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THRUST REVERSER SYSTEM - PART 2

Cover: Detail of carbon fibre cloth (photo Patrick Dubroca/Aeroformation)

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current use are: glass fibre reinforced plastic (GFRP), aramid fibre reinforced plastic (AFRP) and carbon fibre reinforced plastic (CFRP). AFRP and CFRP are sometimes referred to as advanced composites.

The intended use and environment conditions the choice of composite material and resin. For example when high strength is combined with high stiffness then a carbon fibre is used. However when lesser levels of stiffness are required glass and aramid fibres are used.

In both cases their performance in service, due to ageing and temperature, will vary depending on the choice of resin used in the bonding process. The choice is made to suit the design case.
Details of the types of composites used at each of the various locations on Airbus aircraft are given in chapter 51 of the applicable Structural Repair Manual. The composite materials are used in different ways.

**SANDWICH STRUCTURE**

Many combinations of composites and metal can be used in sandwich construction. Figure 1 shows a typical layup of a composite panel.

The sandwich is typically a honeycomb core between multiple plies of composite cloths pre-impregnated with a resin, laid at different angles to each other and cured under pressure in an autoclave.

**MONOLITHIC STRUCTURE**

Sheet, angle, ribs, frames, top hat sections, etc. are built up in the same way as the outer layers of the sandwich structure.

Figure 2 shows an A310 spoiler with skin panels and ribs made of CFRP. This combination gives a rigid and strong structure to which the metallic fittings are attached.

**MIXED CONSTRUCTION**

To comply with design requirements some composite structures are part sandwich and part monolithic construction as is used for the A320 flap shown in figure 3.

**CERTIFICATION OF COMPOSITE COMPONENTS**

Besides the fact that these components had to be developed, designed and manufactured, a major task was to obtain the Certificates of Airworthiness required for them.

The final proof of the structure is demonstrated through full scale static and fatigue tests under quite particular conditions.

In addition to the so-called external-loads generated through gusts and manoeuvres, environmental effects, particularly those of temperature and humidity, are predominant for the performance of composite structures.

The static test is performed on an "aged" structure and at the appropriate temperature corresponding to the load case. That means that the component has first to be conditioned to the maximum service moisture content, by exposing it in a climatic chamber to elevated temperature and humidity until saturation, followed by a fatigue cycling for one life time at least.

The fatigue test is performed
on a service moisture conditioned structure for at least three life times, including a one life time test period for damage tolerance investigations with artificial damage applied.

Environmental tests have also been conducted and these have shown that:
- composite tests pieces and structure are not sensitive to the aggressive fluids normally used on aircraft such as in hydraulic and fuel systems and for cleaning and de-icing,
- when the paint surface has been eroded ultra violet light may, very slowly, superficially spoil the resin and direct sunlight would cause local increase in temperature. However these conditions are catered for in the design of the particular unit.

**REPAIR OF COMPOSITE COMPONENTS**

Generally speaking composite components are easy to repair. The main causes of damage are from mishandling, or impact of different types, therefore evaluation of the damage is made as a function of the type and extent of the damage and the area of the component which is damaged.

Repairs fall into two groups, cosmetic and structural. Repair techniques have been limited to three standard groups: all structures, sandwich structures and monolithic/integrally stiffened structures. These three techniques are used in conjunction with standard processes which are applicable to all three groups.

As a general rule, for repairs of the composite components used on Airbus aircraft, the repair materials shall be the same as the original component material but in specific cases there may be deviations.

Note: The following text must not be used as a substitute for the instructions in the Structural Repair Manual (SRM).

**INSPECTION PRIOR TO REPAIR**

Careful inspection of the damage is essential, to define the extent of the damage, its location in relation to adjacent structure, and the extent of any separation of layers due to the damage. The inspection can be carried out by optical or accoustic means. X-ray can be used to check for accumulation of water in a honeycomb structure. Evaluation of the information leads to classification of the damage as follows:

- allowable damage,
- repairable damage,
- specific damage requires manufacturers approval.

Figure 4 shows the area to be inspected when surface damage
TYPICAL REPAIR SEQUENCE

1. Type of damage.

2. Removal of damaged area and installation of insert and doublers.

3. Installation of insert.

4. Installation of repair doublers.
is detected, since an impact on composite sandwich structure can lead to significant internal damage, such as delamination in the skin, or debonding between skin and core, covering an internal area larger than is apparent from the external damage.

**REPAIR CLASSIFICATION**

Evaluation of the evidence from the inspection then leads to classification of the repair into one of four categories:
- temporary repair,
- permanent non-structural cosmetic repair,
- permanent structural repair,
- rework.

Note: Should damage of two different types be superimposed, e.g. scratch and delamination, then the two corresponding repair schemes are to be superimposed.

**METHODS OF REPAIR**

Before starting any repair ensure that the area to be repaired is adequately cleaned and dried. Paint should be removed by sanding, taking care not to damage the fibres. Two methods of repair are given in the Structural Repair Manual. The first is for repairs which can be conducted at room temperature (about 20°C minimum). Curing takes longer at low temperatures. Depending on the adhesive material and temperature, curing time can vary from 45 minutes to 7 days. Curing times can be reduced by using heating equipment giving temperatures up to 80°C. Figures 5, 6 and 8 show typical repair schemes for use at room temperature. The second method is for hot bonding repairs at temperatures of 125°C to 180°C for which an autoclave is needed.

**SKIN REPAIRS**

Typical repair schemes for damaged skin are also shown in figures 5, 6 and 7 and explained in chapter 51 of the SRM. Specific repairs are to be found in chapters 52 to 57 of the SRM. Standard repairs are applicable when there is very little or no internal damage. If the damage penetrates the skin and the internal structure is affected it must also be repaired.

**REPAIRS TO SANDWICH STRUCTURE**

These repairs cover damage to skin and honeycomb. Damage of the honeycomb core can be repaired simply by removing the damaged core and filling up the
void with a mixture of adhesive and thickening agent as is shown in figure 8. The core can also be cut away then a repair plug of honeycomb is inserted and hot bonded with adhesive films and glassfibre cloth as is shown in figure 9. The skin is then repaired in the same manner as already described. The core materials used are standardized for repair independently of those used for production.

**REPAIRS OF DELAMINATION AND DEBONDING**

A composite structure is normally a build-up of several plies of a composite all stuck together. Delamination occurs when two or more plies become separated from each other, often due to impact.

Having determined the exact extent of the delamination by tap test and/or non destructive testing (NDT), blind rivets may be used to join the delaminated plies together again. Appropriate NDT procedures, mainly ultrasonic, are being defined and will be published in the Non Destructive Testing Manual (NTM) soon.

If there is also damage to the honeycomb structure, adhesive should be injected through the rivet holes as shown on figure 10.

Debonding occurs when the honeycomb core separates from its outer skin. Repair can be effected simply by injecting adhesive into the honeycomb through holes drilled in the skin as shown on figure 11. Pressure should be applied to the skin surface to ensure proper bonding between the core and the skin.

**SPECIFIC REPAIRS**

Damage which cannot be defined in the SRM is classed as specific damage. Repair solutions for specific damage will be covered by specific repair drawings upon request to Airbus Industrie. These repair solutions will be included in the SRM if their use is repetitive or considered likely to be.

**CONCLUSION**

Composite materials provide many benefits to the Airbus operator. Not only are the operating costs of the aircraft reduced but maintenance costs will also be reduced. Repair tools are standard and simple. Composites do not suffer from cracking or corrosion and have very good fatigue strength. Inspections are simple and repairs are easy.
The integrated drive generator (IDG) is a very compact, highly efficient machine, located in a high temperature environment. To work properly it requires an efficient cooling system which must be properly and regularly serviced. This article describes in a general sense, the evolution of aircraft generation systems up to the latest version of the IDG. More particularly it highlights developments to ease the oil servicing of the IDG system and thereby increase the reliability of a very expensive piece of machinery.
In the last ten years the generation system in aircraft has seen great improvements in reliability and in particular in power to weight ratio. The "old" air cooled generators were mated with hydraulic differential (known as AD) constant speed drives (CSD). They were followed by the axial gear differential (AGD) types in the early 1960s which have gradually been replaced by a much lighter and more compact system called the integrated drive generator (IDG). Early IDGs had the CSD and the generator inline. The Sundstrand IDG installed on the A310 and A300-600 has them mounted side by side within a single housing, thereby reducing length, overhung moment, vibration and weight. Each evolution of the CSD/generator system has resulted in improvements in the power to weight ratio as shown in figure 1. The weight of the aircraft generating equipment, including the attachments (QAD), has been reduced from 211 lbs per engine on the A300 to 125 lbs per engine on the A310 and A300-600.

Oil spray cooling is used within the IDG, however the location of the IDG on the engine means that it may have to work in a very diffi-

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**Figure 1**

Evolution of CSD generator system
cult environment which necessitates a highly efficient cooling system. The oil coming from the IDG passes through one, or two (depending on the engine manufacturer) fuel/oil coolers and a complementary air/oil cooler (figure 2). The fuel/oil coolers also serve as oil/fuel heaters. There is approximately eight litres (two gallons) of oil in the IDG system of which about half is in the IDG itself.

**SERVICING**

All systems or machines which use oil for lubrication as well as for cooling, need to be checked regularly to ensure that the oil quantity is kept at the required level. It is important that the servicing procedure be performed correctly, to avoid under or over fill which may lead to extensive damage. This is just as important for the continuing good health of the IDG as for your car.

The simplest method of assuring the correct oil level is a system which fills up till it overflows just like in the differential gearbox in a car. Servicing of the IDG follows that principle by having a stand pipe located in the sump, into which all the excess oil flows (figure 3).
Whilst the principle of checking the oil level is easy, the methods chosen previously gave rise to some difficulty in checking the actual oil level, inconvenience during replenishment and sometimes considerable waste of oil. Incorrect procedures observed during servicing are illustrated in figure 4.

The fact that some oil flows out when the drain valve is depressed does not mean that the oil level is correct in the IDG and its cooling circuit. That is why it is necessary to let at least one litre (1 quart) of oil overflow when pumping oil in.

**OLD SERVICING METHOD**
The MPD (Maintenance Planning Document) requires verification of the oil level at each A check and the Aircraft Maintenance Manual (AMM) gives the procedure to be used when the oil is at 50°C or less - the "cold" procedure. Service Information Letters (SIL) gave procedures to be used on the different engines when the oil was too hot - the "hot" procedure.

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**Figure 4**
Incorrect procedures observed during servicing

- Overfilling due to an undetected kink in the overflow drain hose.
- Stand pipe will always be full after an engine run.
- Overfilling due to incorrect position of the hose.
These procedures were either time consuming or wasteful. The "cold" servicing procedure required motoring of the engine since the IDG cannot be replenished after a time delay longer than an hour, which is likely to happen in order to allow the oil to cool. The "hot" method in effect cooled down the oil by flushing out eight litres (two gallons) of hot oil with the same amount of cold oil.

NEW SERVICING METHOD

The new method of servicing the IDG has been developed by Airbus Industrie and Sundstrand and is described in detail in Airbus SIL 24-026 issued on 8 October 1986. The procedures have been reduced to three simple steps, as shown on figure 5, to be carried out on a weekly basis.

**Figure 5**

New replenishing procedures

**STEP ONE**
Attach overflow drain and pressure fill hoses. Some oil may come out the overflow drain hose when it is connected. Pump oil into the IDG until at least an additional litre (one quart) of oil comes out the overflow drain hose.

**STEP TWO**
Remove pressure fill hose only. Install dust cap.

1 litre of oil (quart)

**STEP THREE**
Remove overflow drain hose when drainage slows to drops. Install dust cap.
The AMM will be revised in June 1987 to show the new servicing procedure and schedule. The significant improvements resulting from the new servicing procedure are:

- reduced task time,
- faster aircraft turn-around,
- deletion of dry motoring in all cases,
- deletion of time and temperature constraints,
- deletion of use of prism sight to determine the low oil level (Prism will only be used for troubleshooting),
- deletion of separate depressurization, now done by connection of overflow pipe.

These procedures are common to the CF6-80A3/C2 and JT9D-7R4 engines and will be applicable to the PW4000 engine if tests are satisfactory.

**OTHER IMPROVEMENTS**

**Sight glass**

Interpretation of a low oil level through the sight glass (figure 6) is not always easy. Since the sight glass is still necessary for trouble shooting, an improved

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**Figure 6**

Principle of operation of existing oil level indicator

Look at the viewing face of the low oil level indicator; change your line of sight until the white marks are aligned:

- Wipe clean if dirty.
- Use a flashlight if too dark to see white alignment marks. Do not shine flashlight directly on the viewing face because reflection will make reading difficult.

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Light absorbed into oil

Light absorbed into oil

Light reflected

NO BRIGHT SPOT:
No servicing required.

ANY BRIGHT SPOT:
Large or small servicing required.
version has been developed to give a clearer indication of low oil level. It is currently undergoing in-service evaluation and subject to positive results being obtained, will be available this year for retrofit on the CF6-80/A3/C2, JT9D-7R4 and PW4000 engines.

Further efforts are being made to develop another type of oil level indication involving a direct float stick showing oil level in front of a sight glass.

No visual indication is necessary to detect an overfilled condition of the IDG since the overflow stand pipe already establishes the maximum oil level during servicing. Light is reflected into the prism only when the oil level is low.

HOLDING TANK

Sundstrand has published the Service Bulletin SB 90 DGS 05-24-24 to introduce a modification to the existing tank within the IDG which will allow the oil circuit to keep the oil level as close as possible to the full level, which is the optimum level, as shown in figures 7 and 8. Incorporation of this Service Bulletin is recommended.
THRUST REVIEW

by Andy I. Currie, Senior Customer Service Engineer, Rohr Industries, Inc., and Michel Trémaud, Powerplant-System Engineer, Technical Support, Airbus Industrie
Since the introduction of the first low bypass ratio turbofan engines, in the early sixties, fan thrust reverser systems have taken an increasing lead over core thrust reverser systems. Although some high bypass ratio turbofan engines originally retained a dual fan/core thrust reverser configuration, the core reverser system has now been abandoned. Fan thrust reverser systems are large and complex structures, aerodynamically efficient and able to withstand the vibration, stress and temperature variations associated with operating close to a jet engine. Their actuating and control systems involve electro-pneumatic and mechanical components, the rigging and interconnection of which is of paramount importance for correct and durable system operation. The following article gives an overview of system architecture and operation and provides guidance on rigging requirements, troubleshooting and maintenance.
THRUST REVERSER
DESCRIPTION

Function
The thrust reverser system is designed for use on the ground to provide maximum aircraft deceleration consistent with safe, efficient airplane operation. Figure 1 shows the thrust reverser functions. When the reverser is stowed, fan air exhausts rearward, providing forward thrust. When deployed, fan air is deflected forward and provides reverse thrust.

Architecture
The reverser fan duct assembly is constructed in two halves that form C shaped bifurcated ducts. Figure 2 shows the right half. Each half is hinged to the aircraft pylon structure at the top, and latched to its counterpart at the bottom. The reverser is deployed upon flight crew command by a pneumatic drive unit (PDU) driving six ball-screw actuators (figure 3) which translate the reverser cowl outer sleeves on tracks, exposing fixed position cascades. Simultaneously, twelve blocker doors are extended into the fan stream to block the normal flow path. With the blocker doors deployed, the fan stream flow is directed outward through the fixed cascades which deflect fan air in a forward direction. This action furnishes the reverse thrust required to aid in aircraft deceleration. On receipt of a reverser stow signal, the translating sleeves, with attached blocker doors, move forward to cover the cascades resulting in the normal forward thrust fan flow and cowl configuration.

PNEUMATIC POWER ACTUATING SYSTEM
A pneumatic drive unit (PDU) provides a reversible power output through an arrangement of flexible shafts, gearboxes, and ball-screw actuators. The complete system controls the function of unlocking, deploying, holding deployed, stowing, and locking of the reverser in response to signals generated by the thrust reverser lever position on the pilot's throttle lever.

During engine operation, pneumatic power is obtained from the engine 15th stage high pressure bleed air. A pressure regulator and shutoff valve (PRSOV) controls the on/off supply of air to the system. When operating the reverser, the valve limits the maximum inlet pressure to the PDU.

For ground maintenance operation, pressurization air may be obtained from the following sources:

- The aircraft auxiliary power unit (APU).
- Crossbleed air from the aircraft's other engine.
- Ground support air supply equipment.
Figure 2
Right hand thrust reverser assembly
- Sleeve
- Slave actuators
- Blocker doors and links
- Master actuator
- Flex shafts

Figure 3
Thrust reverser actuation (looking forward)
- Sleeves
- Slave actuators
- Master actuators
- Flex shafts
- PDU
- Splitter gear-box
THROTTLE CONTROL INTERLOCK
The master actuator for each thrust reverser half incorporates a fail mechanism which provides reverser positional feedback to the aircraft throttle control system to prevent application of engine power above idle until the reverser sleeves reach the commanded position.

INDICATION SYSTEM
Reverser system indication consists of a reverser unlock signal and a reverser deploy signal. The unlock signal indicates release of either the pneumatic drive unit primary brake, master actuator secondary locks, or indicates that the reverser sleeve(s) have translated out of the stowed position. A reverser deploy signal indicates the reverser has reached the fully deployed position.

LOCKING FEATURES
Two separate locking devices are provided within the system:
- The primary means of holding the system stowed is a pneumatic brake in the pneumatic drive unit. The brake is also applied once the fully deployed position is reached.
- The secondary locking feature is incorporated into the reverser master actuators. The master actuator locks function only in the stowed condition to assist in securing the system while also guarding against sleeve drift-back.
Locks are released by pressurizing the lock actuator chambers, during the system arming phases.

OPERATION
Stowed configuration
In the stowed mode the reverser translating sleeves and attached blocker doors are locked in forward configuration position to allow normal forward thrust. Unlock and deploy lights are extinguished.

Deploy cycle
Operation is initiated by crew action. Moving the power control (throttle) lever to idle and rotating the reverse thrust (throttle piggy-back) lever upward arms the system and translates the sleeves in the deploy direction. Interlock mechanisms provide inputs to the aircraft throttle control system which indicates that both sleeves of the reverser are deployed and ready for application of reverse power. Upon reaching the fully deployed position, a reverser deployed signal is provided and the reverser unlock signal is cancelled.

Safety features
Should an equipment failure cause the reverser sleeve(s) to drift back inadvertently in flight, the reverser unlock light illuminates. Driftback is limited to 0.5 inch of travel by the master actuator secondary lock pin and lock cam engagement, at which time the system automatically locks to prevent further deployment.

GROUND OPERATION
The thrust reverser actuators contain cranking provisions to allow manual translation of the reverser sleeves. In order to accomplish this, the brake in the pneumatic drive unit primary system and both of the locks in the master actuator secondary system must be manually released initially and held to allow sleeve movement.

As can be seen from the complexity of the above systems, proper rigging is essential to ensure the smooth and durable operation of the total system.

RIGGING REQUIREMENTS
It is essential that the sleeve halves are synchronized and sequenced and that all six screwjacks maintain alignment during each excursion of the sleeves. The actuators must be rigged to obtain this symmetry in relation to the sleeves. It is critical that the master actuator pointer (figure 4) is in line with the indication triangle when the actuator is on its forward stop. The flexible driveshafts are inserted between the master actuators and slave actuators, and a flexible driveshaft from each master actuator is inserted in a splitter gearbox, at top

Figure 4
Master actuator and pointer

When the master actuator is fully retracted, the pointer on its secondary lock must be on the \( \nabla \pm \) one half the width of the \( \nabla \)
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<tr>
<th>Item</th>
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...centre, to ensure synchronization of the sleeve halves. A final hookup of the master (primary) flexshaft connecting the splitter gearbox to the pneumatic drive unit (figure 3), establishes sleeve travel on command.

**The relationship between the sleeve position and the pneumatic drive unit must be established before the master flex shaft is installed.** A new or repaired pneumatic drive unit is supplied, and tagged, in the "nominal" position. The sleeves must also be put in their "nominal" position. This is achieved by driving the sleeves to the full deploy position then by cranking the sleeve forward from full deploy, seven and a half turns of the actuator or flexshaft. This establishes the correct nominal relationship of pneumatic drive unit and sleeves, for insertion of the master shaft in the pneumatic drive unit to rig the reverse mechanical system.

**Caution:** Engaging the flexshaft in the PDU in the reverse stowed position could cause serious and expensive damage to equipment as the position of the PDU is only known when it is in the "nominal deploy position". There is no indication of PDU position. If required, the only way to set the PDU in the "nominal deploy position" is by applying air pressure to the unit. The PDU must never be mechanically actuated.

After changing a component or on suspicion of a discrepancy, it is necessary to check and/or perform system rigging. Deviations or improper operation of the system could cause flight delays and damage to the thrust reverser.

The following components must be carefully adjusted and checked in the order shown below to provide troublefree operation:

- Actuators (masters and slaves)
- Stow switch
- Throttle feedback
- Deploy switch
- Pneumatic drive unit
- Primary (master) drive flexshaft
- Electrical system

It is essential that all conditions laid down in the Airbus Maintenance Manual chapter 78 be maintained at all times as there is no "hard time" maintenance cycle for the thrust reverser components.

An ongoing inspection should be maintained whenever the thrust reverser doors are open. Checks should be made for sleeve leading edge gap, delamination, deterioration, chafing or damage. These line maintenance checks are necessary because the unit is not normally removed and therefore does not receive adjustment in a shop.

**TROUBLESHOOTING**

Troubleshooting should be accomplished using flowcharts provided in the Airbus Trouble Shooting Manual (TSM). Precise knowledge of the system architecture and operation, due awareness of intercorrelation between thrust reverser components and their respective rigging requirements will yield time and cost saving.

**CONCLUSION**

Since the entry into revenue service of the JT9D-7R4 propulsion system in 1983, a continuous effort has been conducted by Airbus Industrie, Pratt and Whitney, Rohr Industries and associated vendors, to improve the training and rigging instructions as well as the overall system reliability and durability. A310 and A300-600 / JT9D-7R4 operators are encouraged to incorporate the available engineering changes listed hereabove, which have proved their effectiveness during revenue service operation.

In addition the maintenance recommendations provided in the Airbus A310 and A300-600 MD (Maintenance Planning Document) Volume 1, section 6, as well as the operational limitations and procedures provided in Airbus A310 and A300-600 Flight Crew Operating Manual (FCOM) Volume 2 should be adhered to.

A properly rigged and well maintained thrust reverser will give continuous good service year after year.

"GIVE YOUR REVERSER A BREAK AND IT'LL BE THE BEST BRAKE YOU EVER HAD".

We are grateful to Pratt and Whitney for their assistance with this article.

FAST / NUMBER 8
In this issue we discuss a potential source of trouble which has caused a high rate of unjustified removals of engine bleed air components. The principle applies to all types of A300 and A310 aircraft versions independent of engine type.

The trouble sources are the flexible bleed air sense lines connected to the engine bleed valve (pressure regulator valve). Those lines were found leaking which created a malfunction of pressure regulation and triggering of the bleed valve FAULT light.

**SYSTEM FUNCTION**

The impact of leaking sense lines can be easily seen on the simplified schematic depicting the bleed valve with its servo controls (figure 1).

The main components are the bleed valve (1), with its actuator and butterfly, ON/OFF solenoid valve (2), reverse flow check mechanism (3), reference regulator servo (4), and for this article of highest interest, the sense line 1 connected downstream of the valve and sense line 2 connected to the regulator pressure sensor (5). The schematic diagram shows a balanced condition with engines running and the bleed valve regulating a pressure of about 46 psi.

The upstream servo pressure (orange) is routed through a shuttle valve (6) to the smaller chamber of the actuator piston. It is also routed via the ON/OFF solenoid valve (2) (de-energized OPEN) to the larger chamber. The downstream pressure (green) is picked off by the sense line 1 and routed to the reference regulator servo (4) which regulates the passage of the upstream pressure (orange) according to the downstream pressure and causes the butterfly in the bleed air valve to be positioned accordingly.

The downstream pressure (green) is also routed to the reverse flow check mechanism (3) and through sense line 2 to the regulator pressure sensor (5). When there is an increase in downstream pressure (green), or a reverse flow, the reference regulator servo (4) causes the butterfly to close accordingly.

**IMPACT OF A LEAK**

**Line 1**

A leak on this line has the same effect as a pressure drop downstream of the valve. It causes the reference regulator servo to fully close, and the increased servo pressure (orange) drives the butterfly more and more to open. This generates an increase in pressure and temperature in the air duct which, depending on the extent of the leak, causes the fan air valve to open in order to keep the temperature in the nominal range. If an excess in temperature or pressure is reached, then the bleed valve FAULT (TEMP. HI/REGUL. FAULT) (figure 2) will be triggered and solenoid valve (2) closes. If there is an extreme leak, the overpressure condition will not be detected by the sensor (5), but the overpressure valve will close (PACK FAULT).

**Line 2**

A leak on this line has not necessarily an effect on the proper regulating function of the valve. But at low engine power settings it has happened that the sensor (5) detects a low pressure condition triggering the bleed valve FAULT (REGUL. FAULT), and closing the solenoid valve (2).
Figure 1
Bleed valve/Servo control simplified schematic diagram

1 BLEED VALVE

Regulator pressure sensor

ON / OFF solenoid valve

Reverse flow check mechanism

Large chamber
Small chamber
Actuator

Close
Open
Shuttle valve

Bleed air flow
Butterfly

Over pressure valve
Precooler

Fan air valve

Sense line 1

Sense line 2

Reference regulator servo

Leak
TROUBLESHOOTING
Whenever flight crew reports FAULT (figure 2), then the first maintenance action should be to test the LRUs on the BITE of the pneumatic system controller (figure 3). To avoid unjustified removals, this action must strictly follow the instructions and procedures of the TSM and the recently revised Airbus SIL 36-012, Revision 2, dated April 1987 for A300 B2/B4 and Airbus SIL 36-011, Revision 4, dated March 1987 for all other Airbus types.

Experience revealed that whenever the consequences of leaking sense lines lead to a BITE indication then it will be indicated by a red light on the bleed valve (pressure regulator) position. That means that the pneumatic controller distinguishes between a big and a small leak. However, there is a high probability that a sense line is involved if one of the following conditions arise:

- FAULT which could be reset,
- FAULT at low engine power settings or power reduction,
- Repetitive FAULT following replacement of components.

Flight crew information can also contribute to quick and pro-
per trouble shooting. The most helpful parameters are the bleed air downstream pressure and pre-cooler outlet temperature. They are either displayed on the ECAM air bleed page (figure 4) or on the indicators of the flight engineer's panel (figure 2b). If there is a significant difference between both systems in downstream pressure following a closure of a bleed valve and opening of the crossfeed valve, then a leaking sense line is to be suspected.

LEAK CHECK
Several methods were developed to trace and confirm leaking sense lines. The simplest is to visually inspect the lines for discoloration (burn marks), in particular at the line connectors, and chafing marks in the area of the line attachment clamps.

A suspected leak can be easily confirmed by pressurizing the bleed air ducts, using the APU, and listening at the sense lines for escaping air. A more accurate method is to disconnect line 1 at the downstream duct and connect an air test set. A pressure drop then indicates a leak either in line 1 or in line 2.

CORRECTIVE ACTIONS
In the majority of cases the leaks in the sense lines are created by cracks in the internal steel bellows or by their separation from the line connectors induced by twisting the line during installation or by vibration. Since the bellows are encased by steel mesh, cracks are only detectable when the line can be easily shortened/lengthened near the connector (figure 5), or when there is discoloration/deformation of the mesh (figure 6). Correct twist free installation is therefore of utmost importance. To better protect the lines against vibration improved clamping has been designed.

All those corrective actions as well as further evaluations, part numbers involved and Service Bulletins are listed in the Technical Follow Up sheet (TFU) 361100 08.

CONCLUSION
To get a quick and accurate result in troubleshooting, the BITE test has to follow the procedures of the SILs and TSM and the leak check of the sense lines should not be overlooked. At scheduled zonal inspections, the proper installation and conditions of the lines should be verified and at the first opportunity, the modifications indicated in the TFU should be incorporated. At the same time the condition of the sense lines of the HP bleed and fan air valves should be also verified.
Airbus Industrie has always considered the efficiency of equipment to assist maintenance to be a major factor in the reduction of operating costs — in particular the direct maintenance costs of electronic equipment.

The area of maintenance equipment has seen spectacular advances since the time of A300, in step with those of aircraft systems themselves. This evolution is in part due to the advent of digital electronics but it stems essentially from a constant effort on the part of Airbus Industrie and its Partners to improve their product.

This article describes those units of on-board electronic equipment which allow maintenance technicians to conduct repairs which are quick, efficient and safe. A quick repair implies a clear indication of the component to be replaced or repaired. A repair is efficient if replacing or repairing the identified component effectively solves the problem. A repair is safe when the integrity of the repaired system has been verified.

When the racks, in which the electronic computers are installed, are examined, it is surprising to find such a panoply of equipment. The range is complete, from the simple Go-No Go indicator associated with a test push-button, to the alphanumeric indicator with direct read-out, including groups of light emitting diodes (L.E.D.) and other coded read-out indicators.

However, it may be noticed that certain A310 computers have blank front faces. From a maintenance point of view, such equipment and the systems that they represent are trail blazers, in that there is a common centralized piece of maintenance and test equipment installed in the cockpit. An example of this is the Automatic Flight Control System (AFCS) computer which has a test panel installed on the maintenance panel in the cockpit of the A310 (figure 2). We have already said that following maintenance action, system integrity must be checked. On the A300 and A310 the Flight Engineer's
and Maintenance panels combine the test controls and fault warning lights on the different systems to aid the checking function. On the A320 the manually operated tests are replaced by automatic tests.

A new man-machine interface allows the almost total deletion of the concept of the maintenance panel in the A310 which itself replaced the Flight Engineer's panel in the A300.

It is acknowledged, maintenance technicians may find that these different types of maintenance equipment are not very easy to use. They vary greatly from one to another, they are sometimes very complicated and sometimes can only be used in conjunction with documentation; all of these factors may cause unjustified removals. It was necessary to improve, simplify, homogenize, facilitate the task of the maintenance technician, i.e. be more efficient on a modern aircraft like the A320.

Following studies carried out by Aerospatiale since 1982, Airbus Industrie has promoted a new maintenance concept, the end product of which is the Centralized Fault Display System (CFDS) of the A320.

**THE CONCEPT**

To define what the maintenance equipment of the A320's electronic systems should be, the following key points have been taken into account:

- All the aircraft's electronic systems may transmit information via a digital bus, and all of these buses may be connected to a central computer.
- The man-machine interface, which on preceding aircraft took the form of the front face of the computers and the maintenance panel, is conducted through a single control terminal, installed in the cockpit.

The A320 is a small aircraft compared to its predecessors. The available space in the electronic bay, and in the cockpit is greatly reduced, so any operations performed in the bay must be limited.

**THE MAIN CHOICES**

When all the data from the different systems converges upon the central computer, a choice must be made between two ways of using it:

- either leave the responsibility for diagnosis to each system on the aircraft and centralize the
presentation of the results via a computer with a simple interface,
- or transmit the data from the systems to an "intelligent" (and necessarily complicated) computer which would have the task of analysis and establishing a diagnosis.

The first solution has been chosen. On the A320 manually operated tests are replaced by automatic tests, performed for the most part upon system electric power energization (power up). The central computer known as the CFDIU (Centralized Fault Display Interface Unit) is a relay computer whose operation is simple and totally independent of the aircraft systems. It has three main functions:
- provide the aircraft systems with correlation data,
- memorize fault messages,
- allow a link between the maintenance technician and the chosen aircraft systems.

THE MAN-MACHINE INTERFACE

To allow this relationship, i.e. to present messages, to have a dialogue with the systems and to trigger the tests, a screen and control buttons were required. Existing control terminals could be used if adapted. The CDU (Control Display Unit) of the FMS (Flight Management System) have become MCDUs; M stands for multi-purpose.

The MCDU shown in figure 3 replaces computer front faces and maintenance panels. The maintenance technician uses the screen and appropriate push-buttons on either side of it, which are known as line keys. He is guided by menu on the CFDS. The system is very easy to use. A few minutes are sufficient to master its use.

HOW IT WORKS

Two operating modes are considered; NORMAL mode for in-flight operations, and MENU mode for the maintenance technician. All the electronic systems of the aircraft are connected to the CFDIU and transmit messages non-stop. This transmission is governed by a precise protocol and initiates the transfer of alphanumeric characters.

The CFDIU monitors the aircraft systems (figure 4) and memorizes any message transmitted to it. If several systems transmit messages following a fault, it is capable of choosing the message which established the fault. The CFDIU establishes reports which will be at the disposal of the ground maintenance technicians through the MCDU. The CFDIU continuously transmits parameters on its output bus to the aircraft systems. These parameters are the time, the date, the flight number, the flight leg, etc. They are taken into account by the system BITES to correlate events.
Two actions are required to obtain the display of the CDS menu processed by the CFDIU.
1. allows the menu of the choice of systems connected to the MCDU to be obtained.
2. allows the CFDS menu to be obtained.

If the technician requests subject (3), the list of all the messages corresponding to the faults which occurred during the previous flight is obtained. The date, the time, the ATA 100 reference and the list of aircraft systems which have been affected by the same fault (4) complement the information given to the maintenance technician who may request the on-board printer to provide a printed report by simply depressing the PRINT key.

On current aircraft it is very difficult to establish a correlation between crew complaints and the data provided by the BITEs. This problem is solved for the A320. While in flight, the CFDIU records all the data presented to the crew by the central warning system, known as ECAM. It compiles an ECAM report which is obtained by depressing key (5).

The date, the time, the ATA 100 reference and the flight references allow the messages of the two available reports to be correlated on one single report, the print-out of which may be obtained from the on-board printer by depressing the key (6).

After a few operations on the MCDU the maintenance technician obtains all the data necessary for a quick repair. Finished are the headaches caused by computer front faces and the maintenance panel.

As well as conducting a dialogue with the MCDU the maintenance technician can also establish a dialogue directly with a system linked to the CFDS. This can be done by depressing line keys (7) and (8).

The operator has entered into communication with the system of his choice. Now it is the system itself which directs the communication and guides the operator by menu, and not the CFDIU.

* System of operator's choice
Some menu headings are standardized for all the systems. However the choice of the other headings to be presented is left to the specialist engineer and to the equipment vendors who define this system. Figure 5 shows some of the titles available on the ECAM system.

Only in-service experience will show if it lives up to expectation. However the simplicity of the command, the homogeneity and the correlation of results should allow for efficient repair and a reduction in the rate of the non-justified removals.

Airbus Industrie and its partners are already working on the aircraft of the future. New techniques are being studied. BITE will probably remain the basis for troubleshooting of future maintenance systems and they will certainly undergo further evolution.
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Reverse thrust, braking, landing gear, all incorporated on a single leg, duplicated for fail safety. Simple, flexible, reliable, highly manoeuvrable and cheap. However prone to occasional breakage with relatively long repair times!
Mr. Gérard Blanc, Senior Vice President, Product Support in Airbus Industrie presented awards to TEA, VARIG and KOREAN AIR for outstanding performance in maintenance, daily utilization and dispatch reliability achieved with the A300 fleets in their airlines during 1986. One hundred and fifty people were in attendance from A300 airlines, suppliers and Airbus Industrie. A great deal of satisfying work was conducted on the in-service performance of the A300 systems and structure.

"A very worthwhile conference"