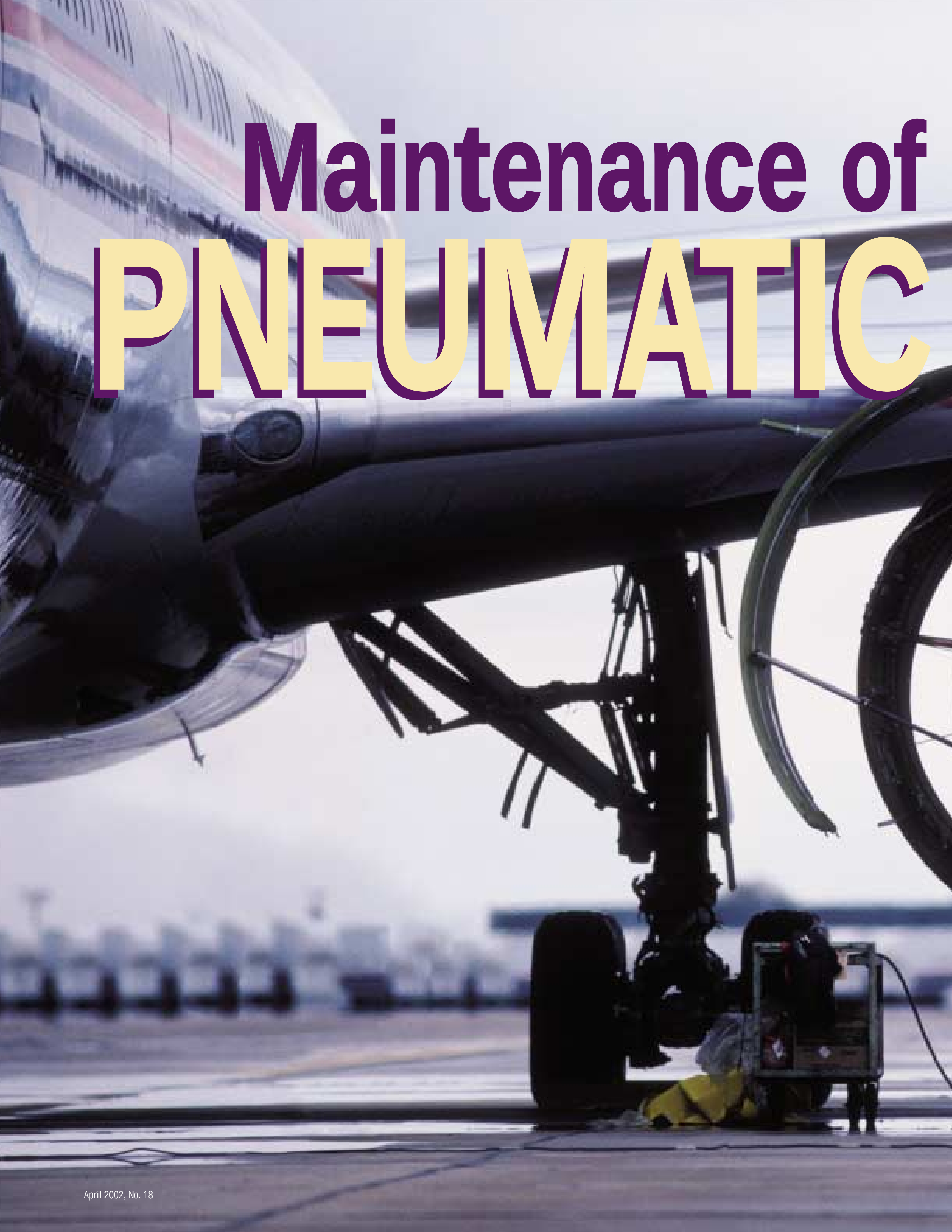
# Maintenance of PNEUMATIC



# 747 and 767 BLEED SYSTEMS

The pneumatic bleed system on 747 and 767 airplanes has been one of the most frequent contributors to airplane dispatch delays. In response, improvements have been made to the design and overhaul of system components, and pneumatic system health checks have been developed to allow operators to identify failing components before they cause schedule interruptions.

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According to Boeing data collected from operators, pneumatics (as defined by Air Transport Association [ATA] Chapter 36) is the third most frequent cause of schedule interruptions for the 747-400 and the fourth most frequent cause for the 767 and the 747 Classic (i.e., 747-100/-200/-300). During 2000 and 2001, the pneumatic bleed system accounted for nearly 7 percent of all schedule interruptions for 747-400 and 767 airplanes.

Some operators experience much greater reliability, with schedule interruptions attributed to ATA Chapter 36 as low as one-tenth of the fleet average. Other operators experience much poorer reliability, with schedule interruptions as much as 3.9 times greater than the fleet average. Although the reasons for this wide range of reliability are not easily determined, maintenance practices by operators can be key to improving reliability — particularly those that check the health of the pneumatic system and allow for replacement of failed components at a scheduled maintenance check rather than at an airport gate.

This article discusses three factors that improve the reliability of pneumatic bleed systems on 767 and 747 airplanes with General Electric (GE) or Pratt & Whitney (PW) engines.

1. Design improvements.
2. Maintenance improvements.
3. Pneumatic system health checks.

## 1 DESIGN IMPROVEMENTS

### High-pressure shutoff valve and pressure-regulating valve position switch.

Some operators experience erroneous indications that the high-pressure shutoff valve (HPSOV) has not closed when commanded. These erroneous flight deck and air supply control test unit or built-in test equipment (BITE) module indications result from a shift in the actuation point of the HPSOV/pressure-regulating valve (PRV) position switch. Debris and plunger wear, which are caused by the angle at which the actuating lever presses against the plunger bore, increase the friction between the inner plunger and the switch housing. This friction causes the switch to travel too far (i.e., overtravel) before actuation.

Bleed component supplier Hamilton Sundstrand (Windsor Locks, Connecticut) has improved the wear characteristics and reduced the vibration effects of the HPSOV and PRV position switches by incorporating new material, coating, and design for the plunger and new coating for the plunger bore (fig. 1). Units returned to Hamilton Sundstrand for overhaul since April 15, 2001, have received the redesigned switches. On March 1, 2001, Hamilton Sundstrand issued service information release (SIR) 747BAS141A/767BAS032A and incorporated information about the new switches into all its HPSOV-PRV component maintenance manuals. Boeing released service letter 747-SL-36-094 on July 12, 2001, announcing the availability of the redesigned switches.

All 767 and 747-400 airplanes with GE or PW engines delivered since July 2001 have the new switches.

### HPSOV-PRV actuator spring.

Hamilton Sundstrand also has improved the HPSOV-PRV actuator spring. The service life of HPSOV-PRV actuator springs varies from 3,000 to 21,000 hr. Spring failures are more prevalent on GE CF6-80C2 engines. The typical failure mode on these engines is spring breakage at the center resulting from high-cycle fatigue.

Hamilton Sundstrand has designed a two-piece spring with guide configuration to address this problem (fig. 2). The new spring requires minor machining in the actuator housing. A 0.025-in by 0.7-in machined cut is made on the inside diameter of the housing in the threaded area. The reworked housing can be used with either the single-spring configuration or the new two-piece spring with guide configuration. The new spring will be available from Hamilton Sundstrand in fourth-quarter 2002.

## 2 MAINTENANCE IMPROVEMENTS

### Component overhaul.

Overhauling pneumatic system components when they are removed for repair — as opposed to only repairing the failed subcomponents — can increase component reliability. Data indicate that this practice keeps mean time between unscheduled removals (MTBUR) near that of the first-time removal MTBUR.

Many operators experience reduced time between component removals each time a repaired-only component is reinstalled on an airplane. However, if the failed component is overhauled as recommended by Hamilton Sundstrand, the time to removal is expected to be at or near that of the first-time removal. Hamilton Sundstrand provides details

FIGURE 1 REDESIGNED HPSOV-PRV POSITION SWITCH


on this overhaul philosophy in its SIR 747BAS:139C/767BAS:030C.

For example, Hamilton Sundstrand recommends overhaul of the HPSOV if it has 8,000 or more hours of service and is removed for repair. If an HPSOV is removed because of a position switch failure at 8,300 hr, the operator should completely overhaul the valve rather than only replace the failed switch. If the switch is the only subcomponent replaced or repaired, the HPSOV will likely fail again in a relatively short time after being returned to service because of other subcomponent failures.

One operator who applied this overhaul philosophy to two of its most problematic components saw reliability improve by as much as 250 percent. As a result, the operator implemented this practice for all of its pneumatic components.

**Service bulletins and hard-timing.** Boeing and Hamilton Sundstrand also recommend that operators incorporate ATA Chapter 36 service bulletins into their fleets to improve component reliability. Incorporating ATA Chapter 36 service bulletins from Boeing and component suppliers provides for incremental improvements to the pneumatic bleed system and its individual components. Boeing reliability data show that operators who incorporate ATA Chapter 36 service bulletins have significantly better dispatch reliability than the fleet average (fig. 3).

Operators also may want to consider removing pneumatic components at defined hours of service (i.e., hard-timing). Some operators have indicated that incorporating the hard-timing of pneumatic components into their maintenance programs increased schedule reliability. One operator removed and overhauled all high-time pressure-regulating and shutoff valves (PRSOV) in its 767 fleet. Until then, PRSOVs had been the operator's primary cause of dispatch delays and flight cancellations. After hard-timing the PRSOVs, in-service data indicated that the operator experienced essentially zero schedule interruptions from the PRSOVs (i.e., 0.0018 interruptions per 100 departures). It should be noted that the hard-timing of components might be inefficient if the hours or cycles are not tracked, if components are removed too early, or if removed components are not overhauled properly.

Operators must decide individually whether or not hard-timing of pneumatic components is economically justified with respect to the potential improvement in the schedule interruption rate. A more economically favorable alternative to hard-timing components is the use of a pneumatic system health check.

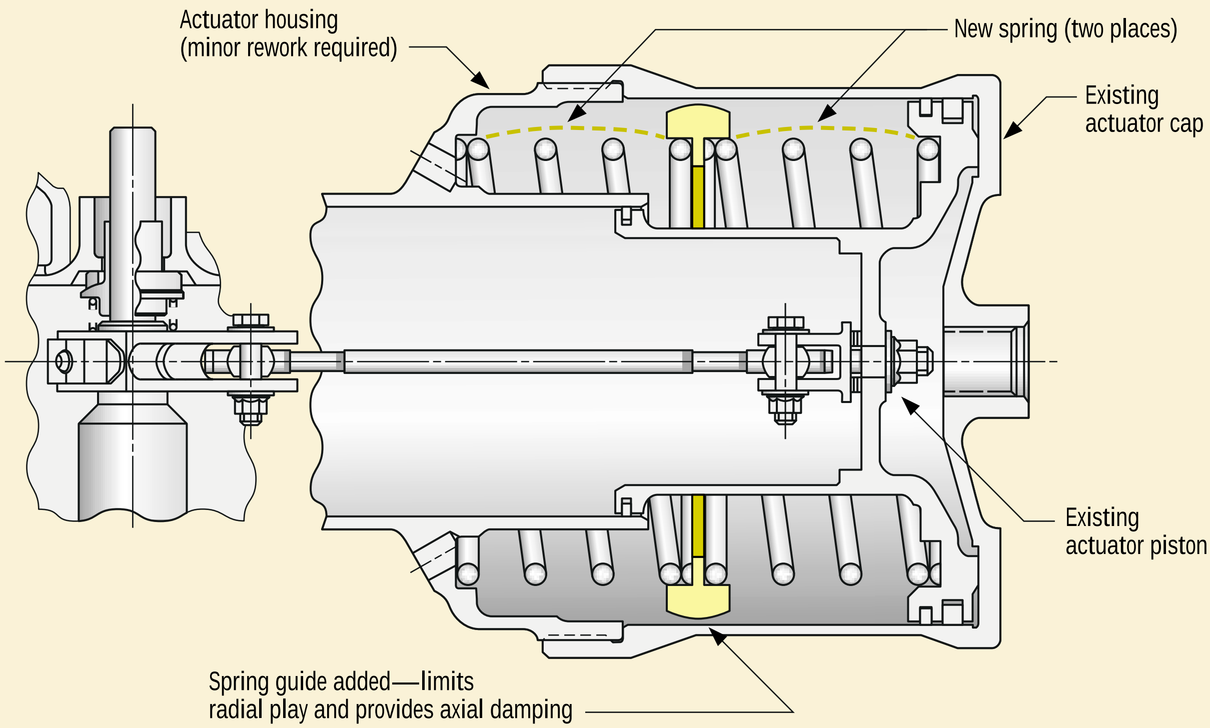
## 3 PNEUMATIC SYSTEM HEALTH CHECKS

**Boeing pneumatic system health check.** Boeing developed a pneumatic system health check (PSHC) for GE CF6-80C2 and PW4000 engines on 767 and 747-400 airplanes with the assistance of United Airlines, other operators, Hamilton Sundstrand, and an ATA Chapter 36 task team. The PSHC improves system reliability by identifying the components that have failed or are about to fail before they cause dispatch delays. (Boeing is developing a PSHC for 747-400 airplanes with Rolls-Royce engines, older 767 airplanes with GE or PW engines, and 747 Classic airplanes.)

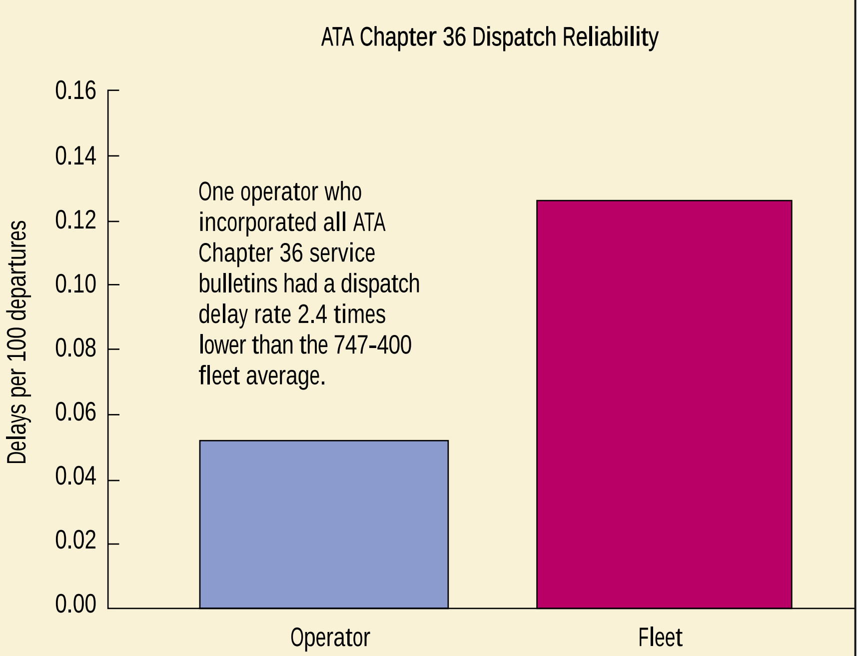
The Boeing PSHC addresses the following components:

- Airplane bleed system wiring.
- Sense lines.
- Position and pressure switches.
- Opening and closing pressures of the HPSOV and the high-pressure controller (HPC).
- The PRV and the PRV controller (PRVC).

## 2 TWO-PIECE SPRING WITH GUIDE CONFIGURATION
FIGURE




## 3 INCORPORATION OF SERVICE BULLETINS
FIGURE




- The PRSOV.
- The fan-air-modulating valve (FAMV).

The PSHC allows the pneumatic system to be tested on wing. Pneumatic system pressurization is not required, but airplane electrical power is needed.

The PSHC uses a test box that includes plumbing, valves, pressure gauges, hoses, and various fittings to connect to bleed system components on the engines and struts (fig. 4). The built-in monitoring systems on the airplane (e.g., the BITE modules on the 767 and the central maintenance computing system on the 747-400) are used during the PSHC to check discrete system inputs.

Several operators have started routinely using the Boeing PSHC during scheduled maintenance checks. One operator removed six components from eight engines as a result of performing the PSHC; all later were validated in the component shop as failed. Similarly, another operator reported that eight engines were checked using the PSHC, and nine components had indications of failure. The components were removed, and all later were validated in the component shop as failed. These results are consistent with Boeing experience during validation testing of the PSHC procedure for 747-400 and 767 airplanes during 1999 and 2000.

In addition, since the introduction of the PSHC, operators have reported a significant decrease in the number of pilot reports related to ATA Chapter 36 and improved knowledge of the pneumatic system and component health on the part of engineers and maintenance crews. Operators also have used the PSHC to examine pneumatic components during troubleshooting to isolate failures to individual components.

Boeing videos on the 747-400 and 767 PSHC are available to operators from their Boeing Field Service representatives. Also, a computer-based training CD on pneumatic system component familiarization and the PSHC is available from Hamilton Sundstrand. (Contact Hamilton Sundstrand, Attn: Value-Added Services Training Coordinator, One Hamilton Road, Mail Stop 1-3-BC34, Windsor Locks, Connecticut 06096-1010; fax: 860-654-6906.)

### United Airlines PSHCs.

United Airlines (Chicago, Illinois) has developed PSHCs for its fleet of Boeing airplanes, and the checks have been part of its maintenance programs for three years. Although United Airlines maintenance manual procedures for PSHCs differ for each airplane model, the test box and adapters are shared across all models in the United Airlines fleet.

All of the United Airlines PSHC tests can be performed on-wing. The 737, 757, and 767 checks do not require airplane power, but a separate 28-V direct current power source is needed to energize the controllers. United Airlines established test limits for each component using its component shop manuals and the vendors' component maintenance manuals. These limits were validated in the United Airlines component shop and on several Boeing airplanes.

A United Airlines PSHC accomplishes the following tests for each of the following subsystems. This example is for the 767.

**PRSOV.**

- Opening, closing, and regulated pressures.
- Resistance and pressures of BITE switches.
- Resistance of position switches.
- Resistance of off and on solenoids.

**HPSOV-HPC.**

- Opening and closing pressures of the HPSOV.
- Resistance and pressures of HPC BITE switches.
- Resistance of HPSOV position switches.
- Resistance of HPC close and automatic solenoids.

**PRV-PRVC.**

- Opening and closing pressures of the PRV.
- Regulated pressures of the PRVC.
- Resistance of PRV position switches.
- Resistance of PRVC close and automatic solenoids.

**FAMV.**

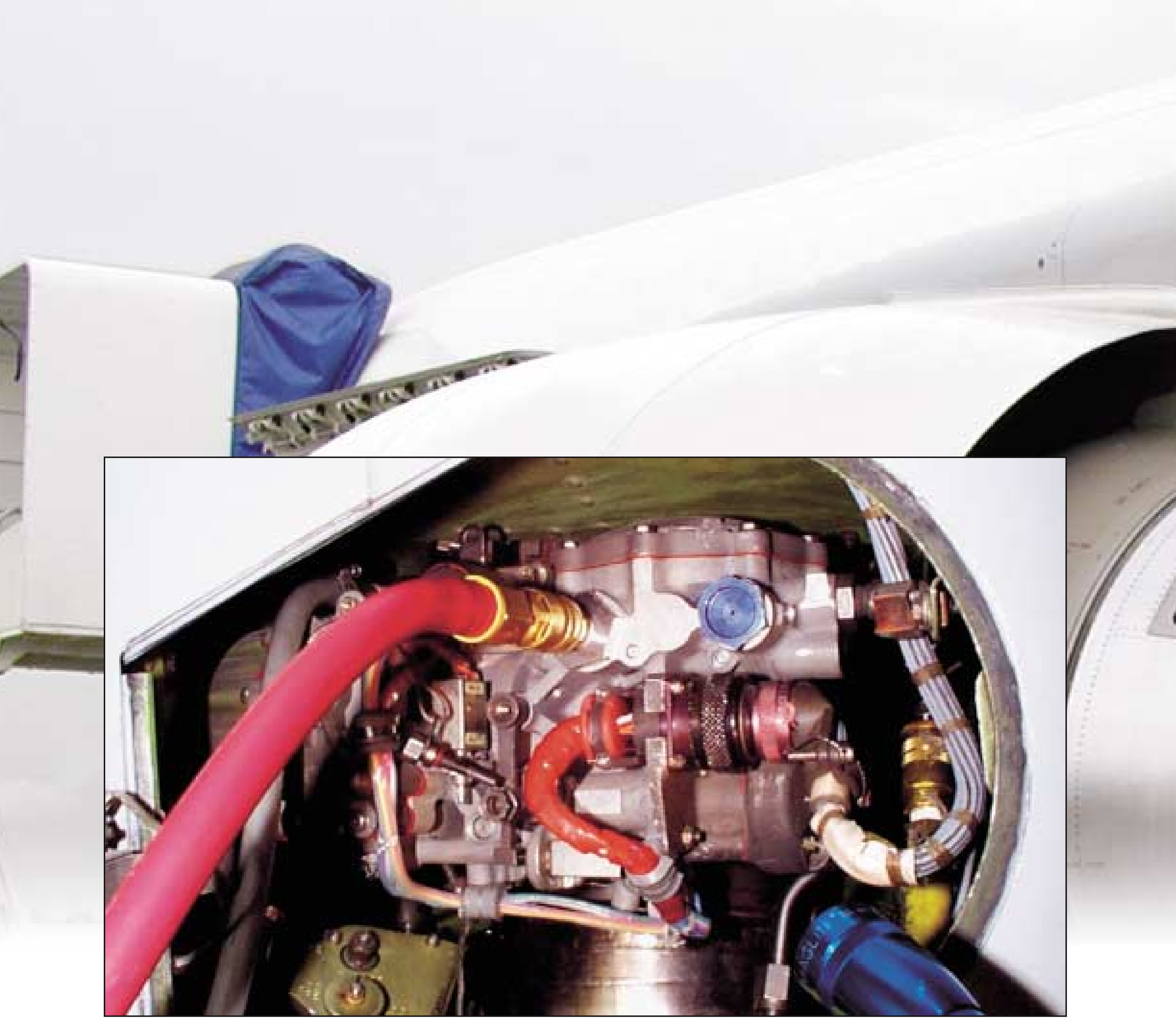
- Opening, closing, and regulated pressures.
- Resistance of position switches.

The United Airlines 767 fleet has experienced a 26 percent reduction in schedule interruptions attributed to ATA Chapter 36 since PSHCs began in December 1998. Of the components that failed the 767 PSHC from January to September 2001, 90 percent were validated by component shop findings as having been removed for the appropriate reasons.

### Incorporation of PSHCs into an airline's maintenance program.

Operators interested in developing and incorporating PSHCs into their maintenance programs should consider the following steps, which outline the process used by both Boeing and United Airlines to develop PSHCs.

FIGURE 4 PSHC TEST BOX



- **Manufacture or purchase PSHC test boxes and adapters.** The Boeing test box and adapters are designed for use on both the 747 and 767. United Airlines test boxes and adapters also are interchangeable among all airplane models in its fleet. Drawings for building the Boeing test box (Boeing part no. G36035-1/-2) are available to operators on line through MyBoeingFleet.com in the engineering drawing database (engineering drawing number 0G36035). Operators may fabricate their own test equipment from the drawings or procure the test equipment from a supplier. Boeing service letters 747-SL-36-093A and 767-SL-36-047A list Boeing-licensed suppliers of ground-support equipment.
- **Create and validate a PSHC maintenance manual procedure.** When possible, Boeing aircraft maintenance manual (AMM) procedures are standardized across airplane models. Several components were tested on wing and in the component shop. The results of these tests, along with Hamilton Sundstrand test limits, were used to validate the AMM procedures. The Boeing PSHC procedure for both the 767 and 747-400 is contained in AMM 36-00-21 for airplanes with GE engines and in AMM 36-00-22 for airplanes with PW engines.
- **Create training programs to properly accomplish the PSHC.** United Airlines conducted maintenance training classes at maintenance bases and key line maintenance stations. The classes included hands-on training using United Airlines test equipment and AMM procedures.

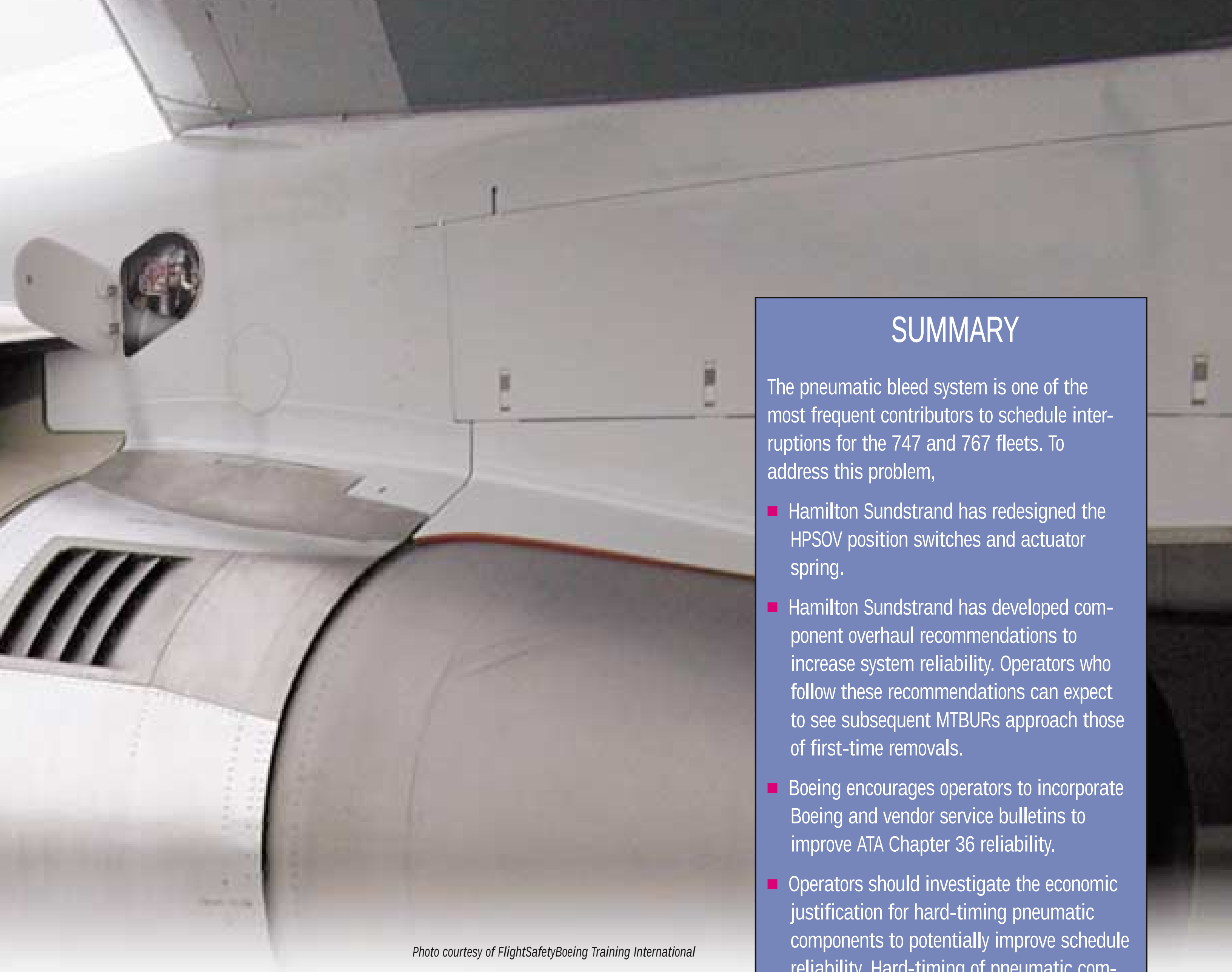


*Photo courtesy of FlightSafetyBoeing Training International*

- **Record findings for each pneumatic component tested.** United Airlines and other operators enter the results from health checks into databases and use that information to predict failures of pneumatic components and to develop and validate minimum build standards for component overhaul shops.
- **Determine the interval in which a PSHC maintenance program should be accomplished.** United Airlines initially checked each pneumatic component during every extensive maintenance check (i.e., 1C). Findings indicated that the check interval for one component could be expanded to every other check (i.e., 2C). Such changes may occur with other components as minimum build standards at component shops are developed and implemented. Operators should evaluate maintenance manual test limits after build standards have been incorporated.
- **Stock spare components.** When first introducing the PSHC, operators should plan for initially higher-than-normal levels of component removal because failed or failing components will be identified that were previously undiagnosed. For this reason, operators may choose to notify Hamilton Sundstrand of when they plan to implement PSHCs to ensure that an adequate supply of spare parts will be available.

## SUMMARY

The pneumatic bleed system is one of the most frequent contributors to schedule interruptions for the 747 and 767 fleets. To address this problem,

- Hamilton Sundstrand has redesigned the HPSOV position switches and actuator spring.
- Hamilton Sundstrand has developed component overhaul recommendations to increase system reliability. Operators who follow these recommendations can expect to see subsequent MTBURs approach those of first-time removals.
- Boeing encourages operators to incorporate Boeing and vendor service bulletins to improve ATA Chapter 36 reliability.
- Operators should investigate the economic justification for hard-timing pneumatic components to potentially improve schedule reliability. Hard-timing of pneumatic components is a decision of the operator based on its operating environment.
- Boeing and United Airlines have developed PSHCs to find failed or failing components at scheduled maintenance checks rather than at dispatch. Operators using PSHCs have reported significant reductions in schedule interruptions, fewer pilot reports, and increased awareness of the health of their fleets' pneumatic systems. The component shops of various operators have validated that removed components identified by the PSHCs as failed had indeed failed.