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U.K. CAA Cites Inadequately Defined Inspection Procedures For Human Errors in Aircraft Inspection

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Barry Rosenberg
Aviation Journalist

To determine which human factors influence aircraft-inspection reliability, the U.K. Civil Aviation Authority (CAA) evaluated the performances of qualified inspectors working for six days under controlled environmental conditions. The study was conducted as part of the joint U.S. Federal Aviation Administration (FAA)/CAA Aging Aircraft Inspection Program.

The results are contained in a 1995 CAA report, *A Study of the Human Factors Influencing the Reliability of Aircraft Inspection*.

The objectives of the study were to determine the reliability of airframe inspectors when working on a typical inspection task; to investigate the influence of selected working conditions on inspector reliability; to identify the causes of human error occurring in the specific task studies; and to propose mechanisms for improving reliability.

During the study, inspectors were asked to find simulated cracks around fasteners through a lap-joint inspection, using the sliding probe eddy-current technique. To perform the work, inspectors had to attach accurately a straight-edge to a fuselage and then scan the row of fasteners. Several ultrasonic inspections were also included in the study. The inspectors participating in the test were from major airlines and maintenance facilities in the United States and Europe.

The report determined that most inspectors in the study made mistakes, and that a lack of standardized training was partially responsible. Differences in error rates among inspectors did not correlate with environmental variables, researchers found. More errors were made during midweek day shifts. Three inspectors made no errors during a six-day study period, causing analysts to suspect that one major factor was "inherent ability."

"The results of the studies showed that a small number of cracks in the vicinity of the fasteners were missed due to deficiencies in scanning technique, particularly misalignment of the straight-edge during scanning," the report said. Mistakes were also made in determining the number of cracks in a cluster, mainly through failure to recognize and report the presence of cracks at the end of the cluster, and in detecting cracks under thick paint.

"The majority of the inspectors failed to detect low-amplitude signals, typical of scanning over regions of thick paint," the report explained, "and this is considered to be a point of major concern since in practice such regions could contain cracks giving low-amplitude signals."

The reasons for inspector mistakes varied, according to the report.

- Crack signals were missed because of inattention to the display on the eddy-current screen. Overlooking the signals was attributed partially to fatigue or boredom.
- The failure to detect low-amplitude signals that identified cracks in areas of thick paint was ascribed to the tendency of inspectors to concentrate on the perceived major task at the expense of other reporting requirements.
- A greater percentage of mistakes was made on day shifts in the middle of the week. A tendency to relax and/or midweek tedium was considered a possible cause, although no firm conclusion was reached.
- The method of fixing the straight-edge to the row of fasteners was not specified, which resulted in some inspectors having a greater error rate. The study concluded that human error can stem from inadequately defined inspection procedures.
- Considerable variability in calibrating ultrasonic inspection equipment was also observed. Depending on the magnitude of the variation, the sensitivity of

the inspection equipment could be significantly compromised. The reason for the variability may have been the complexity of the calibration process, but no conclusion was reached.

Some inspectors did not overlook any cracks. "This may be due to them having an inherently better inspection capability, suggesting that inspector selection is important," the report said.

Phase 1 of the study (Table 1, page 4), which was to provide baseline information on performance under "relatively benign" conditions, included three inspectors from U.K. maintenance facilities working in a "pleasant, laboratory atmosphere."

Phase 2 (Table 1) included five inspectors from major carriers and maintenance facilities in the United Kingdom and three from major airlines in the United States. This phase was designed to test the inspectors under less-than-ideal conditions such as would be encountered in an actual maintenance operation.

One such condition was a "short-shift" system, in which inspectors must try to quickly adjust from working a daytime schedule to working a nighttime schedule or vice versa. In Phase 2, inspectors worked two night-shift sessions, followed by a day and a half on the day shift and then two sessions back on the night shift. A relatively high temperature of 30 degrees C (86 degrees F) was maintained in the working facility.

The six-day test duration was chosen because previous human-factors studies indicated that two to three days are usually required for subjects to lose their self-consciousness and begin to behave normally. Six days was also judged long enough for boredom to set in.

Phase 1 studied the effect on reliability of the length of time spent continuously on an inspection task; inspection sessions were set at either 30 minutes or 90 minutes. Phase 2 attempted to include some of the random variations and disruptions that would occur in an actual work session. The length of time spent on lap-joint inspection and the method of finishing the task were varied, and inspectors were moved without warning onto different tasks.

The test specimen was a computer-aided design (CAD) tablet with a cover plate constructed to look like a section of aircraft fuselage. The cover plate simulated three rows of 40 flush fasteners at a lap joint, and had body stations situated 20 fasteners apart. The CAD tablet was connected to a computer simulator so that eddy-current signals stored in the computer could be "played" to the inspector at various locations along the row of

Table 1
Test Parameters and Conditions of U.K. CAA Human-factors Inspection Study

Item	*Condition or Value Selected*		*Typical value in practice*
	Phase 1	*Phase 2*	
Inspection task	Lap-joint inspection	As for Phase 1	
Technique	Sliding probe	As for Phase 1	One of four techniques recommended by manufacturer.
Inspector qualification	Relevant nondestructive testing technique	As for Phase 1	
Work pattern	Day shift	Night/day/night shifts	Short, two-day shift change system can occur in practice.
Inspection period	Fixed, 30 or 90 minutes	Variable, 30 minutes to 120 minutes	Lap-joint inspections are often "fitted in" between other inspections.
Work disturbance	Not included	Interruptions to some sessions	Interruptions often occur in practice.
Inspection position	Row height at eye level	Row height at either eye or knee level	Row height can vary in practice over this range.
Test surface orientation	Vertical	Vertical or 30 degrees overhung	A range of orientations is possible around fuselage.
Surface curvature	Flat	As for Phase I	Actual surfaces are slightly curved, but are effectively flat compared with the probe dimensions.
Surface finish	Smooth, grey painted surface. Fastener head outlines are visible	As for Phase I	The chosen finish is representative of a good surface finish. In practice the paint may be flaking.
Temperature	Ambient	30 degrees C	Chosen for Phase 2 to induce a low level of arousal during the tests.
Humidity	30%–50%	As for Phase I	Ambient values.
Noise level	60dB–70dB	As for Phase I	Typical of background hangar conditions. In practice louder bursts of up to 100 dB can be caused by riveting operations etc.
Lighting	Normal laboratory standard	As for Phase I	Hangar lighting is generally adequate.

Source: U.K. Civil Aviation Authority (CAA) fasteners. The set-up allowed researchers to simulate an infinite number of test samples with differing crack densities and distributions.

The eddy-current signals differed between Phase 1 and Phase 2. Those in Phase 1 "did not have the small variations in phase angle and path encountered in practice and this tended to facilitate differentiation between signals from good and cracked material," the report said. Signals generated in Phase 2 more closely approximated those that would be found in actual working conditions; they included more subtle variations and required a greater degree of discrimination to interpret cracks.

Two other types of signals were generated, both representing anomalies. One type was typical of the low-amplitude trace that would result from scanning over regions of abnormally thick paint. The second type simulated the response that would be seen from scanning nontypical fastener material.

Cracks occurred either singly or in clusters of two to eight. The average rate of crack presentation was every one minute to three minutes, and clusters were presented every one minute to seven minutes. At those rates, cracks occurred in one of every 150 fasteners, a relatively low figure. For thick paint signals, the rate was one crack per 2,000 fasteners.

Five of the 11 inspectors in both phases of the study accurately detected every crack and cluster of cracks. Of the remaining six inspectors, four had a crack-detection error rate under 0.6 percent and a cluster-detection error rate under 1.4 percent. One inspector had a crack-error rate of 1.2 percent and cluster-error rate of 2.7 percent.

Another inspector made significantly more mistakes, with a 3.8 percent error rate on cracks and a 6.2 percent error rate on clusters. Visual analysis showed that he manually held the straight-edge during scanning, which caused it to slip. He also scanned faster than the inspection procedures specified, which caused him to miss cracks. But he changed his technique during the later phase of the study so that the straight-edge was attached to the fuselage with two-sided tape, which was the method used by the other inspectors. His results then improved significantly.

"Overall, the performances of all the inspectors [were] good, [but] a small number of cracks were missed and the causes can be established, in most cases, from the video recordings and [investigator's] notes," the report said. "In Phase 1 [Table 2, page 6], the major cause of error was failure to interpret accurately the extent of a crack cluster. The video records show that on some occasions an inspector did not stop scanning

Table 2
Phase 1: Inspector Performance on Cracks

Inspector	*1*	*2*	*3*
Number of Rows Inspected	867	814	877
Number of Fasteners Inspected	35,547	33,324	35,957
Length of Fuselage (Feet)	2,961	2,778	2,997
Duration (hours:minutes)	23:57	24:02	23:22
Number of Cracked Rows	119	112	112
Number of Cracked Fasteners	507	471	465
Number of Crack Clusters	223	209	207
Errors			
Number of Cracks Missed	6	2	0
Number of Clusters Incorrectly Sized	6	2	0
Error Rate (%)			
Cracks Missed (%)	1.2	0.4	0
Clusters Incorrectly Sized (%)	2.7	1.0	0
Source: U.K. Civil Aviation Authority (CAA)			

as the first signal in the cluster came on the screen; the inspector reacted as if the second signal was the first signal he had encountered. Except for the case where a crack in a row of 'thick paint' low-amplitude signals was recorded, no single cracks were missed.

"In Phase 2 [Table 3, page 7]," the report continued, "both single cracks and cracks in a multicrack cluster were missed. The most common cause of failure was for an inspector to scan faster than specified in the procedure, with the result that the signal trace normally displayed

Table 3
Phase 2: Inspector Performance on Cracks

Inspector	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Number of Rows Inspected	605	369	626	617	735	821	559	461
Number of Fasteners Inspected	24,805	15,129	25,666	25,297	30,135	33,661	22,919	18,901
Length of Fuselage (Feet)	2,067	1,260	2,136	2,106	2,511	2,805	1,908	1,575
Duration (hours:minutes)	21:23	19:51	20:42	20:19	21:35	22:57	19:46	21:34
Number of Cracked Rows	88	51	94	92	100	109	82	79
Number of Cracked Fasteners	361	219	383	375	402	453	340	324
Number of Crack Clusters	166	98	182	181	193	211	159	145
Errors								
Number of Cracks Missed	0	0	0	1	1	17	0	2
Number of Clusters Incorrectly Sized	0	0	0	1	1	13	0	2
Error Rate (%)								
Cracks Missed (%)	0.0	0.0	0.0	0.3	0.3	3.8	0.0	0.6
Clusters Incorrectly Sized (%)	0.0	0.0	0.0	0.6	0.5	6.2	0.0	1.4

Source: U.K. Civil Aviation Authority (CAA)

on the screen was incomplete or missing.

"Other causes of error observed in Phase 2 were: Loss of place, whereby the inspector paused during scanning and then continued from further along the row; loss of concentration, where the inspector looked away from the screen at a crucial moment, sometimes due to a distraction; and failure to detect a crack near the lower end of the amplitude range. In one case there was a decision error at the analysis stage."

The most difficult task for the inspectors was detecting low-amplitude signals that simulated cracks in areas of thick paint (Table 4, page 8). Inspectors in Phase 1 did well because of the clarity of the display

Table 4
Inspector Performance on Signals Representing Thick Paint

Phase 1

Inspector	*1*	*2*	*3*
Number of Rows Inspected	867	814	877
Number of "Thick-paint" Rows	8	8	7
Number of "Thick-paint" Fasteners	78	78	73
Number of "Thick-paint" Fasteners Missed	20	0	0

Phase 2

Inspector	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Number of Rows Inspected	605	369	626	617	735	821	559	461
Number of "Thick-paint" Rows	2	2	2	2	2	2	2	2
Number of "Thick-paint" Fasteners	11	10	10	10	10	10	10	10
Number of "Thick-paint" Fasteners Missed	0	10	5	10	3	10	8	8

Source: U.K. Civil Aviation Authority (CAA)

provided. Performance in Phase 2 was different.

"Only one inspector successfully detected all the low-amplitude signals, and three inspectors did not detect any of them. The others detected a percentage in the range 30 percent to 80 percent. The main factor governing the detection of 'thick paint' signals appeared to be the ability of the inspector to distinguish between fastener signals from the low end of the amplitude range and the lower amplitude anomalous signals."

A variety of ultrasonic inspections were also given to the inspectors, although they were included mainly as alternatives to lap-joint inspections to introduce some variety into the work schedule.

Ultrasonic results were not as good as expected. Calibration variations of at least 10 decibels (dB) were common in most inspectors' results, and in one case a difference of 25 dB was recorded for an inspector performing one of the calibration procedures. Only one inspector showed uniformity in calibration, while differences of more than 20 dB occurred among inspectors.

"This variability may be due, in part, to the complexity of the calibration operation," the report said, "but nevertheless the procedures and calibration blocks were provided by a major [air] carrier and were typical of a practical inspection. ... Clearly, such variation in calibration settings would have a profound effect on the sensitivity of an inspection, and there is a need to ensure procedures and techniques are developed in a way which minimizes the potential for error."

In one-to-one interviews after the tests, inspectors cited several variables that affected their performance. Boredom, high ambient temperatures and sleeping difficulties were said to be major problems. Less troublesome for the inspectors were observation by the video cameras, the constant noise level employed (to recreate a realistic working environment) and the isolated working conditions.

The results of Phase 2 showed a clear superiority between the performances of the first three inspectors (with an error rate of zero) and those of most of the others. " ... [T]he first three inspectors occupied leading positions in their inspection departments, which suggested that they were above-average inspectors," the report said. Although the study's analysts considered other possible explanations, they tentatively concluded that "the results indicate that the inherent ability of an inspector is an important parameter."

The results could not be correlated with variations in the work environment, length of inspection sessions or interruptions, the report said.

The CAA report made several recommendations to improve inspection reliability.

The failure to detect low-amplitude signals that are typical of scanning over regions of thick paint was of particular concern to the researchers. Their solution was that "refresher courses be given at appropriate intervals to ensure that inspectors are skilled at meeting all reporting aspects of an inspection, including the observation and detection of low-amplitude signals in regions of thick paint."

Along the same lines, the report noted that human errors were often caused by inadequately defined inspection procedures. For instance, the method of affixing the straight-edge to the row of fasteners was not specified in the procedures, and the inspector responsible for the largest number of errors initially used poor technique before correcting himself. Said the report, "It is therefore concluded that the reliability of inspections would be improved if a systematic analysis of inspection procedures [was] carried out ... to identify and control potential sources of simple human error."

The report also recommended a larger study to analyze a greater number of inspectors in a more detailed study "to examine more closely the influence of the caliber of an inspector on reliability."♦

Editorial note: This article was based on *A Study of the Human Factors Influencing the Reliability of Aircraft Inspection*, by R.A. Murgatroyd, G.M. Worrall and C. Waites. U.K. CAA paper no. 95005. London, England, 1995.

About the Author

Barry Rosenberg is a New York–based journalist covering aerospace and defense. He is senior correspondent for the Aviation Week Group's Overhaul & Maintenance *magazine.*

Turbine Engine and APU Schools Scheduled

UNC Airwork has finalized its 1996 schedule for the company's Turbine Engine Line Maintenance and Field Troubleshooting Schools. Held each year at the Airwork facilities in Millville, New Jersey, U.S., and Miami, Florida, U.S., the schools are intended for experienced turbine-engine technicians, supervisors and managers who need the latest information on engine and auxiliary power unit (APU) technology. The early-1996 schedule includes:

Date	Program	Location
January 23–24	RR Spey	Millville
January 25	GTCP 36-100 APU	Millville
February 6–7	P & WC JT15D	Millville
February 20–21	P & WC Twin Pac	Miami
February 20–21	P & WC PT6A	Millville
March 5–6	GE CJ610/ CF700	Millville
March 7	T62-T40 APU	Millville
March 19–20	Allison 250-C28/C30	Millville
April 2–3	Allison 250-C20B	Millville
April 23–24	P & WC PT6A	Miami
April 25–26	Allison 250-C20B	Miami

For more information, contact the School Coordinator at 1-800-257-7077 (in the United States and Canada), fax (609) 825-6408 or write: UNC Airwork, Millville Municipal Airport, 101 Bogden Boulevard, Millville, NJ 08332-4814 U.S.

One-hour Seminar Scheduled for Maintenance Products

Loctite Corp., maker of the Loctite and Permatex products used in aviation maintenance, has issued a 10-page booklet that also outlines its technical support program. Training and technical support are offered to airframe and powerplant (A & P) technicians, including those with inspector authorization privileges (IA's), line crews and maintenance managers.

For more information, contact the Loctite Aviation Market Manager at 1-800-323-5106 (United States and Canada only).

Laser Technology Detects Damage in Composite Materials

Fiber-reinforced materials (polymer matrix composites) are being more widely used in high-performance aircraft because they can be fabricated easily into parts of high strength and low weight. Nevertheless, such composite materials may seriously degrade in strength when exposed to elevated temperatures from sources such as lightning, misdirected jet exhaust or inadvertent exposure to fire or hot gases.

Although composite material can appear undamaged to the naked eye, invisible thermal damage can cause the material to lose more than half of its design strength. Such damage is usually detectable in metal structures, but the increasing use of composite materials that cannot be inspected with the same evaluation methods as metals has concerned the aviation maintenance community.

Researchers in the U.S. Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) have developed a method of imaging heat-induced damage in epoxy-resin composites. Early signs of thermal damage in advanced aircraft composite materials can be pinpointed quickly using ORNL's Composite Damage Imager (CDI).

The system consists of a video camera, laser, computer and special optics. The system is claimed to offer a fast, flexible, accurate and easy-to-use means for imaging damage to aircraft flaps, control surfaces, doors, etc.

The high-resolution image is recorded on video equipment using a camera containing a charge-coupled device and special optical filters. The device enables the production of a false-color image that highlights the damaged areas.

The technology was originally developed to support work for the U.S. Air Force and U.S. Navy. For more information, contact the ORNL Public Affairs office at (615) 574-4160.

First Working Maintenance Technician Appointed as NTSB Member

On Aug. 17, 1995, U.S. President Bill Clinton nominated and the U.S. Senate confirmed John Goglia as the newest member of the U.S. National Transportation Safety Board (NTSB). Goglia, with more than 30 years of experience in the aviation industry, has worked with a major air carrier and has been involved with the International Association of Machinists and Aerospace Workers (IAMAW). He was the IAMAW's principal specialist on aviation issues, serving as their liaison to the U.S. Federal Aviation Administration (FAA) and other agencies. Goglia was also the IAMAW representative on the Aviation Rulemaking Advisory Committee, which evaluates and recommends changes regarding aviation safety and operational regulations.

Employed by USAir in Boston following his graduation from East Coast Aero Technical School in Bedford, Massachusetts, U.S., Goglia undertook a wide range of increasingly responsible positions, from entry-level mechanic to lead mechanic and later inspector. He received the 1994 FAA/Industry Aviation Mechanic of the Year Award and he is chairman and founding member of the National Coalition for Aviation Education. His NTSB term will expire Dec. 31, 1998.

New Diagnostic System Trials To Begin

America West Airlines is to engage in a field trial of an airline maintenance and operations support system (AMOSS) developed by Honeywell Inc. and Computing Devices International. The ground-based software system is intended to address the rising cost of airline maintenance and flight operations.

AMOSS is said to provide state-of-the-art fault isolation and diagnostic capability that integrates aircraft and ground-support services. The system provides for various ground services to interact electronically with each other and with in-flight aircraft.

Honeywell says that benefits include reduction of diagnostic and maintenance time, improvement of diagnostic accuracy and minimization of paperwork and duplication. AMOSS is also intended to reduce turnaround times at the gate by improving troubleshooting and eliminating instances in which faults cannot be found or duplicated on the ground after being reported while the aircraft is airborne.

The trial, with AMOSS supporting daily operations of America West, will begin in March 1996. The results will be incorporated into the system offered for sale to airlines.♦

Corrosion Results in Another Landing Gear Failure

Corrosion problems are most commonly associated with aluminum structures that have poor drainage or are subjected to exhaust gases. Even modern aircraft can have highly stressed components that are intolerant of defects or lack of preventive maintenance, such as routine lubrication and maintenance of sealants.

In September 1995, a Boeing 767, operated by a major international air carrier, suffered a collapse of the right-main landing gear (MLG) during taxi-out for takeoff. The airplane was just over five-years-old and had accumulated 3,807 flight cycles and 25,196 flight hours. Postaccident examination of the failed landing gear revealed multiple fractures of the outer cylinder aft trunnion, which had broken into three large sections. Metallurgical analysis of the failed component revealed multiple stress corrosion cracks emanating from the outer cylinder aft trunnion bore.

The B-767 MLG is a conventional, four-wheel, dual-tandem gear that has a metering pin orifice shock strut (Figure 1). The gear has four support points attaching to the airframe structure. The outer cylinder of the MLG assembly transfers operational loads from the truck assembly (the wheels and tires) to the four support points.

The aft trunnion support point is a pin-in-socket design, in which the pin is held inside the trunnion by a crossbolt. The trunnion pin connects the outer cylinder to the outer cylinder of the MLG beam. The trunnion pin is housed inside the upper aft end of the outer cylinder using temperature differential shrink fit.

The outer edges of the bushing flange and the cylinder are covered by a putty-like flexible fillet seal intended to prevent moisture from entering under the bushing flange and cylinder chamfer area. The trunnion cylinder bore has a five-inch-(12.7-centimeter-)wide increased-diameter section along the inner circumference of the cylinder that serves as a lubrication reservoir.

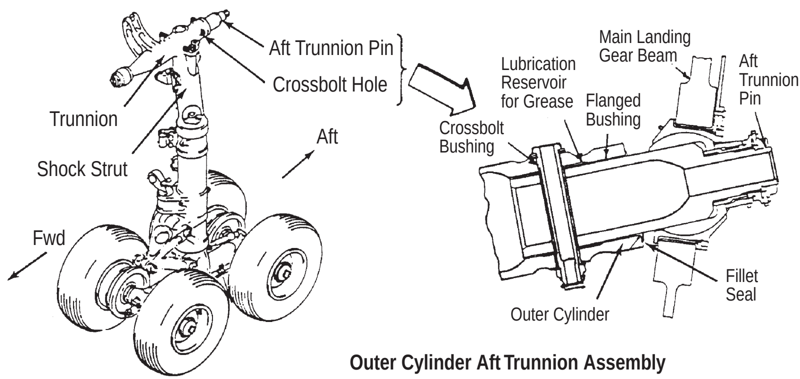
The U.S. National Transportation Safety Board (NTSB) laboratory examination of the failure fragments revealed that the aft trunnion had six areas of stress corrosion cracking (SCC). The largest area of SCC originated at a corrosion-pitted area on the inside corner of the crossbolt hole, extending through to the outside diameter wall approximately five inches (12.7 centimeters) in the aft-and-up direction. Other SCC cracks were as small as 0.04 inch (one millimeter) deep by 0.1 inch (2.54 millimeters) wide.

The inside surface of the outer cylinder aft trunnion was heavily corroded in two distinct circumferential bands. The corrosion bands were located at the forward and aft edges of the lubrication reservoir. The reservoir contained a layer of dried grease that covered the lower half of the reservoir. After it was cleaned, examination of the reservoir surface disclosed severe corrosion damage under the dried grease. Three of the SCC areas emanated from these corrosion-damaged areas.

There have been three previous fractures of B-767 landing gear trunnion assemblies, but these fractures have originated from corrosion damage at the aft end of the aft trunnion near the chamfer area under the trunnion-pin bushing outer flange. This most recent failure was induced by corrosion on the trunnion bore.

The three earlier fractures had all occurred while aircraft were parked at the gate. The three aircraft were from six-years-old to eight-years-old and had accumulated respectively 6,640, 13,745 and 14,046 cycles and 25,841, 27,177 and 28,887 flight hours at the times of the failures. The manufacturer had issued a service letter (SL) to provide visual inspection procedures and repair

Boeing 767 Landing Gear Assembly



Source: U.S. National Transportation Safety Board

Figure 1

instructions following the third incident. The U.S. Federal Aviation Administration (FAA) followed the SL with an airworthiness directive (AD).

The AD was applicable to aircraft having MLGs older than 5 1/2 years or that had been in service more than 5 1/2 years since last overhaul, and required visual inspection of the outer cylinder aft trunnion of the MLG to determine if the fillet seal was cracked or missing. If the seal was found to be defective, the AD called for removal of the fillet seal, cleaning with a solvent, application of a corrosion inhibiting compound (CIC) and a visual inspection to detect corrosion. If any corrosion was detected, the AD called for removal of the aft trunnion and repair before further flight. The AD and SL did not specify how to detect corrosion after applying the CIC or whether the CIC was to be used in detecting the corrosion.

Following the fourth failure, the FAA issued a telegraphic AD calling for an external general visual inspection of the lower half of the aft trunnion of B-767 MLG within 48 hours to detect discrepancies, to be repeated each 48 hours thereafter on airplanes having MLG older than four years. The NTSB did not believe that the AD went far enough in its inspection requirements and was concerned that internal corrosion might be present and remain undetected. The NTSB believed that a reliable inspection technique should be developed to detect corrosion and cracks in the trunnion bore area.

The manufacturer and other operators are developing nondestructive inspection (NDI) techniques to detect internal corrosion and cracks in the trunnion bore area, but such developments may require a significant amount of time. Until an effective and definitive NDI technique is established, the NTSB recommends that the entire MLG outer cylinder aft trunnion surfaces be inspected frequently, and in detail, for cracks and corrosion.

In-flight Fire Traced to Improper Electrical Wiring

In December 1994, a Learjet 35A crashed while operating in support of a military training mission in the western United States. The aircraft was under contract to the U.S. Air Force and had been modified with electronic equipment to provide special capabilities to support F-16 fighter aircraft training of the U.S. Air National Guard.

While inbound to their normal operating base, the flight crew declared an emergency because of engine-fire indications. They flew the airplane toward a right base leg for the requested runway, but the airplane continued past the airport. During the radio transmissions to the tower, the crew was discussing their attempts to diagnose the emergency conditions and control the airplane. It crashed in a housing area, with the landing gear extended. Both pilots were killed, 21 persons on the ground were injured and 12 apartments in two buildings were destroyed or substantially damaged by impact and fire.

The NTSB determined that the probable causes of this accident were:

- Improperly installed electrical wiring for special mission operations that led to an in-flight fire that caused airplane systems and structural damage and subsequent airplane control difficulties;

- Improper maintenance and inspection procedures followed by the operator; and,

- Inadequate oversight and approval of the maintenance and inspection practice by the operator in the installation of the special mission systems.

Although the airplane was operating as a public-use aircraft, the contract with the Air Force required the contractor to maintain the aircraft in accordance with FAA regulations. The Air Force and the Air National Guard had therefore relied on the FAA-approved maintenance program and the FAA-approved Form 337 (covering the installation of the special mission equipment) to ensure that the airplane was properly maintained and altered.

Nevertheless, as a public-use aircraft the altered Learjet was subject to the Air Force's inspection program and oversight, which the NTSB found to be less comprehensive than the FAA oversight under U.S. Federal Aviation Regulations (FARs) Part 135. Accordingly, the NTSB stated its belief that the U.S. Department of Defense should have conducted more thorough audits of contractor maintenance actions on specific aircraft.

A similar airplane had been altered with the installation of this special mission equipment in 1989, in accordance with the provisions of an FAA-approved Form 337 and was approved by an FAA avionics inspector. When the accident aircraft was later altered, the work was done under the previously approved Form 337 and no further FAA approval was required. The work was accomplished by the contractor's technician, who held inspection authorization (IA) privileges. This technician signed off the installation and thereby accepted responsibility for the quality and oversight of the installation in accordance with the originally FAA-approved Form 337.

According to the NTSB, the technician failed in these responsibilities.

The NTSB said that a qualified technician should not have overlooked basic electrical-wire installation practices, such as ensuring proper current-overload protection for the entire system. Similarly, the failure of the FAA-certified avionics inspector to compare the actual installation with the specified installation procedures was found to be inexcusable. The instructions for the work specified the proper installation, but were not followed by the technician, and the IA did not meet his inspection responsibilities. The failures, coupled with the fact that 14 additional airplanes had been altered incorrectly, reflect on the competence of the individuals involved and a lack of adequate oversight by the operator's management personnel.

All the altered airplanes were grounded until each aircraft was inspected and properly reworked. A new Form 337 was written and approved. The revised form included more detailed instructions on the proper installation.

The NTSB has issued a recommendation calling for the FAA to publish a special bulletin describing the circumstances of this accident, including the consequences of improper installation of the special mission wiring, in which electrical power wires were unprotected by current limiters. In addition, the NTSB recommended that the FAA emphasize that all major aircraft repairs and alterations requiring Form 337 must be performed in strict accordance with the technical data it contains, and that it is unacceptable to use similar work done on another aircraft as a technical guide in lieu of the information on the Form 337.♦

High-resolution Protractor Offers 0.01-degree Accuracy

Kell-Strom Tool Co. has introduced the Pro 3600 high-resolution digital protractor. This electronic protractor, which is an upgrade from the original Pro 360 unit, is said to provide the highest degree of accuracy available in a digital-reading protractor. The manufacturer claims accurate readings to within 0.01 degree throughout its 360-degree range.

Pro 3600 high-resolution digital protractor from Kell-Strom Tool Co.

The unit provides immediate digital indication of level, plumb and all angles in-between. It includes an alternate reference (ALT Zero) button, ALT Zero annunciator, HOLD annunciator and a liquid crystal display. The device also has an RS-232–compatible serial port connector for a computer interface.

For more information, contact: Kell-Strom Tool Co., 214 Church Street, Wethersfield, CT 06109 U.S. Telephone: (203) 529-6851.

Splicing Shielded Cables Made Easier

The termination or splicing of shielded wires and cables has always been a time-consuming and sometimes difficult task for technicians. With the development of its SolderShield sleeves, Raychem Corp. claims to have solved this problem.

SolderShield is a flux-coated, solder-impregnated copper shield encased in a heat-shrinkable insulation sleeve. During installation, the SolderShield is positioned over the completed conductor splice area or onto the feed-through eyelet and the entire assembly is heated. The manufacturer says that as the assembly heats, the insulation shrinks, the solder melts and flows, and the braid conforms to the cable shields. Because the sleeve is transparent, the completed splice or joint is fully inspectable.

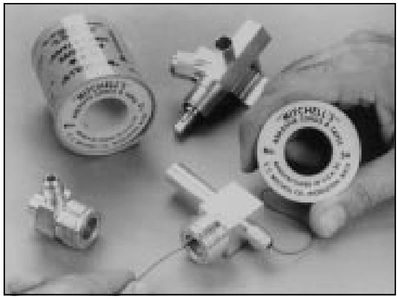
The manufacturer says that these splices maintain the electrical grounding and electromagnetic-interference (EMI) protection that is increasingly required in more systems in modern aircraft. In addition to their use for splices and repairs, these devices are designed to terminate single or multiple shielded cables to a bulkhead or box. The technique is said to eliminate EMI problems in sensitive electronic systems, and provides strain relief for the cable without the problems associated with some special connectors.

For more information, contact: Raychem Corp., 300 Constitution Drive, Menlo Park, CA 94025-1164 U.S. Telephone: (415) 361-3333.

Abrasive Cords Remove Contaminants in Hard-to-reach Spots

Removing burrs, deposits or contaminants from inside valves or fittings is often difficult without special tooling or fixtures. E. C. Mitchell Co. has introduced a line of flexible abrasive cords that it says will solve many of these problems. These abrasive cords range in size from 0.012 inch (0.3 millimeter) to 0.150 inch (3.8 millimeters) in diameter, or in the form of a flat tape ranging from 1/16 inch (1.6 millimeters) to one-fourth inch (6.4 millimeters) in width.

The cords are impregnated with aluminum oxide or silicon carbide to remove stubborn contaminants or deposits, and crocus for ultrafine polishing of internal areas. Flexible enough to reach into holes, slots and contoured surfaces, these abrasive



Abrasive cords from E.C. Mitchell Co.

cords can be used to grind machining burrs, remove baked-on deposits, or polish hard-to-reach places.

For more information, contact: E.C. Mitchell Co., 88–90 Boston Street, Middleton, MA 01949-0907 U.S. Telephone: (508) 774-1191; Fax: (508) 774-2494.

Plastic Abrasion Protector Provides Damage Resistance

M. M. Newman Corp. has introduced a line of spirally cut plastic wrapping material to protect hydraulic, fuel and pneumatic hoses, as well as wiring bundles, from abrasion and damage that can result in leaks or system failure. The protective wrap can be applied to new or existing installations without tools.

According to the manufacturer, the material conforms to American Society for Testing and Materials (ASTM)

Specification Taber D 1044 for abrasion resistance. It is recognized by Underwriters Laboratories (UL) and available in polyethylene, ultraviolet-(UV-)resistant polyethylene for outdoor use, self-extinguishing nylon and Teflon, which is chemically inert and nonflammable. Bright colors are also available to simplify safety marking of bundles and plumbing runs.

For literature and a free sample of the Heli-Tube Abrasion Protector, contact: M. M. Newman Corp., 24 Tioga Way, Marblehead, MA 01945 U.S. Telephone: (617) 631-7100; Fax: (617) 631-8887.

Self-stick Cable Ties Ease Installation

Nelco Products Inc. is marketing self-stick cable tie mounts that are said to have an "aggressive" adhesive backing. These nylon cable tie mounts feature a pressure-sensitive, rubber-based adhesive backing that the manufacturer says will stay in place on almost any clean and dry surface. The mounts are packaged two to a strip in three-fourth-inch or one-inch square sizes. The mounts can be supplied with a wide variety of permanent or releaseable cable ties in various lengths.

These cable tie mounts should be suitable to separate and secure wires, cable and tubing and will enable technicians to install cable ties at inaccessible locations without the need for drilling holes or using additional tools. According to the manufacturer, the adhesive exhibits a static shear of 17.6 pounds per square inch (PSI) at 72 degrees F (22.2 degrees C) and maintains its bond to 120 degrees F (48.8 degrees C).

For more information, contact: Nelco Products Inc., 77 Accord Park Drive, Norwell, MA 02061 U.S. Telephone: 1-(800) 346-3526 (United States and Canada only) or (617) 871-3115; Fax: (617) 871-3117.

Cleaners Formulated to Clean with Safety

Church & Dwight, makers of the familiar Arm & Hammer bicarbonate of soda products, has introduced aviation cleaning products that the company says addresses the full range of ferrous and nonferrous metal cleaning requirements. Marketed under ARMAKLEEN, these products are based on a what the manufacturer says is unique inorganic carbonate-based chemistry that will clean a variety of soils at a faster rate and more effectively than previously available products.

ARMAKLEEN M-Aero is corrosion-inhibited for cleaning aluminum alloys and other nonferrous metals and, according to the company, has met rigorous aerospace/aircraft specifications including those set by the Boeing Co., McDonnell Douglas and Lockheed Martin. These products are mildly alkaline, nonhazardous, nontoxic and nonflammable.

For more information, contact: Church & Dwight Co. Inc., 469 North Harrison Street, Princeton, NJ 08543-5297 U.S. Telephone: 1-800-221-0453 (United States and Canada only) or (609) 683-5900.

Adapter Couples Video To Conventional Borescopes

Welch Allyn has introduced a special adapter for use with its VideoProbe XL flexible video borescope system for aircraft use. The XLBA1 adapter is said to enable users to attach their rigid or flexible borescopes to the XL and view the high-resolution image on a video monitor.

The adapter is a single plug at one end for connection to the light source, and eyepiece and light guide connectors at the opposite end that couple to the borescope's eyepiece and light guide post. According to the manufacturer, connectors are available to fit almost every make and model of rigid and flexible borescopes.

For more information, contact: Welch Allyn, Imaging Products Division, 4619 Jordan Road, Skaneateles Falls, NY 13153-0187 U.S. Telephone: (315) 685-8969; Fax: (315) 685-7905.

Metal Lubricants and Coatings Supplied in Non-CFC Aerosol Containers

Aviation Laboratories has specialty coatings and lubricants for use in aviation maintenance. Its product line includes:

- AVL Greaseless Lubricant 1 — Forms a greaseless, almost dry film that resists dust and dirt build-up. Suitable for electrical and avionics use;
- AVL Industrial Strength Lubricant 2 — Penetrates with added corrosion protection for up to one full year. Forms a nondrying oily film;
- AVL Heavy-Duty Rust Inhibitor — Forms a soft waxy film designed to stop rust and corrosion. Provides up to two years protection;
- AVL Fast Acting Cleaner/Degreaser — A one-step process that both cleans and degreases. Requires no rinsing, and is suitable for electrical and avionic uses;
- AVL Eco-Safe Cleaner/Degreaser — An environmentally

friendly product intended to be safe on all metals and most plastic parts. Replaces trichloroethane.

- AVL Electro Contact Cleaner — A premium aviation cleaner that penetrates, cleans and degreases, removes dust and buildup without leaving a noticeable film.

None of the AVL products contain any chlorinated fluorocarbon (CFC) products and the U.S. Occupational Safety and Health Administration (OSHA) Material Safety Data Sheet (MSDS) forms are provided with each product.

For more information, contact: Aviation Laboratories, 5401 Mitchelldale, #B6, Houston, TX 77092 U.S. Telephone: (713) 864-6677; Fax: (713) 864-6990.

Strap-on Footwear Provides Traction on Icy Ramps

For technicians working outside during cold-climate winters, icy ramps pose a hazard of slipping and falling. The Jordan David Safety & Health Products Co. has improved its Ice Grips, which are strap-on footwear designed to be worn over shoes and boots. The sole of each Ice Grip has a total of 18 big hex-head screws, which provide gripping power on thick ice. The Ice Grips are intended only for use by personnel who are working on ice-covered ramps or parking areas.

Ice Grips from Jordan David Safety & Health Products Co.

For more information, contact: Jordan David Safety & Health Products, P.O. Box 400, Warrington, PA 18976 U.S. Telephone: 1-800-331-4268 (United States and Canada only); Fax: (215) 343-9343.

Hose Couplers Designed To Avoid Accidental Disconnection

Dragging coupled hoses across the floor or over obstructions poses a possibility of unintentional disconnection. To reduce that likelihood, new AirMate quick-connect couplers from TOMCO have an integral front flange designed to absorb stress forces from dragging.

The couplers, available in one-fourth-inch and three-eighth-inch hose internal-diameter sizes, have a brass body and steel sleeve. The flange guards the retractable sleeve.

AirMate from TOMCO Division C.S.P. Inc.

For more information, contact: TOMCO Division C.S.P. Inc., 30520 Lakeland Blvd., Willowick, OH 44095-9986 U.S. Telephone: (216) 944-9000; Fax (216) 944-8203.

Remote Visual Inspection Units Feature Built-in Light Source

Olympus America Inc. offers two new, portable remove visual inspection units that combine a built-in light source and video imaging equipment. The units can be used with video imagescopes, flexible fiberscopes or rigid borescopes.

The new units are designated the ILK-C video/light source combination unit and the MH-542 video frame. The ILK-C is equipped with a built-in 150-watt light source, and connects to Olympus's IV-5A video camera with a detachable liquid-crystal display (LCD) monitor. The MH-542 accepts a 300-watt light source and also accepts the IV-5A, whose features are said to include an integration circuit to increase light sensitivity for imaging in low light; high resolution; digital freeze-frame capability; and automatic light-source brightness, gain control and white balance.

Visual Inspection Unit from Olympus America Inc.

For more information, contact: Olympus America Inc., Industrial Fiberoptics Division, 2 Corporate Center Drive, Melville, NY 11747-3157 U.S. Telephone: (516) 844-5888.♦

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