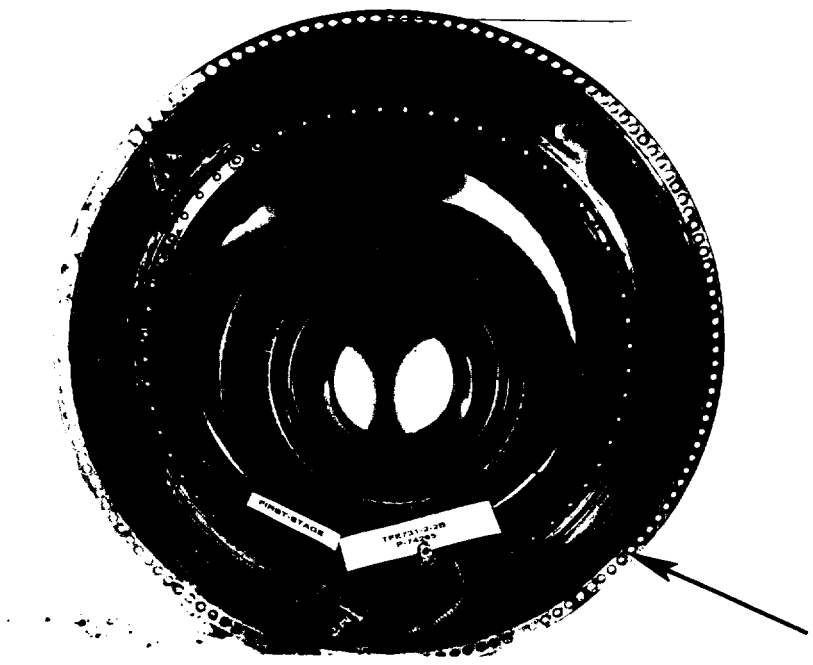

Figure 239. (Photo No. 39-12) Broken Mount.

Figure 240. (Photo No. 39-14) Worn Honeycomb Seal.

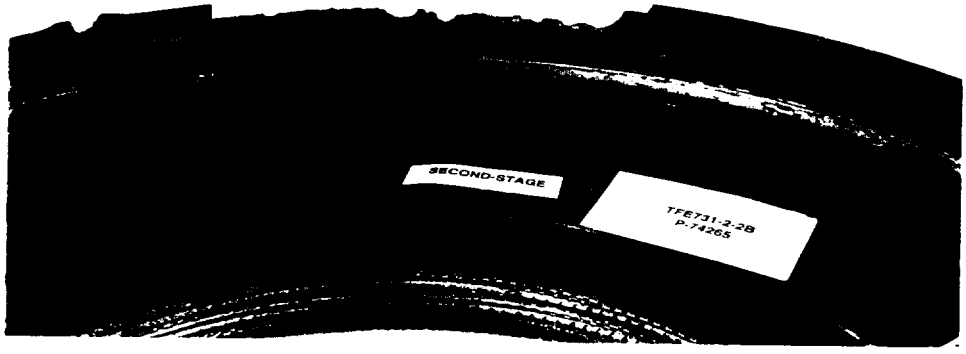

Figure 241. (Photo No. 45-17) Fractured Second-Stage LP Turbine Blade-Tip Shroud.

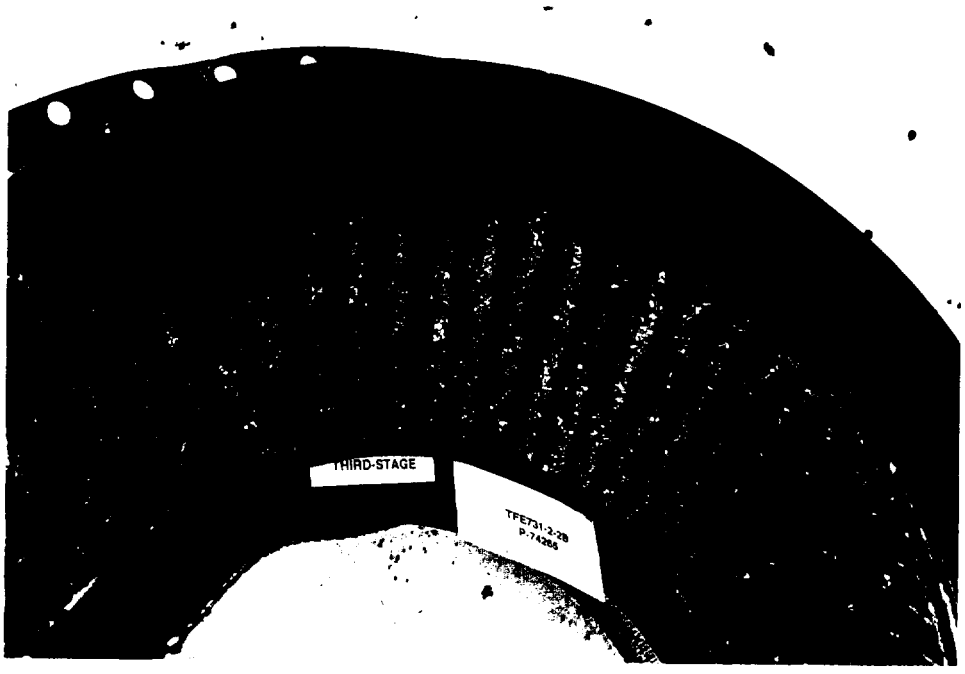

Figure 242. (Photo No. 39-3) Metal-Spray Deposits on the Third-Stage LP Turbine Stator Vanes .

Figure 243. (Photo No. 45-31) Broken LP Turbine Tie Shaft, and Damaged LP Shaft and Seal Assembly Curvic Coupling.

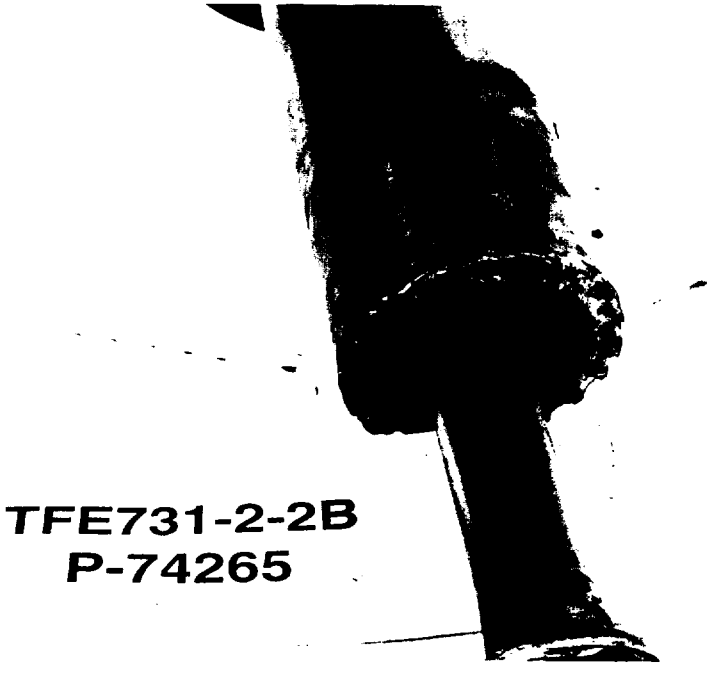

Figure 244. (Photo No. 45-30) Damaged Curvic Coupling.

Figure 245. (Photo No. 45-33) Scored LP Shaft and Seal Assembly.

Figure 246. (Photo No. 45-34) Scored LP Shaft and Seal Assembly.

Figure 247. (Photo No. 45-22) Damaged LP Rotating Seal Forward Curvic Coupling Teeth.

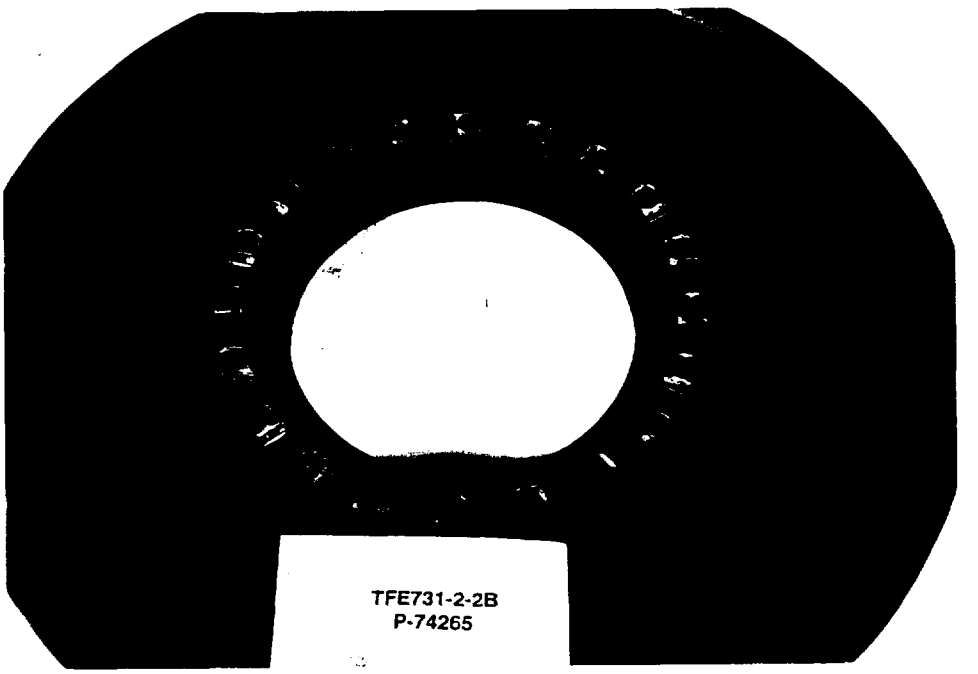

Figure 248. (Photo No. 45-23) Damaged LP Rotating Seal Aft Curvic Coupling Teeth.

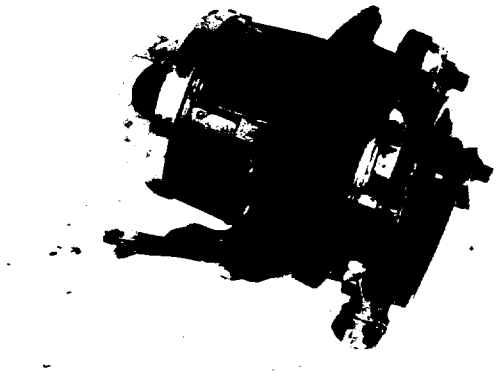

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Figure 249. (Photo No. 28-21) Damaged Surge Bleed Valve.

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P-74264

Figure 250. (Photo No. 28-23) Damaged Surge Bleed Valve.

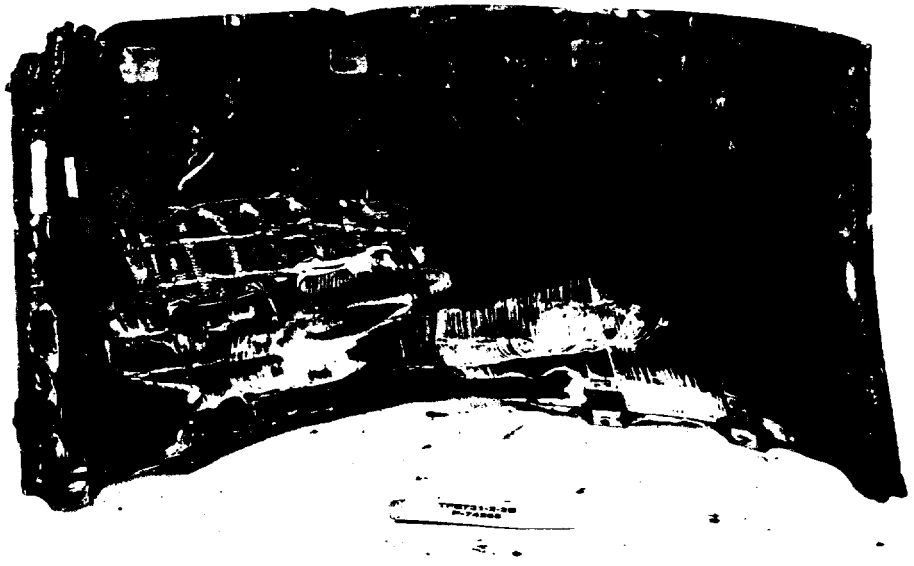

Figure 251. (Photo No. 38-27) Score Marks on the Top Air/Oil Cooler.

Figure 252. (Photo No. 38-28) Score Marks on the Top Air/Oil Cooler.

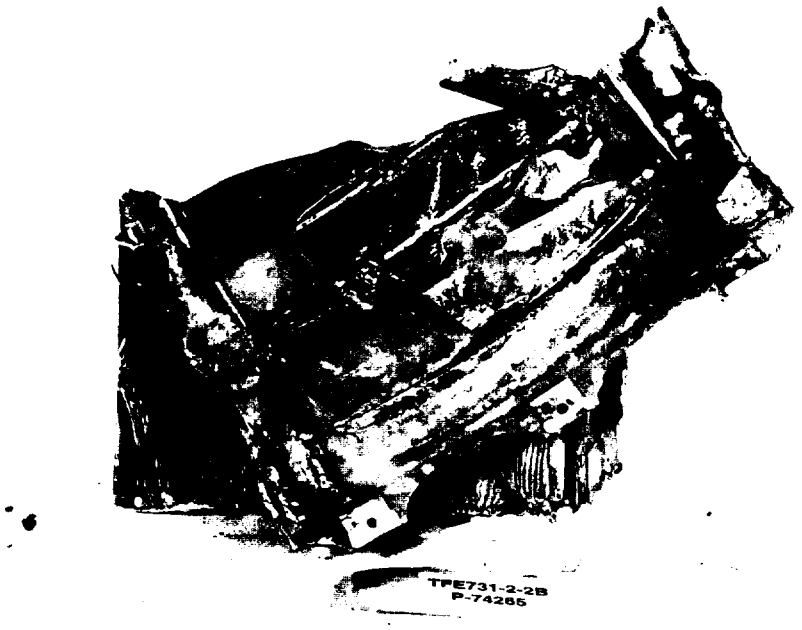

Figure 253. (Photo No. 38-23) Score Marks on the Left Air/Oil Cooler.

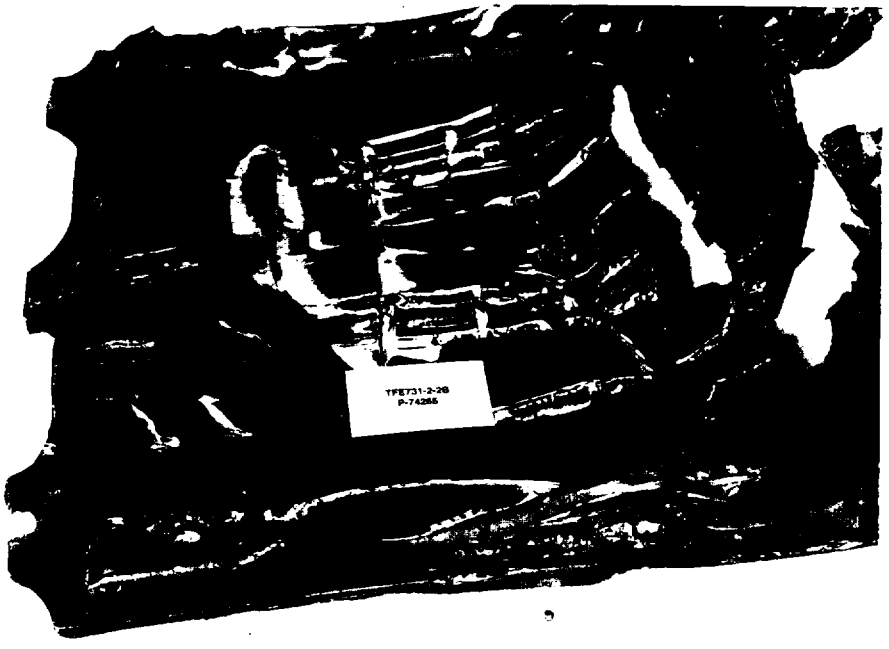

Figure 254. (Photo No. 38-22) Score Marks on the Right Air/Oil Cooler.

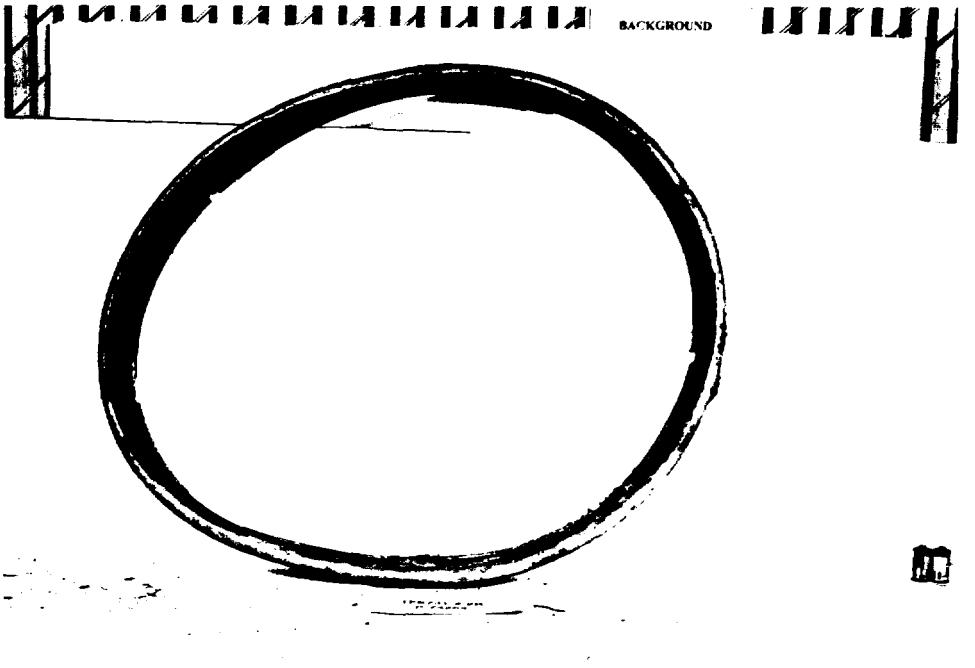

Figure 255. (Photo No. 32-22) Distorted Containment Ring.

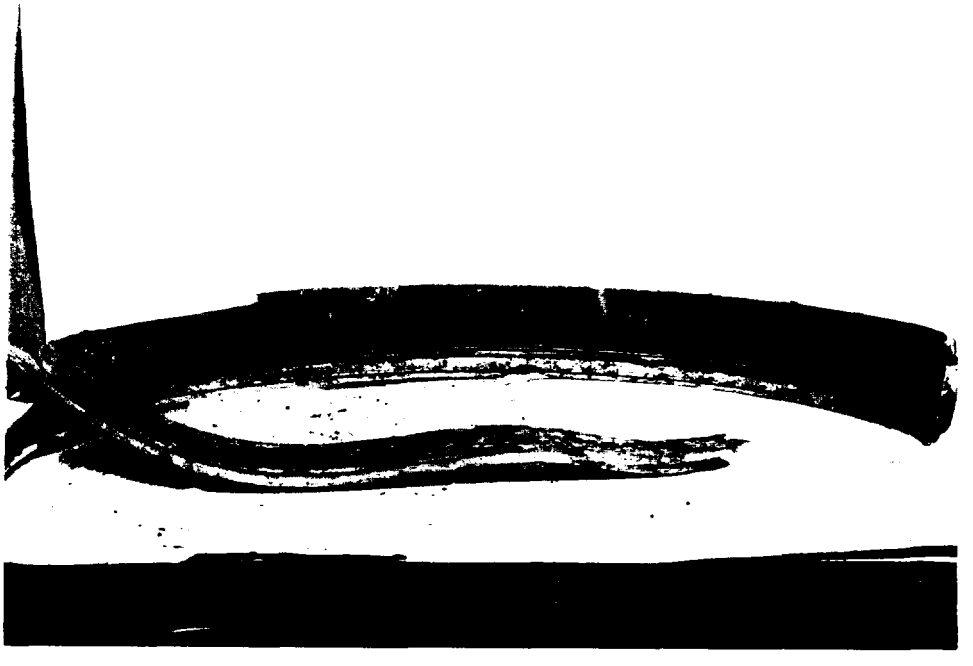

Figure 256. (Photo No. 42-8) Damaged Containment Ring.

Figure 257. (Photo No. 28-28) Fragments of Compressor Inlet Stator and Fan Bypass Stator.

Figure 258. (Photo No. 42-9) Fragments of Compressor Inlet Stator and Fan Bypass Stator.

Figure 259. (Photo No. 28-8) Bent Accessory Gearbox Drive Shaft.

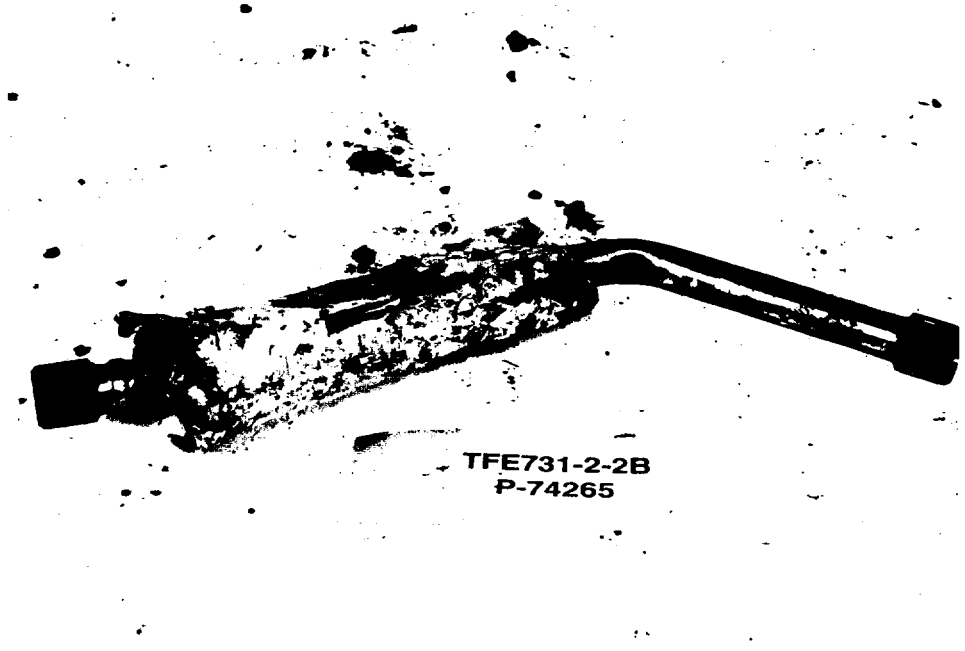

Figure 260. (Photo No. 40-18) Bent Accessory Gearbox Drive Shaft.

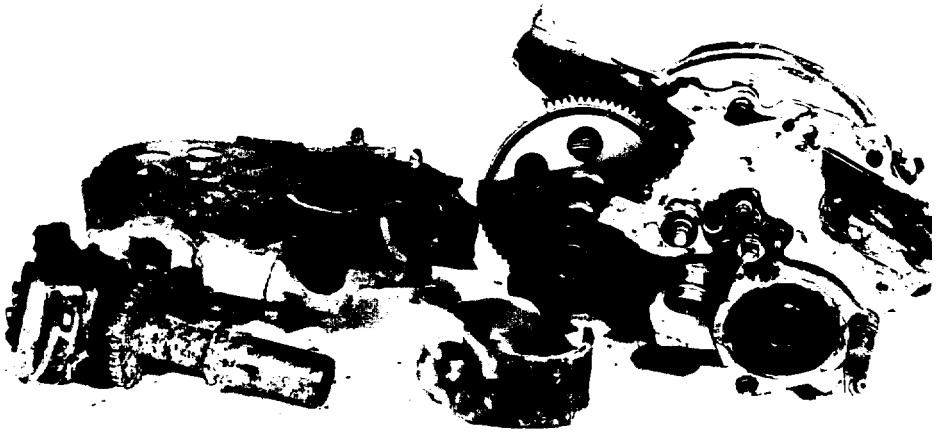

Figure 261. (Photo No. 28-26) Fragments of Accessory Drive Gearbox.

Figure 262. (Photo No. 40-12) Fragments of Accessory Drive Gearbox.

Figure 263. (Photo No. 32-4) Transfer Gearbox.

Figure 264. (Photo No. 40-9) Transfer Gearbox.

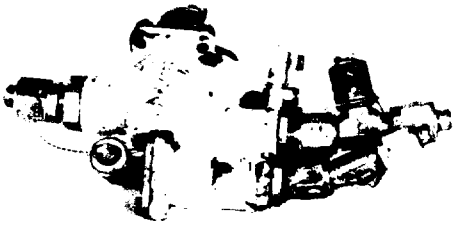

Figure 265. (Photo No. 28-19) Damaged Flow Divider and Drain.

Figure 266. (Photo No. 40-4) Damaged Flow Divider and Drain.

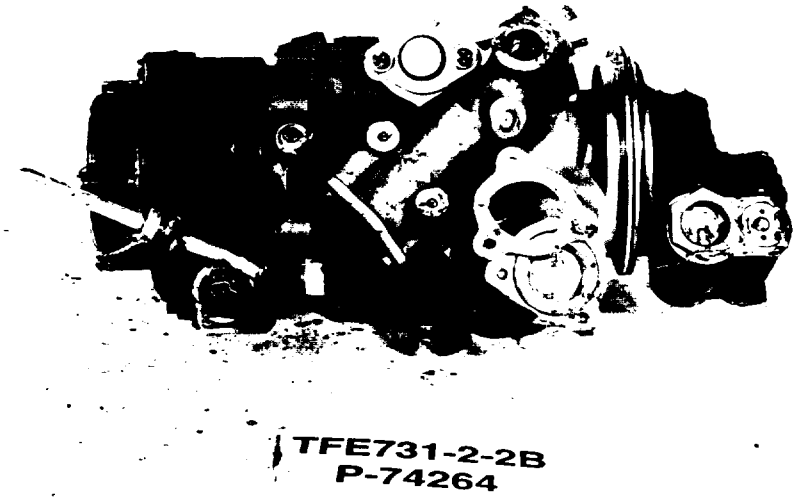

Figure 267. (Photo No. 32-10) Fuel Control with Fuel Pump Flange.

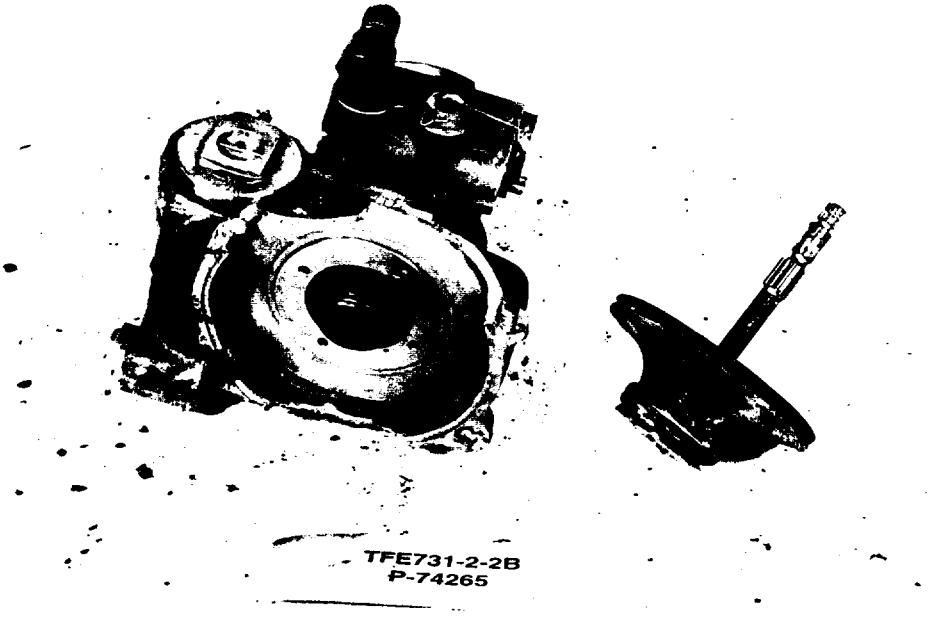

Figure 268. (Photo No. 40-13) Damaged Fuel Pump.

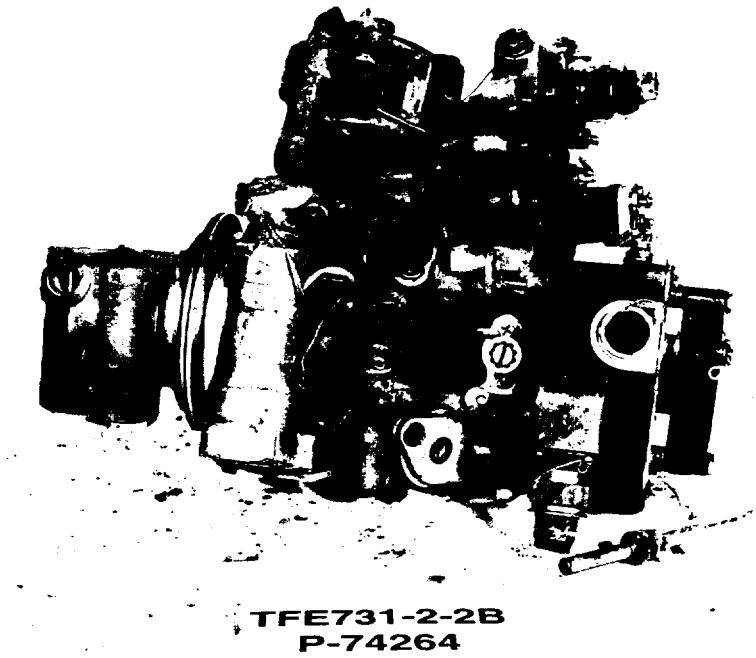

Figure 269. (Photo No. 32-12) Fuel Control.

Figure 270. (Photo No. 40-16) Damaged Fuel Control.

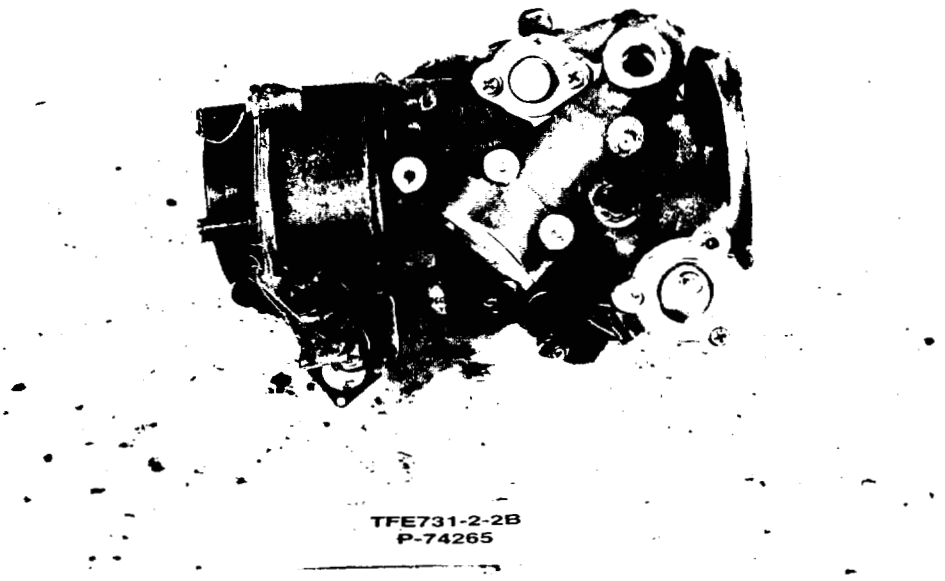

Figure 271. (Photo No. 40-17) Damaged Fuel Control.

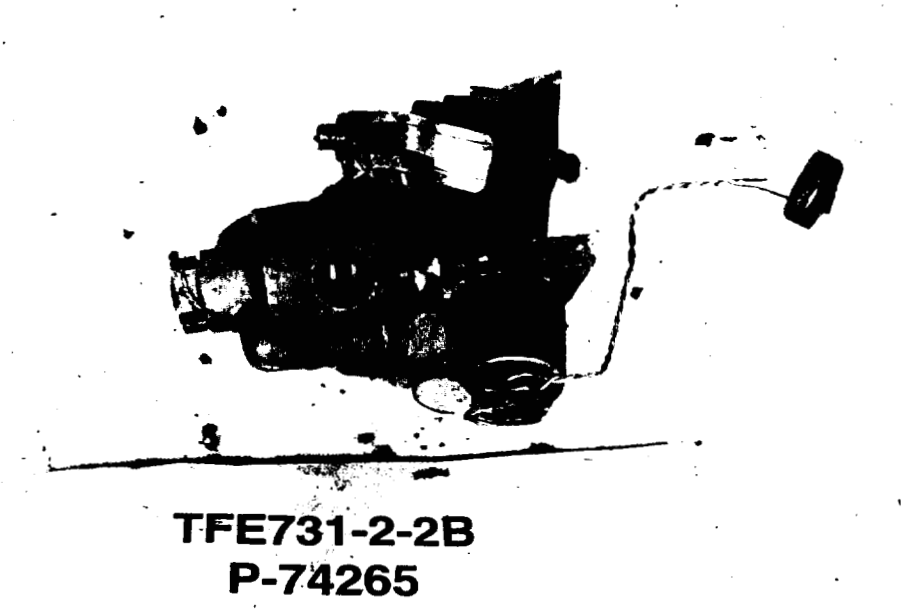

Figure 272. (Photo No. 38-31) Separated P3 Limiter.

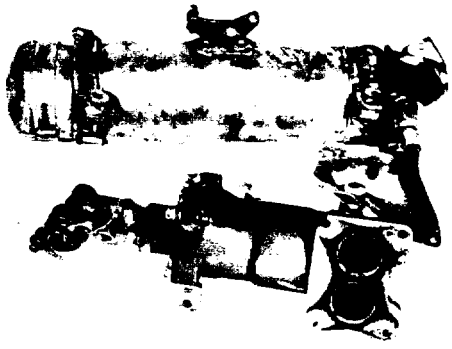

Figure 273. (Photo No. 28-18) Damaged Fuel/Oil Cooler.

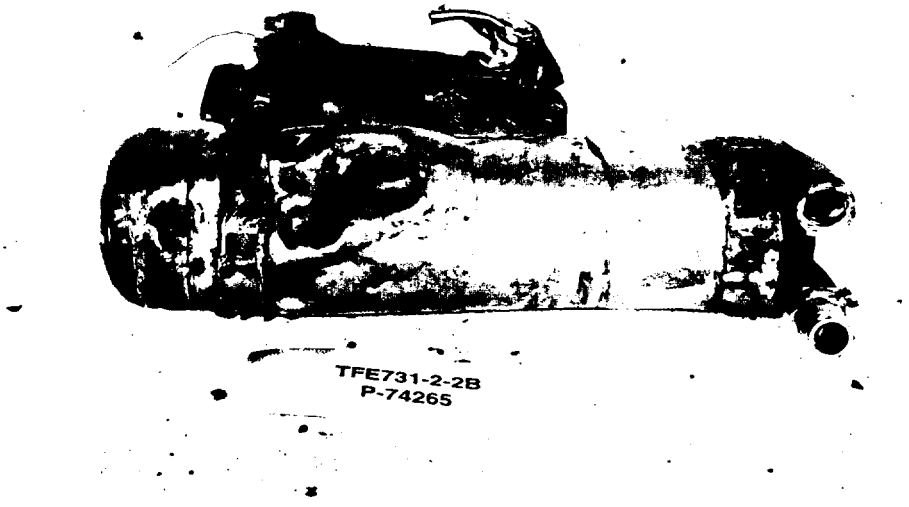

Figure 274. (Photo No. 38-34) Damaged Fuel/Oil Cooler.

Figure 275. (Photo No. 28-31) Damaged Oil Filter.

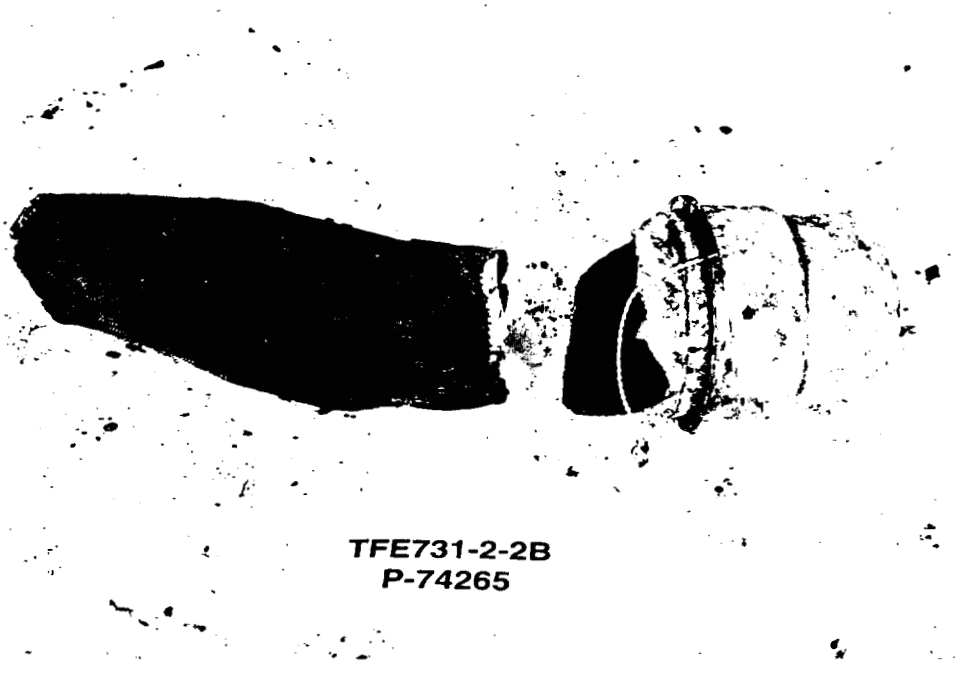

Figure 276. (Photo No. 42-15) Damaged Oil Filter.

Figure 277. (Photo No. 32-2) Oil Tank Fragments.

Figure 278. (Photo No. 40-5) Oil Tank Fragments.

Figure 279. (Photo No. 32-7) Damaged Oil Lube and Scavenge Pump.

Figure 280. (Photo No. 40-8) Damaged Oil Lube and Scavenge Pump.

Figure 281. (Photo No. 28-34) Damaged Oil Temperature Control Valve.

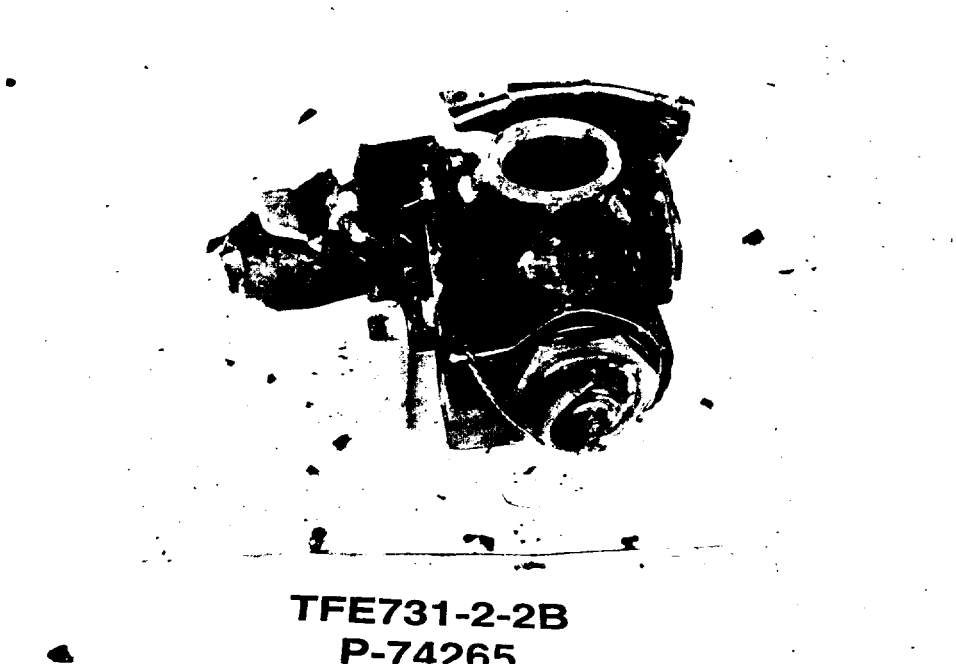

Figure 282. (Photo No. 38-33) Damaged Oil Temperature Control Valve.

Figure 283. (Photo No. 32-1) Damaged Ignition Leads.

Figure 284. (Photo No. 28-35) Damaged Solenoid Controller Valve.

Figure 285. (Photo No. 32-13) Damaged EEC.

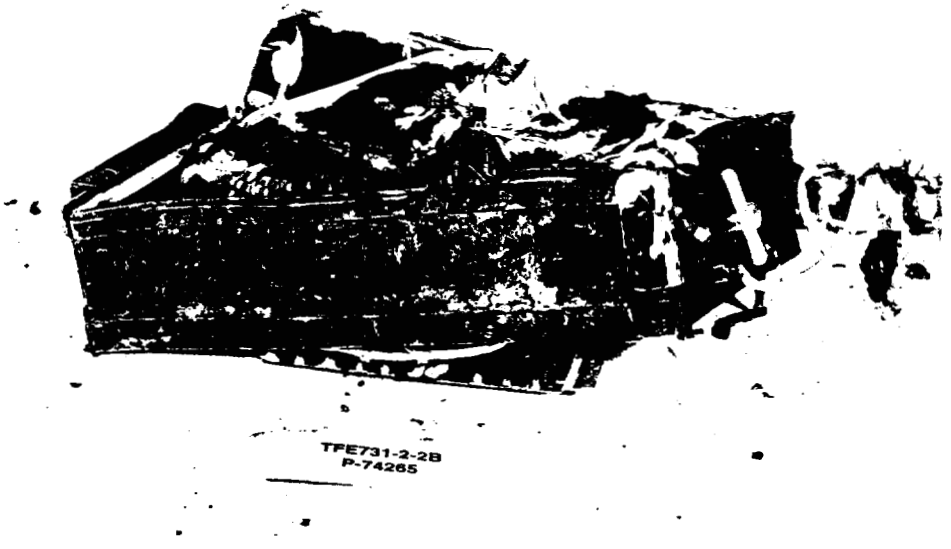

Figure 286. (Photo No. 38-36) Damaged EEC.

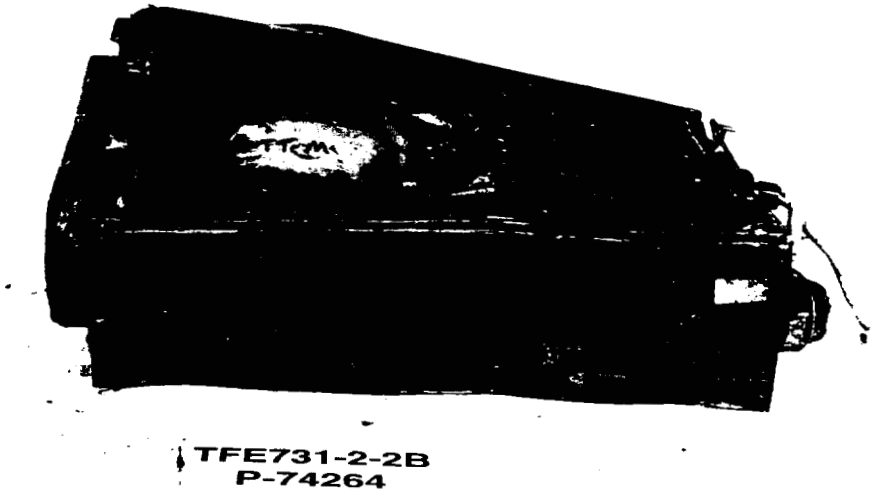

Figure 287. (Photo No. 32-14) Damaged EEC.

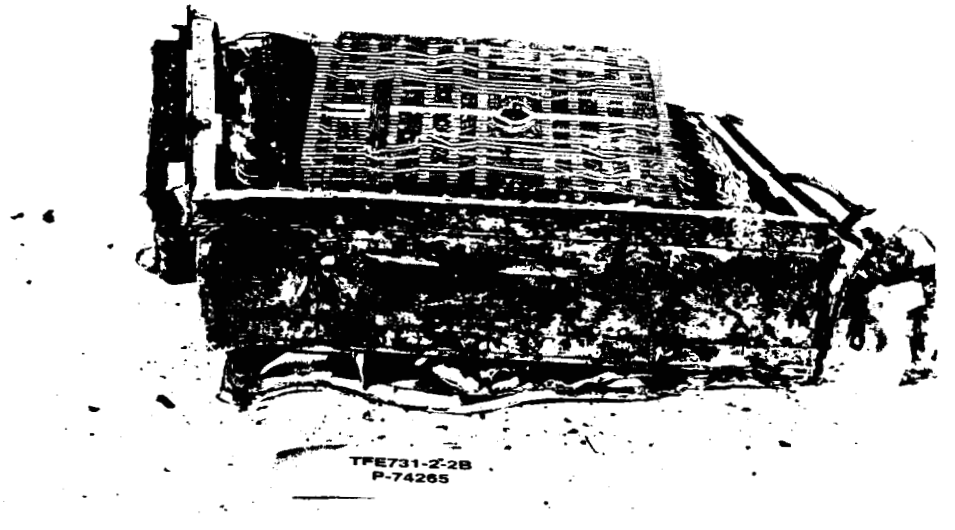

Figure 288. (Photo No. 38-37) Damaged EEC.