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# **Mechanical Systems Characterization of Boeing 747 Aging Systems Test Bed Aircraft**

December 2002

DOT/FAA/AR-TN02/119

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**20030123 045**

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**Technical Report Documentation Page**

|   |  |  |  |   |           |
|---|--|--|--|---|-----------|
| 1. Report No.<br>DOT/FAA/AR-TN02/119  |  | 2. Government Accession No.                          |  | 3. Recipient's Catalog No.                              |           |
| 4. Title and Subtitle<br>MECHANICAL SYSTEMS CHARACTERIZATION OF BOEING 747 AGING SYSTEMS TEST BED AIRCRAFT  |  |  |  | 5. Report Date<br>December 2002                         |           |
|   |  |  |  | 6. Performing Organization Code                         |           |
| 7. Author(s)<br>Prepared by Total Aircraft Services, Inc. under contract with Sandia National Laboratories  |  |  |  | 8. Performing Organization Report No.                   |           |
| 9. Performing Organization Name and Address<br>FAA/AANC NDI Validation Center<br>3260 University SE<br>Albuquerque, NM 87106  |  |  |  | 10. Work Unit No. (TRAIS)                               |           |
|   |  |  |  | 11. Contract or Grant No.                               |           |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>Federal Aviation Administration<br>Office of Aviation Research<br>Washington, DC 20591   |  |  |  | 13. Type of Report and Period Covered<br>Technical Note |           |
|   |  |  |  | 14. Sponsoring Agency Code<br>ANM-100                   |           |
| 15. Supplementary Notes<br>The FAA William J. Hughes Technical Monitor was Robert McGuire.  |  |  |  |   |           |
| 16. Abstract<br><br>As part of the Federal Aviation Administration (FAA) Aging Aircraft Program, the FAA purchased a Boeing 747 to be used as a test bed aircraft for investigating aging mechanical and electrical systems. When retired, the airplane was decommissioned in a way to preserve the functionality of the mechanical and electrical systems. Total Aircraft Services, Inc., under contract to the FAA Airworthiness Assurance Nondestructive Validation Center located at Sandia National Laboratories, was charged with assessing the status of the aircraft's systems. The purpose of the assessment was to determine the condition of the mechanical systems on the airplane and to determine what would be required to make any nonworking systems functional. This report documents the results of this assessment.<br><br>This assessment determined that most of the mechanical systems that are significant to the Aging Mechanical Systems Project are operational or are capable of easily being made operational. |  |  |  |   |           |
| 17. Key Words<br>Boeing 747, Mechanical systems, Maintenance manual, Test bed aircraft  |  |  | 18. Distribution Statement<br>This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. |   |           |
| 19. Security Classif. (of this report)<br>Unclassified  |  | 20. Security Classif. (of this page)<br>Unclassified |  | 21. No. of Pages<br>10                                  | 22. Price |

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## EXECUTIVE SUMMARY

In response to the recommendations of the White House Commission on Aviation Safety and Security, chaired by then Vice President Gore, Jane Garvey, the Federal Aviation Administration (FAA) Administrator, directed the creation of a new program to address the safety and reliability of nonstructural systems in aging aircraft. The Aging Nonstructural Systems Program research tasks were incorporated into the existing FAA National Aging Aircraft Research Program. In support of this new program, the FAA purchased a Boeing 747-136 to serve as a test bed for investigating aging electrical and mechanical systems. The aircraft was decommissioned in a manner to ensure the continued functionality of its mechanical and electrical systems. An effort was undertaken to determine which systems were still functional and which were not.

Most of the systems, required for ground testing, were found to operate and function in accordance with basic system functionality requirements specified in the Boeing 747-100 Maintenance Manual. A few systems were either not tested or found to be nonoperational and would require a substantial financial expenditure in replacement components to make them operational.

## INTRODUCTION

### PURPOSE.

While it is known that the Boeing 747 aging systems test bed aircraft was decommissioned to preserve the mechanical and electrical systems, it is not known exactly how successful this effort was. A task was undertaken to determine which systems were still functional and which were not.

### BACKGROUND.

In response to the recommendations of the White House Commission on Aviation Safety and Security, chaired by Vice President Gore, Jane Garvey, the Federal Aviation Administration (FAA) Administrator, directed the creation of a new program to address the safety and reliability of nonstructural systems in aging aircraft. The Aging Nonstructural Systems Program research tasks were incorporated into the existing FAA National Aging Aircraft Research Program. To support the program, the FAA purchased a Boeing 747-136 (registration number G-AWNH, serial No. 20270) from British Airways to serve as a test bed for investigating aging electrical systems (wiring, wire bundles, connectors, and circuit breakers) and mechanical systems (e.g., cables and mechanical linkages, pneumatic systems, hydraulic systems, fuel systems). The aircraft was decommissioned in a manner to ensure the continued functionality of its mechanical and electrical systems. Currently, the airplane is located at the FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) in Albuquerque, NM.

## EVALUATION APPROACH

### APPROACH.

This effort was divided into two Phases. Phase I was intended to establish the approximate cost, schedule, and installation manpower required to bring the aircraft to minimum functional requirements. The results of the Phase I survey were then to be submitted to the FAA AANC for review and approval. After approval, Phase II would be initiated. Phase II would consist of executing the plan established by Phase I to bring the aircraft to basic minimum functional requirements. Total Aircraft Services, Inc. (TAS), of Van Nuys, CA, was contracted to conduct Phase I and Phase II tasks.

Because the intent is to use the aircraft as a test bed for research and testing purposes on the ground only, it is considered exempt from Federal Aviation Regulations. Thus, any corrective actions would not necessarily have to involve FAA-certified components and/or procedures. For example, non-yellow tag (unserviceable) components could be installed provided they meet minimum operational and functionality design requirements.

### SYSTEM TESTING RESULTS.

Operational testing of the aircraft systems was initiated using ground support equipment, since the engines and auxiliary power unit (APU) had been removed during part-out. During this

exercise, it was determined that several components had been removed, during the part-out of the aircraft, that were required for system operation. These units had to be procured and installed before the investigation could continue. A list of these components is shown in Table 1. TAS representatives and AANC management concluded that the cost of sourcing and installing the necessary components did not warrant a formal Phase I report. The decision was made by AANC to purchase and install the necessary components and begin Phase II activities.

TABLE 1. REQUIRED COMPONENTS FOR SYSTEM OPERATION

| Qty. | Description                               | Part Number | IPC Reference        |
|------|---|-------------|----------------------|
| 1    | Module Assy-Equip Cooling                 | 69B46104-9  | 21-58-30-01 Item 5   |
| 1    | Module Assy-Gen Cooling                   | 69B46101-9  | 24-21-50-04 Item 145 |
| 1    | Module Assy-Essential Bus                 | 69B46135-24 | 24-21-50-04 Item 195 |
| 1    | Indicator-3-in-1 Control Surface Position | 9819-29     | 27-18-20-06 Item 5   |
| 2    | Indicator-TE Flap Position                | 9801-09-03  | 27-58-15-03 Item 5   |

The components listed in table 1 were installed and functional tested during the time period of February 4-6, 2002. All systems tested were shown to operate and function in accordance with the Boeing 747-100 Maintenance Manual requirements.

A brief description of the individual system functionality testing follows:

PNEUMATIC SYSTEM. Since the engines and APU had been removed during the part-out phase of this aircraft, portable ground air units had to be used to supply the required air pressure to the pneumatic system ducting and components. Proper operation of the pneumatic system requires that these portable ground air units be capable of supplying at least a 300 pounds per minute (ppm) flow rate at a pressure of 20 pounds per square inch (psi) minimum. Each of the four air-driven hydraulic pumps (ADPs) requires 75 ppm to supply sufficient hydraulic pressure for flight control operation. Each air cycle machine (ACM) requires 100 ppm flow at a pressure above 12 psi to function. To operate all three ACMs simultaneously, requires 300 ppm each. Additionally, master and zone trim air systems requires an additional 50 ppm to each of the three ACMs. The ACM must be operating prior to use of the trim air system. The right wing bleed air isolation valve was found to be stuck in the closed position and had to be opened manually. Once opened, both left and right isolation valves functioned properly.

Note: During summer months, the aircraft cannot be cooled sufficiently using ground equipment to provide acceptable working conditions. Portable air conditioning units may need to be provided for work inside the aircraft.

HYDRAULIC SYSTEM. During the test, all four hydraulic system ADPs operated normally. The pressure indicating lights functioned normally, with the pressure gage indicating normal pressure throughout the test. The hydraulic fluid temperature remained in the normal range, however, the outside temperature remained in the mid-20°F range. The hydraulic fluid is cooled using aircraft fuel through a heat exchanger located in the wing fuel tank. Since it is anticipated that future testing will be conducted without fuel onboard, the hydraulic fluid temperature must

be monitored closely to ensure temperature limits are not exceeded. One solution to this would be to acquire or fabricate external hydraulic coolers containing approximately 100 gallons of water/glycol mixture. The input and output lines could then be routed into the case drain module, to allow for adequate cooling of the hydraulic fluid.

Alternatively, in accordance with the manufacturer's maintenance practices outlined in Boeing's 747 Maintenance Manual, Chap. 29, Section 11, Subject 00, the ADPs can be operated for 15 minutes without fuel in the tanks. This 15-minute period must be followed by a 20-minute cool down cycle before operation can recommence. This should be taken into consideration during the planning phase of future tests that will require utilization of the hydraulic system.

#### TRAILING EDGE FLAP SYSTEM.

Outboard System. The hydraulic/electric flaps and indicators operated as specified in the maintenance manual. The outboard positioning indicator is out of adjustment, but can be corrected using procedures specified in the maintenance manual. This adjustment will require approximately five man-hours to accomplish.

Inboard System. The hydraulic/electric flaps and indicators operated as specified in the maintenance manual.

LEAD EDGE DEVICES. Leading edge devices operate primarily from the pneumatic system with an electrical system backup. During testing, the leading edge devices operated normally (pneumatically) as the trailing edge flaps advanced to the 1- and 5-degree positions. The system functioned electrically as well, however, the device positioning indicators are inoperative at this time. To obtain leading edge position indication, a leading edge display logic card file assembly will need to be acquired and installed at fuselage station 400. Refer to the Boeing Illustrated Parts Catalogue, Section 27-88-10-01, Figure 5, P/N 65B47501-7, or -9, -12, -14. Note: indication is not necessary for basic deployment of the flaps. It is only required to provide indication of their position.

#### AILERON SYSTEM.

- The inboard aileron operated normally.
- The outboard aileron and lockout system operated normally.
- The position indicator operated normally.

#### SPOILER SYSTEM.

- The in-flight spoiler system operated normally. However, operation requires that the primary landing gear disconnect (J4), alternate landing gear disconnect (N7), and ground power sensing (P3) circuit breakers be pulled.
- The ground spoilers operated normally.
- The spoiler position indicator operated normally.



## ELEVATORS

- The elevator system operated normally.
- The elevator position indication system operated normally.

## RUDDER SYSTEM.

- The upper rudder operated normally.
- The lower rudder operated normally.
- The rudder position indication system operated normally.

## HORIZONTAL STABILIZER

- The horizontal stabilizer operated normally with manual control, when the no. 2 and 3 hydraulic system pressure was available.
- The horizontal stabilizer position indicator operated normally.
- The horizontal hydraulic brake shutoff valves operated normally.

## HYDRAULIC SHUTOFF VALVES.

- The wing valves (aileron, spoiler, and central control actuator) operated normally, shutting off the hydraulic pressure.
- The tail valves (elevator, rudder) operated normally, shutting off the hydraulic pressure.

## AIR CONDITIONING.

- The no. 1 ACM operated normally in both manual and automatic positions.
- The no. 2 ACM operated normally in both manual and automatic positions.
- The no. 3 ACM operated normally in both manual and automatic positions.
- The flight deck fan operated normally.
- The recirculating fans operated normally.
- The pneumatic duct pressure gage indicated normal pressure for the unit that was used during the testing.
- The equipment cooling system operated normally.

Note: Master and zone trim air system was not tested due to the low available airflow. This low airflow was due to availability and use of only one ground air cart. With sufficient airflow, it is assumed that these systems would function normally.

FUEL SYSTEM. Since the aircraft fuel tanks had been drained and purged, this system was not tested. However, the system was fully operational when the aircraft was acquired and is presumed to operate normally should fuel be added.

LANDING GEAR RETRACTION, EXTENSION, STEERING SYSTEM. Landing gear components were not tested due to the lack of aircraft jacks to elevate the aircraft. However, the system was fully operational when the aircraft was acquired and is presumed to operate normally should the need to test ever arise.

LIGHTING. All aircraft lighting (external and internal), with the exception of internal instrument lighting of removed instruments, is fully functional.

DOORS AND ESCAPE HATCHES. All doors and hatches function properly including electrically driven cargo doors. Escape slides were removed during part-out.

CARGO HANDLING SYSTEM. The cargo handling system is fully functional.

POTABLE WATER AND LAVATORIES. Both the potable water system and lavatory system have been drained to prevent freezing, but are functional if serviced.

#### CONCLUSION

Most of the systems required for ground testing were found to operate and function in accordance with basic system functionality requirements specified in the Boeing 747-100 Maintenance Manual. Though the functionality of the components and systems are adequate for the purposes of testing, they are not certified for flight and should not be used in this capacity. The following systems were either not tested or found to be nonoperational. These systems would require a substantial financial expenditure in replacement components to make them operational; however, these systems are not needed for

- Cabin pressurization system (Pressure controller removed, possibly other components)
- Autopilot
- Navigation
- Communication/Radio equipment
- Entertainment systems
- Interphone/Public address system
- Oxygen system (storage cylinders and regulators removed)
- Ice and Rain Protection (components removed during part-out)
- Fire Systems (Halon bottles in place, but controls and indicators were removed during part-out)