NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

January 15, 2004

ADDENDUM NUMBER 6 TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION – YAW DAMPER EXAMINATION

DCA02MA001

A. ACCIDENT

Operator: American Airlines
Aircraft: A300-600R
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 09:16 EDT

B. SYSTEMS GROUP

Chairman — Steven Magladry
National Transportation Safety Board
Washington, DC

Member — Gerald Gaubert
Bureau Enquetes - Accidents
Paris Le Bourget, France

Member — Albert Urdiroz
Airbus France
Toulouse Blagnac, France

Member — David Seratt
American Airlines
Tulsa, Oklahoma

C. SUMMARY

On November 12, 2001, American Airlines flight 587, an Airbus Industrie A300-600R, N14053, crashed at Belle Harbor, New York, shortly after takeoff from John F. Kennedy International Airport (JFK), Jamaica, New York. The aircraft was equipped with General Electric CF6-80C2A5 engines. The airplane had taken off from runway 31 left and had turned southbound when it crashed. The aircraft was operated under the provisions of Title 14 of the U.S. Code of Federal Regulations Part 121 as a regularly scheduled international passenger flight from JFK to Santo Domingo, Dominican Republic. The 2 pilots, 7 flight attendants, and 246 passengers plus 5 lap children on board were killed.

The systems group recovered the yaw damper actuator from the accident site. The group convened at the manufacturer (Goodrich), in Vernon, France on June 4-5, 2003 to examine and disassemble the actuator. The following provides the details of the activities.

D. DETAILS OF THE INVESTIGATION

1.0 Description of Yaw Damper Actuator

The yaw damper actuator is an electro-hydraulic mechanism installed in the rudder frame. Figure 1 shows a functional schematic of the actuator. The actuator consists of two cylinders capable of simultaneous or independent operation. The two cylinders have a common output axis, which is connected to two output levers to the differential unit. For a description the installation of the yaw damper, refer to the Systems Group Chairman's Factual Report of Investigation. One of the yaw damper cylinders is called the Driving cylinder, the other the Driven cylinder. The Driving cylinder directly actuates the common output shaft. The Driven cylinder actuates the common output axis through a hydraulic transparency system.

The purpose of the transparency system is to compensate for the difference in the relative positions between the two cylinders. The transparency system allows a difference in cylinder positions, which corresponds to up to 9 degrees of control surface deflection.

The position of the each cylinder is controlled by an electro-hydraulic servovalve, which applies hydraulic pressure to the respective chambers according to the control signals provided by the Flight Augmentation Computers (FACs).

Each cylinder has a locking cam, which locks the output shaft in neutral when hydraulic pressure in not provided to the release cylinder. Either release cylinder is able to unlock both cylinder locking cams.

Figure 2 and Figure 3 show the location of the components on the actuator. Figure 4 shows a more detail functional schematic using the same reference numbers shown in Figure 2.

Actuator Architecture
This actuator is composed of two channels :
- the driving channel associated with yaw damper 1 (FAC1)
- the driven channel associated with yaw damper 2 (FAC2)
Each channel consists of :
- a release cylinder (1)
- a locking spring (2)
- a solenoid valve (3)
- an electro-hydraulic servovalve (4)
- a locking cam (5)
- synchro resolvers (6).
On driving channel is :
- a driving cylinder (7)
- a pressure switch (8).
On driven channel is :
- a driven cylinder (9)
- a transparency device piston (10).
<u>NOTE</u> : The driven cylinder is fitted with a transparency system.
(Ref. Fig. 004)

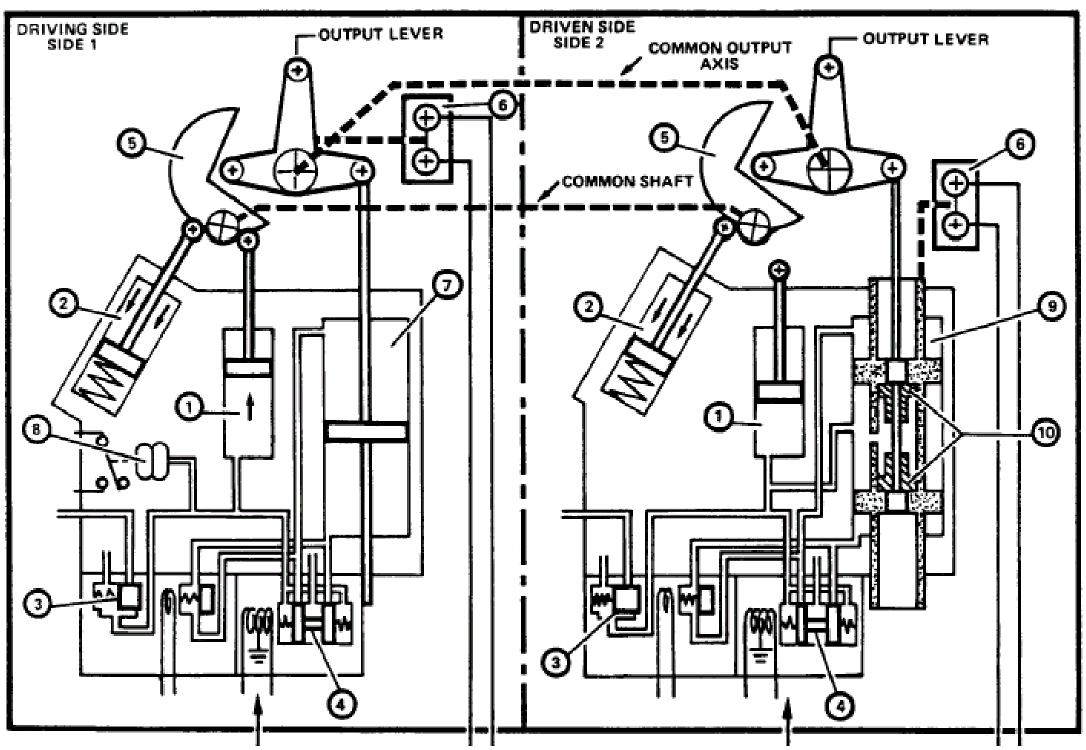
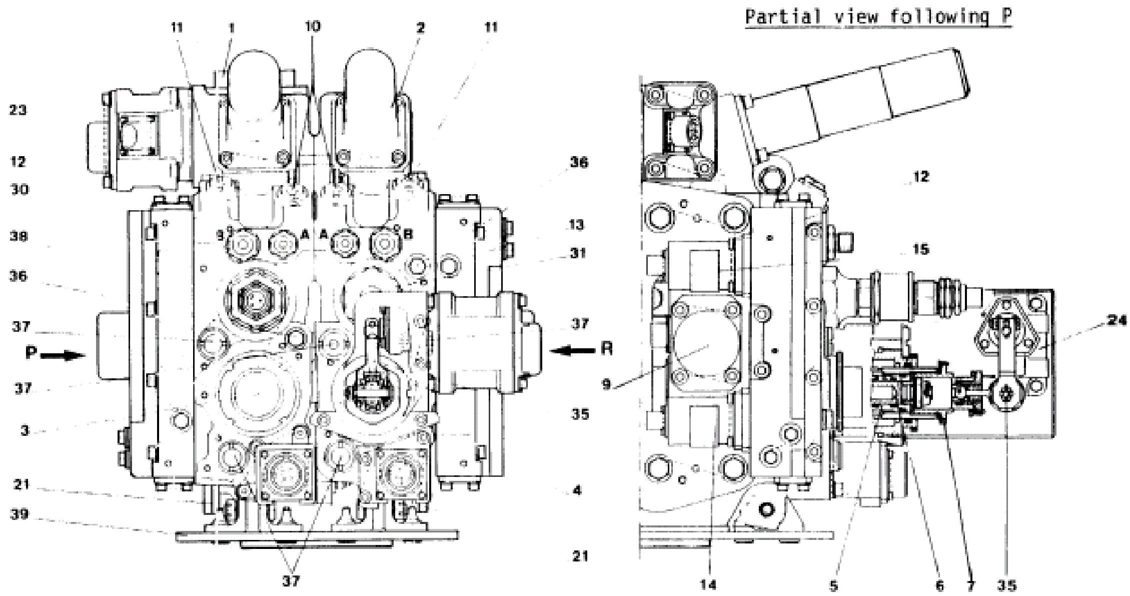


Figure 1. Functional Schematic of the Yaw Damper Actuator.



1 - (Drive) body
2 - (Driven) body
3 - Drive cylinder
4 - Driven cylinder
5 - Piston (transparency device)
6 - Piston rod (driven cylinder)
7 - Outlet rod
8-9 - Servovalve
10 - Filter (on pressure inlet)
11 - Filter (on return to reservoir)
12-13 - Distribution block
14-15
16-17 - Electric distributor
18-19 - Outlet lever
20 - Serrated shaft
21 - Flange
22 - Mechanical link-rod
23 - Drive synchro box
24 - Driven synchro box
25 - Slave control synchro-resolver
26 - Monitoring synchro-resolver
27-28 - Locking cam
29 - Serrated shaft
30-31 - Unlocking jack
32-33 - Locking spring rod (Unlocking jack)
34 - Cap
35 - Mechanical link-rod
36 - Plug, with diffuser
37 - Plug
38 - Pressure switch
39 - Baseplate
40 - Square bracket
41 - Cap
A - Inlet pressure port
B - Reservoir return port

Figure 2. Location of Yaw Damper Actuator Components.

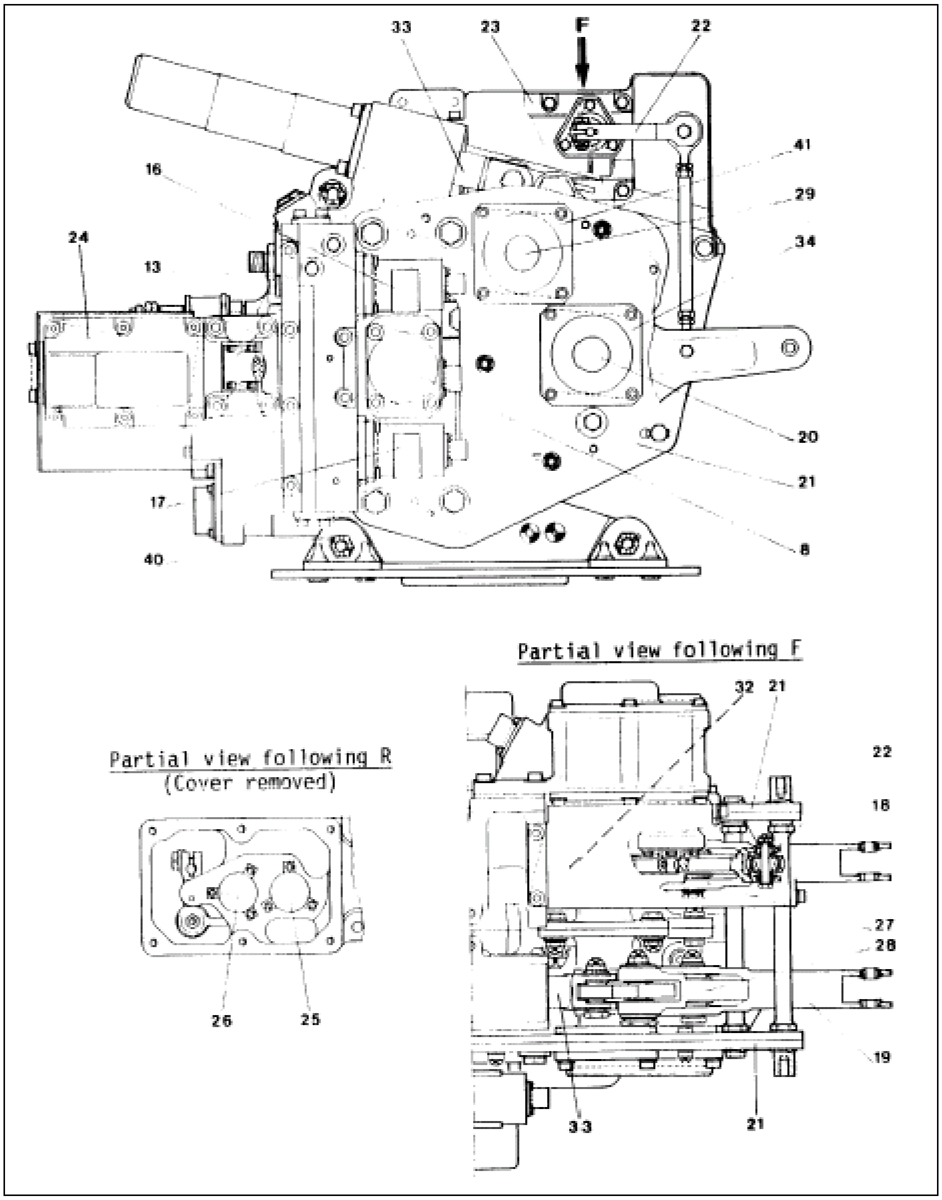


Figure 3. Location of Yaw Damper Actuator Components

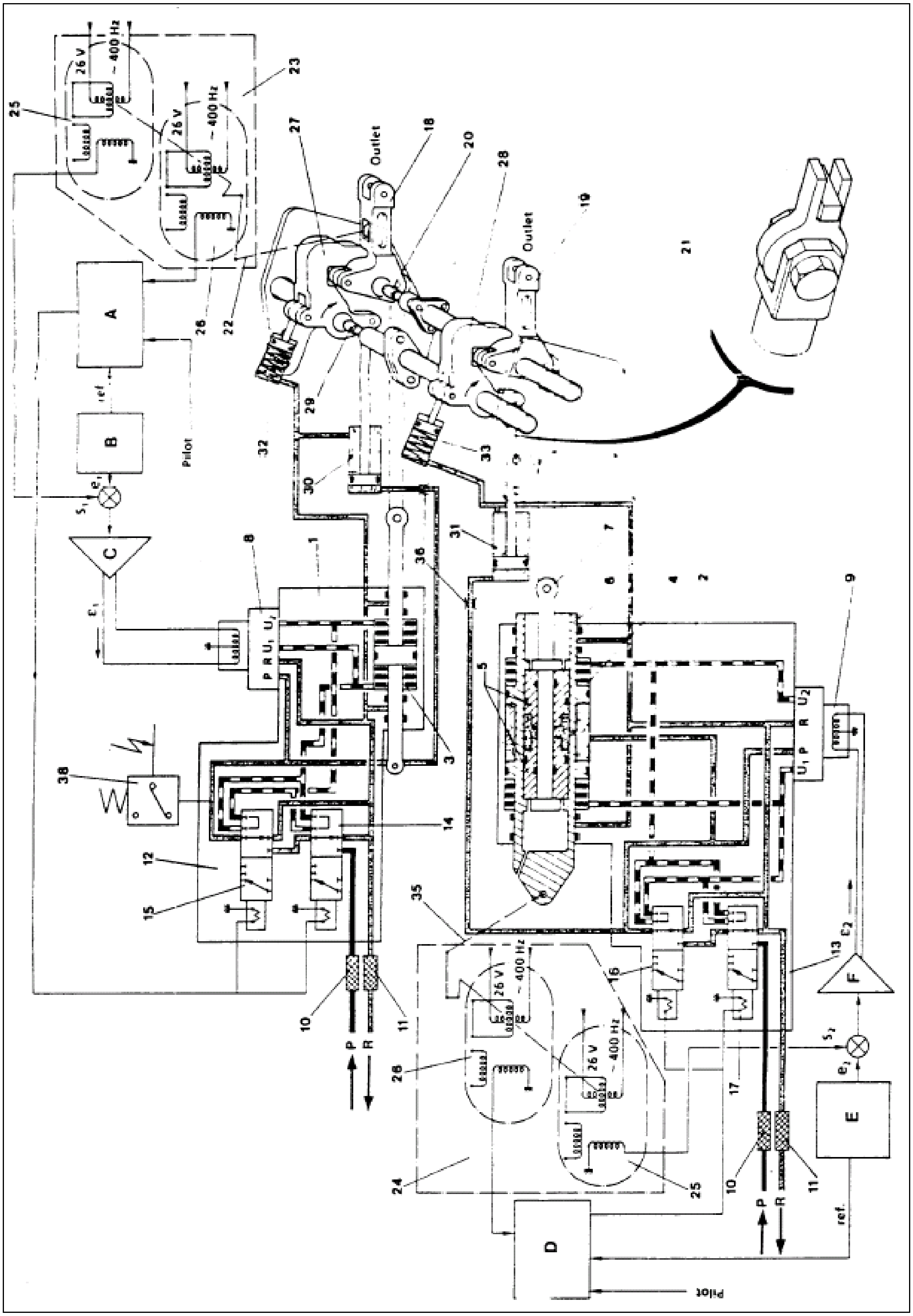


Figure 4. Functional Schematic of Yaw Damper Actuator.

2.0 Condition of Accident Airplane Yaw Damper Actuator.

The yaw damper actuator was recovered from the accident site. It was attached to a large piece of re-solidified molten metal and debris (Figure 3). The wreckage was moved to NTSB Headquarters, Washington DC. The unit was cut away from the debris and shipped to France for further examination.

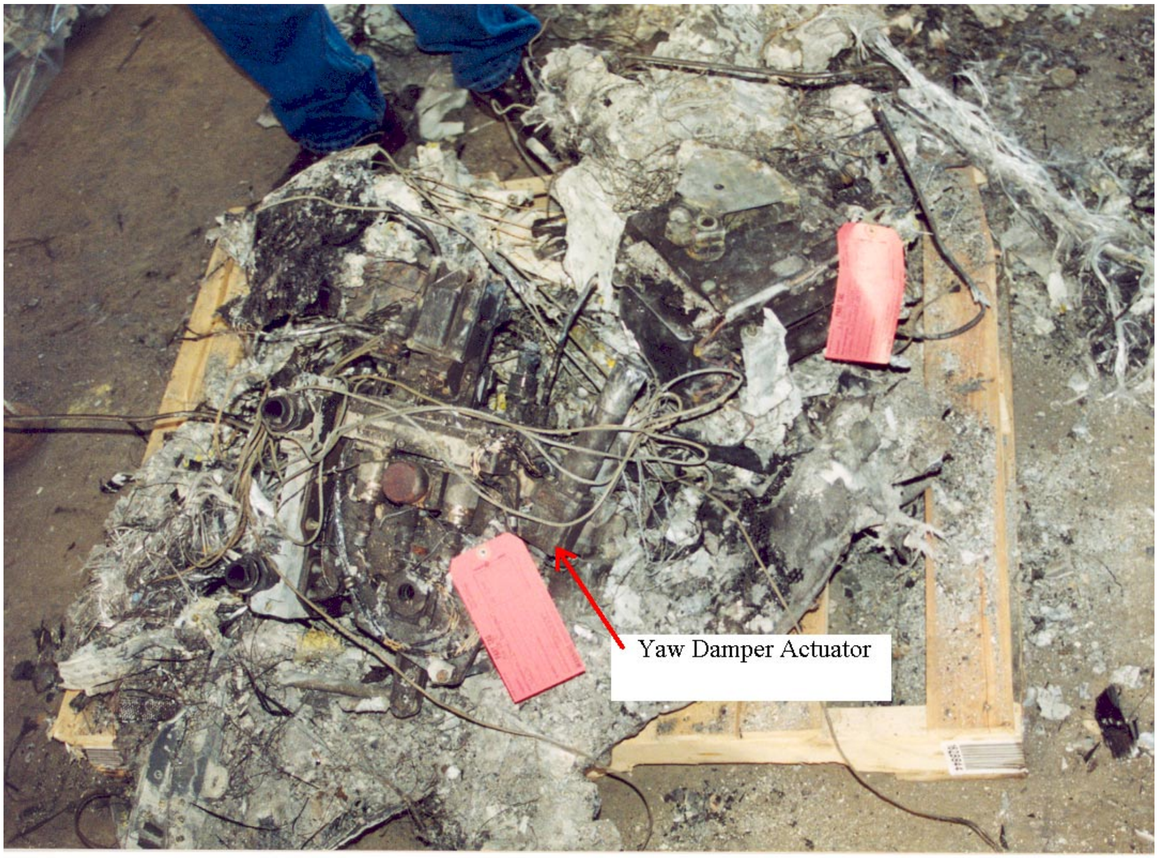


Figure 3. Yaw Damper Actuator as Recovered from the Wreckage.

3.0 Examination and Teardown.

The Systems Group convened at the manufacturer (Goodrich), in Vernon, France on June 4-5, 2003 to examine and disassemble the actuator. The group was assisted by the following:

Goodrich Investigation Team:

Jean-Francois Coillard	Project Manager
Cedric Klein	Commercial Manager
Charles Boutelleau	Engineering
Davy Binois	Product Support
Patrick Le Digabel	Repair shop

Airbus Engineering Support:

Jean-Christophe Brody	Flight Controls Design Office Engineer
Francis Fernandez	Flight Controls Design Office Engineer

The group began by documenting the external condition of the Yaw Damper Actuator (YDA). Figures 4 to 8 show the unit as received in France. All references to the Illustrated Parts List (IPL) can be found in Appendix A. The first number in the reference indicates the figure number and the second indicates the item (Ex. IPL 5-100, can be found in Appendix A, Figure 5, item number 100).

Observations

The Driving side synchro box input rod was fractured. This occurred while the unit was removed from molten metal parts which re-solidified on the component during the post accident fire. The synchro box linkage, which connected to the output arm was bent.

The Driven side synchro box attachment to the actuator was broken.

The locking forks were engaged, consistent with a locking to neutral when there is no hydraulic power.

The spring housings (IPL 5-020) were damaged. The Driven channel had two springs, the Driving side had only one spring (IPL 5-060).

The actuator output levers had a segment of the airplane control rods still connected.

The linkage from the output levers (IPL 6-740), through the common output shaft (IPL6-620), and to the Driving cylinder (IPL 7-130, 7-150) and Driven cylinder (IPL 8-300, 8-380) was intact (Figure 9).

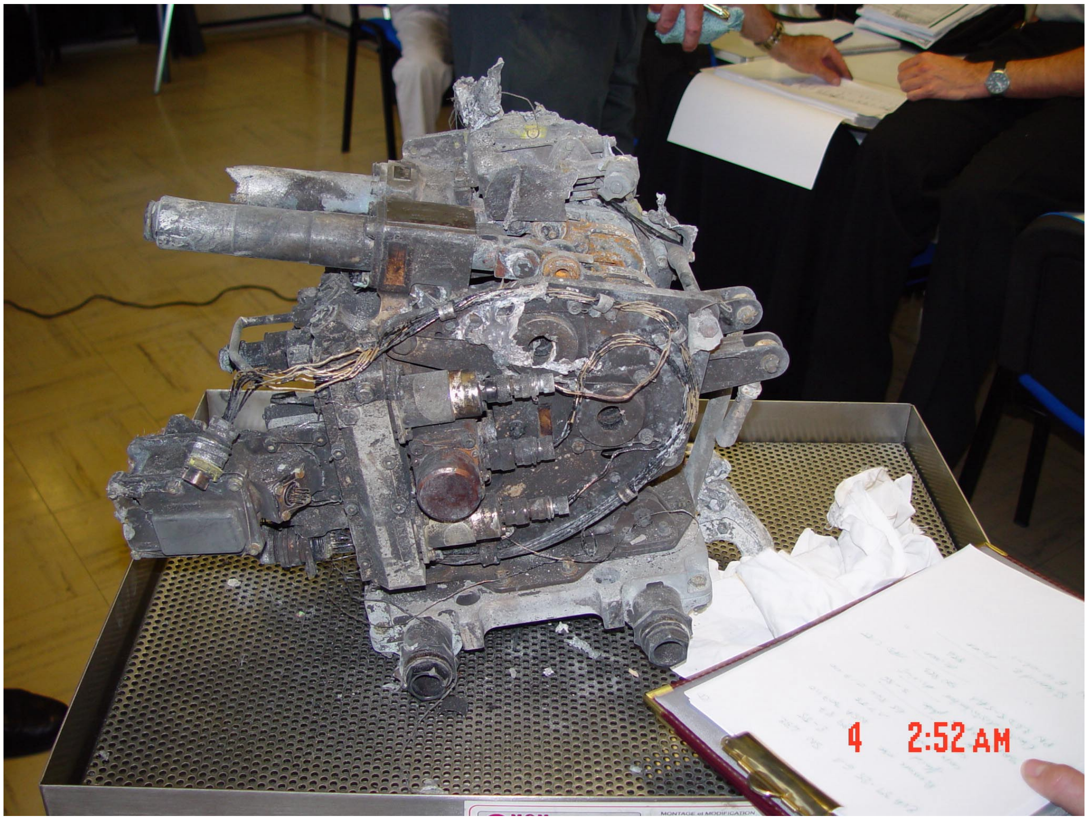


Figure 4. Yaw Damper Actuator Driven Side.

Figure 5. Yaw Damper Actuator Aft View.

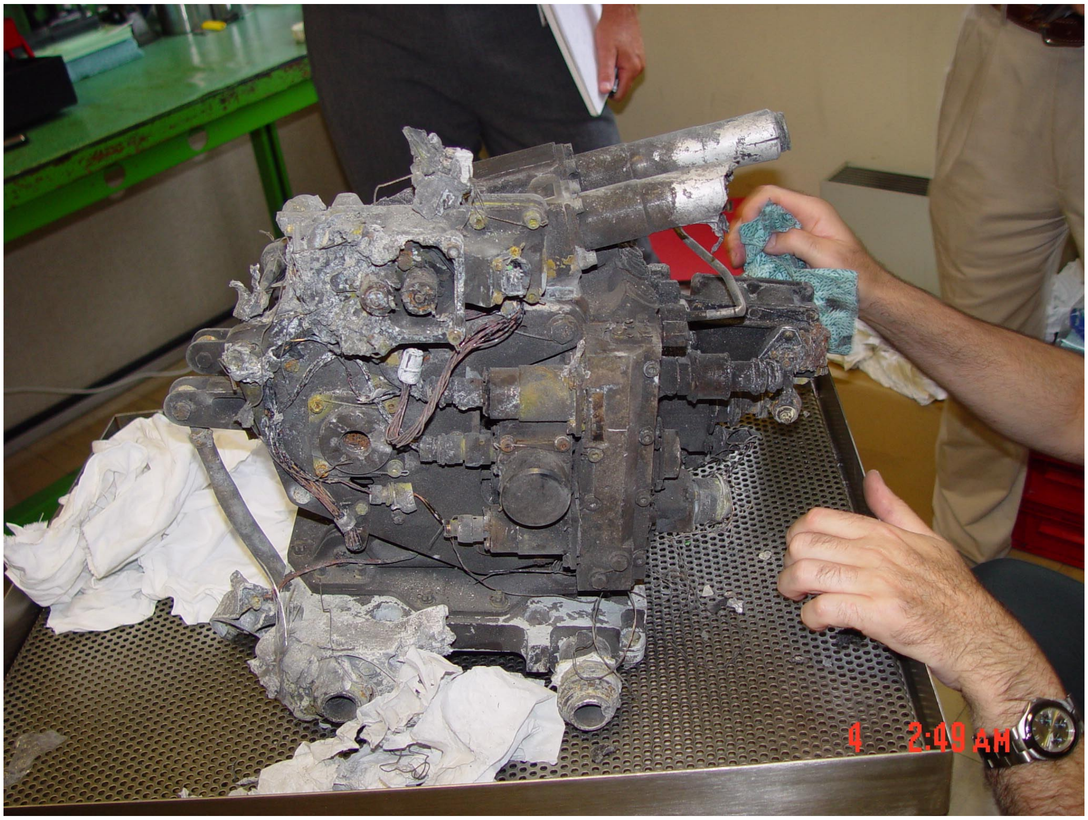


Figure 6. Yaw Damper Actuator Driving Side.

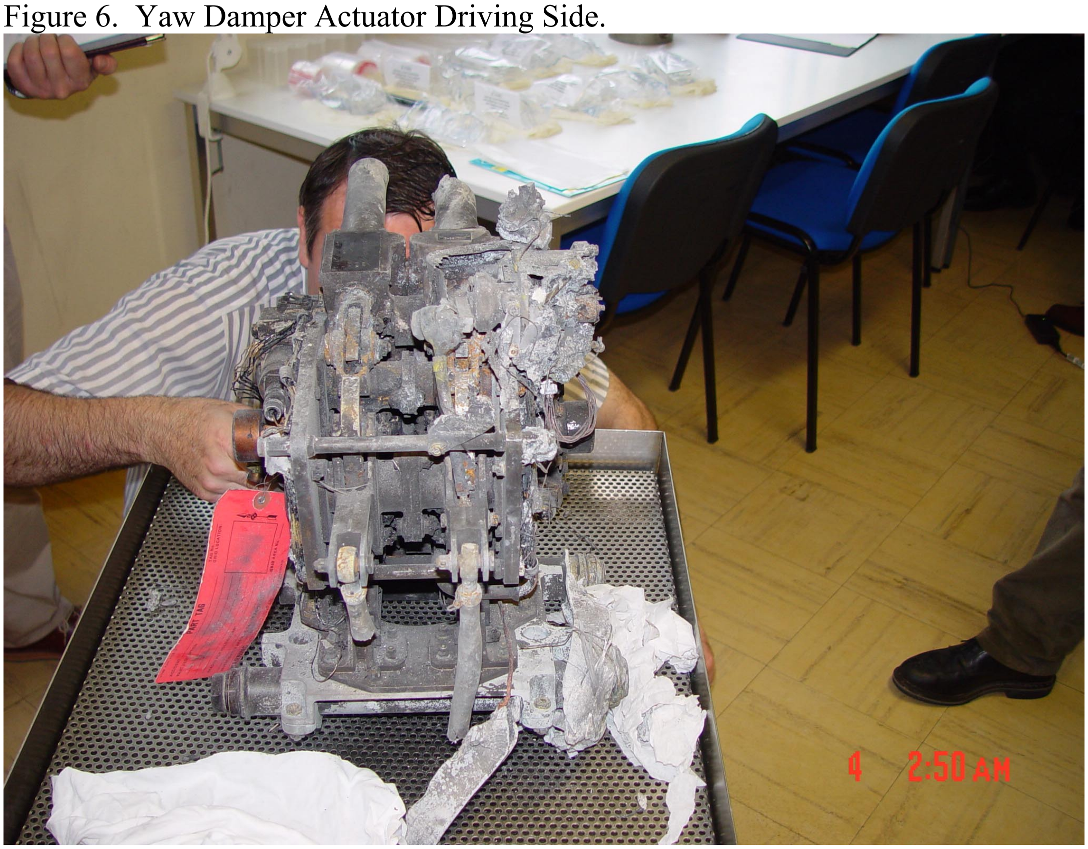


Figure 7. Yaw Damper Actuator Front View.

Figure 8. Yaw Damper Actuator Top View.

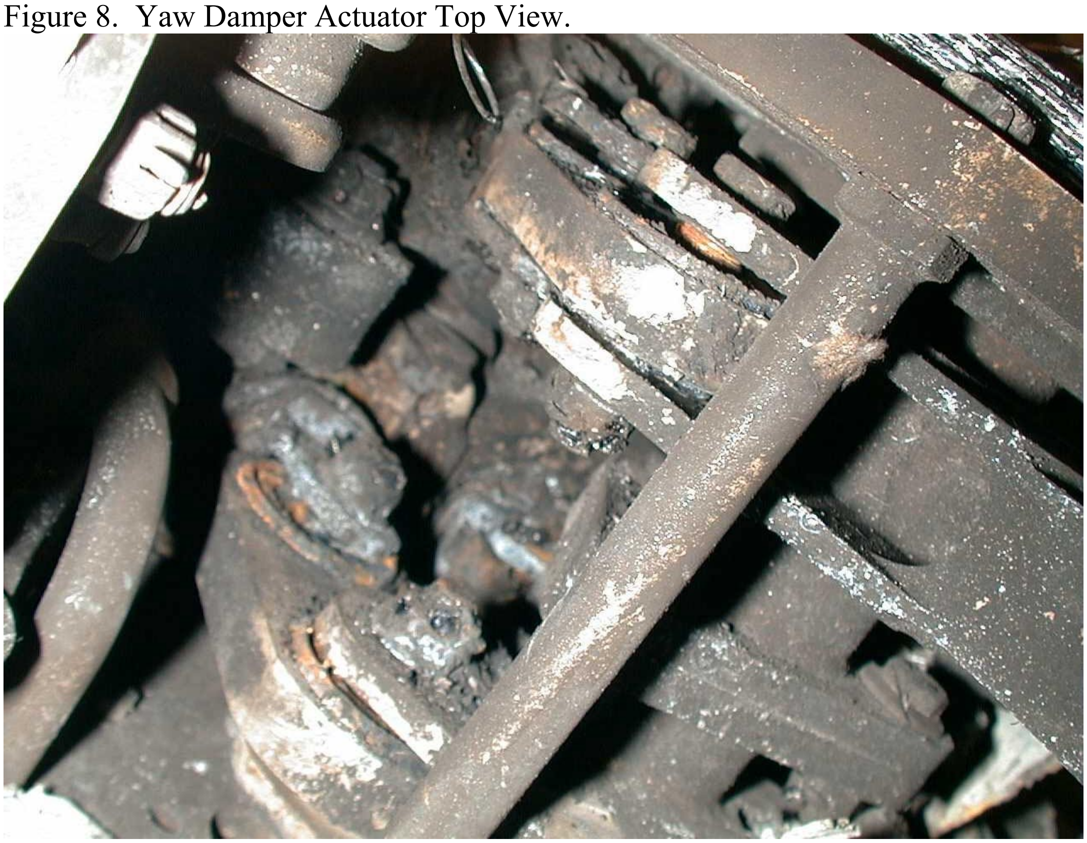


Figure 9. Yaw Damper Output Linkage.

The group recorded all visible part numbers and identification plates. The following information was obtained:

Identification plates

Yaw Damper actuator PN 2VA39-25G1, SN 432, MFD 2-85, cure date 1Q85, SAMM repair plate 3-86. This is the same serial number actuator that records indicate was installed prior to delivery of the airplane.

Driving electric distributors PN 2ED8-5A1, MFD 2/85, S/N 883
Driving servovalve, Abex model 410-1612, PN 78142, SN 1044, MFD A30/84
Driving Solenoid ED1 PN E10-02-1, SN 3851, MFD 05/83
Driving Solenoid ED2 PN E10-02-1, SN 3884, MFD 05/83

Driven electric distributors PN 2ED8-5A1, MFD 2/85, SN 884
Driven servovalve, Abex model 410-1612, PN 78142, SN 799, MFD A10/82
Driven Solenoid ED1 PN E10-02-1, SN 3853, MFD 05/83
Driven Solenoid ED2 PN E10-02-1, SN 3832, MFD 05/83

Wiring checks

The airplane electrical connectors were removed. The actuator receptacles pins were in good condition and could be identified with the connector key. Continuity checks showed that because wiring insulation was heat damaged there were many shorts. The wire harnesses for both Driving and Driven sides were removed in order to physically confirm the wiring connections.

Driving channel

The connections as per CMM, Figure 505 (Figure 10) were confirmed except SV-C splice to SV-B (Splice melted).
Note: Pin arrangement at synchro box was deduced from pin A that had no wire connected.
The resistance at the solenoids pins A and B was measured to be 83.9 ohms at ED1 and 82.2 ohms at ED2.

Driven channel

The connections as per CMM, Figure 506 (Figure 11) were confirmed except ED1-A to splice with ED2-A (Splice melted).
The resistance at the solenoids pins A and B was measured to be 82.4 ohms at ED1 and 81.6 ohms at ED2.

The resistance at the synchro resolvers and transmitters of the synchro box was measured to be 0.3 ohms pins G to F, 0.27 ohms pins C to D, 0.23 ohms pins H to K, and open circuit between pins B and J. The synchro box cover was removed, but routing of the wires could not be confirmed visually.

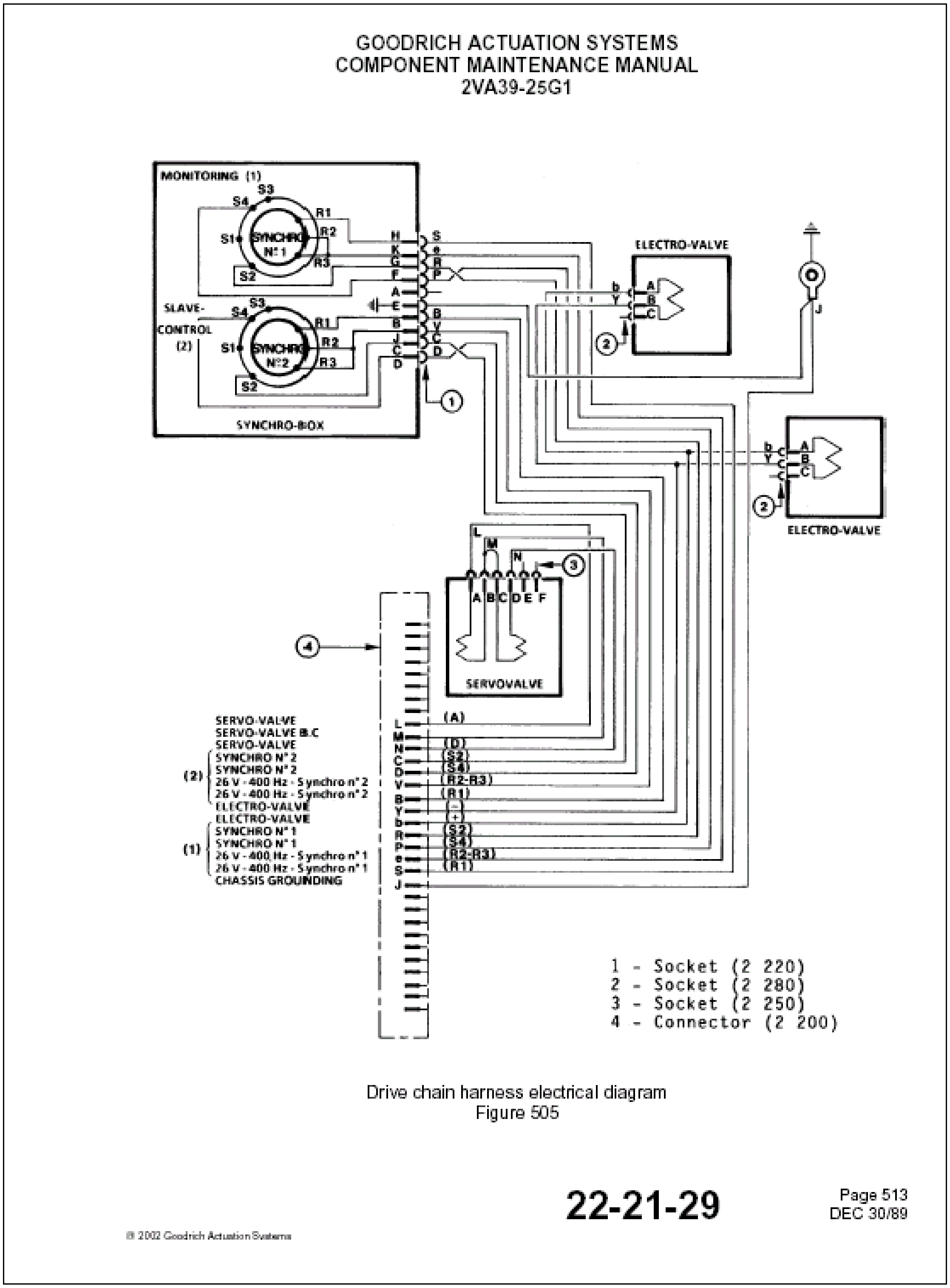
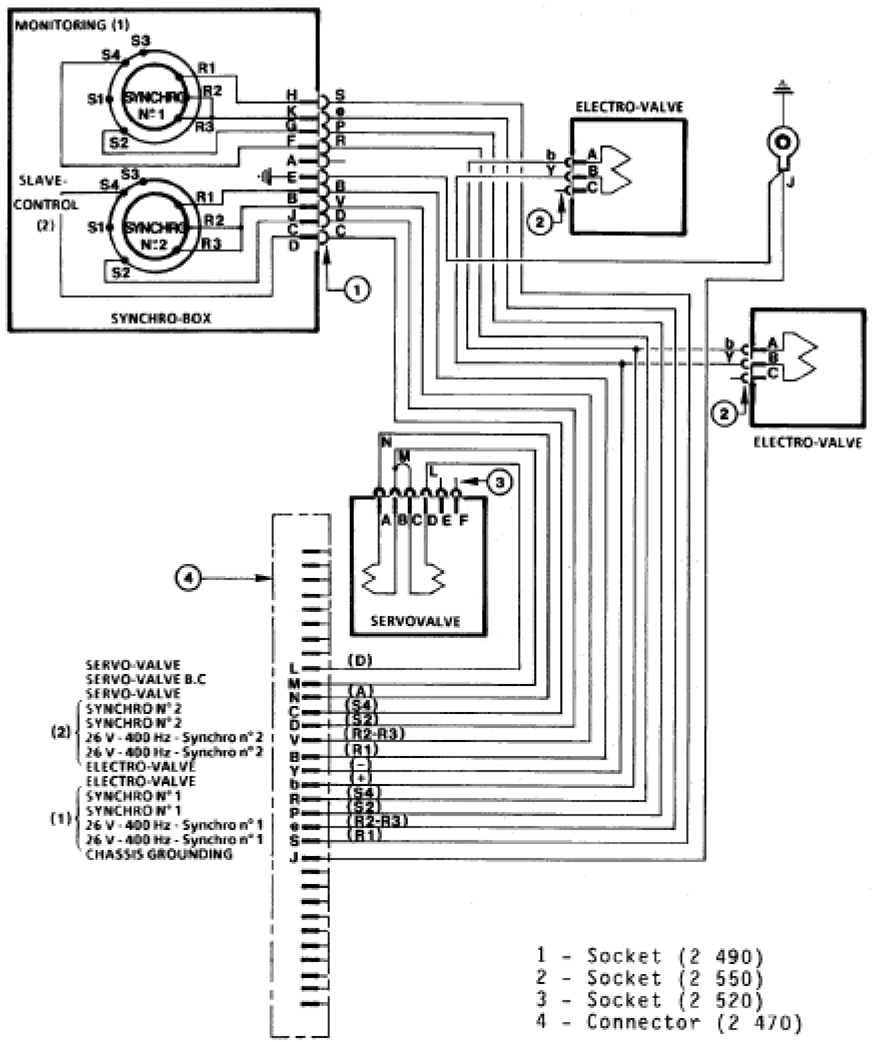


Figure 10. Yaw Damper Actuator CMM, Figure 505.

GOODRICH ACTUATION SYSTEMS
COMPONENT MAINTENANCE MANUAL
2VA39-25G1



1 - Socket (2 490)
2 - Socket (2 550)
3 - Socket (2 520)
4 - Connector (2 470)

Driven chain harness electrical diagram
Figure 506

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DEC 30/89

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Figure 11. Yaw Damper Actuator CMM, Figure 506.

Component Disassembly

The Driving side electric distributor block was removed (IPL 1-80A), Appendix B, Figure 1 and Figure 2.

The Driving side servovalve was removed (IPL 1-20A), Appendix B, Figure 3.

The Driven side distribution block was removed (IPL 1-80A), Appendix B, Figure 4 and Figure 5.

The Driven side servovalve was removed (IPL 1-20A), Appendix B, Figure 6.

The Driving and Driven side locking cylinders were removed (IPL 5-20), Appendix B, Figures 7 to 9.

The Driven side lock linkage and piston were removed (IPL 5-150,5-190), Appendix B, Figures 10 to 12.

The Driving side synchro box was removed (IPL 1-140), Appendix B, Figure 13.

The Driving side lock linkage and piston were removed. During the removal the piston fractured (IPL 5-190), Appendix B, Figures 14 to 16.

The Driven side synchro box was removed (IPL 1-140), Appendix B, Figures 17 to 19.

The cover of the Driven side synchro box was removed, Appendix B, Figure 20.

The engage pressure switch was removed (IPL 1-250), Appendix B, Figure 21.

All filters were removed, Appendix B, Figure 22.

The fork portions of both unlocking pistons were removed (IPL 5-350). They were found to be fractured from the unlocking piston (IPL 5-400), Appendix B, Figures 23 to 26.

Attempts were made to remove the caps, which cover the unlocking pistons, but the parts were seized and could not be removed (IPL 5-260, 270). The Driven side cap was partially removed by destructive means. The piston segment was removed, Appendix B, Figure 27.

The parts which retain the Driving piston (IPL 7-190) and Driven piston (IPL 8-490, 450) were seized and could not be removed.

Electric Distributors Bench Tests

The electric distributors were installed on a hydraulic test bench as removed. Pressure was slowly increased, without any flow established. The solenoids were then energized. There was still no flow for either distributor.

Driving Side Electric Distributor

An external leakage was observed from cap (IPL 3-110).
Electrical consumption of the 2 solenoids was measured to be 300 mA each under 28V. Solenoids were energized. ED1 was confirmed to be operating by the observation that external leakage increased when it was energized. ED2 did not operate.

Driven Side Electric Distributor

Electrical consumption of the 2 solenoids was measured to be 300 mA each under 28V. Solenoids were activated and their operation assessed by feeling the vibrations from the outside. ED1 did not operate. ED2 was confirmed to be operating.

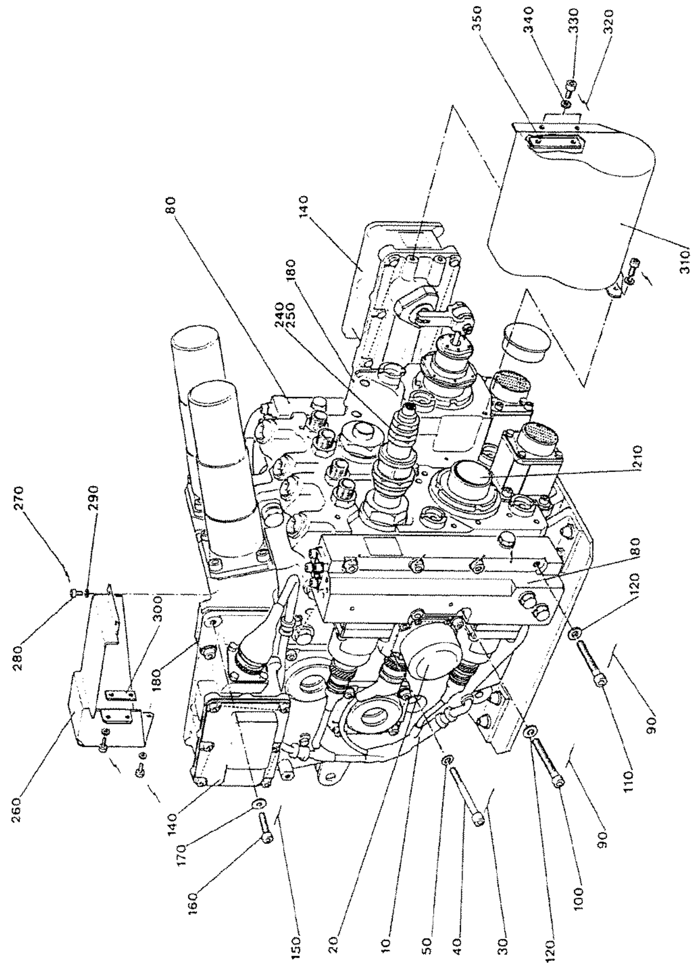
Steven H. Magladry
Aerospace Engineer

APPENDIX A

TO

ADDENDUM NUMBER 6 TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION – YAW DAMPER EXAMINATION

GOODRICH ACTUATION SYSTEMS
COMPONENT MAINTENANCE MANUAL
2VA39-25G1



Damper
Figure 1

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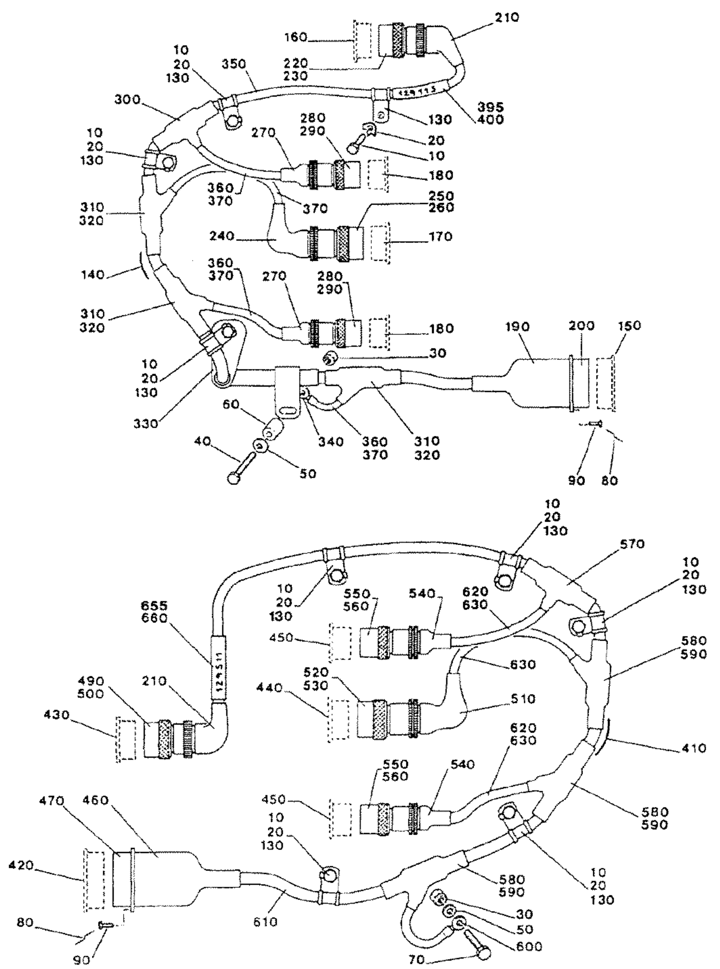

Electrical equipment
Figure 2

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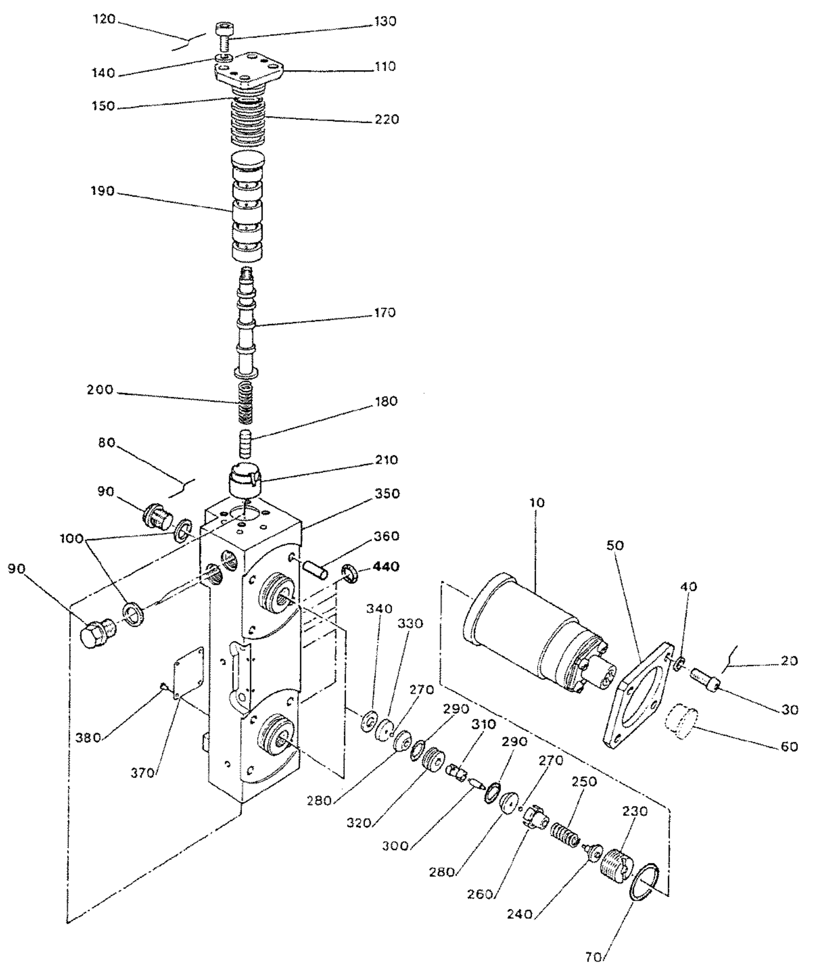

Electric-distributor
Figure 3

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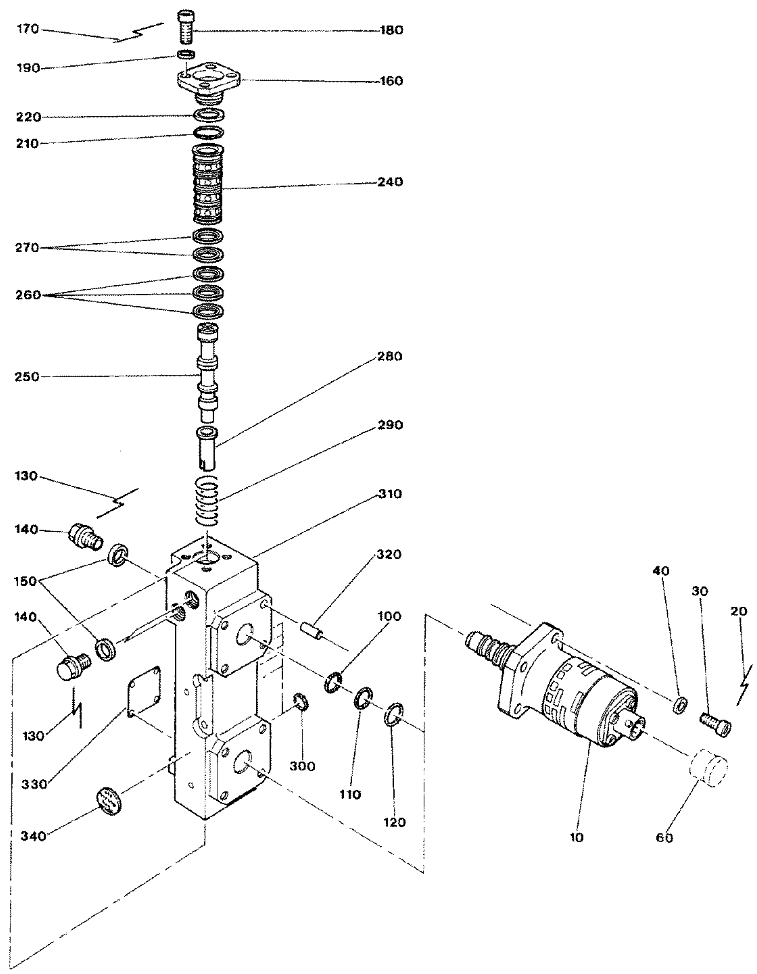

Electric-distributor
Figure 3A

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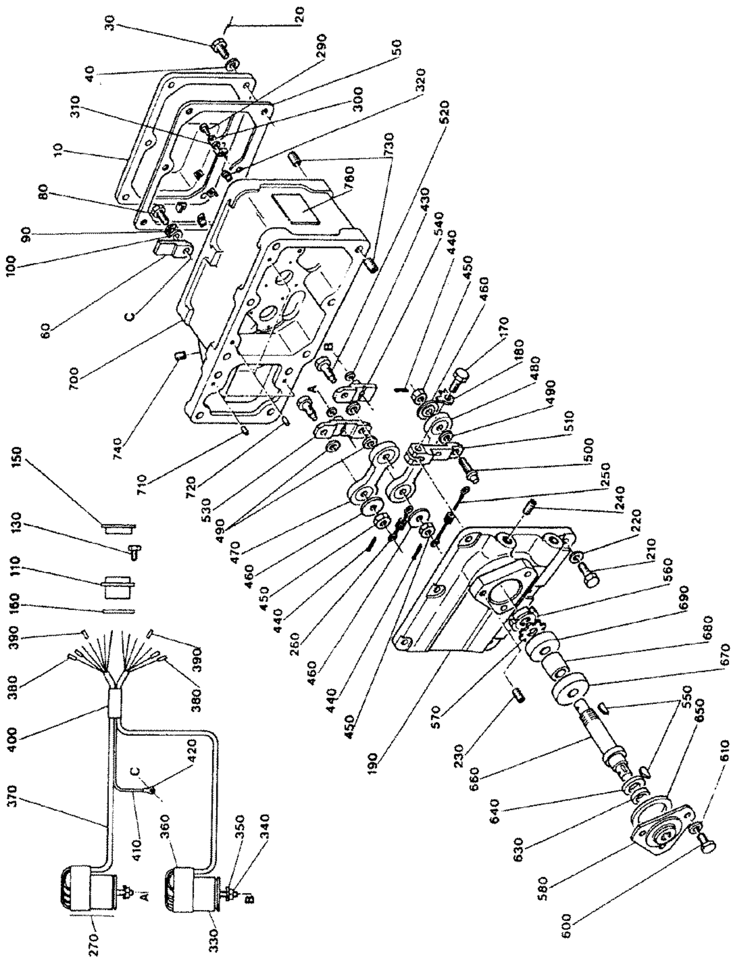

Box, synchro
Figure 4

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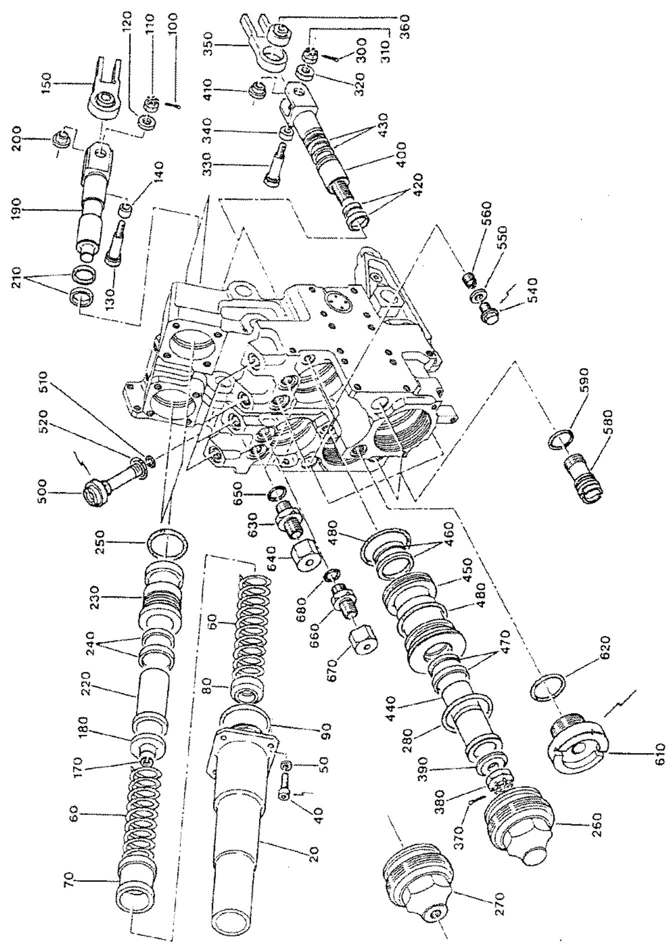
COMPONENT MAINTENANCE MANUAL
2VA39-25G1



Locking and unlocking cylinders, common assembly
Figure 5

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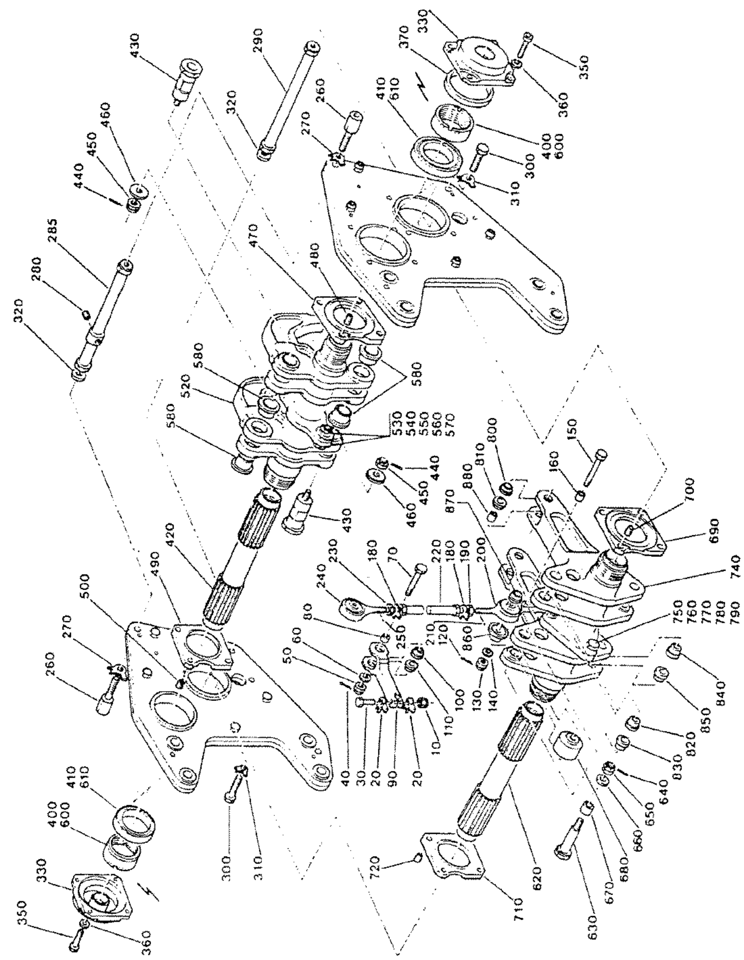

Locking, assembly
Figure 6

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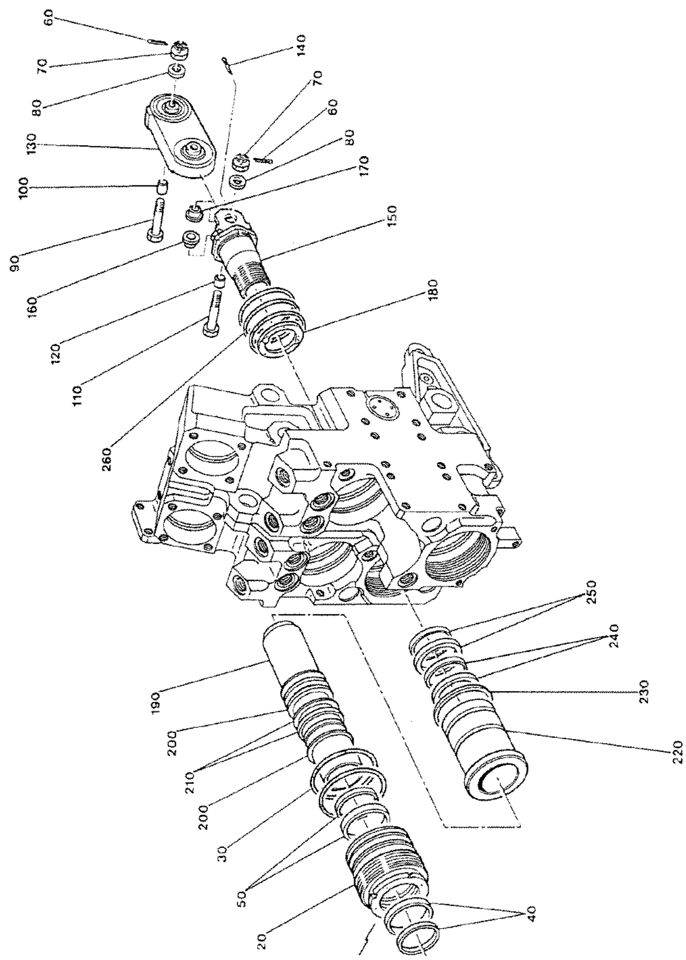
2VA39-25G1



Cylinder drive
Figure 7

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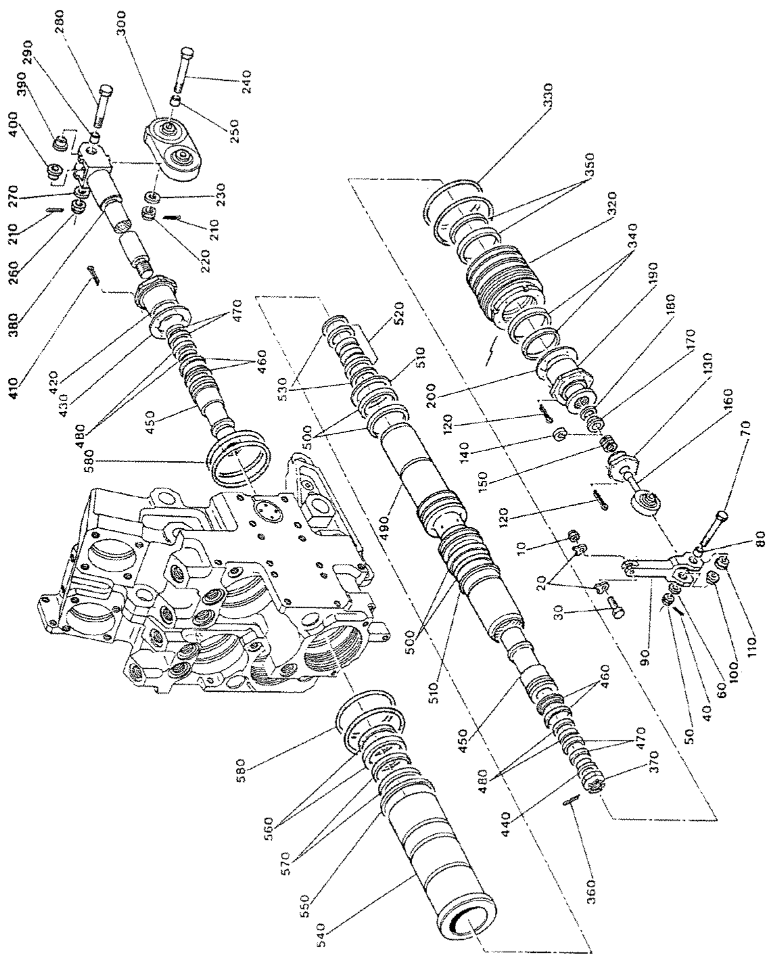
COMPONENT MAINTENANCE MANUAL
2VA39-25G1



Cylinder, driven
Figure 8

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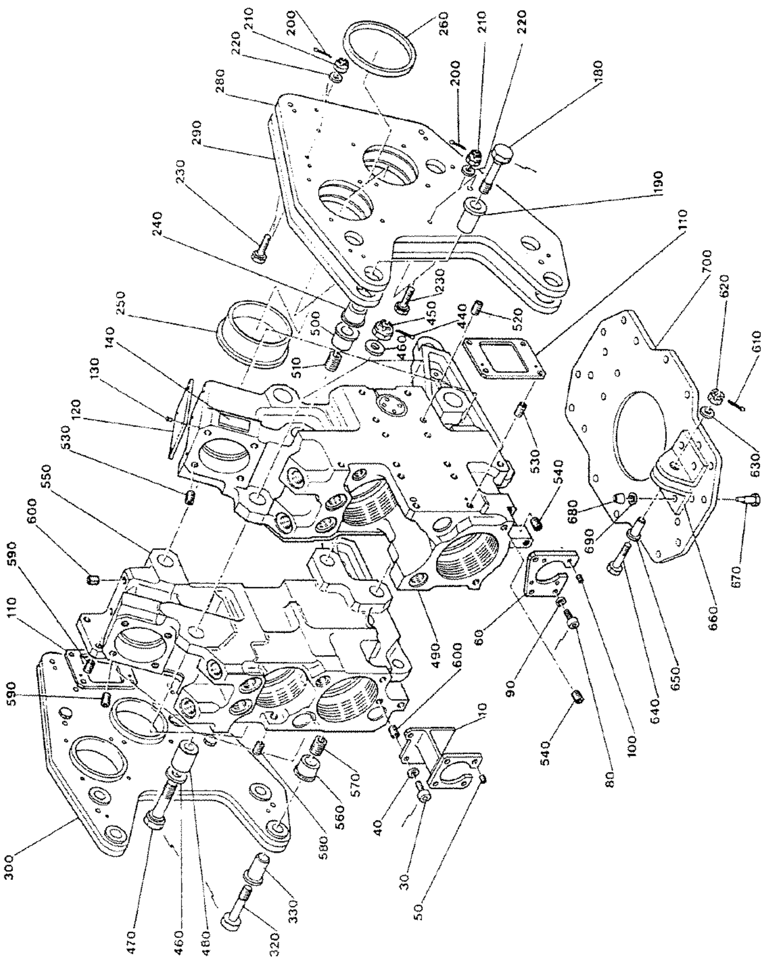

Assembly, bodies and flanges
Figure 9

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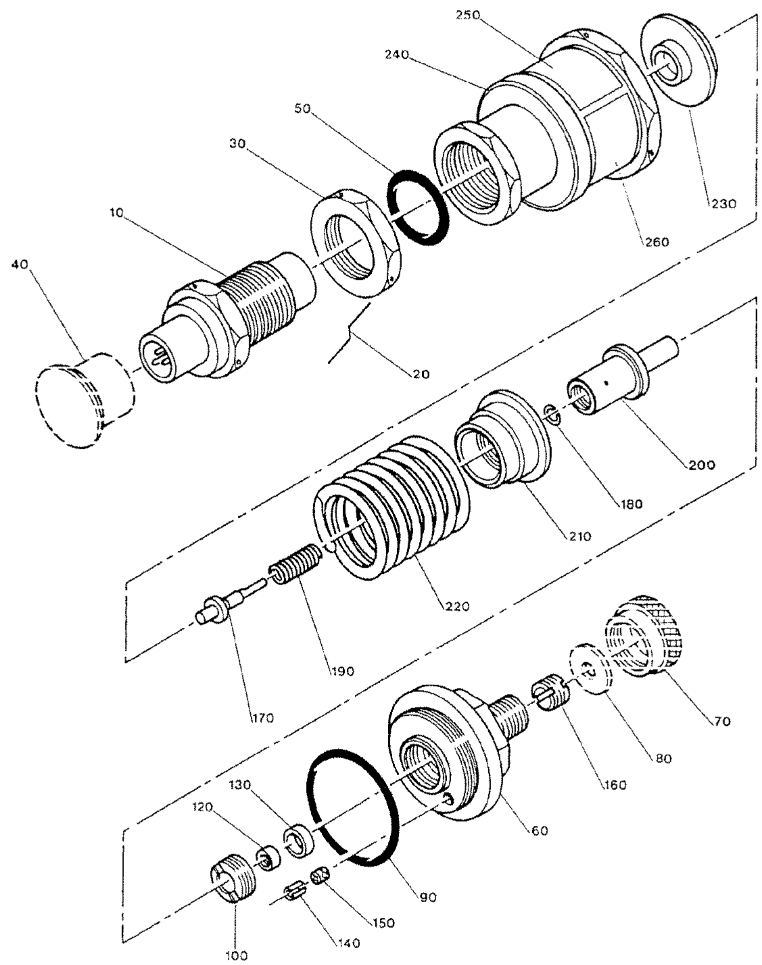

Switch, pressure
Figure 10

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APPENDIX B

TO

ADDENDUM NUMBER 6 TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION – YAW DAMPER EXAMINATION

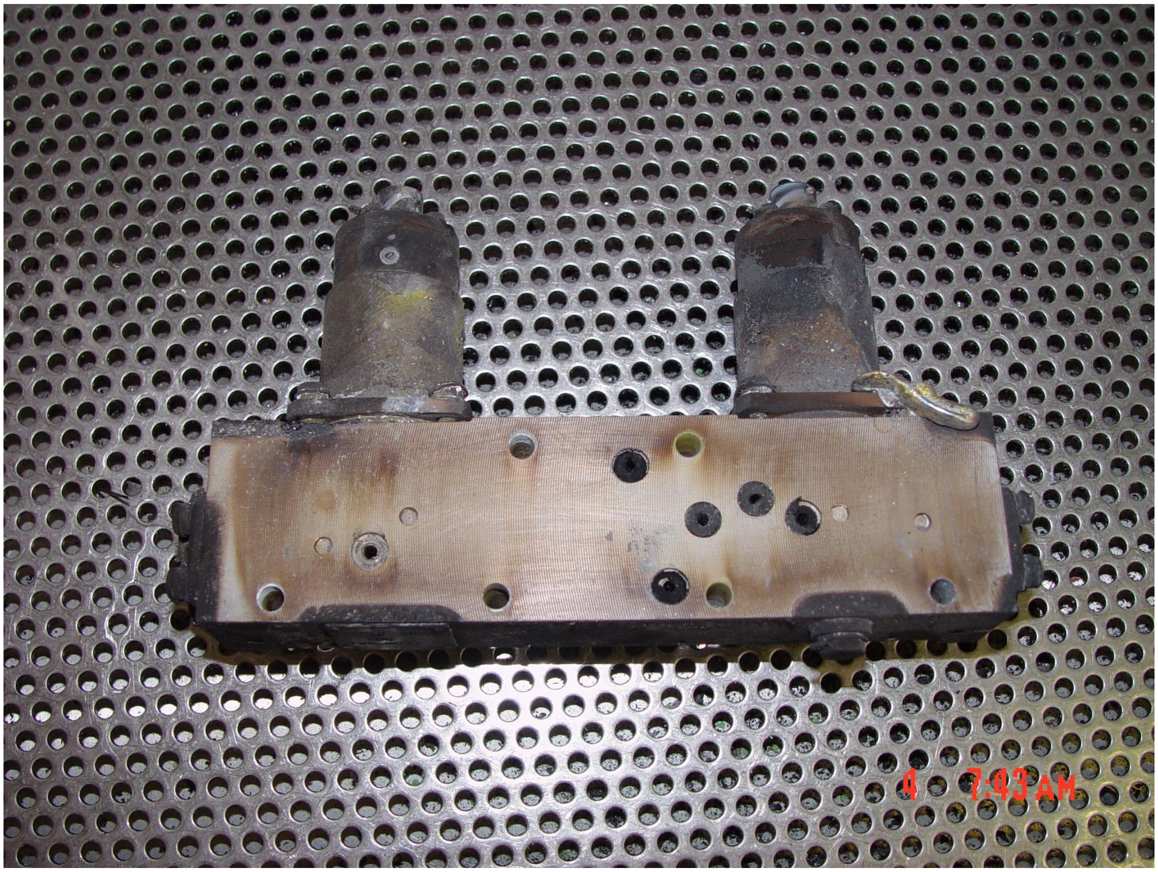


Figure 1. Electric Distributor Block and Solenoids – Driving Side.

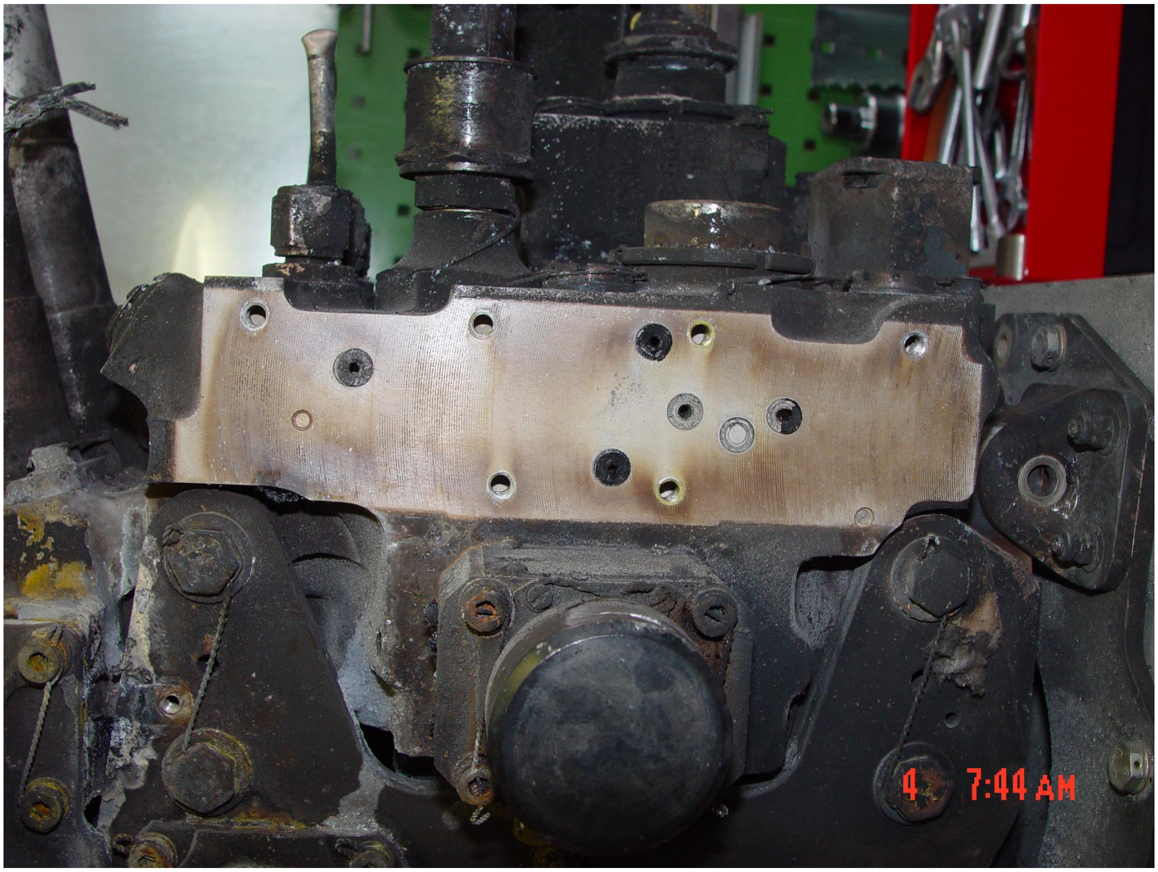


Figure 2. Driving Side of Actuator with Distribution Block Removed

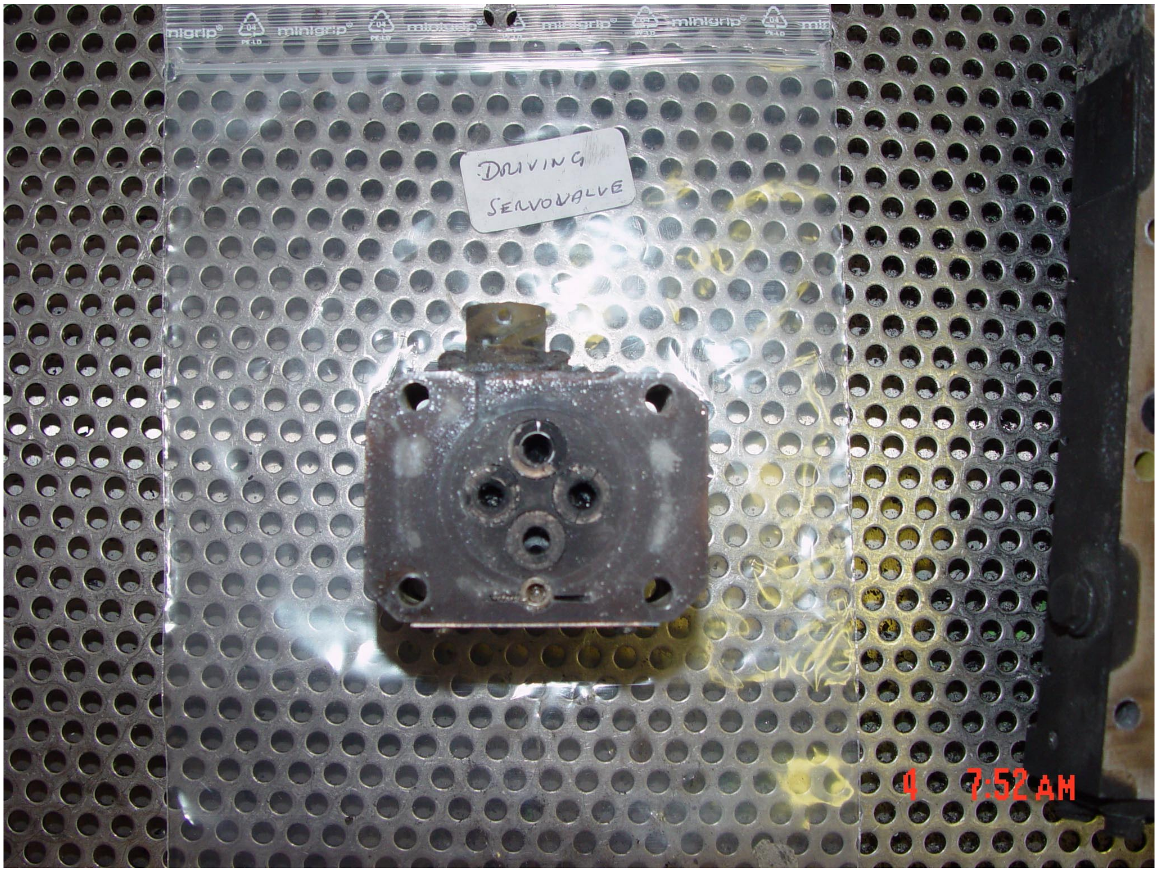


Figure 3. Driving Side Servovalve.

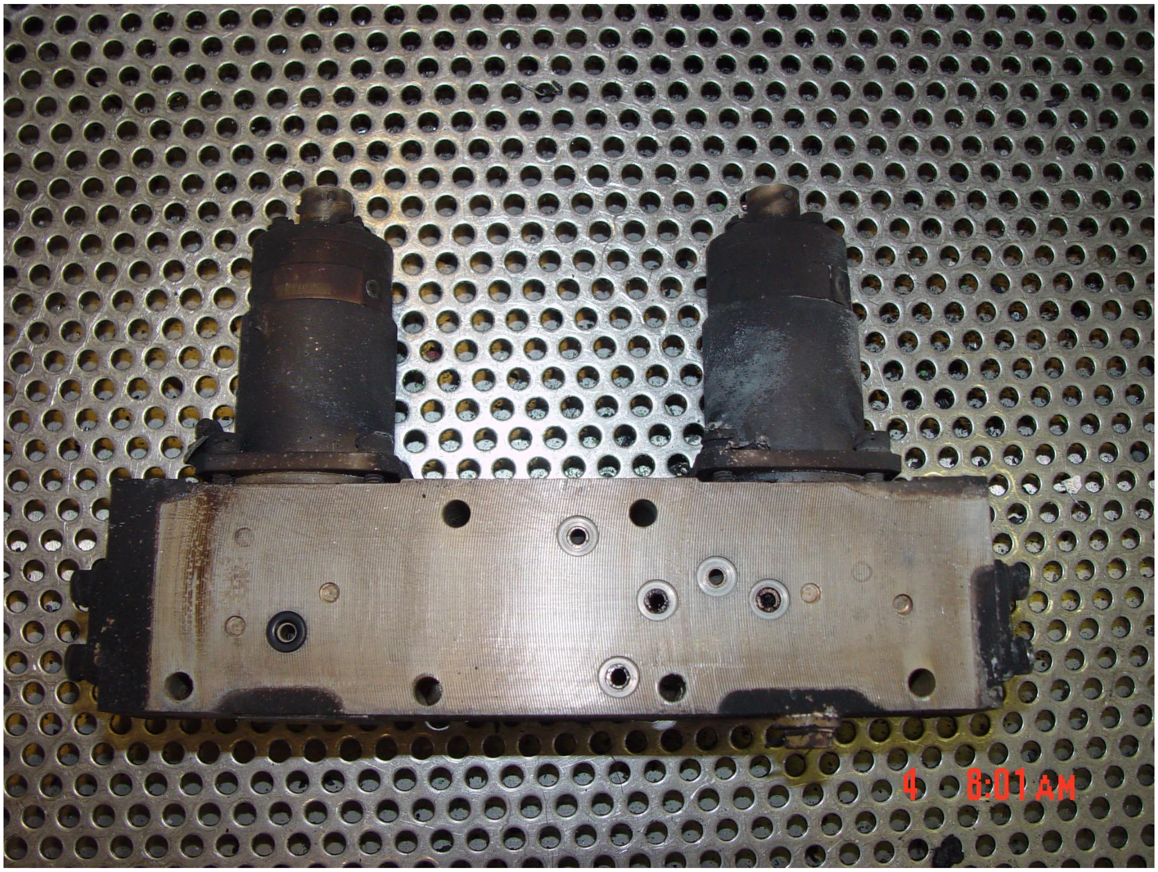


Figure 4. Driven Side Electric Distribution Block

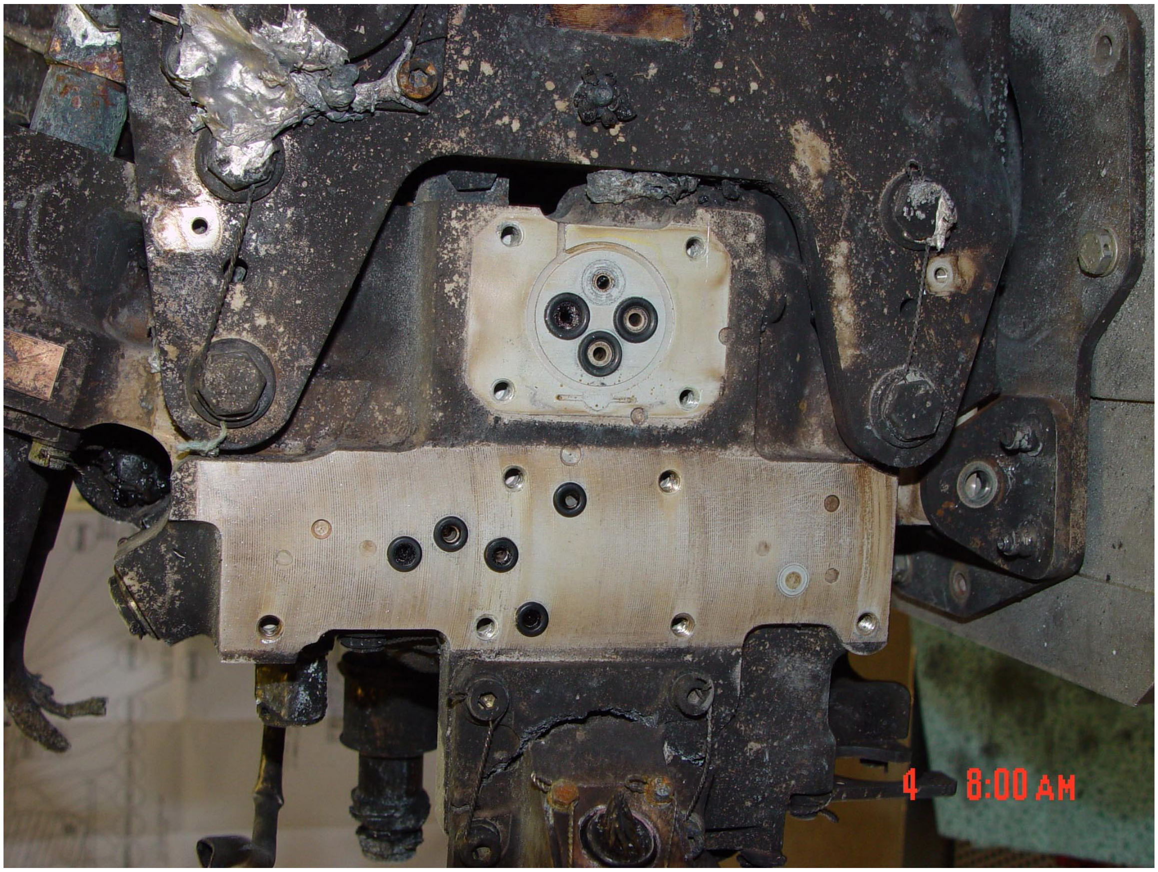


Figure 5. Driven Side of Actuator with Servovalve and Hydraulic Block Removed.

Figure 6. Driven Side Servovalve.

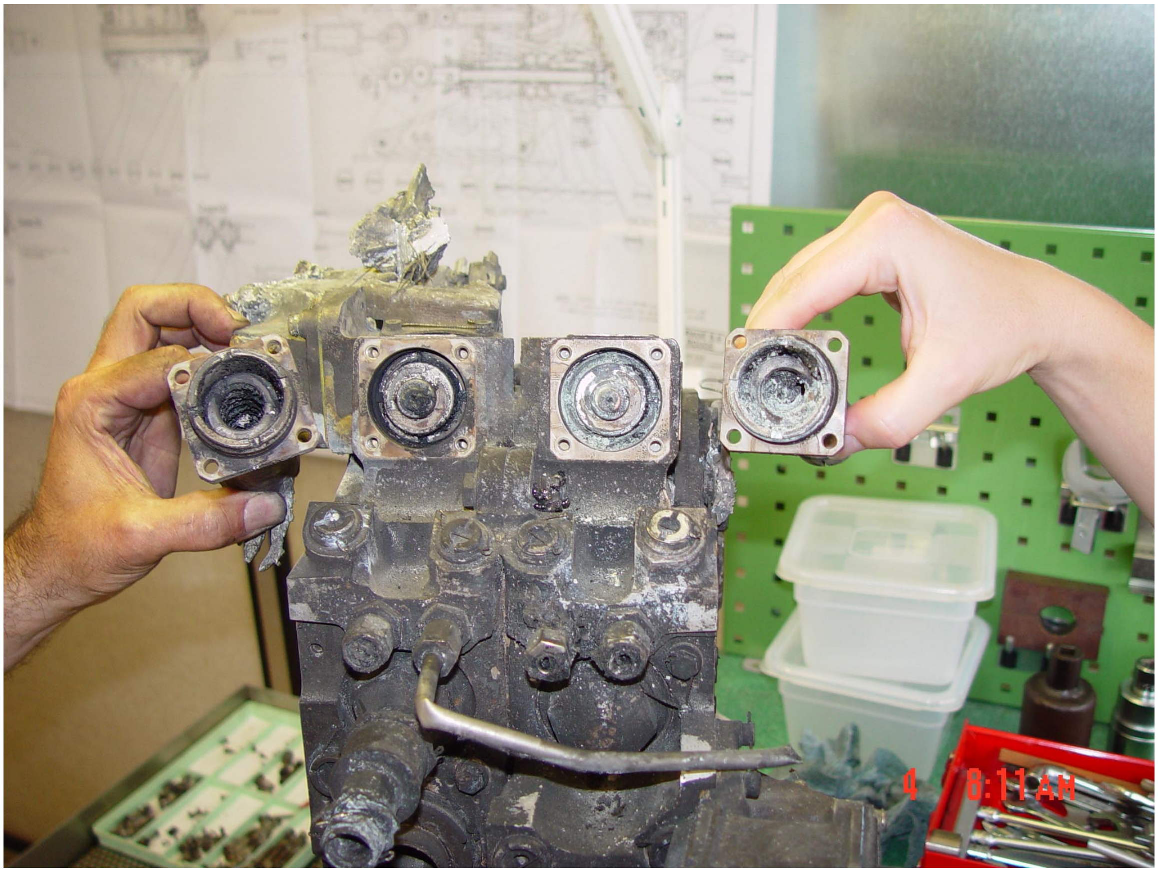


Figure 7. Driving (left) and Driven (right) Locking Cylinders Removed.

Figure 8. Driven Cylinder with Springs Removed.

Figure 9. Driving Cylinder with Spring Removed.

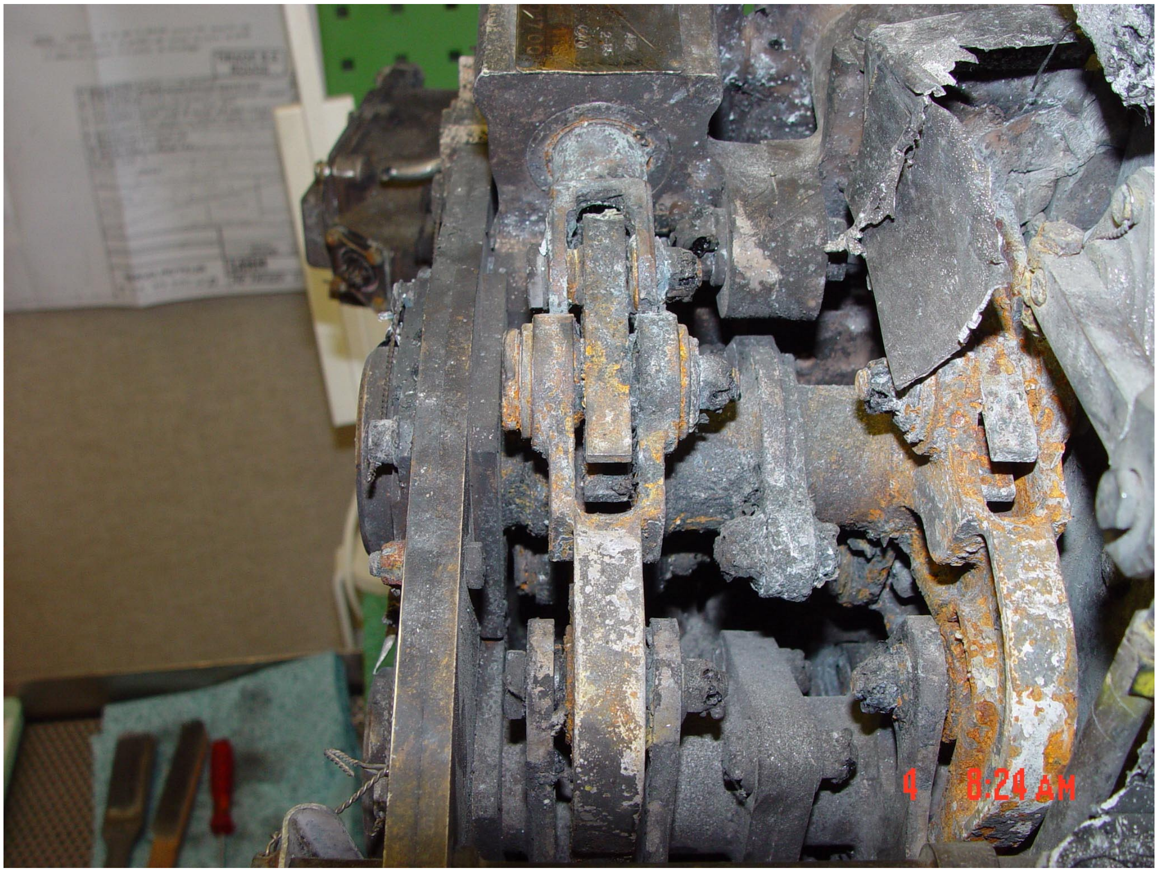


Figure 10. Driven side Locking cam linkage (left)

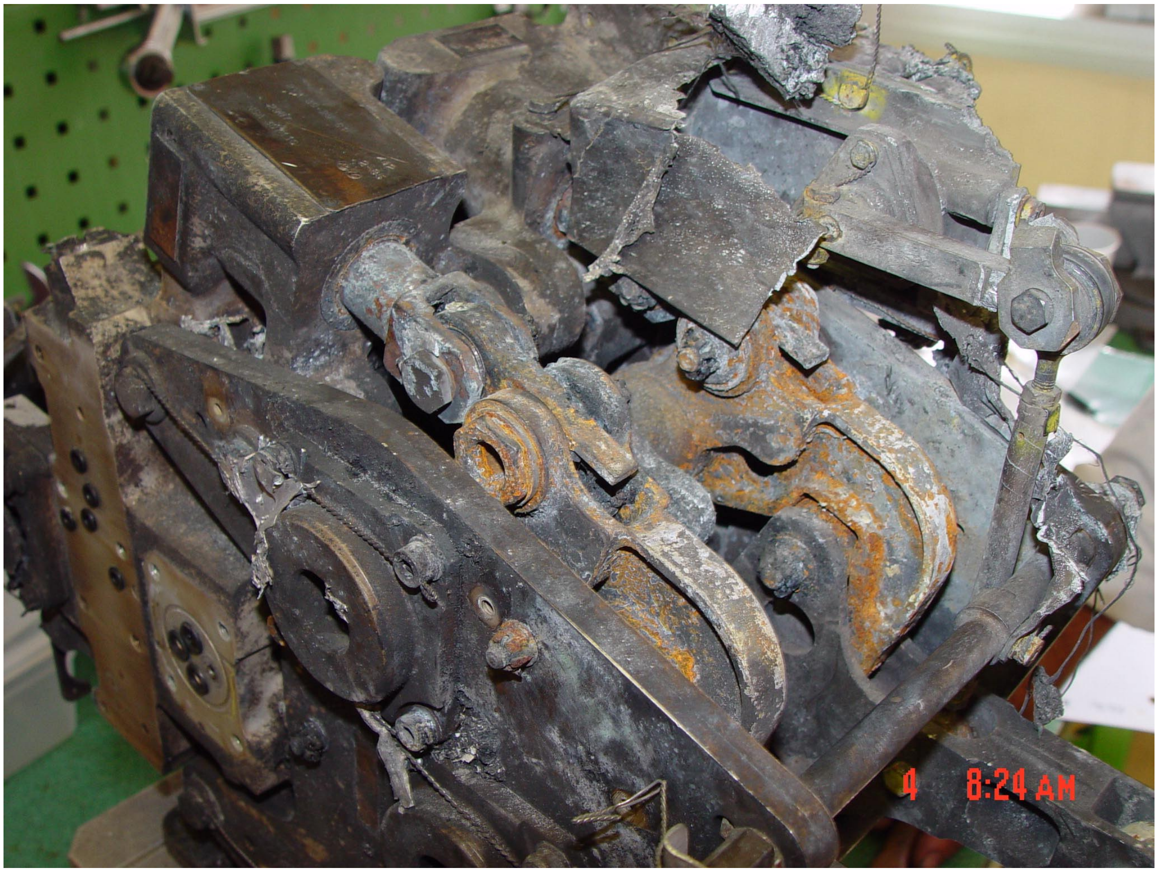


Figure 11. Driven Side Locking Cam Linkage.

Figure 12. Driven Side Locking Linkage Removed.

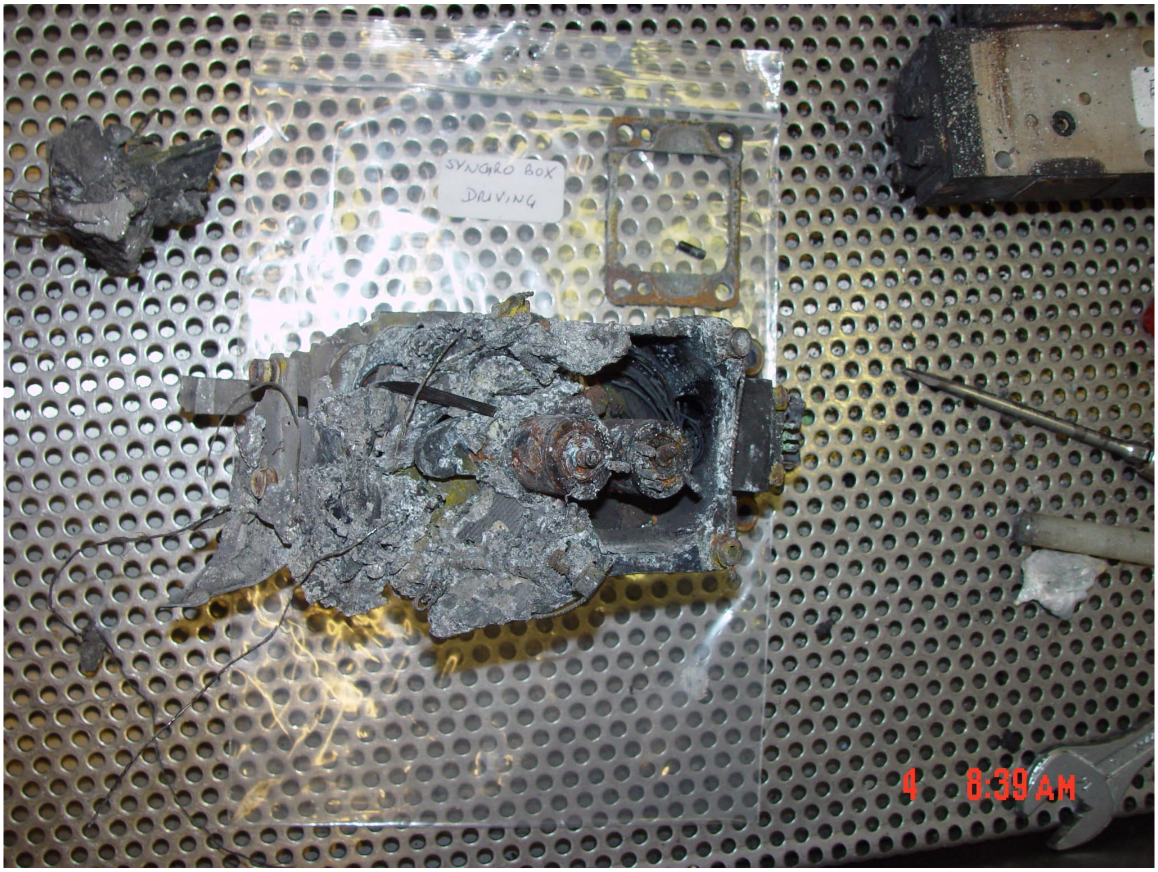
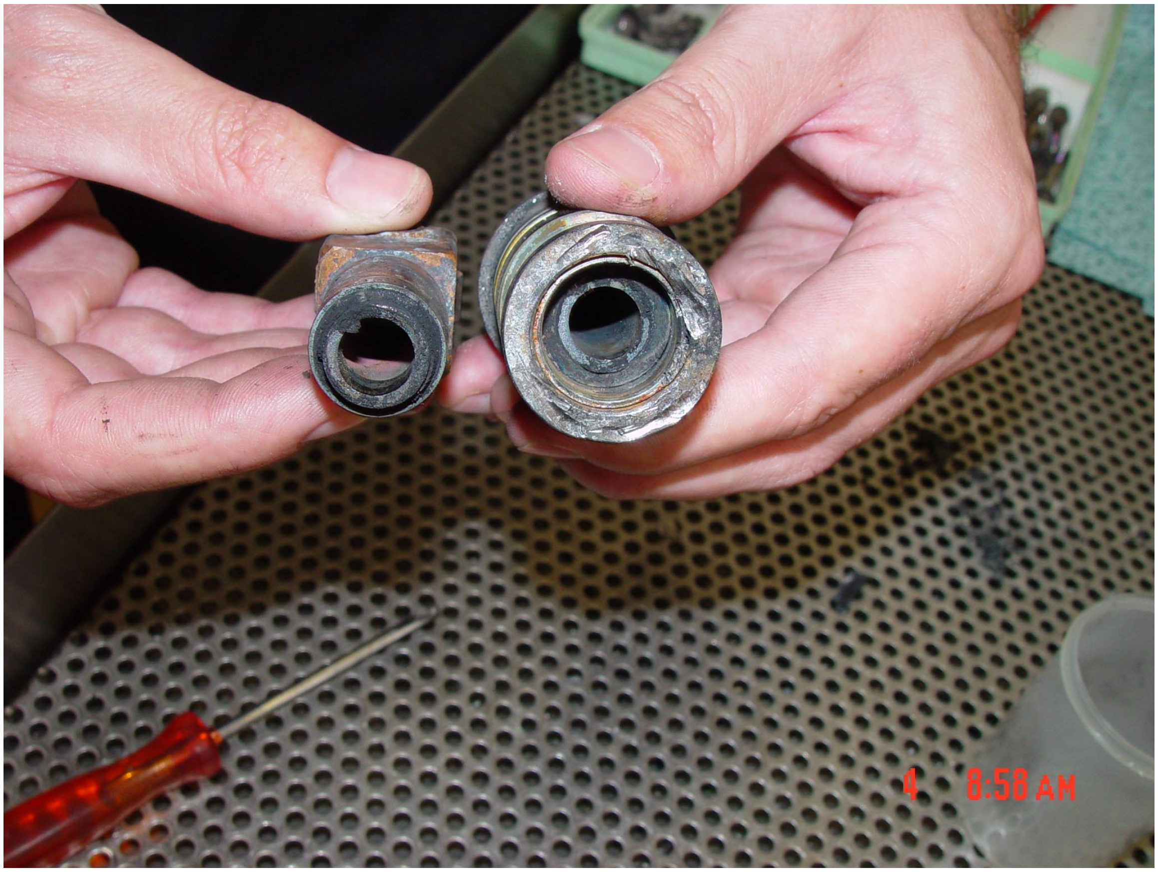


Figure 13. Driving Side Synchro Box Removed.


Figure 14. Driving Side Locking Cam Linkage (fractured).



Fiogure 15. Driving Side Locking Cam Linkage Removed (fractured).

Figure 16. Driving Side Locking Cam Linkage (fractured).

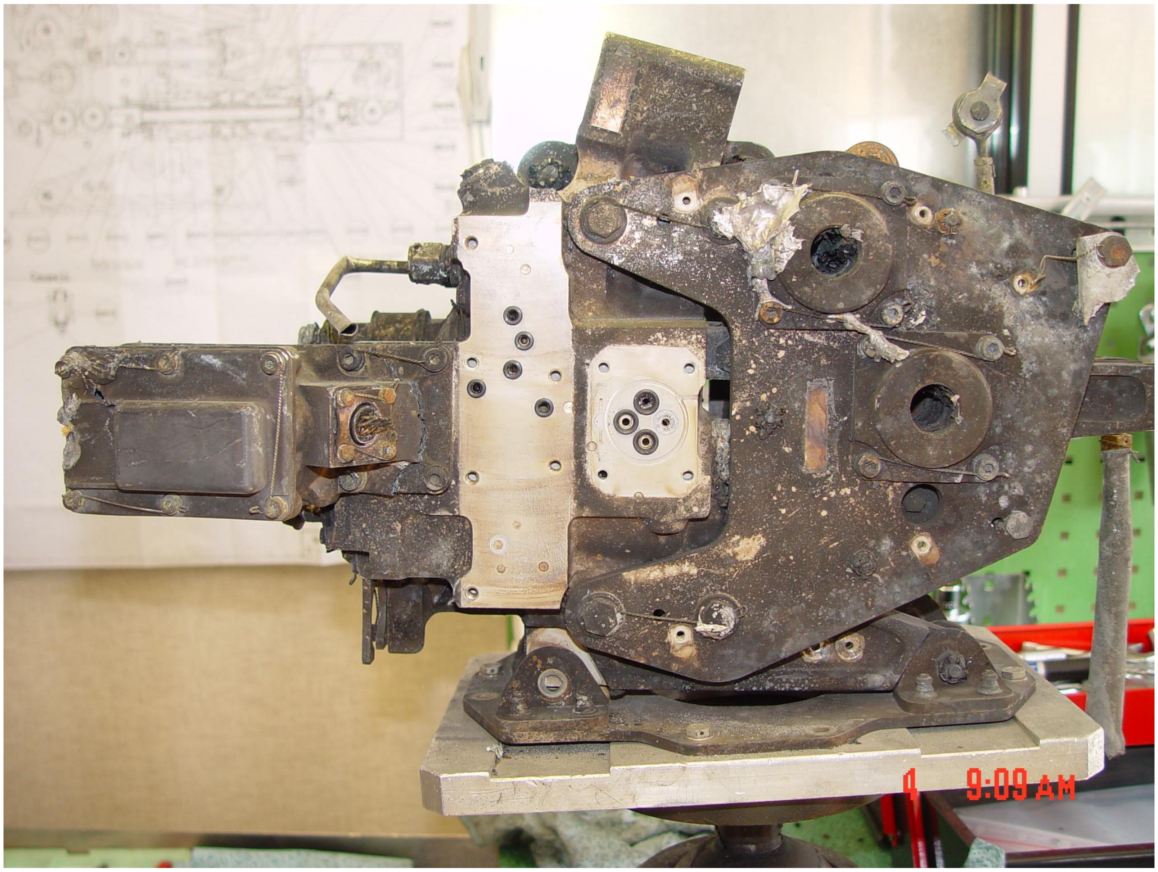


Figure 17. Driven side Synchro Box Installed (left).

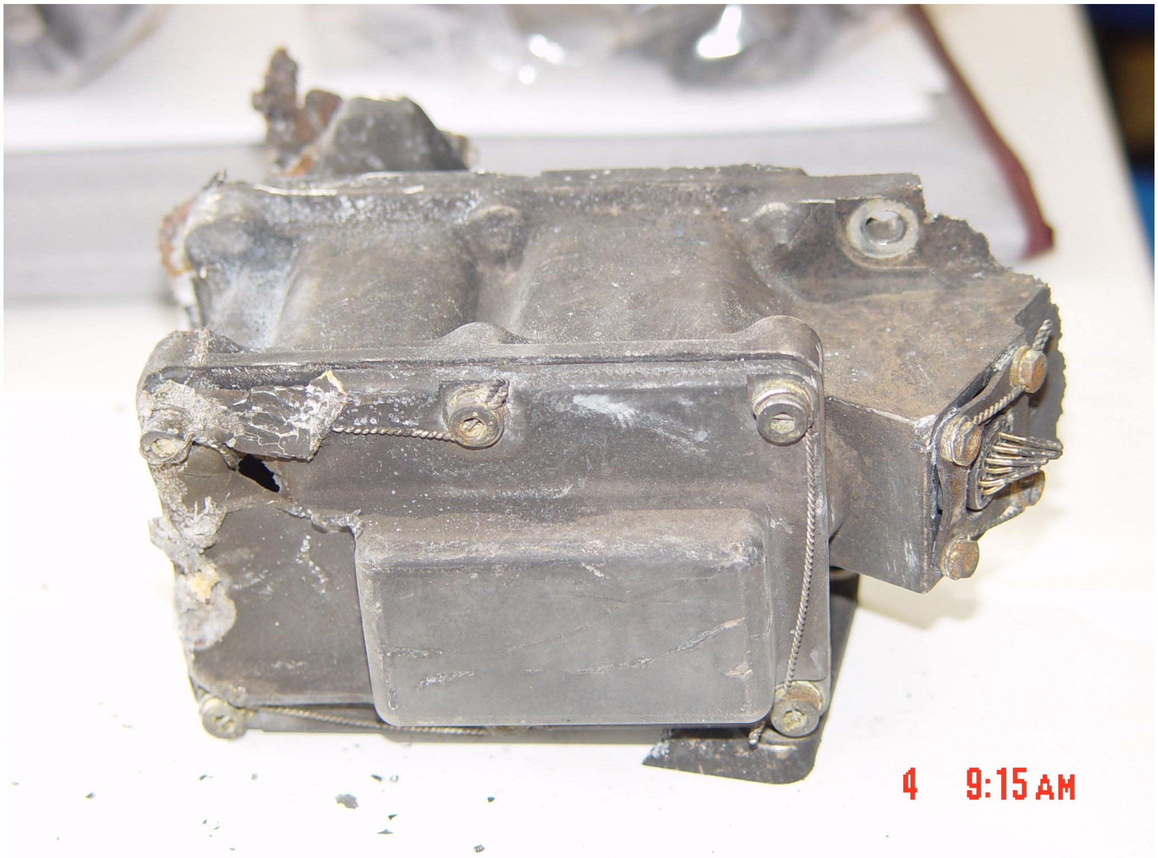


Figure 18. Driven Side Synchro Box Removed.

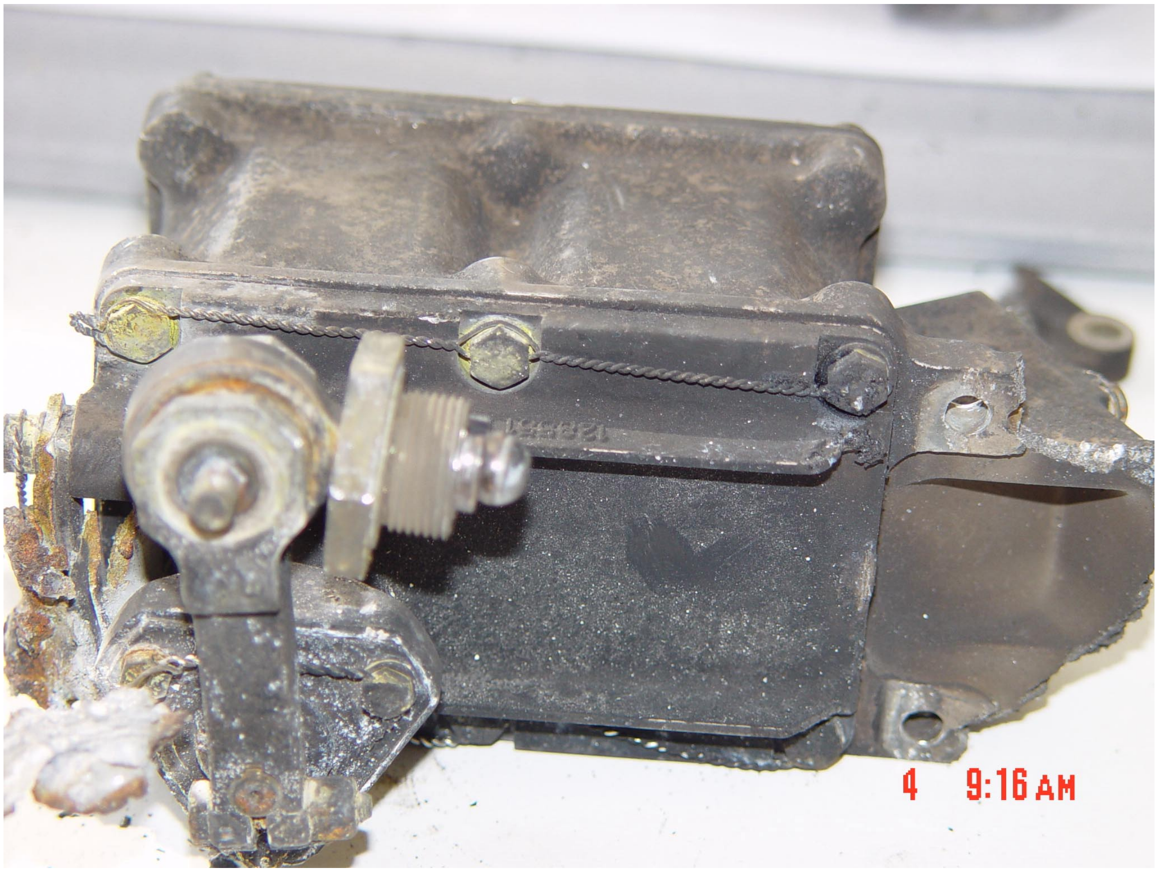


Figure 19. Driven Side Synchro Box.

Figure 20. Driven Side Synchro Box with Cover Removed.

Figure 21. Engage Pressure Switch Removed.

Figure 22. Removed Filters.

Figure 23. Driven Side Unlocking Piston and Fork (fractured).

Figure 24. Driven Side Unlocking Piston and Fork (fractured).

Figure 25. Driving Side Unlocking Piston and Fork (fractured).

Figure 26. Driving Side Unlocking Piston and Fork (fractured).

Figure 27. Driven Side Unlock Piston.