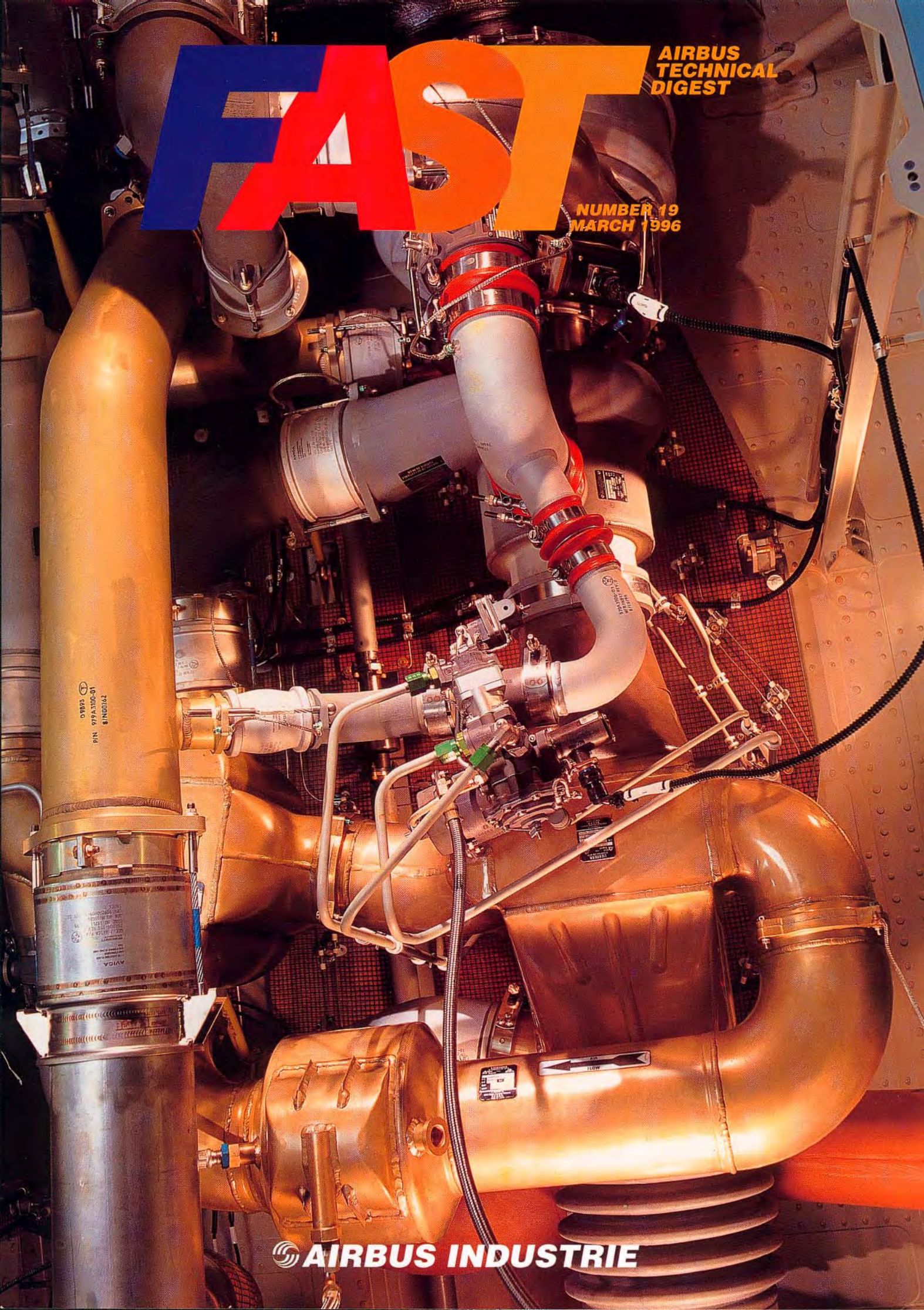


FAST

**AIRBUS
TECHNICAL
DIGEST**

**NUMBER 19
MARCH 1996**



 **AIRBUS INDUSTRIE**

FAST

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Cover photo - Air conditioning pack on A330/A340

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S

**tate-of-the-art
Training for
tate-of-the-art
Technology**

With the new generation of Airbus Industrie aircraft, A319/A320/A321, A330/A340, computer-based technology has changed the passenger cabin of these aircraft. This has resulted in many benefits for passengers and crew alike.

Lufthansa Cabin Crew Training copes with the "Digital Challenge"

*by Ruth Maute
Section Manager
Service and Emergency Training
Flight Crews
Lufthansa*



The Cabin Intercommunication Data System (CIDS) and the Cabin Management Terminal (CMT) are primary examples. Although relieved of some of the more mundane cabin tasks, Cabin Attendants require a most extensive and thorough training to be familiar with these new features. This guarantees the highest comfort possible for passengers. As launching customer of the A340 in 1992, Lufthansa quickly realized the need for training components detached from the aircraft and tailored to the needs of the crew. Together with Daimler-Benz Aerospace Airbus and Matsushita, Lufthansa designed and constructed simulators for both CIDS and CMT, underlining our philosophy that "learning by doing" is the best training method.

THE CABIN INTERCOMMUNICATION DATA SYSTEM

The CIDS cabin crew trainer represents a part of the aircraft cabin, complete with passenger seats, in-seat videos, side-wall linings and hat racks. There is also an instructor panel equipped with a portable computer from which the instructor can simulate the complete range of signals, indications and system messages which can occur on board. These include:

- passenger address
- cabin interphone
- flight crew interphone
- emergency evacuation signalling
- passenger lighting signs and passenger call
- cabin signalling of lavatory smoke detection
- control of passenger service, system control of cabin illumination
- door status indication
- slide armed/disarmed status
- control of reading lights

- door and escape slide bottle pressure monitoring
- signalling of water ice protection
- signalling of potable water indication and preselection
- waste indication
- temperature indication and control in a defined range.

The CIDS cabin crew trainer is a unique tool, which, aside from being cost-effective and readily available, allows for practical training and for simulation of system failures.

After training on the CIDS cabin crew trainer, our Cabin Attendants are able:

- to use efficiently the Forward Attendant Panel which monitors the cabin systems
- to interpret the messages of the CIDS
- to perform failure analysis for almost all instances
- to describe effectively system failures in the Cabin Log Book, thus supporting maintenance personnel
- to use optimally CIDS functions, guaranteeing top passenger service.



THE CABIN MANAGEMENT TERMINAL

THE ENTERTAINMENT SYSTEM MATSUSHITA 2000

The CMT, with its supply of news, information, flight data etc., will become an increasingly important feature of passenger comfort in the future. A well-trained cabin crew, able to use this tool effectively, insures the smooth adaptation of this aircraft into the fleet, as well as a daily trouble-free operation.

Our CMT trainer is installed next to our CIDS trainer, and is also furnished with the original aircraft software. The trainees receive a thorough training, practical in nature, in which problems, which could never be simulated on our actual aircraft, are reproduced with life-like accuracy.

In order to take better advantage of the hands-on practice in our trainers, we designed computer-based training programs so that trainees can first familiarize themselves with

the systems on board, allowing them to work out on their own any problems they may have.

After having finished our computer-based program for A340, we channelled our knowledge into developing a program for the CIDS on A320/A321 and A319, and constructed a cabin crew trainer as well. Lufthansa then found it necessary to decentralize the locations of its flight crews by creating bases in different cities in Germany. We were then faced with the problem of having to train crews quickly in different parts of Germany on an aircraft less complex than the A340, while investing a minimal amount of time and money. The solution - *a mobile cabin crew trainer*. This greatly boosted our flexibility; as the training equipment could be brought to our trainees, the trainees did not have to be taken to us. ■

To summarize, the complete range of training elements we have acquired, which are also suitable for any refresher training courses, include:

● **A319/A320/A321**

- computer-based training program for CIDS
- mobile crew trainer which simulates all CIDS functions consisting of five boxes weighing not more than 40 kg each

● **A330/A340**

- computer-based training program for CIDS
- computer-based program for Matsushita 2000
- CIDS cabin crew trainer
- CMT cabin crew trainer

The standard for our computer-based training is Windows compatible and the PCs have AICC (Aviation Industry Computer-based-training Committee) Standard.

The new Airbus generation may offer the most sophisticated cabin system in the world. That, however, means nothing if the crew is not adequately and/or properly trained to operate it. With our Airbus training program, we have laid our fears of the "digital challenge" to rest.



Lufthansa

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The natural environment at 40,000 ft is a harsh one. Air less than one quarter of its density at sea level, temperatures down to minus 60 degrees Celsius, and levels of relative humidity that are equal to the driest parts of the earth's surface. No life forms inhabit this environment. It is not surprising that considerable efforts are necessary to care for the occupants of aircraft that travel through this part of the atmosphere.



by Douglas Carlile, Department Manager, Environment Systems and Cabin Interior
Airbus Industrie Customer Services Directorate

Over recent years the media has taken much interest in the possible effects of the cabin environment on passenger well-being and comfort. In fact the media interest has usually centred on the so-called Cabin Air Quality, this is a title that easily captures the imagination of the man in the street. For engineers, though, this title should only describe one part of the cabin environment that is dependent on the air conditioning system.

The typical passenger gives the general title of air-conditioning to the on-board systems that make the cabin environment habitable. For the engineer the air-conditioning system is made up of several subsystems that control cabin pressurization, air flow and distribution, air extraction and temperature.

This article discusses, in turn, the parameters considered during the design and certification of the air conditioning systems and their physiological significance. It will be seen that considerations fall into two categories, firstly factors necessary to sustain life and, secondly, more subtle factors that influence comfort.

Cabin air comfort

CABIN PRESSURIZATION

The air pressure in the cabin is the most significant factor needed to sustain life at high altitude.

The proportion of oxygen in the atmosphere remains constant at approximately 21% as altitude increases. But, as the pressure reduces with altitude, the oxygen transfer to the bloodstream also reduces. This is due to the process by which oxygen is absorbed into the blood-stream through the lungs.

This has been addressed in aviation in two ways, the quantity of oxygen available can be increased or the air pressure can be increased in order to reduce the equivalent cabin altitude. Increasing the quantity of oxygen has been the preferred method in military aviation. The oxygen mask is part of the classic fighter pilot image, but is clearly not a practical solution for passengers in day-to-day commercial air transport. Therefore, the fuselages of commercial aircraft are constructed as pressure shells designed to contain a higher internal pressure than that of the external ambient air. With increased air pressure the so-called 'partial' pressure of the oxygen content is maintained so that absorption into the bloodstream is equivalent to that at much lower altitudes.

Cabin altitude is such an important factor that Airworthiness Authorities regulate the maximum allowable level. Authorities have varying regulations for different areas of aviation, for example private pilots are allowed to fly at up to 10,000 ft without supplemental oxygen. However, the worldwide limit for cabin altitude during normal commercial air transport operation is 8000 ft. This lower value makes allowances for the health condition variation across passenger populations. Natural adaptation to altitude increase does occur, unnoticeable changes in breathing rates compensate for changes at typical cabin altitudes. However, one effect of smoking and alcohol consumption is a significant reduction in the altitude compensation abilities of the body.

The foregoing explains why cabin pressurization is necessary to sustain life. Another effect on comfort is the rate of change of the cabin pressure. This is most noticeable as pressure on the ears. The ear drum can be considered as a simple mechanical diaphragm, sensitive enough to detect mechanical movement of molecules. Changes of pressure on only one side of a diaphragm will result in distortion, and that is basically the sensation experienced in the ear when changing altitude. The human body has necessarily evolved to minimize discomfort when pressure changes occur naturally, for

example as the atmospheric pressure changes due to the weather or when walking up or down hills. The body has not evolved to cope with some man-made causes for rapid pressure/altitude change, this includes driving uphill/downhill in motor vehicles as well as aviation.

Fortunately the human ear has sufficient margin in adaptation that rates of change of up to 500 ft/min when climbing and 300 ft/min when descending can usually be comfortably accommodated.

In order to achieve a minimum rate of climb or descent of cabin altitude, the ideal design for pressurization control system will ensure a constant rate of change between take-off and cruise altitude. State-of-the-art digital controller design, as installed on all Airbus fly-by-wire aircraft, allow such constant rates of change to be maintained even with stepped climbs and descents that are typical of realistic air traffic control conditions. Control systems installed on earlier Airbus aircraft ensure rates of change of cabin altitude within the limits of 500 ft/min climbing and 300 ft/min descending.

So, the first design requirement for the well-being of aircraft occupants is a pressurized cabin to enable adequate oxygen absorption into the bloodstream. Secondly, the rates of change of pressure should be minimized as much as possible to be undetectable by the human ear.

AIR FLOW AND QUANTITY

A great deal of media attention has dealt with the quantity of air supplied to the cabin and the mix of fresh and recirculated air. We will deal with the quantity aspect first.

How much air do humans need? The answer of the engineer is "not very much - when compared to the quantities supplied". The normal amount of air necessary to meet the oxygen requirement of a seated person is 0.24 cubic feet per minute (cfm), that is equivalent to 6.8 litres per minute.

As long as the oxygen partial pressure is maintained as previously described, the essential quantity of air needed to be supplied for oxygen provision is small. So why is the nominal flow on all Airbus aircraft 20 cfm per person, that is more than eighty times the amount dictated by the minimum oxygen requirement?

In fact the quantity of air delivered per occupant is not defined by the oxygen requirement but by two main factors that affect comfort; carbon dioxide removal and a homogeneous temperature distribution throughout the cabin.

Carbon dioxide is a by-product of hu-



Air conditioning pack

man respiration. As a gas in the lungs it acts as a stimulus to regulate the depth of breathing. Harmful effects appear only when the proportion of CO₂ in the air becomes excessive. Another source of CO₂ on the aircraft is the dry ice used by many airlines to chill food in the galleys. As the dry ice vaporises it gives localized areas of higher CO₂ concentration in the galleys. The actual and allowable cabin levels of CO₂ are described later, suffice to say at this point that the rate of dilution and removal of CO₂ is related to the quantity of air flow into and out of the cabin.

The second consideration for the quantity of air supplied to the cabin is temperature distribution. If you use the words "air conditioning" with anyone other than a specialist, their first and perhaps only thought is of temperature. In order to maintain a particular temperature in a closed area, it is necessary to either add or take away heat. It is the air flow into and out of the aircraft cabin that is used to transport this heat. The air may be relatively warm to bring heat into the cabin or the air may be relatively cool to remove heat from the cabin. In physical terms it is the quantity of heat that is significant. A lot of air at medium temperature can contain as much heat as a little air at high temperature. So large amounts of heat can be transferred by moving large amounts of air, at the same time avoiding extremes of temperature.

Also to be considered is that, for a comfortable environment, we need

Background to Airworthiness Requirements

The Airworthiness Authorities define a minimum fresh air quantity for flight crew members of 10 cfm.

□ JAR 25 ACJ 25-831

Gives a guideline figure of 0.4 lb/min (approximately 5 cfm) of fresh air per passenger as a minimum comfortable level when only one air conditioning pack is operative. This level may be lower providing it is demonstrated that no hazardous condition results from the lower level.

Carbon dioxide (CO₂) and carbon monoxide (CO) concentrations should not exceed certain defined limits :

- CO₂ not to exceed 3% by volume.
- CO not less than 50 parts per million by volume.

Airbus Industrie has demonstrated during the aircraft flight test phase that the aircraft air conditioning system meets these minimum requirements with significant margins under all normal and failure conditions.

□ FAR 121.578

Requires that concerned operators demonstrate that cabin ozone concentrations do not exceed 0.1 parts per million by volume during any four hour interval above a flight level of 27,000 ft and that the concentration does not exceed 0.25 parts per million at any time above 32,000 ft. Compliance with this requirement is achieved by the installation of an ozone converter or by showing, via calculation based on statistical atmospheric ozone concentrations, that the routes flown do not lead to these amounts of ozone in the cabin.

1 BLEED AIR REGULATION

Fresh air, taken from the engine compressor, is regulated to constant pressure and pre-cooled to approximately 200°C. APU bleed air is usually used on the ground.

2 FLOW CONTROL VALVES

The quantity of fresh air flow into the cabin is controlled by the flow control valves. The level of flow is selected manually from the cockpit.

3 AIR CONDITIONING

Air cooling is accomplished by the packs. These consist of an air cycle machine and heat exchangers.

4 TRIM AIR VALVES

Hot air can be added to the pack outlet air for each cabin zone. This trim air allows a fine regulation of the individual zone temperatures.

5 CABIN ZONES

Cabin zones are designated to allow independent temperature regulation of separate areas. The zones usually approximate to the seating class divisions.

- The A319/A320/A321 have two cabin zones.
- The A300/A310 and early A330/A340 have three cabin zones,
- The A330/A340 after MSN 123 have six cabin zones.
- The cockpit is a separate zone for each aircraft type.

6 EXTRACTION SYSTEM

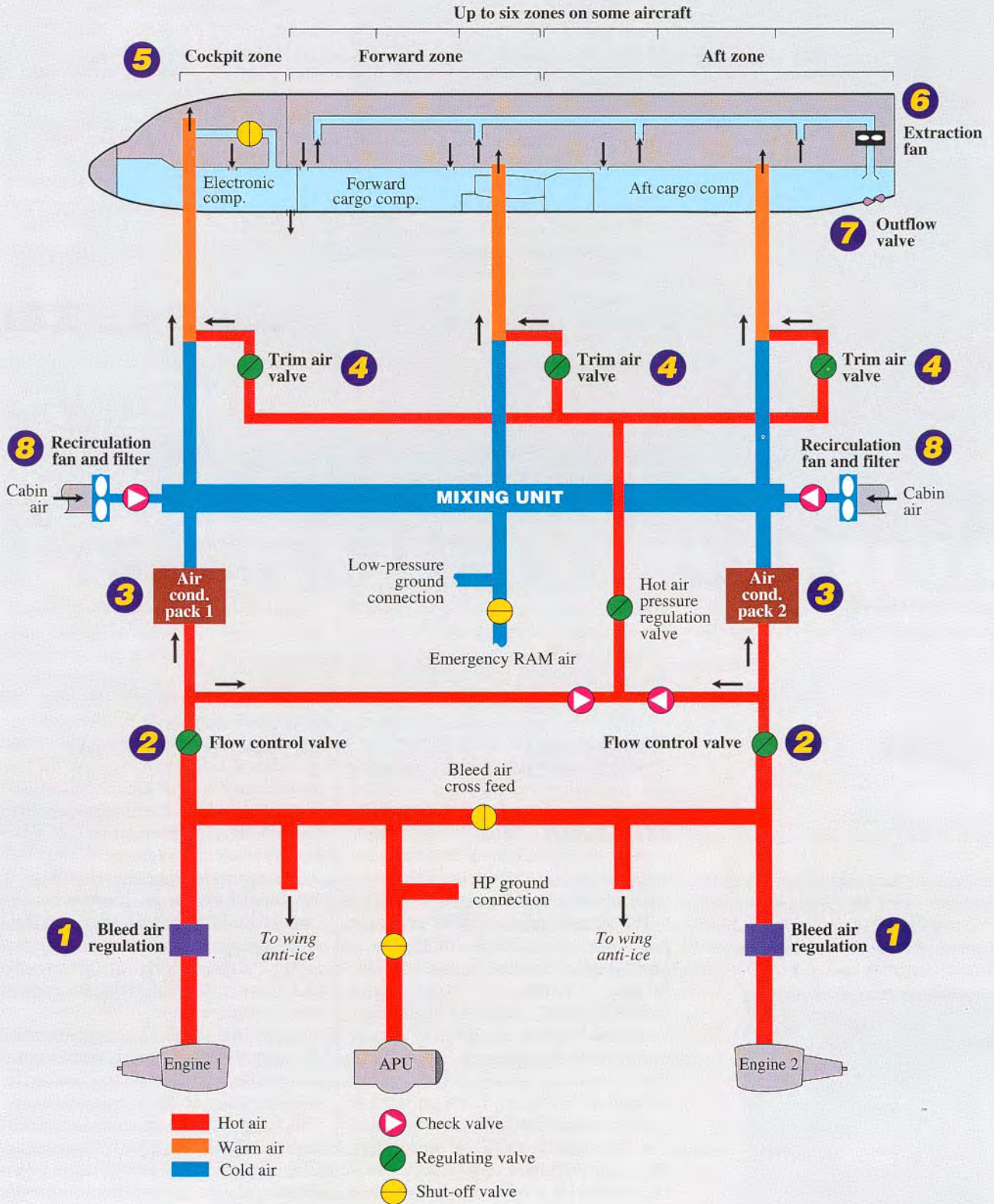
The extraction system removes odours from the galleys and lavatories.

The fan runs on the ground and when the cabin differential pressure is low.

7 CABIN PRESSURE

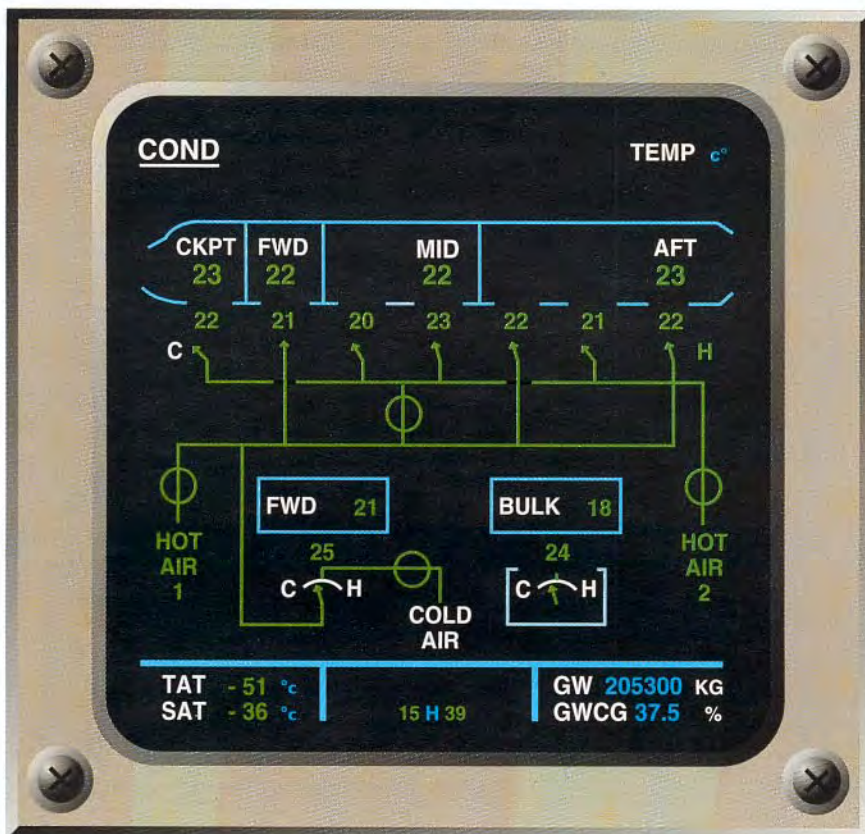
Cabin pressure is regulated by the outflow valve controlling the discharge of air. The computer logic ensures maximum comfort by monitoring the rate of change of pressure as well as the cabin equivalent altitude.

GENERAL SYSTEM DESCRIPTION



8 RECIRCULATION

Approximately 40% of the cabin air is recirculated. This facilitates an even temperature distribution, and carbon dioxide dispersion. It also significantly increases the cabin humidity levels in cruise. State-of-the-art filters remove dust and cigarette smoke.



A330/A340
 Typical ECAM air conditioning page.
 Pressurization is shown on a separate
 page

more than the air temperature to be correct. The temperature of structure and furnishings is significant too. After changing the selected temperature in the aircraft cabin by a set amount, it will take at least twenty minutes before fully stabilized temperatures are reached. These twenty minutes include ten minutes for the air temperature to stabilize and a further ten minutes for the temperature of the structural furnishings to stabilize. Therefore, large quantities of heat have to be delivered to the cabin or removed from the cabin and this requires large air flows.

The quantity of air supplied to the cabin on the latest Airbus aircraft can be controlled to three particular separate levels, "Normal", "High" and "Low/Economy". There are some small variations between the different aircraft models but in general "High" and "Low" represent plus or minus twenty percent of "Normal". Each setting has particular conditions for recommended use. "Normal" is the usual day-to-day selection. With reduced passenger loadings and with a fully serviceable air supply (two packs and recirculation fans 'ON'), "Low" can be selected to save fuel while still maintaining the quantity at 20 cfm per occupant.

The Flight Crew Operating Manual (FCOM) gives clear criteria for passenger numbers for which "Low" can be selected.

"High" flow is automatically set if one of the air conditioning refrigeration packs is not operating. With two packs operating, "High" is a recommended

selection (again in the FCOM) in abnormally hot and humid conditions. Selection of "High" flow creates an additional fuel burn of up to one percent, so there is good reason to use the selection judiciously.

Finally, a quick look at the Airworthiness requirements for air supply. Interestingly, there are no minimum limits set for the passenger cabin for normal operation. In the failure case (that is with one pack inoperative), JAA standards give only a guideline of a minimum of 0.4 lb/minute/occupant of air at an aircraft altitude of 41,000 ft. 0.4 lb/minute is equivalent to approximately 7.3 cfm or 198 litres/minute.

AIR RECIRCULATION

Many press articles with the general message "Airlines save money by starving passengers of air" have been published in recent years and adverse comments about the recirculation of air are often included. There seems to be a common understanding that, because some cabin air is being recirculated, passenger comfort must be being compromised. The details show quite the opposite.

Taking compressed air from the engines for use other than as motive power does cost something; you never get something for nothing. The cost is in fuel burn and typically the air conditioning accounts for three or four percent specific fuel consumption. Fuel burn has a major cost impact and so there is no denial of the fact that minimizing losses is a consideration in the design of every aircraft system. However, the cabin air systems on all Airbus aircraft types are sized to give 12 cfm of fresh air per cabin occupant (that is not including recirculated air). Already, this figure far exceeds the minimum for essential oxygen supply and provides large margins for carbon dioxide removal.

In addition to the 12 cfm of fresh air, all current Airbus production aircraft recirculate a portion of air in order to deliver a total of 20 cfm per occupant. This brings several advantages, in addition to temperature distribution and CO₂ dispersion, the recirculation of air also increases the ambient humidity level. The quality of the recirculated air is maintained by filtration. The state-of-the-art high/performance filters available today catch particles down to 0.3 thousandths of a millimetre in diameter (0.01 thousandths of an inch) with an efficiency of 99.95%. This efficiency means that normal 'household' dust, tobacco particles, individual bacteria and nearly all viruses are removed from the distribution system. The level of filtration is equal to that used in hospital

operating theatres. In fact, the filtration performance is such that when the aircraft is on the ground, because of normal surface level atmospheric pollution, the recirculated air can be purer than the so-called 'fresh air' supply.

If there are any doubts left concerning the sufficiency of the cabin air supply, consider this; *on the largest Airbus aircraft in service, the A330/A340-300, the total cabin air content is replaced more than thirty times an hour, that is more than once every two minutes.* Excluding the recirculated air gives an exchange rate of more than eighteen times per hour, more than once every three minutes. These rates far exceed the exchange rates in buildings.

The constant delivery of such large quantities of air to the cabin presents particular design challenges. Both noise and nuisance air drafts have to be avoided, at the same time the space available for the air distribution ducting is limited.

Careful duct design and, where practical, large diameter outlets are used to minimize noise. The velocity of the air as it enters the cabin is also carefully decided in order to minimize drafts but also ensure full ventilation of the complete cabin.

Therefore it can be seen that the quantity of air supplied to the cabin is relatively large, and that the recirculation of air brings definite advantages.

HUMIDITY

At cruise altitudes the external air is exceptionally dry. An undesirable consequence of this is dryness of the eyes nose and throat. These, along with thirst, are two of the first symptoms of dehydration and would be followed by headaches.

When breathing, moisture is lost from the body with the exhaled air. The humidity level of the cabin air will then be increased via the recirculation system. The result is measurable, from an empty cabin level of 2% relative humidity, this will increase up to almost 20% with a full passenger load when the recirculation fans are selected on. These figures are typical for all aircraft types.

AIR QUALITY

The foregoing has described the oxygen supply and the quantity of air delivered to the cabin. The general term air quality has sometimes been used to describe the combined over-all effects of the air conditioning system, including other parameters such as temperature and humidity. We will now consider the term not in the general sense but in the nar-

rower sense of the content of the cabin air.

The atmosphere is a homogeneous mixture of gases, with localized concentrations of what can be termed pollutants.

Air is composed of 78% nitrogen, 21% oxygen, and the remaining 1% a mixture of inert gases and carbon dioxide.

Inside the fixed volume of the aircraft cabin these ratios can be changed by the following influences :

● **Carbon dioxide** (CO₂) is generated by respiration and the vaporization of dry ice that is used by some airlines as a chiller in the galleys. The level of CO₂ in the lungs stimulates the breathing rate, consequently artificially high concentrations can lead to hyperventilation and eventually unconsciousness.

● **Carbon monoxide** (CO) is a by-product of combustion, the sole source of this in an aircraft cabin is cigarette smoking. In sufficient quantities CO is toxic. It has no smell.

● **Ozone** (O₃) is a molecule of three oxygen atoms, this occurs naturally in the upper atmosphere with seasonal variations in concentration, higher concentrations generally occur in polar regions. O₃ has a distinctive smell and so is easily detected. High concentrations lead to irritation of the eyes and throat.

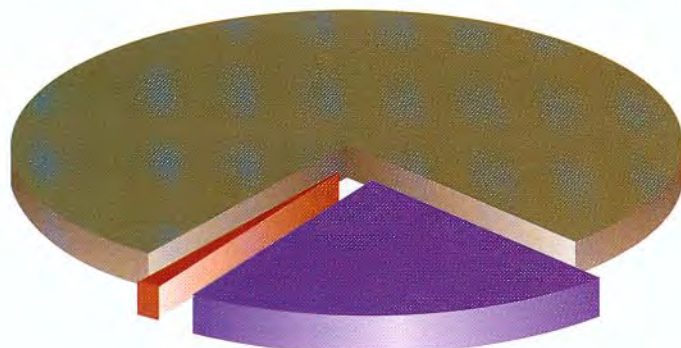
Other potential additives to cabin air are:

● **Aerosols** (another name for liquid or solid pollutants) are mainly the by-product from combustion. On the ground these include vehicle exhaust fumes, factory outputs, agricultural and forest fires. At cruise levels the main contributor would be cigarette smoking, but one periodic natural source can occur following volcanic eruptions where large quantities of dust and ash can be projected into the upper atmosphere.

● **Dust.** Considering only the dust generated within the cabin, the sources are the same as in any household

"Fresh" air

● Nitrogen 78% ● Oxygen 21% ● Carbon dioxide and inert gases 1%



Service Information Letters (SIL)

- ❑ 21-050
All Airbus aircraft types - Aircraft cabin air quality - Gives details of air flow and exchange rates, fuselage volumes and Airworthiness Authority requirements.
- ❑ 21-065
All Airbus aircraft types - Improved and alternative source for recirculation filters
- ❑ 21-072
A330/A340 - Lavatory, galley and cabin temperature, sense line contamination.
- ❑ 21-073
A330/A340 - Cabin temperature sensor cleaning, intervals and procedures.
- ❑ 21-076
A330/A340 - Trouble-shooting procedure following passenger discomfort reports.
- ❑ 21-080
A319/A320/A321 - Heat exchanger cleaning - benefits for air cycle machine performance.
- ❑ 25-089
A330/A340 - Galley air extraction filters - Reduced interval for discard of filter elements.

Flight Crew Operating Manual

Standard operating procedures, cockpit preparation, pack flow selection

- ❑ A300-600/A310 Part 2.03.06
- ❑ A319/A320/A321 Part 3.03.06
- ❑ A330/A340 Part 3.03.06

environment. Fibres from furnishings and clothes, hair and exfoliated skin.

There are two techniques to eliminate any adverse effects of these substances, air replacement and filtration.

The rates of air exchange were described earlier. Considering filtration, all recirculated air is filtered. High-efficiency filters available for use today are able to remove smoke particles and bacteria. Therefore, any nuisance related to odours or tobacco smoke can only occur due to the immediate proximity of other passengers, their habits and meals etc.

Ozone converters are available for installation on all Airbus aircraft and are recommended for long-range routes that pass through polar regions.

Measurements of air quality are performed prior to certification of the aircraft and occasionally repeated during service. These measurements confirm that not only are the airworthiness requirements (where established) bettered, but the cabin environment on the ground is cleaner than the external air. When the "no smoking" sign is obeyed the cabin air quality is equivalent to hospital operating theatre conditions.

TEMPERATURE

The influence of temperature on health and well-being, rather than as an effect on simple comfort (too warm or too cool) is often overlooked by the non-specialist. The body's core heat is a vital parameter to well-being, it is regulated by several biological 'sub-systems'

including blood capillary dilation/contraction (evidenced by skin colour changes), rate and depth of breathing (evidenced to an extreme level by animals that pant without physical exertion), perspiration when too warm and shivering when too cold.

These physiological temperature regulation methods have evolved to allow the human animal to cope with climatic variations. However, the temperature also changes with altitude and humans have not evolved to naturally cope with the temperature variations that can be experienced in aviation. It can also be noted that some of the mentioned regulation functions of the body such as breathing rate and blood circulation will have a direct affect on adaptation to the thinner air at altitude. The temperature regulation of aircraft cabins is therefore a significant factor in occupant well-being and comfort.

For a passenger in his/her seat, the influences on local temperature include:

- the temperature of the air delivered by the air conditioning system,
- the temperature of surrounding furnishings and structure,
- the number of other passengers in the immediate vicinity,
- solar radiation during daytime and
- the position relative to the air outlet.

The designer of the air conditioning system has to consider a slightly different set of parameters to ensure a constant cabin temperature:

- the outside air temperature,
- the thermal conductivity of furnishings and structure,

- the variations in heat load due to the different classes of seating.

Consider the technical aspects of some of these parameters in turn. Cabin temperature control has to deal with both *steady state* and *dynamic* conditions:

- In *steady state*, to maintain a constant temperature the amount of heat delivered to the cabin must equal the heat lost. Other than the air conditioning supply the main source of heat on board is the occupants themselves. Each person generates approximately 80 to 100 watts of heat when at rest. Consider a 300-seat A340 and that means more than 25 kilowatts of heat to be continuously dissipated. So, with a full passenger load, it is easy to see that the air conditioning system will be working continuously to cool the cabin, that is supply cool air to remove heat, and this even when the exterior temperature may be as low as minus 60°C.

With lower passenger numbers the cabin may have to be heated to maintain a constant temperature. Most operators fly with more than one seating layout, typically First, Business and Economy Classes. In each of these areas the seating density (the number of passengers per square metre) changes and consequently the heat load also changes. So throughout the cabin some areas may need to be heated while simultaneously other ones are cooled.

- *Dynamic* temperature regulation comes into play on three occasions:

- At the power-up of the aircraft the cabin temperature will have to be increased (in cool climates) or decreased (in warm climates) to achieve comfortable temperatures preferably prior to

passenger boarding. These two pull up/down cases dictate the maximum performance required from the air conditioning packs.

- Then, when the passengers do board, a significant heat load arrives in the cabin. This is now more than the nominal 80 watts per person when at rest because moving to one's seat and lifting hand luggage into lockers calls for a certain amount of exertion and so increases the heat output.

- The third dynamic situation is climb/descent where the exterior temperature changes significantly and the aircraft structure and furnishing temperatures follow.

So, the air conditioning system design incorporates the ability to precisely regulate the temperature to selectable levels with different selections in the different cabin zones.

Discomfort due to temperature is usually thought of as being too cold or too warm, and this is certainly a prime consideration in the design process. However, too-high temperatures can cause particularly severe physiological effects. In attempting to dissipate heat, hyperventilation can occur which, in extreme cases, can result in loss of consciousness.

Routine maintenance is essential to ensure optimum temperature regulation. Specific points are listed in the Maintenance Planning Document, but particular items are the cleaning or renewal of:

- cabin temperature sensors and ducting
- recirculation filters
- lavatory/galley air extraction system
- pack heat exchangers.

SUMMARY & CONCLUSION

Cabin pressurization is essential to sustain life but it is a relatively separate factor to consider. Its physiological influence is little effected by other parameters such as temperature, humidity, air flow quantity and velocity. The interaction of these latter factors, as much as their direct effects, does influence comfort significantly.

The nominal quantity of air supplied to the cabin is decided during the design process by consideration of temperature control and CO₂ removal. The air flow required only to ensure a sufficient supply of oxygen would be much less than is actually supplied.

The recirculation of filtered air brings direct benefits in comfort by increasing the cabin humidity level.

Temperature regulation is a very significant factor in the well being of cabin occupants. It is essential that scheduled maintenance actions are carried out to ensure accurate temperature control.

To ensure a safe and comfortable cabin environment there are several parameters that must be monitored and controlled. Some of these parameters are immediately obvious, others are not so apparent. The ideal air conditioning system is one that is taken for granted and goes unnoticed.

Air travel is such a widespread and common activity that a comfortable flight is a basic passenger requirement. The development of the highest standards of comfort is and will remain a continuous objective for Airbus Industrie. ■

A320/A321 TECHNICAL SYMPOSIUM

CANNES (FRANCE) 6-10 November 1995

Cannes, famous for its annual film festival, is situated in that part of the French Mediterranean coast known as the Cote d'Azur and was chosen for the first combined A320/A321 Technical Symposium. Three previous A320 Symposiums have been held. The next A320/A321 Technical Symposium will also include the A319 and will take place in the last quarter of 1997.

The Symposium opened in the now traditional fashion, with a reception, which was a suitable venue to give recognition to those A320/A321 customers who have excelled in the operation of their aircraft. The competition was extremely close with very little separating winners from runners-up.

Gulf Air, All Nippon Airways and Air Inter were the three airlines presented with the 1994/1995 Awards for Operational Excellence by Roger Lecomte, Vice President Engineering and Technical Support.

The 288 representatives from 51 airlines and 49 major suppliers were



briefed on the product improvements developed since the previous Symposium to enhance the operational capabilities of the A320 and A321. The average Operational Reliability of the A320 and A321 fleet over the last twelve months has remained steadily in the 99-100% band. The delegates were also briefed on the development status

of the A319 the first of which will be delivered to Swissair in April this year.

During the four and a half day meeting some 300 questions were discussed and fully answered.

This symposium provided an excellent forum for customers, suppliers and Airbus staff to meet and further understand each other's needs. ■

HUMAN FACTORS SYMPOSIUM

Sponsored by Royal Jordanian in AMMAN (JORDAN) 4-7 December 1995

Amman, capital of the Hashemite Kingdom of Jordan, was the venue for this regional symposium on Human Factors organised by Airbus

Industrie. This was the first event of its nature and was a real success, with 86 attendees from 16 airlines in the region.

Five main topics were addressed in

different sessions:

- Design and validation of crew and aircraft interfaces
- Automation
- Crew behaviour and training
- Airline environment
- Airline incident reporting.

This symposium differed from other Airbus symposiums in that airlines from the region gave presentations on mutually agreed topics in the morning sessions, each of which finished with a period for discussions. The afternoons were devoted to working sessions with all parties contributing suggestions and solutions to identified issues.

Rather than merely teach or give lectures, the emphasis was on discussions and mutual exchanges.

Different regions in the world have different cultural orientations which have to be taken into account, particularly when dealing with Human Factors, so the next symposium will take place in Miami, followed by two more to be held in the autumn in the Far East and Europe. ■



MAINTENANCE OF AIRCRAFT PAINT SYSTEMS

*by Thomas McVeigh
Materials and Technologies
Structure Engineering
Customer Services Directorate*



*Following the article
"CHOOSING AN EXTERNAL
PAINT SCHEME FOR YOUR
AIRCRAFT" in the last
FAST magazine, this
article expands on the
subject and describes
some of the in-service
post-delivery
experience.*



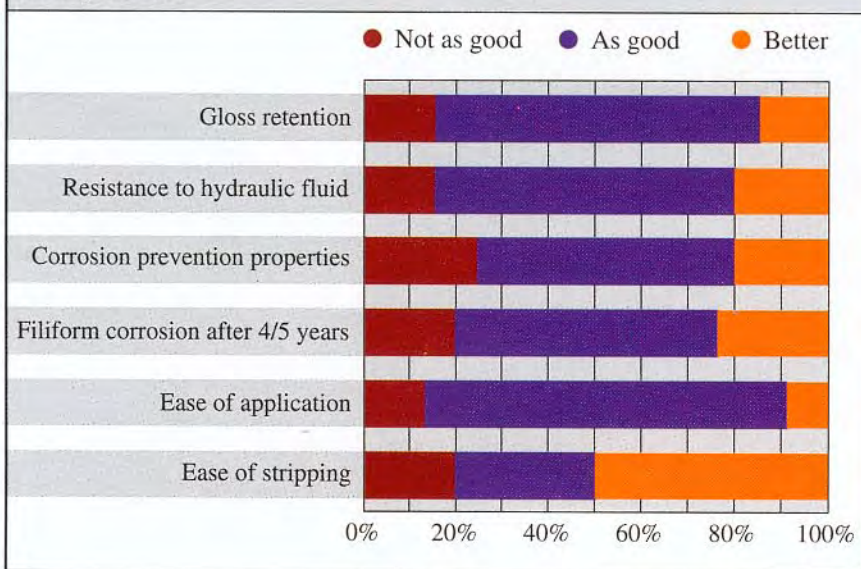
As the aircraft roll out of the Paint Shop in their spectacular new livery, few would believe that this initial impression could shortly be marred by premature deterioration. Sometimes it will be the case, but why?

There are various reasons for deterioration of an external paint system with consequences ranging from touch-up repairs to complete repainting. This situation is experienced by all aircraft manufacturers and also third party re-

pair facilities who may be required to perform repainting during the course of scheduled maintenance contracts.

In a recent Airbus Industrie survey concerning the subject of external paint systems, and their removal, some interesting facts and trends were revealed. Operators having 57% of the Airbus fleet responded. The main conclusion of the survey is the confirmation that the weaknesses of paint systems apply equally to all manufacturers and nearly all aircraft are affected.

"How do you rank the Airbus aircraft paint schemes compared to other manufacturers?"



Airlines which use polyurethane (PU) tape

The most common application for polyurethane tape is on horizontal and vertical leading edges. Some operators have used PU tape for many years and are very happy with it. (Also, operators of military helicopters have used it on neoprene leading edge boots on the blades rotating at nearly supersonic speed.) As with many things, the answer would appear to be good preparation and application.

Good and bad opinions appear to be independent of geographical areas and climatic conditions.

- Satisfied
- Unsatisfied

<i>Paint survey - Peeling</i>					
	Yes	No	NA*	Listing	(*No answer)
<i>Are there any particular common fleetwise areas?</i>	26	5	9	All leading edges, radome, cockpit windows, fastener heads, lower wing, wing trailing edge, door edges, belly, slats, wing root	
<i>Similar areas on other manufacturers aircraft?</i>	16	13	11	Radome, wing leading edges, belly, front and rear spar, engine cowlings, fastener heads	
<i>Any particular materials which the paint peels from more often?</i>	15	8	17	Fasteners Composites: radome, fin leading edge	
<i>Do you use the Airbus Industrie repair paints and schemes?</i>	18	14	8		
<i>After repair: do you experience further paint peeling?</i> <i>If not Airbus Industrie scheme: which one?</i>	23	8	9	Akzo Aviox HS, Crown Metro, DeSoto 1000 Series, Sikkens	
<i>Do you use the Airbus Industrie recommended antierosion paint scheme?</i> <i>If no, which paint scheme do you use?</i>	18	13	9	Akzo / Aviox HS, Alumigrip, Sikkens CAAP-Coat FP200 / C-W4, Chemglaze, Courtaulds, Crown Metro, DeSoto 1000 Series Laminar X500 (Magna Coatings/Dexter)	



APPEARANCE

The general appearance and gloss of the external paint will, in time, deteriorate due to ultraviolet attack, scouring from atmospheric particles and the nature of the aircraft operation. Also, there is some evidence that certain elements in the atmosphere have a chemical effect on paint resins. New generation materials have an improved resistance and have demonstrated success in increasing the gloss retention. One option which has proved successful is the application of ultraviolet-resistant clear coat varnish on top of the standard paint scheme. In principal, this application provides an extra layer of non-pigmented resin which will act as an ultraviolet absorbing coat extending the life of the paint systems. As some colours can deteriorate faster than others, an application of a coat of clear PU varnish can be beneficial.

AIRBUS INDUSTRIE STANDARD PAINT SYSTEM

On the A319, A320, A321, A330, A340 a basic primer is applied to all aluminium structural parts at the manufacturing detail stage; this is known as the Basic Primer Concept (BPC).

The Basic Primer Concept

From the beginning of the Airbus family, the philosophy of high quality corrosion prevention has been a priority and following very early in-service experience the decision to use Chromic Acid Anodizing (CAA) on aluminium alloy substrate was employed to give superior corrosion prevention. Having chosen this route as a priority, a useful by product was revealed; when an alu-

minium substrate is freshly anodized (unsealed) the surface has open pores, but as the surface begins to naturally age these pores begin to close over (known as "aged or sealed"). Therefore Airbus Industrie applies a primer to the unsealed surface within approximately sixteen hours of CAA application to benefit from a mechanical linking which occurs due to the penetration of polymer into the pores. This linking could be compared to the follicles which link the person's hair to his head.

There are two main benefits in using the BPC concept:

- the mechanically linked primer provides an excellent organic base for the adhesion of other organic material,
- the formula of the primer contains corrosion-detering inhibitors which gives a corrosion prevention bonus.

Note:

For customers repainting aircraft which have the BPC applied, it is advisable, if at all possible, to retain it, as the various new paint systems which are evolving due to international environmental regulations may benefit from an existing organic adhesion base.

EXTERNAL PAINT SYSTEMS IN SERVICE

Paint surfaces in service suffer from three principal maladies, peeling, erosion and chemical attack.

Paint peeling

No matter what the actual reason is for paint peeling, the fundamental reason will be an adhesion failure, but why? There are two principal reasons: contamination and poor application.

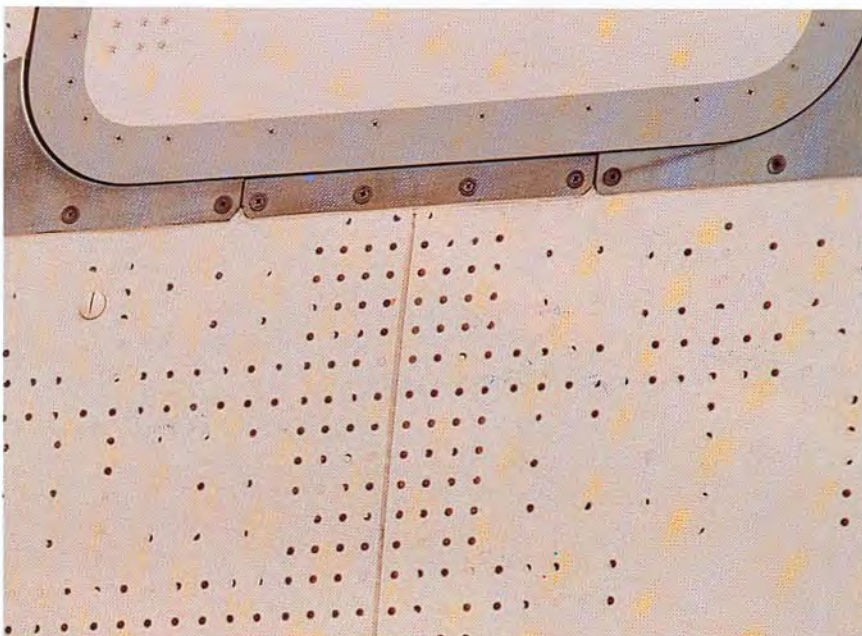
Contamination

Contamination can appear in a variety of forms, and for many different reasons such as:

- The release agent used in the manufacturing of composite parts which, if not removed, provides a magnificent means to remove component paint systems in one complete piece.
- To assist installation of interference fit structural fasteners, they are coated with a lubricant which can be very difficult, or virtually impossible to remove if the correct cleaning procedure is not employed.

The result of ineffective preparation can produce an interesting appearance which may be compared to a structure which has been subjected to machine-

Rivet rash



gun fire. This effect has also been referred to as "rivet rash".

Rivet rash can also be caused by the materials used for fastener manufacture or their surface treatments. For instance, materials such as stainless steel and titanium will provide almost no base for adhesion without special preparation. Sulphuric acid anodizing of titanium substrates creates a porous surface which is more prone to retaining contaminants than untreated titanium.

● Cup washers used extensively on composite panels are normally manufactured from stainless steel thus posing an industrial headache for the painter. The material is chosen for structural and compatibility reasons. The washers are specially designed for load spreading and utilize the mechanical properties of the stainless steel. They also avoid possible galvanic corrosion when used in conjunction with carbon fibre reinforced plastic. To achieve the best adhesion base on stainless steel or titanium, it is necessary to dry- or wet-blast the surface just prior to painting, but because cup washers must be installed before painting it is not industrially feasible. However, further to a recent test programme we have obtained positive results by passivating the washers.

Application

Application is an art and no matter how well developed it is, it is dependant on the preparation of the surface - and that is a science.

The successful application of the external paint system depends not only on the written procedures, but relies on the skill and professional approach of the craftsmen applying the paint. For example, if the final top coat is too

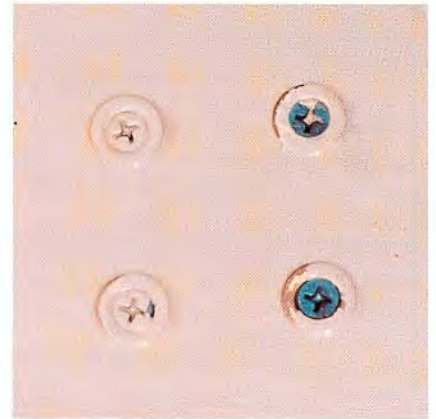
thick then at some point during the life of the paint scheme there will be an adhesion failure at the primer-to-paint interface due to the ageing and rigidity of the top coat. Unfortunately it may take some years before the failures are observed.

The science of pre-painting preparation is probably more complex than the average engineer would expect due to the many substrates and contaminants used during the manufacture and assembly of the aircraft structure. To find one common procedure which could cater for all situations is most unlikely. However in its quest for excellence Airbus Industrie has created a list of all the potential contaminants which are used in its production areas and also those used by its sub contractors. The next phase will be to analyze this extensive list of contaminants and to pursue the possibility of placing them in groups. This will be followed by research to find a cleaning agent to suit each group so as to simplify the final cleaning and preparation stage. This will reduce the probability of the paint peeling in service.

Erosion

Erosion of the paint system can be found in all the classic areas such as leading edges, panel edges, wing tips, radome and other areas subjected to high aerodynamic loads (ram areas).

In the past the loss of the paint system would have been considered as mainly an aesthetic annoyance, but today many of the traditional alloy structures have been replaced with composite materials which, when exposed following the loss of the paint system, can suffer structural erosion damage.

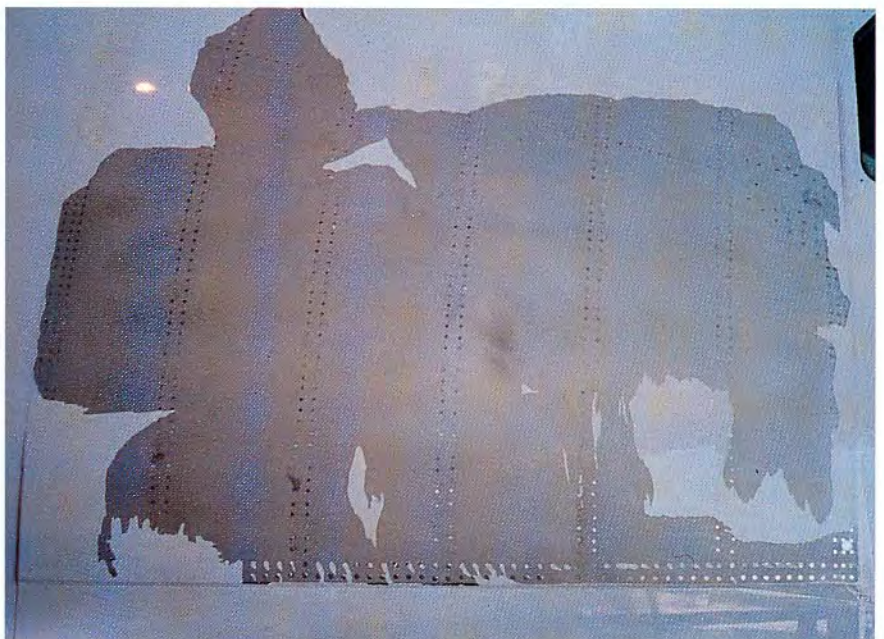


*Double trouble!
Stainless steel washers with titanium fasteners which have been treated with sulfuric acid anodising.*

Paint system is too thick



Preparation - an inexact science



Under normal aerodynamic loads the qualified paint systems are more than adequate, but in certain cases they will suffer. For example, where sealant beads are lost between panels the exposed panel edges can suffer unacceptable vortices which will eventually break down the paint system and then attack the composite matrix (resin system), which even the existing anti-erosion paint systems may have difficulty in resisting. The same type of attack can be observed where removable panels may be refitted with the panel leading edge, slightly proud into the airflow.

This type of structural damage is normally prevented temporarily by paint touch-up, or the application of aluminium high-speed tape along the area of eroded paint which is then permanently repaired during a convenient servicing period.

Note:

The actual effectiveness of paint touch-up repairs in such areas of high erosion may be limited in their success, because to achieve complete cure and hardness of the paint system can take up to nine days. However if a policy of touch-up is employed, more complicated composite repairs may be avoided.

The subject of erosion of composite materials is at present under study, and engineering solutions have already been employed, but in parallel, research for preventive solutions rather than repair solutions is still the priority.

COMPOSITE COMPONENTS

The standard Airbus Industrie paint system is applied to the majority of composite components, but its function is not only cosmetic.

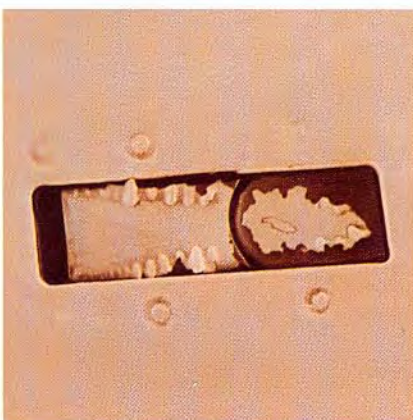
Delamination of a composite component, which has been caused by an impact, can be difficult to detect due to "spring back" (the ability of a material to return to its original shape). Therefore the external paint system, which will crack on impact, performs as an impact indicator.

Ultraviolet attack of the composite matrix (resin system) is also prevented by the paint system. Prolonged exposure to ultraviolet rays will cause embrittlement of the resin molecular chain.

Note:

The paint system must be considered technically as porous and does not act as a barrier against moisture ingress.

If only some paint strippers were as efficient as hydraulic fluid!



INDUSTRIAL CONSTRAINTS

To achieve a homogeneous finished product, the magnitude of the manufacturer's task must be understood.

A single aircraft and its component parts will be painted in a variety of colours and in a variety of paint shops. All of the paint shops have to obtain a consistent quality level, that is, good adhesion, colour matching, mechanical and resistance properties. The application of the paint system in each of the paint shops has therefore to conform to common standards which have to be closely controlled to achieve consistent results.

To contend with this situation, Airbus Industrie has upgraded its technical training programmes for all paint shop staff to ensure all concerned have an understanding of the importance of their role.

CHEMICAL ATTACK

The Airbus Industrie qualified paint systems are, of course, tested for their resistance to chemicals, but like many materials the finished product is a compromise to achieve a flexible coating to cope with a constantly moving structure.

The situation is then that we achieve the flexibility but reduce the resistance to staining and to attack from contaminants. Although manufacturers are obliged to live with this compromise, Airbus Industrie can still claim to have one of the highest qualification specifications with all of the affected coatings possessing a high resistance to chemical attack.

Probably the most aggressive of the chemicals used in conjunction with the aircraft operation are the phosphate ester hydraulic fluids which have a performance somewhat similar to a chemical stripping agent.

Note:

Although the resistance testing is performed on a complete paint system, should there be an entrance point such as scratches, fastener countersinks, cup washers or panel edges, the paint system failure will be accelerated due to cross sectional attack.

This can be retarded to some extent by ensuring that areas which are subjected to hydraulic fluid contamination are decontaminated as soon as possible after spillage or leaks, and performing touch-up repairs in areas where the paint system has been damaged.

Tips and Highlights

- Not all soils or contaminants need to be removed by solvents; occasionally simple cleaning with soap and water will suffice.
- Do not remove basic primer unnecessarily.
- When performing paint repairs on composite parts, do not remove the primer coat, as sanding equipment may damage fibre or resin.
- When applying exotic coatings, such as anti-static, anti-erosion or anti-abrasion, pay particular attention to the paint manufacturer's recommendations.
- When paint has peeled from fasteners, revealing blue coloured heads, special attention by scouring the head (using simple domestic abrasive) will improve the adhesion.
- Where paint is seen to peel from titanium parts (for example the reinforcing doubler forward of the windshield) revealing a blue surface treatment (sulphuric acid anodizing), then light abrasion of the surface will greatly improve the adhesion.
- As a general policy it is preferable to use the same paint supplier for the various primers and top coat used within a complete system. Qualification testing is performed in this way.
- When paint erosion is observed on composite parts, swift paint repair action may prevent unnecessary structural repairs.
- Paints primers and coatings may be found in the Airbus Industrie Consumable Materials List (CML), Part 1, Section 16.000, or a listing of qualified coatings in the Process and Material Specifications manual (PMS), Reference 02-05-00 TN A .007.10050.
- When replacing decals or markings, overcoating with clear polyurethane varnish will help protect them from erosion and chemical attack.
- When performing structural repairs or any touch-up involving abrasion, always remember to reprotect bare metal areas with Alodine 1200 or wash primer.
Alodine 1200 will provide good protection against corrosion and a good adhesion base for painting.
If Alodine 1200 is not available, then it is mandatory that you should at least apply wash primer.
- Performing a water break-free test in many cases will confirm a well prepared surface, as shown below:



Aged primer surface

Abraded surface

Aged primer surface

*Abraded surface:
water does not break free*

Completely abraded surface

Left side contaminated with oil: water breaks free

Right side clean: water does not break free

INDUSTRIAL SOLUTIONS

In September 1993, Airbus Industrie decided to create a working group to monitor the in-service behaviour of the external paint systems for all programmes. This group, known as the "QIG 4" (Quality improvement group for final painting) consists of specialists from Quality, Engineering, Materials, Processes, Production and Customer

Services. Its main missions are to:

- identify recurring in-service reports and take appropriate action to correct and improve the situation;
- study the present industrial processes and procedures employed during the manufacture of Airbus aircraft with a view to simplify application of the final painting and so improve the general external paint quality with regards to paint peeling and erosion.

CONCLUSION

Although the elements influencing the success and longevity of external paint systems will always remain a challenge, Airbus Industrie will continue to pursue its research and development in order to find the optimum materials and successful preparation procedures, not only for today's paint systems but also to cope with the future environmental regulations and reformulated paint systems. ■

WHEN MERCURY ATTACKS

Recently an Airbus Industrie A310 was under inspection following its return from lease. It was found necessary to inspect the antenna of the radio-altimeter and evidence of mercury spillage was found.

Decontamination was performed in accordance with chapter 51.78.30 of the Structure Repair Manual.

However, following an X-ray, tiny particles of mercury were found to be suspended in the water displacement compound used to protect the bilge area. These particles were removed using special procedures.

Further investigation revealed that the mercury had been spilled some seven months previously, and the structure, treated with the standard Airbus anti-corrosion paint system, had not been attacked at all.

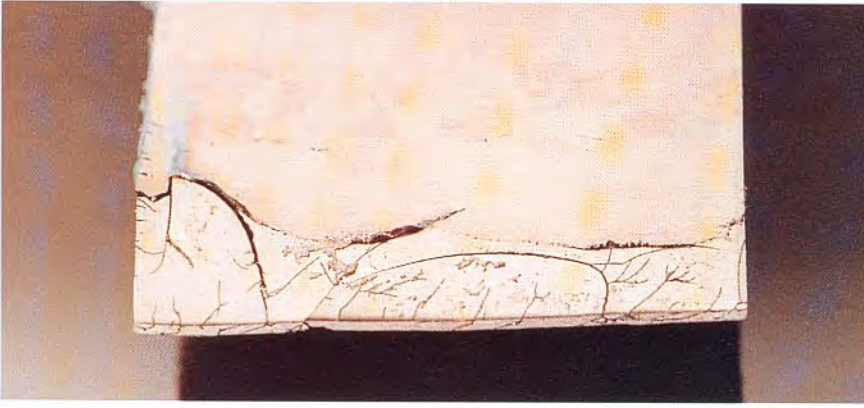
The carriage of mercury as cargo in an aircraft is very strictly controlled.

The IATA Dangerous Goods Regulations states the maximum quantity that can be carried in an aircraft (35kg) and gives the specifications for inner and outer packaging. Unfortunately the carriage of mercury is not always declared and it is not always properly packed.

In the past, spillage of mercury on non-Airbus aircraft has had very serious consequences. Often, the whole lower fuselage structure had to be replaced.

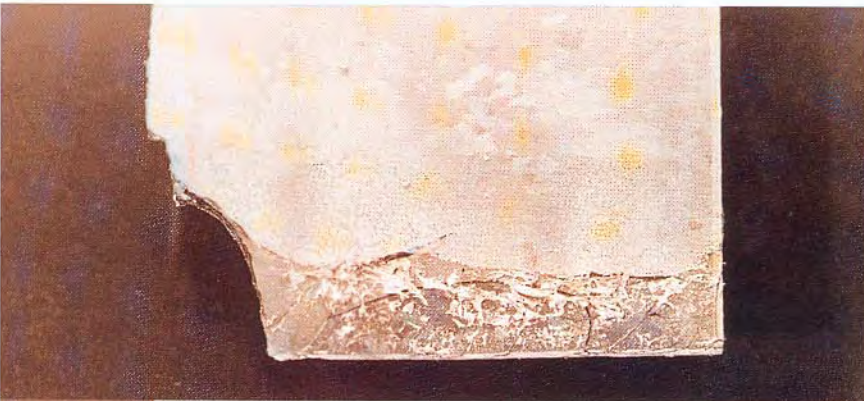


EFFECT OF MERCURY ATTACK ON 2024 ALUMINIUM ALLOY



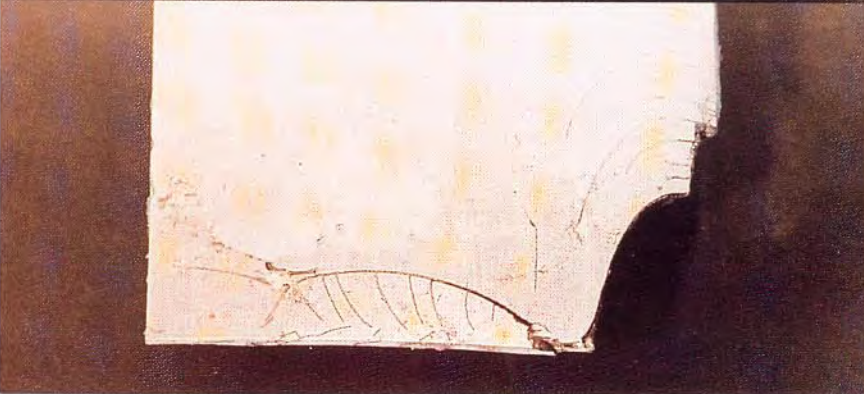
● In just 24 hours

With the piece of 1mm thick 2024 sheet immersed in 25mm of mercury in a laboratory, the alloy has been so severely attacked that it had cracked in numerous places.



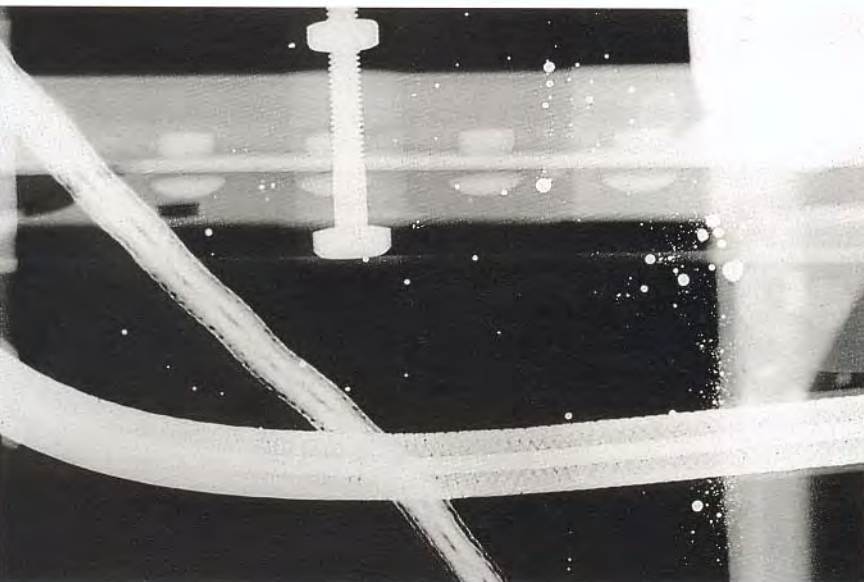
● In 48 hours

In calm, unstressed conditions, pieces had broken off. Had the sheet been the lower fuselage skin of an aircraft with rows of rivet holes and subject to normal pressurisation cycles the failure would have been accelerated.



● Behaviour of mercury

Molten at room temperature, it amalgamates readily with aluminium alloys if their naturally formed oxide films are temporarily removed by scratching, and rapid corrosion occurs on subsequent exposure to moist air or water. Cracking will frequently result, since mercury penetrates into the aluminium alloy selectively at grain boundaries.



□ It is interesting to note that mercury evaporates and condenses.

This explains the location of some of the minute particles (shown as white spots on the X-ray photo on the left) between the flange of a stringer and the fuselage skin. These were removed by heating the structure, thereby causing the mercury to evaporate again, and collecting it as a vapour.

A340 PERFORMANCE AS PLANNED



by Captain Pierre BAUD
Vice President Training and Flight Operations Support Division
Airbus Industrie Customer Services Directorate

The A340 was the first four-engined aircraft to join the Airbus widebody family when it entered airline service in March 1993. Although it does not share the spectacular power-to-weight ratio of a twin-jet, the performance of the A340 is more than adequate for its intended long-range mission. April 1996 will see the introduction of a new, increased gross weight, A340-300. This model will extend an already-considerable payload-range capability while preserving the greatest possible operating flexibility.

The A340, and all previous Airbus Industrie aircraft, were designed to meet well-defined and agreed customers' requirements. Where performance is concerned, these include not only precise payload-range needs (to assure the revenue-generating capability of the aircraft) but also all aspects of the flight profile that materially concern operating economy. Thus the scope for profit is maximized.

Airline judgements must make allowance for the many variables that effect day-to-day operation, so as to provide margins permitting reliable, repeatable scheduling. Working group members must be alert to unforeseen changes in operating costs which are beyond the control of any airline. Past experience has shown that fuel price is the most volatile of all, followed by charges for landings or overflight fees, which are most often weight related.

The consensus delivered by the A340 launch customer group was for climb performance similar to that of the 747s, DC-10s and L-1011s to be replaced, matched with cruise performance that

fell between that of the 747 and the first-generation, widebody twin-jets.

The A340 was conceived as a long to ultra-long-range aircraft. With such a design objective, airframe weight became of prime importance, strongly influencing both engine thrust and specific fuel consumption. The CFM56-5C series of engines provides an excellent relationship between these vital parameters. Low installed weight and slim profile are used to keep wing, pylon and nacelle weight and drag down. The quadri-engine configuration increases wing bending relief, permitting further weight savings.

Low airframe weight was achieved from the first aircraft, providing A340 operators with the best possible protection against any increase in weight-related costs. 15 tonnes lighter than the equivalent 777-200, the A340 will always have the lowest empty weight in its class.

TAKEOFF PERFORMANCE

To the casual observer, an A340 departure may seem like a relaxed affair. A long takeoff roll followed by a leisurely

looking lift-off. This unhurried performance reveals nothing of the efficiency of the A340 wing. For all that a 747 departure may look more impressive by virtue of the sheer size of the "jumbo", the propulsive thrust required is proportionally much higher than that of the A340. The low-speed aerodynamic efficiency of the A340 wing is such that takeoff weights of 275 tonnes are possible with four CFM56-5C4 engines giving 136,000lb SLST. By comparison, the 395 tonne 747-400 needs up to 246,000lb of installed thrust - a 26% higher power-to-weight ratio.

The A340's excellent performance standard is maintained in hot and high conditions, where comparable twin-engine performance is only achieved at the expense of the exorbitant thrust needed to satisfy the engine-out condition at takeoff.

CLIMB PERFORMANCE

For pilots used to the much higher power-to-weight ratios of the A310 or A300-600R, A340 takeoff and climb must certainly seem somewhat sedate at first. In practice, the A340 time-to-climb performance is similar to that of the 747-400 to reach upper airspace.

At higher altitudes, later model 747s enjoy a higher vertical speed, thanks to the greater residual thrust available. However, the A340 is still able to surpass the altitude capability of the 747 in many instances, due to a lift-over-drag ratio advantage of some 14%.

CONTINUING DEVELOPMENT

The A340 airframe and the CFM56-5C engine have seen continuous development since the first aircraft were put into service in March 1993.

FADEC, version C3D, introduced a modification which smoothed the transition from takeoff to climb thrust and produced an improvement in time to initial cruise altitude. For best time-to-climb, crews should adopt a lower climb Mach number (0.79 for example). This will be easier and possible via the managed speed mode in a forthcoming standard of FMS. Increased climb thrust in ISA+15 (and above) conditions will be available, either with the introduction of FADEC version C3E during the first quarter of 1996, or from use of the 5C4 rating.

CFMI have introduced progressive improvements in the build standard of the CFM56-5C, raising both thrust available and the maximum exhaust gas temperature (EGT). The CFM56-5C4 has, for example, 9% greater available climb thrust at 5000ft than the original 5C2 engine standard.

FAST / NUMBER 19



The result of these changes has been a steady improvement in climb performance over early standards and are of particular value in reaching favourable initial altitudes where ATC constraints are most chronic.

CRUISE SPEED

The A340 is optimized for a cruise Mach number around 0.82. The aircraft is equally comfortable at Mach 0.80 if required by ATC to match the cruise performance of the slower twin-jets such as the 767 or increased to Mach 0.83 to dove-tail into a stream of 747s. Ability to accept higher altitudes rounds up a performance standard that helps ATC to manage efficiently the increasingly diverse range of long-haul aircraft types.

REAL WORLD OPERATIONS

The cruise speeds used by A340 operators are dictated by many factors beyond the immediate consideration of fuel burn. Some carriers have adopted a universal Mach number, choosing to ignore the fine-tuning adopted by other operators who include time-related costs to produce a range of cost indices to suit individual route conditions.

Yet other operators vary cruise speed by route to optimize connections at their principal centre of operations, flying faster to preserve lucrative interline opportunities. Over some routes, flying slower provides a more humane arrival time after passage through multiple time zones into the darkness of early morning.

Crew duty times also play their part in the determination of cruise speed over longer routes.

Over the longest A340 routes, presently accounting for less than 2% of all those flown, operators may elect to use a cost index which approximates to minimum fuel burn *so as to maximize payload* when departing at high takeoff weights. Depending upon the flight conditions, this can equate to a cruise speed of Mach 0.81.

The longest route flown today is from Bahrain to New York, by Gulf Air, which takes up to 15 hours west-bound. For that route the airline uses a cruise speed of Mach 0.81.

An optional upgrade of maximum takeoff weight to 260 tonnes has been available from January 1996 for existing operators of 257 tonne aircraft. In April 1996, the first high gross weight A340-300 will be handed over to Singapore Airlines. This model features a takeoff weight of up to 275 tonnes and higher fuel capacity. These features will considerably enhance overall A340 performance.

ETOPS

The A340 enjoys freedom from the constraints of ETOPS, present or fu-

ture, minimizing the constant threat of a costly diversion to some remote airfield.

MISSION ACCOMPLISHED

A340 operators have seen very considerable fuel burn savings over previous equipment, especially the early generation 747s.

Although fuel prices show no sign of rising from their present modest levels, past volatility suggests that the A340 fleet, in the course of its long service life, will return significant benefits.

Fuel savings deliver more than a positive effect on the cost of operation. As the environmental debate intensifies, the A340 fleet is making a major contribution to the reduction of potentially harmful emissions.

FANS

The global development effort to implement a Future Air Navigation System (FANS) is gathering momentum, bringing with it the promise of much reduced congestion at the more notorious airspace bottlenecks that exist today.

Development of AIMFANS-A continues apace, a package that will allow the A340 to take maximum advantage of the CNS/ATM facilities now being created. The greater en-route freedom promised by these advances will help A340 operators to extract even greater efficiency from an aircraft family that has already set the performance standard for the approaching millennium.

CONCLUSION

Did the Airline Working Group produce an accurate vision of the future when guiding the A340 design team? Did the A340 design team deliver an aircraft with a performance standard envisaged by the Airline Working Group? Yes, on both counts. The A340 is a supremely efficient long-range airliner with an *unbeatable efficiency when cruising at Mach 0.82*. As its nearest rival takes engine development beyond the 100,000lb thrust level, the wisdom of selecting a four-engine configuration becomes increasingly evident. ■





PILOT GUARD SYSTEM

Monitoring attentiveness in flight

Jean-Jacques Speyer
 Manager Operational Evaluation
 Flight Operations Support
 Airbus Industrie
 Customer Services Directorate



Captain Adrian Elsey
 Page Aerospace (1)
 Designer of the PGS,
 Airline Captain

Between 1989 and 1994, Airbus Industrie conducted a three-phase research project on long-range crew alertness and pilot vigilance. This endeavour was sponsored by the French Direction Générale de l'Aviation Civile and was conducted with the invaluable cooperation of the Laboratoire d'Anthropologie Appliquée (LAA from René Descartes University), of the Laboratoire de Physiologie des Adaptations (LPA from Cochin Faculty of the same university) and of statisticians from Dunlap & Associates in the USA. Volunteer crews from several airlines, Sabena, Northwest, UTA, Aeromaritime, Lufthansa and Air France participated at various stages. A total of 156 commercial flights was made on different types of aircraft: Boeing 747-200 and 747-400, Boeing 767, McDonnell Douglas DC-10, Airbus Industrie A310, A320 (delivery flights) and A340.

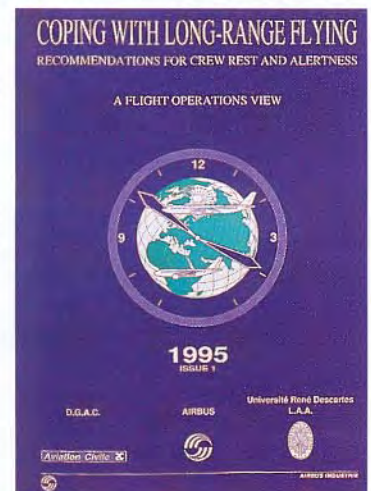
The three stages of this project consisted of:

- objective measurement of crew workload, of alertness decrement occurrences and of sleep loss for pilots engaged in long- and ultra-long-haul flights,
- development of recommendations,
- validation of recommendations.

The Guide for Recommendation became available in December 1995 entitled "*Coping with Long-Range Flying - Recommendations for Crew Rest and Alertness*". Covering more than 200 pages, this guidebook consists of three parts:

- a brief summary of the research conducted,
- practical cards concerning pre-flight and in-flight rest, and layover rest for westward, eastward and north-south flights,
- short summaries concerning alertness levels, alertness decrement, sleep, jet-lag effects.

Summaries are provided to help with adapting or customizing recommendations, keeping all personal or cultural sleep habits and social rhythms in mind. They can be used as a basis for adapting recommendations to cope with extreme cases.



(1) Page Aerospace is a long established company specialized in the design, development, manufacture, qualification and support of a wide range of specialist products for use in the aerospace and associated industries. Based in Sunbury-on-Thames, UK, its product range covers Power Conversion, Digital Systems, Control Systems, Display and Warning Systems and Emergency Lighting Systems.

INTRODUCTION

Both NASA and Airbus Industrie/LAA/LPA have conducted in-flight research and have produced literature which clearly establishes that work underload in flight can lead to inattentiveness and distraction. Crew members may omit to notice or respond to essential items and fail to attend to important duties concerning the progress of the flight. During cruise, the level of workload is such that the work can easily be accomplished by one pilot only. This low workload level can be inadequate to retain the attention of two pilots sharing it. To overcome this problem, a scheme of Active/Passive Vigilance was recommended by the joint team of LAA/LPA and Airbus Industrie.

Under this scheme, the active pilot would concentrate on maintaining interaction with the flight management and aircraft monitoring systems and perform en-route navigational and communications requirements. The passive pilot would take a rest period spanning 20 to 40 minutes, when he could oversee the operation and/or indulge in relaxation or remote activities - such as eating, reading, napping. Adequate attention for the efficient and safe progress of flight will thus be maintained by alternating the active and passive pilots on a periodic basis as mutually agreed, with both pilots being active when operationally required.

The suggested time periods should definitely not be longer, as it was demonstrated that prolonged "loneliness" (next to a napping fellow pilot) can induce 'underarousal' and consequent lack of vigilance on the part of the active pilot.

NASA Ames and the LAA/LPA in Paris have shown that a nap taken dur-

ing cruise can enhance the alertness and performance of flight crew, particularly in the more critical final stages of flight. Reports also show that napping on two-crew flight decks happens frequently, either inadvertently or planned, although not officially approved by most national airworthiness authorities.

Activity away from the flight deck, such as a short walk into the cabin, has been shown to have beneficial effects on overall alertness and performance.

Likewise, activity on the flight deck, such as physical interaction with the electronic interfaces/aircraft systems, also has been shown to improve alertness and performance from a flight operations point of view.

DESCRIPTION OF THE PILOT GUARD SYSTEM

Basic features

The Pilot Guard System (PGS) is a timing device, that facilitates active/passive vigilance on the flight deck. Its function is to keep track of each pilot's physical activity, utilizing a three-phase operational cycle :

- standby
- inhibited
- monitoring.

The PGS is in standby mode while the aircraft is on ground. After becoming airborne, it is inhibited for 20 minutes, following which it enters a monitoring cycle which defaults to a period of 25 minutes, unless otherwise selected.

Monitoring

If no pilot action is detected during the monitoring period, the PGS will trigger a visual warning which flashes for one minute, unless activity is detected, whereupon the unit resets.

If no activity is detected during the one minute flashing period, an audio alarm sounds. This can be cancelled by detection of activity, but the PGS will now enter an "alertness" sequence and will only reset to a one-minute timing period (Figure 1). Reset is inhibited during this one-minute period, after which the visual warning activates again.

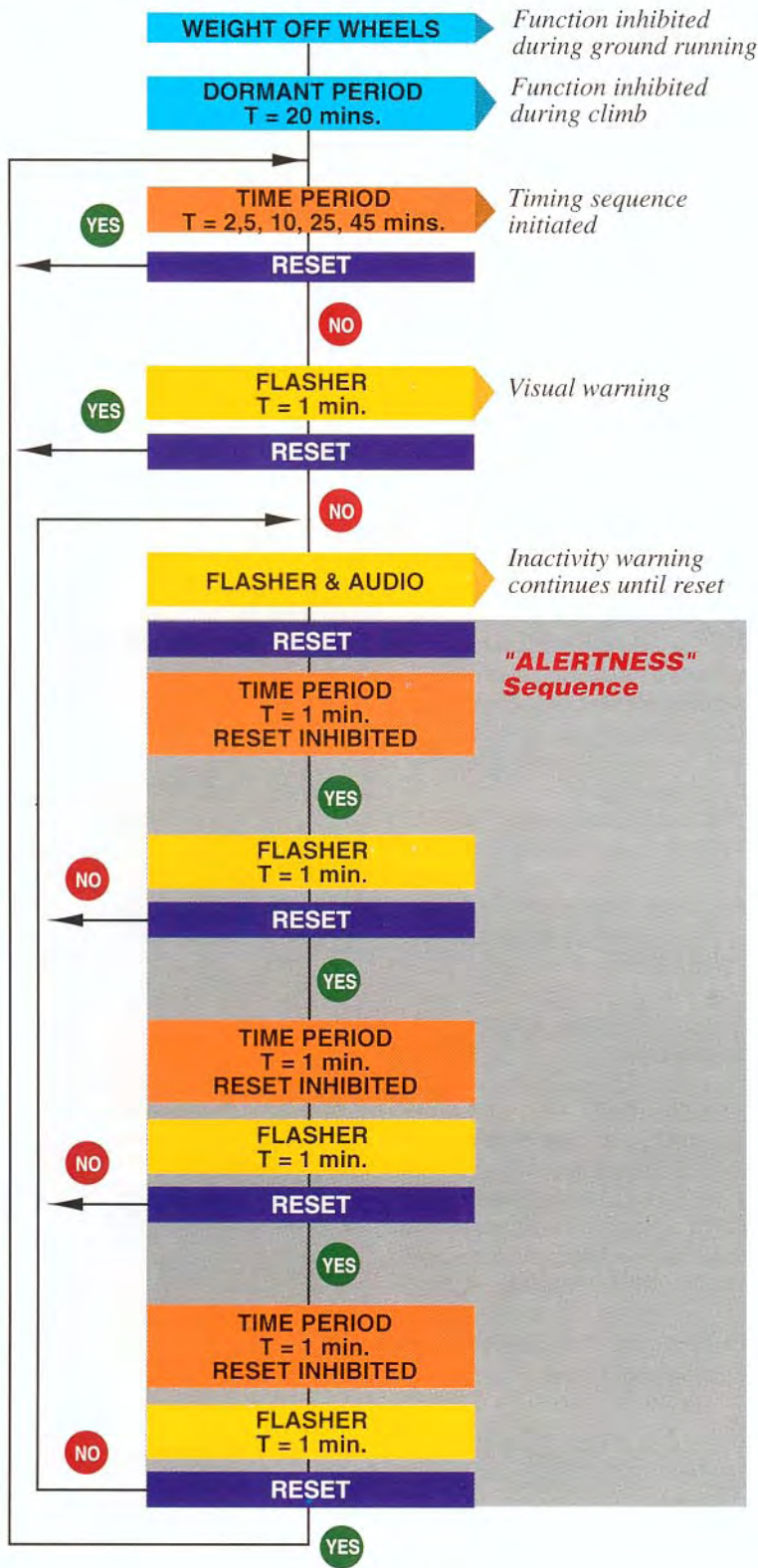
If the unit is now reset by detection of activity, the one-minute inhibition period will start again and this cycle will be repeated. If it is not reset, then the audio will sound again and the "alertness" sequence will restart. When this "alertness" sequence is complete, the PGS will reset to its previously selected timing period. This process should ensure that pilots become aware of their decreased activity and prompt them to adopt proper countermeasure tactics to improve their attentiveness.

A310 cockpit with left pilot's (CM1) PGS in view at extreme left of glareshield.



Figure 1

Pilot Guard System - Operational cycle



Timing periods

The PGS effectively permits napping by the "passive" pilot, by detecting the activity of the "active" pilot.

The pre-set detection periods for the "active" pilot are 2, 5, 10, 25 and 45 minutes.

The "passive" pilot will set his timer to his period of relaxation - between 20

to 40 minutes - at the end of which it will provide an audio alarm. During this period, the "active" pilot should set his PGS to a setting dependent on his estimated level of alertness. For example, on day flights the default setting of 25 minutes should prove adequate. On night flights, he should set either 10 or 5 minutes dependent on his subjective sleep pressure.

OPERATIONAL EVALUATION

Objectives of the evaluation

After testing the PGS unit in the laboratory of Page Aerospace, the next step was to arrange for a flight test in an operational environment. The objectives were:

- to ascertain the viability of the Pilot Guard System (PGS) as an automatic activity detection device,
- to determine if the PGS can perform the function of a fail-safe operation of monitoring one pilot while the other takes a nap,
- to determine if the PGS can support the active/passive recommendations jointly developed by the LAA/LPA.

The equipment

Under normal operation, two PGS units would be installed in the aircraft - one for each pilot. The PGS has a facility for six input reset functions. Full installation would involve a modification to the wiring of the aircraft systems- i.e. connecting into the ARINC 429 databus and electronic units.

The pilots were briefed on the PGS use (see Figure 2) and were given Pilot User Instructions.

The remote reset button was pushed, thus resetting the corresponding pilot's unit to the beginning of its timing period, whenever one of the pilots:

- operated the VHF/HF, VOR/DME, ADF selection panels,
- made a selection on the FCU panel,
- used the FMS CDU,
- operated the ECAM control panel,
- operated the PGS itself.

These interactions were chosen because they pertain to the most commonly used systems and, as they send signals down an ARINC databus, they could be intercepted to provide the signals for resetting the PGS unit if an interface were to be developed.

Experimental design

SN533 from Brussels to Boston on 22nd November 1994, divided into five segments, permitted a general daytime familiarization with the system.

At the end of this initial flight, it was found necessary to develop an experimental design for the routine flight, utilizing the PGS as a tool to enable active/passive vigilance and napping.

The return night flight Boston to Brussels was SN534 operated on 24th November 1994 and was divided into 14 segments to help evaluate various operational combinations of active/passive/PGS timer/rest/napping crew configurations.

Example of the evaluation

Chosen amongst others in this trial the following example (Figure 3) illustrates the contribution of the PGS as a tool:

- to facilitate the organization of alternation between active/passive vigilance by the flight crew,
- to warn of decreasing involvement, prompting reaction.

Figure 3
PGS in visual and audio modes

In this example, from 03:22 to 03:52, CM1 is passive while CM2 is active, but, in order to trigger the PGS, he does, at some point, simulate passive behaviour.

The PGS was set to CM1 30 minutes timer and to CM2 10 minutes detection mode.

We indeed can see that CM1 is mainly in "passive" mode. CM2 is "active" on his own. At 03:34 the PGS visual warning triggers for CM2 and at 03:35, the PGS audio alarm sounds and this is then cancelled by CM2. The "alerting" sequence is entered and results in CM2 resetting at 03:36 and for the third time at 03:39.

Figure 2

Pilot Guard System - Control panel

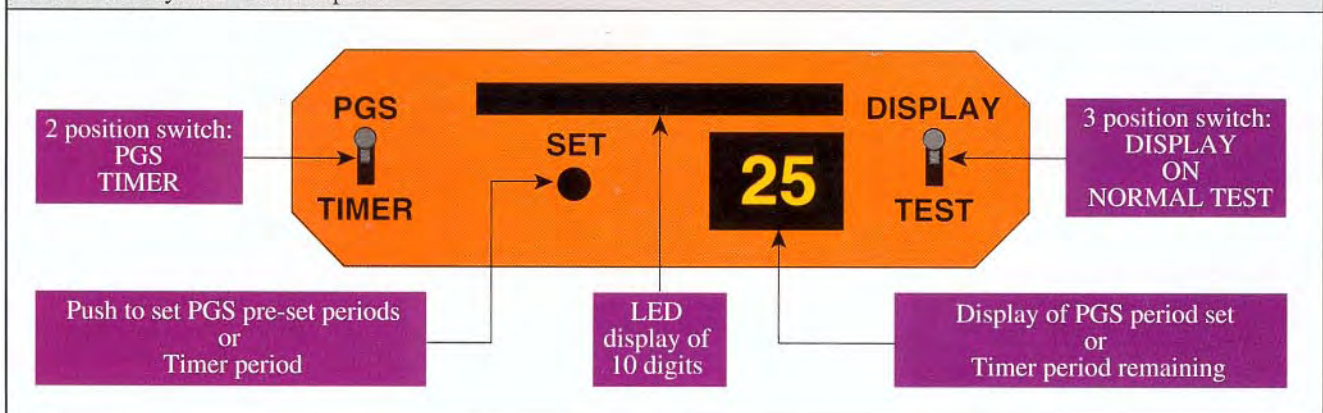
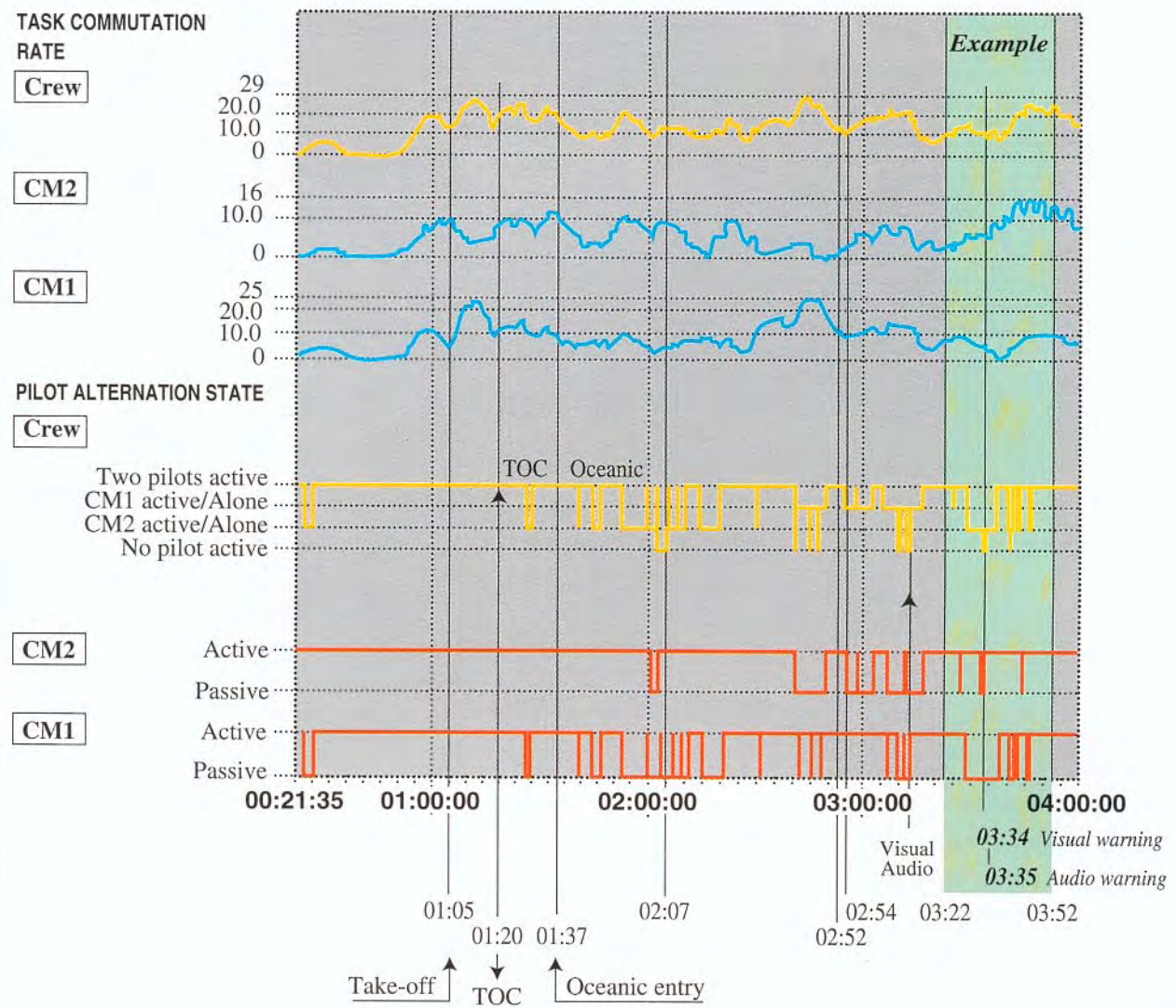


Figure 3

Time line plots for PGS in visual/audio modes



CONCLUSION

The PGS appeared to be a useful electronic interface tool to support the procedure of alternate active/passive vigilance. This procedure was also found to be adequate by the pilots to cope with the rigours of long-range night flying. The PGS was not found distracting or obtrusive. The unit was found easy to operate and deemed a useful tool to monitor a lonesome pilot's activity. As such it is recommended as a tool for allowing the practice of alternative crew rest to enable napping on the flight deck.

Standard operating procedures are not being followed by the significant number of pilots inadvertently napping or taking pre-planned naps. The active/passive vigilance scheme will address this problem and standard operating procedures should be changed accordingly to reflect this.

Although this trial was conducted on a long-haul flight, the active/passive vigilance scheme should also prove beneficial for short-haul flights of more than two hours duration, on which the maintenance of vigilance is a potential issue. When combined with multiple stops and with night flying, these sectors may lead to fatigue problems also.

The PGS can be coupled with the active/passive vigilance scheme. Active/passive vigilance enhances Crew Resource Management by distributing workload to prompt attentiveness not only during the cruise but also for descent and approach. A better crew-member dialogue and hence substantial crew synergy will result from adapting the suggested procedures. Under certain conditions, the PGS may also simplify crewing requirements by obviating the need to have an additional crew-member. It fulfils a safety requirement and can be cost effective. ■

This evaluation was conducted in cooperation by Page Aerospace, Sabena and Airbus Industrie.

A detailed paper is available upon request as well as the Guide of Recommendations for Crew Rest and Alertness developed with the Laboratory of Applied Anthropology and under the auspices of the DGAC, from

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AMMAN	Jordan	962 (8) 51 284	962 (8) 51 195	AMMBI7X
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MUSCAT	Oman	968 519 835	968 521 286	-
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		81 (3) 5756 8770	81 (3) 5756 8772	-
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CABIN AIR COMFORT

Part 2

The quality (and quantity) of air and the comfort associated with a cabin, quite naturally is associated with the amount one chooses to pay for one's ticket.

Those passengers who pay least get the most air, over which they have no control, with the least comfort and no cabin service.



Thirteen passengers in a twin-engined Farman Goliath which flew on the Paris-London and Paris-Brussels routes in 1919

Business passengers tend to go for more comfort. They have a cabin but service is still difficult and there is noticeably less fresh air.



In a Caudron C-23 leaving Paris for Brussels in 1919

First class passengers get what they pay for - A cabin, comfortable seats, service, fresh air louvres which they can control and individual reading lights.



Lunch over the English channel. The steward prepares the tables in a Short Scylla before take-off from Croydon (London) for the short trip to Paris. 1935



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