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Human Factors in Aircraft Maintenance and Inspection

by
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Human factors and their influence on flight safety are usually associated only with pilots and flight operations. In the maintenance area, a mistake or omission by a technician is frequently viewed as a not unexpected "technician error." The fault, in fact, may have been a human factors-based error, in an area that has received less attention by researchers in human factors. Yet, the errors could impair the safety of flight as much as those in flight operations that, heretofore, have received the most attention and research.

The importance of human factors in technician performance is currently receiving more recognition as a result of several serious and potentially catastrophic incidents within the past few years. The inflight failure and loss of a major portion of the upper fuselage skin of an Aloha Airlines Boeing 737 in 1988 was the catalyst for the initiation of a major study into the human factors aspects of aircraft maintenance and inspection under the direction of the U.S. Federal Aviation Administration (FAA).

Other instances of undetected defects have occurred in the past. A McDonnell Douglas DC-9 aircraft suffered an inflight failure of the aft pressure bulkhead due to faulty interpretation of previous radiographic (X-ray) inspection results. A Fairchild F-27 suffered an inflight failure of a wing panel several years ago. The subsequent investigation disclosed that the previous X-ray inspection showed the defects, but they were overlooked by the technician reviewing the X-ray images. Many general aviation aircraft have had accidents or incidents attributed to defects which had been overlooked during normal inspections and maintenance.

The spectacular nature of the Boeing 737 fuselage skin failure, however, was the one instance which served to wake the industry and the regulatory agencies responsible for assuring the safety of the travelling public. In investigating this fuselage structure failure, it was found that the defects which resulted in the loss of the top of the fuselage covering several seat rows had been present for some time and should have been detected by the inspections called out by the manufacturer and included in the operator's inspection program. The defects initially consisted of small fatigue cracks in the skin originating at rivet holes, a problem not uncommon in many aircraft. What was uncommon in this case was that the "system" — the maintenance program — failed to detect these defects while they were minor and they were allowed to progress until the cracks joined. Consequently, the top of the fuselage ripped open as if there was a zipper in the skin while the aircraft was pressurized.

The technicians who performed the previous inspections certainly did not intend to overlook the defects, so how did the system allow this to happen? Among the actions coming out of this investigation is the major study of the human factors in aircraft maintenance and inspection that is ongoing under the direction of the FAA. However, participation is worldwide and the results will certainly change the methods in which the technician is trained, supervised and assigned, as well as change the tools and equipment the technician uses to accomplish various inspection and maintenance activities.

Human factors being studied include the following categories:

- Information transfer and communications
- Work environment
- Selection and training of inspectors
- Equipment and job performance aids
- Inspection methods
- Human limits and capabilities
- Problems of vigilance/ boredom/complacency
- Non-destructive Inspection (NDI) techniques and equipment

Although individual managers and supervisors may not be in a position to make major human factors-related changes or improvements in their own shops and hangars, it is important that individual technicians be aware of these potential problems and take personal steps to reduce technician error.

Communications Is Never-ending

Information transfer and communications are never-ending. The scope and volume of technical manuals and inspection/maintenance instructions have multiplied as aircraft and systems have become more complex. Whereas a single loose-leaf binder or two were previously adequate to outline the workings of an entire airplane, it is not uncommon now to have an entire bookcase filled with manuals for the information on just one aircraft type.

New technologies are being explored by those who are researching methods of presenting necessary information to the technician. The use of on-line computer technical data which can be accessed by the technician is one of the devices being explored. This would enable the user to access a central data file, which is up-to-date, and would not require anything on-site except a terminal and printer.

A more recently implemented means of storing aircraft maintenance data for ready recall is that of compact disc/read only memory (CD/ROM) storage devices that can accommodate text and graphics of an entire aircraft library on a single disc. Such sophisticated equipment is available now; however, we cannot realistically expect these advances to be practical for any but the largest air carriers in the near future.

Another aspect of the information exchange problem is that of knowing what is happening to other aircraft similar to those in your operation. Each individual has a vital role in this aspect of communications. Manufacturers and many of the regulatory agencies have database programs to collect in-service reports of maintenance irregularities and defects. These programs however, can only be effective if you, the technician, submit reports of occurrences in your operation.

Data Exchange Is Important

In the United States, the FAA system for collecting and disseminating maintenance irregularity data is called the service difficulty report (SDR) program. The SDR program has grown so large that it has become limited in its responsiveness to the individual technician. The FAA has recognized the limitations of the SDR program and is working to develop a more responsive system which is capable of issuing alerts when a trend or series of like events occurs.

Manufacturers are usually responsive to reports of defects or irregularities in their equipment; however, individual manufacturers may not readily exchange data with each other. Airlines and other commercial operators do exchange some technical data, but the stress of competition and simply taking care of one's own business have reduced the effectiveness of this informal exchange.

On a local level, the use of more specialists and specific job assignments have reduced the ability of the technician to "know what is going on" outside of his direct area of responsibility. All of these points merely serve to illustrate the importance of technicians telling each other, the manufacturers and the regulatory agencies when something out of the ordinary takes place. Individuals and supervisors must take the initiative to seek data pertinent to the aircraft in their operation and to share that information.

Work Environment Affects Performance

The work environment provided for

the technician has proven to be an important factor in assuring consistent quality in the performance of maintenance and inspection tasks. It is unrealistic, for example, to expect an inspector to perform a detailed inspection of an extensive structural area outside, in the dark, using only a flashlight. Similarly, an inspector should not be assigned to perform a critical inspection of a structural component that is covered with dirt and grease.

Perhaps more than any other human factor affecting the technician's performance, the work environment is directly within the control of the local operator and the supervisor.

Selection and Training Of Inspectors Needs Re-evaluation

In the past, it was common practice that the most senior mechanic became the next inspector, in the ever-present seniority system. Although this usually assured that the inspector had a reasonable amount of experience, it did not necessarily ensure that the new inspector was qualified to perform the assigned tasks. As for educational opportunities, other than the largest air carriers and manufacturers, very few operators had formal training programs for inspectors.

In the 1950s and 1960s, this reliance on experience to qualify as an inspector may have been valid. In the 1990s, experience as a technician alone does not qualify one to be an inspector. More complex aircraft and more highly stressed components in fail-safe and damage-tolerant structures demand more knowledge. Training and expertise in the use of NDI techniques is now a common prerequisite for an inspector in any but the most basic aircraft.

Managers and supervisors should restudy their inspector selection and training programs to assure that the persons selected for those positions are qualified to perform reliably the required tasks.

Equipment and Job Performance Aids Relate to Quality Work

Years ago, every technician was required to have a basic toolbox; there were one or two copies of the maintenance manual somewhere in the hangar; and the company had a few "special tools" in the stockroom. This way of performing aircraft maintenance will not get the job done in the 1990s. Analyses of maintenance costs have shown that the cost of acquiring adequate tools, equipment and manuals is minuscule compared to the high cost of ineffective maintenance resulting from a lack of these job performance aids.

It is the task of the manager or supervisor to assure that the manuals are usable on the job. Job performance aids, coupled with training, can reduce errors and cut required maintenance time.

Errors Can Be Costly

Technician errors fall into four categories:

- False removal (generally high when there is time pressure)
- Failure to isolate or detect
- Damage during the work performance
- Time error, which usually involves self-detected error and simply extends the overall time to complete the task

All these errors can be reduced substantially or eliminated with adequate and effective job performance aids. Unfortunately, simply having the manuals available does not guarantee that they will be used. Some technicians tend to go to the manual either because they recognize its value or because they have no other place to go for help, while others will tend to rely on memory or will ask peers or supervisors for information.

The use and usability of manuals are two separate but closely related issues. If the usability is high, it will foster but not guarantee usage. Factors affecting the usability are:

- Accessibility — is it convenient and available; does it break the work down into convenient packages?
- Portability — can it be taken to the job site?
- Completeness — does it cover the entire task?
- Accuracy — is it accurate and applicable to the equipment?
- Flexibility — can it be used for various tasks?
- Presentation — is it clear and easy to read; are there sufficient pictorials and charts?

The wording and language used in job performance aids should be simple, concise and consistent. The use of the same terms for various steps should be enforced. If the word “raise” is used, then do not use “elevate” or “lift”; it must always be “raise.”

The importance of job performance aids is emphasized, for example in the United States, by the fact that nearly 40,000 of the current 65,000 aircraft technicians currently on the job will qualify for retirement in the next 10 years. Their replacements will be learning on-the-job and the effective use of job instructions, manuals and equipment will be a critical factor in ensuring safety and reliability.

Choice of Inspection Methods Is Critical

The selection of the inspection method to be used in searching for a particular aircraft defect is critical to the reliability of the inspection findings. Up to now, little research has been conducted to determine the efficiency of various inspection techniques. It has more or less been assumed that if a defect was present, it would always be found by a conscientious inspector. Unfortunately, the Aloha Airlines accident and other incidents have proven the fallacy of this assumption.

On the other hand, engineers have researched the efficiency and reliability of inspection methods in other applications, and some of this knowledge can be applied to aircraft inspection.

In the manufacturing environment, inspections can be repeated by a second individual or reject parts can be subjected to a more detailed inspection to verify the defects or return the part to service. Studies have shown that the number of missed defects can be affected by the work place environment, training, worker attitudes and fatigue or boredom.

In fault-finding inspections of aircraft structures, however, there should be little concern for a false indication of a fault because this can be identified in the course of repair. On the other hand, there should be little tolerance for a missed defect in aircraft structural inspections. Inspection intervals are established based upon the anticipated in-service growth rate of a defect. If the defect is missed at one inspection, it may grow to an unsafe condition prior to the next scheduled interval.

In order to reduce the exposure to a missed defect, should aircraft structure inspections be doubled by having the same items inspected by a second individual? It is required practice in air carrier and common practice in many corporate maintenance operations to have a second set of eyes reinspect work performed for jobs that could affect airworthiness; it is logical to consider this same level of assurance for other aircraft structural components.

Other aspects of the inspection method also can have a profound effect on the success of the inspection. Often, the inspector has never seen an actual example of the defect which he or she has been assigned to detect. The vast majority of inspected parts are defect-free, and the inspector therefore has a tendency to see what he expects to see: nothing. It is very valuable to have a sample of the defect for an inspector to examine prior to performing the on-site inspection.

The need for a sample defect is particularly important for the various NDI techniques. The inspector needs to see how the defect will appear on the film or display of the inspection device. If the inspector has never seen a defect in conducting the NDI, it is likely that a small defect could be overlooked.

The second inspection, or supervisor review, of NDI results also has proven to be advisable for critical inspections. Under the pressure of time, an evaluator can overlook a defect indication on an X-ray film. Eddy current, ultrasonic inspection and dye penetrant inspections do not provide a permanent record, and the supervisor review must be performed by looking over the inspector's shoulder or by performing a repetitive inspection.

There Are Limits to Human Capabilities

What can we reasonably expect of a human inspector? Is it reasonable to expect an inspector to find virtually every crack in a skin section which may total 60 square yards (50 square meters) or more? Industrial studies have explored such limitations in non-related fields, but these aspects of inspector job performance are just now coming under serious review.

How small a defect can an inspector be expected to see with the naked eye? If a magnifying glass is called for, is the size and optical quality of the lens specified? There can be a vast difference in the clarity and detail of the view provided by a cheap, 10-power magnifier compared to an industrial-quality lens of high quality.

Other aspects of human limits should also be considered when assigning an inspector to look for structural defects. It is not reasonable to perform detailed structural inspections for an entire shift without adequate breaks to rest and to relieve the stress of constant close inspection through a magnifying glass. Consideration should be given to rotating assignments among the available inspection crew members and to provide variation in the work in order to optimize the efficiency of the inspection. For critical areas, managers should consider assigning a supervisor or different inspector to spot check or completely reinspect the area to assure that defects are not overlooked.

The attitude of the individual is critical to the consistent performance of quality work. An individual who has personal problems is likely to not pay attention to details. Supervisors must be alert and cognizant of individual attitudes of inspection personnel. If someone is functioning poorly, assign that individual to a less critical task.

Problems of Vigilance And Boredom Addressed

Boredom and complacency are a constant threat to the proper performance of aircraft technicians. One of the more serious incidents that resulted from the repetitive nature of a simple task was the inflight loss of oil from all three engines on a Lockheed 1011 that resulted from the O-ring seals being omitted from the sump plugs on all three engines after servicing. This near catastrophe is an example of what can occur when technicians lose interest in the job and management fails to establish adequate safeguards. Supervisors must be alert to the onset of boredom or developing complacency. If the factors causing the condition cannot be altered, additional checks or balances must be established to counteract it and assure that safety is not compromised.

Reliability of NDI Activities Examined

One promising area of improvement that resulted from industry aging aircraft conferences [FSF-sponsored Second Annual International Conference on Aging Aircraft; proceedings available for $30 to FSF members and $35 to non-members] has been that of improved NDI techniques. The U.S. National Aeronautics and Space Administration (NASA), FAA, airlines and manufacturers of NDI equipment have redoubled their efforts to improve existing NDI methods and to accelerate development of new technologies.

Based upon information compiled to date, existing X-ray, eddy current, ultrasonic and dye penetrant inspection techniques appear capable of detecting defects with acceptable reliability. Where errors have occurred, human faults in application or interpretation have usually been found responsible. For those NDI methods that produce a permanent record, a second opinion of the radiographic films or video record of the inspection results has proven to be an excellent method of assuring that defects are detected.

Future NDI methods may be automated and less prone to human error, such as infrared thermography using differences in heat energy to pinpoint defects or leaks, and various acoustic devices using the reflection and refraction of sound energy to locate defects.

In the meantime, operator technique and proper evaluation of the test results remain central to assuring that NDI produces reliable and accurate results. Experience has proven that proper training is critical not only in the use of the equipment, but in the application and evaluation of the results for each specific area or component being inspected. The availability and use of defect samples and measurement standards such as test blocks is of paramount importance to assure that the equipment is functioning properly and will produce the desired result.

No single agency, operator or individual has all the answers to eliminate the human factor errors from aviation technician performance. Communication is one of the most effective means of eliminating hidden hazards and preventing incidents and accidents. Your admitted "almost mistake" may prevent someone else's accident. ♦

NEWS & TIPS

NIOSH Publishes Schedule of Courses

The U.S. National Institute for Occupational Safety and Health (NIOSH) has released a complete schedule of courses in various facets of occupational safety and health through August 1992. NIOSH Educational Resource Centers are located at 32 universities throughout the United States. Each center conducts courses in subjects such as:

- Hazardous waste worker training
- Sampling and analysis of asbestos materials
- Waste management workshops
- Industrial ventilation

- Occupational medicine update
- Effective risk management
- Respiratory protection
- Fundamentals of work-place safety
- Radio frequency and microwave radiation safety
- Environmental audits
- Audiometric training

Individuals or companies wishing to obtain a copy of this catalog may send a request to Midwest Center for Occupational Health and Safety Program in Continuing Education, 640 Jackson Street, St. Paul, MN 55101 U.S.

Safety Orientation Program Offered in Spanish

The DuPont Safety and Environmental Resources division of the DuPont Co. in Wilmington, Del., U.S., has developed a program titled "Safety Orientation — Employees" in a Spanish language version. This session provides beginning and experienced Spanish-speaking personnel with information about the company's safety philosophy and the individual employee's role in safety.

The program is based upon a course originally developed by DuPont for its own employees. This special version is translated into "international" Spanish for clarity in all Spanish-speaking countries.

The training program is available as a package which includes an administrator's and leader's guide, a videotape, and 10 participant workbooks. Components can also be purchased separately.

Companies interested in this program may direct their inquiries to "Safety Orientation — Employees," Spanish Version, DuPont Safety and Environmental Resources, P.O. Box 80800, Wilmington, DE 19880-0800 U.S.

Shedding Light on the Subject of Lighting

Many light assemblies in aircraft cockpits and cabins are multiple lamp assemblies, and technicians frequently are called upon to replace individual bulbs as they fail. One major airline operator has found, however, that the replacement of only the defective lamp is not cost effective.

Analysis has shown that when one lamp fails, the others in the fixture are likely to be close to the end of their useful lives as well. Replacing bulbs on a one-at-a-time basis results in multiple write-ups and additional maintenance time. Maintenance management has therefore issued a directive calling for the replacement of all lamps in a multiple installation whenever a single lamp fails.

Many industrial and commercial facilities have adopted similar practices for general lighting in large spaces. Many facilities simply replace all lamps on a calendar or operating-hours basis. Experience has proven that the time and effort expended in gaining access to elevated light fixtures far outweighs the minimal savings realized by getting a few more weeks of life from an individual lamp. ♦

MAINTENANCE ALERTS

This information is intended to provide an awareness of problem areas through which such occurrences may be prevented in the future. Maintenance alerts are based upon preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be entirely accurate.

Blue Ice Stories Continue

An international airline received a captain's report stating that a "thump" was heard from the region of the front galley during cruise at FL370 over the North Atlantic. The aircraft simultaneously pitched up slightly and the altitude hold function of the autopilot automatically disconnected. The aircraft was manually returned to level flight and the altitude hold re-selected.

About 15 minutes later, a louder thump was heard and felt from a position just aft of the first officer's seat. The aircraft pitched up and yawed to the right, again tripping off the altitude hold. The first officer proceeded to the cabin to investigate but found nothing to account for these strange bumps; all systems were functioning normally. The remainder of the flight was completed without further incident.

During the walkaround inspection after landing at the destination, a large block of ice was found inside the forward lavatory drain panel and a blue stain was evident around the panel. A large blue stain was also noted on the leading edge and root of the right wing.

After servicing the lavatories, a leak was noticed at the forward lavatory drain fitting. This lavatory was drained and declared unserviceable for the following flight. Upon termination of the day's flying for that aircraft, the lavatory dump valve was cleaned and no further "thumps in the night" were reported.

Be Wary of a Pressurized Cabin

Recently, an airline technician was injured when he opened an Airbus A-300 forward entry door from the outside. The plane had inadvertently been pressurized.

During troubleshooting a pilot-reported discrepancy on the cabin outflow valve, both outflow valves had been closed and the related circuit breakers were opened. A decision was made to replace one of the outflow valves. A technician who had not been involved in the troubleshooting process was sent to the aircraft to replace the valve. The replacement valve, new from stock, was in the closed position.

The technician climbed up the entry stand that was located at the forward door after completing the valve replacement. Because the aircraft was parked outside in inclement weather, all doors and hatches had been closed. Also, the auxiliary power unit (APU) was operating and cool air was being supplied to the aircraft. This caused the aircraft to be inadvertently pressurized. When the technician unlatched the forward entry door, it opened with unexpected force, throwing him against the side rail of the stand. He sustained a back injury and was almost pushed off the stand.

Aircraft maintenance procedures contain these precautions:

Caution: Before supplying air by external source or APU, make certain that:

- At least one flight compartment window or cabin door is open, and remains open during servicing.
- If the aircraft is parked outside and is not protected from inclement weather, one maintenance door or avionics access door is open and remains open during servicing.

Also, some operators require that a "Caution — Do Not Operate" tag be attached to a door that is left open to preclude inadvertent pressurization.

Right Idea, Wrong Tape Sets Stage For Trouble

An international operator of wide-body aircraft recently reported a minor incident which could just as easily have been a major catastrophe. After removing a damaged overhead storage compartment, the line technician tied back the disconnected wiring and taped the ends of the wire. The problem, however, was that he used aluminum tape to cover the wire ends.

No one knows why the technician used conducting tape to cover an electrical connector. Possible factors could have included convenience, time pressure, running out of insulating tape or just plain not knowing any better. Later, an avionics technician, who was working in the area, received an electrical shock when he accidently came in contact with the improperly wrapped wire ends. Fortunately, the injury was insignificant.

The consequences could have been much more serious had the wrapped but conductive wire ends shorted and caused a fire or had the technician made a firm contact with the hot wires.

This incident only serves to remind us that all tasks, no matter how insignificant they may seem, require safe practices. ♦

NEW PRODUCTS

Industrial Adhesives Catalog Is Available From Pacer Technology

The Pacer Technology Co. has recently published a revised and updated product catalog describing its line of cyanoacrylate adhesives, retaining compounds/sealants, threadlocking and anaerobic compounds. Other specialty items are also listed.

The manufacturer claims that these products have a wide range of uses in the aerospace field, in both manufacturing and maintenance applications. Product application, properties, gap-filling abilities and service temperature range and cure times are presented for each material.

Obtain a copy of this brochure by request from Pacer Technology, 9420 Santa Anita Avenue, Rancho Cucamonga, CA 91730 U.S. Telephone (714) 987-0550, Fax (714) 987-0490.

Industrial Air Cleaner Clears Shop Air

The Smog Hog industrial air cleaner developed by United Air Specialists Inc. is said to be capable of capturing virtually all airborne particulates from .01 microns to 100 microns in size. The maker claims that this unit can solve problems caused by welding, cutting, grinding, machining, and other processes which release unwanted smoke or mist into the working atmosphere.

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Employee health risks, maintenance and housekeeping costs are said to be drastically reduced with the use of the Smog Hog unit. The unit incorporates a two-stage electrostatic precipitator. It is available in ducted or non-ducted configurations, as well as portable installations.

United Air Specialists markets its products through a network of more than 100 distributors throughout North America and is represented in more than 40 other countries. Contact Fran Andreotta, Industrial Marketing Specialist, United Air Specialists Inc., 4440 Creek Road, Cincinnati, OH 45242-2832 U.S. Telephone (513) 891-0400.

System Warns of Lightning Threat

An automated lightning warning system made by Dimensions, of France, is currently in use at several aerospace facilities. The maker claims that the system gives a 15- to 45-minute advance warning before lightning discharges occur.

The system monitors electrostatic charges that build up in the atmosphere and conducts a real-time analysis of conditions to identify storm development, intensity and distance from the station, as well as the probable danger of a cloud-to-ground strike.

Three warning levels include unstable atmospheric conditions, distant storm

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conditions, and imminent danger of a nearby lightning strike. Contact Dimensions, Parc des Algorithms, 91194 Gif-sur-Yvette, France. Telephone (33-1) 69412701, Fax 60192642.

Gloves Protect Hands, Components

The increasing use of miniature electronic components and microscopic parts has emphasized the need for clean working environments for technicians involved in maintaining equipment that incorporates these units. The Thomas West Co. has introduced a line of powder-free latex gloves for use by workers in such clean room environments.

The manufacturer claims that these gloves have a unique microtexture that ensures a secure grip on even extremely small objects. The natural latex material gloves have a thickness of seven mils, and are said to be comfortable for extended wear periods.

No donning powder, starch, talc or other potential contaminants are used in these gloves which are said to reduce dermatitis problems.

The 12-inch-long gloves are available in several sizes and can be packaged in separate left- and right-bags or packed in pairs if desired.

Contact Thomas West Inc., 298 Harbor Blvd., Belmont, CA 94002 U.S. Telephone (415) 592-0806. ♦