Human Factors Study Suggests CRM Training Shows Promise in Aviation Maintenance

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Editorial Coordinator

In 1989, the U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine contracted with Galaxy Scientific Corp. to conduct a study published in several increments as *Human Factors in Aviation Maintenance*.[1] It is the first objective, scientific study ever conducted in this field.[2]

Galaxy involved many industry experts and government personnel in the project, and:

- Conducted seven workshops, involving nearly 1,000 participants overall;
- Developed a demonstration computer-based training

program covering the environmental control system for a large jet aircraft. The completed program has been distributed to more than 100 aviation maintenance technician (AMT) training schools (certificated under U.S. Federal Aviation Regulations [FARs] Part 147) and most of the large U.S. airlines;

- Developed a CD-ROM-based hypermedia information system to demonstrate this technology for presenting vast quantities of technical information by combining text, graphics, animation and sound. More than 700 copies of the CD-ROM disk have been distributed;

- Published more than 100 articles and scientific papers;

- Developed a computer-based performance enhancement system as a job aid for FAA field inspectors; and,

- Issued four progress reports of 150 to 200 pages each, which detailed individual projects and summarized findings and plans.

In the first progress report, "human factors" was defined:

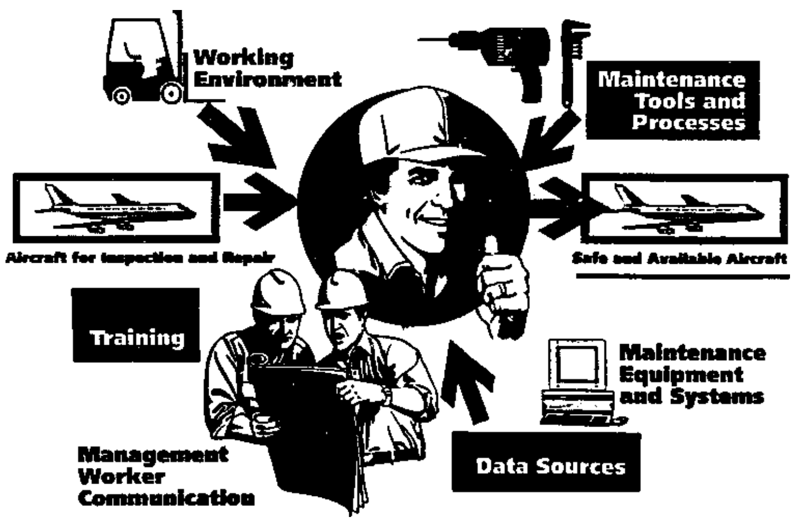
"Human Factors studies the performance of the human as an operating element within a goal-directed system. In the design and use of a system, the human is viewed in the same manner as any system component. If the system is to function effectively and efficiently, the designer must understand the operating characteristics of each component, including the human. Human Factors research seeks information on laws of human behavior, the capabilities and limits of humans, effects of environmental factors, and rules for optimizing the use of humans in present-day systems. The research team recognizes that it is not always possible to treat the human as a predictable element in a system. Human nature, work ethic, and a variety of such innate behavioral variability threatens a classical engineering treatment of the human in a system.

"The broad goals of human factors research require a multi-disciplinary effort drawing on information from specialties such as: psychology, physiology, ecology, engineering, medicine, education, computer science, and others. Information from these sources is used to develop procedures for system design, for operational system use, and for ongoing evaluations of system effectiveness. In all cases, primary attention is given to the human operator."

Figure 1 illustrates the variables that affect the performance of the AMT. Human factors examines these variables and their potential to affect the efficiency and quality of the work performed by the AMT. Understanding the human factors involved and taking action to optimize their effects can help operators make more efficient use of manpower while enhancing the margins of safety.

The study analyzed several maintenance organizations from both the organizational and systems engineering perspectives. It assessed the interaction of AMTs with the organization, focusing on communications, and how the technical goals were established and accomplished.

Eight U.S. companies were studied. More than 200 AMTs, their foremen and managers were interviewed and observed. The study indicated that AMTs did not always have a complete understanding of the company's policies and goals, nor did they understand their individual roles in meeting these goals.



Source: U.S. Federal Aviation Administration, Office of Aviation Medicine

Figure 1

The survey confirmed that effective communications is paramount for ensuring coordination, cooperation and improved work performance. Where communication was found not to be a high priority, there was usually higher-than-average personnel turnover, low morale and frustration among the work force. Teamwork is necessary to facilitate coordination among maintenance, planning, stores and back shop personnel.

Crew resource management (CRM) training was developed in the late 1970s. (It was then called "cockpit resource management" and thought to apply only to cockpit crew members). The value of such training was quickly recognized and it has subsequently been adopted and spread throughout the worldwide aviation industry, including aircraft maintenance.

CRM typically involves training in communications, self-knowledge, situational awareness and assertiveness. One of the most valuable aspects of CRM training has proven its benefit in promoting effective communications and teamwork.

During the study, a major U.S. air carrier was observed as the airline developed and implemented a CRM program for its maintenance managers and supervisors. The airline intended to train all of its 1,800 maintenance directors, managers, supervisors and assistant supervisors.

The general objectives of the CRM training were to:

- Diagnose the organizational "norms" and their effects on safety;
- Promote assertive behavior;
- Understand individual leadership styles;
- Understand and manage stress;
- Enhance rational problem solving and decision making skills; and,
- Enhance interpersonal skills.

By its second year, more than 1,000 individuals had received the training and its effect on subsequent performance and attitude changes could be realistically evaluated.

The company gave a questionnaire to each of the trainees before they attended the CRM course. Each trainee used a unique code identifier so that responses could be anonymous and therefore candid, while providing for each participant's later responses to be compared with the original answers. A post-training questionnaire was also completed by each trainee, and follow-up questionnaires were mailed to participants at two, six and 12 months following their CRM training.

The combined results after the first full year of the CRM training confirmed an improvement. Many individuals reported changing their behaviors to take advantage of what they had learned in the CRM training. Overall, the trainees showed improved attitudes toward sharing responsibility, coordinating, speaking up and recognizing the causes and effects of stress within their work groups.

Specific operational improvements, which were felt to be directly related to CRM training, were noted. These included a reduction in aircraft ground damage incidents and occupational injuries. Intangible results were also realized in that many individuals said that they were communicating better and working better with others after the CRM training. Some also reported that they believed that they were better listeners and were more aware of others. Informal comments from individual workers within the groups included comments such as “the boss’s style has changed considerably.”

The air carrier’s experience suggested that CRM has promise in the aviation maintenance arena. The study noted that maintenance management had generally been more enthusiastic and receptive to CRM concepts than the airline’s pilots.

A Phase 2 study classified human error into two fundamental categories: slips and mistakes.

Slips were defined as resulting from automated behavior when the goal was correct but some aspect of the execution was flawed.

Mistakes were defined as the result of a flaw in the cognitive process, such as not understanding the goal of the task.

Slips were considered minor and the offender frequently corrected the error. Mistakes, on the other hand, were more serious and usually were not recognized by the offender.

Current aircraft structural designs are intended to be used indefinitely and are certified as “damage-tolerant.” This approach accepts that cracks and corrosion in metal aircraft will develop, but by establishing inspection intervals that will detect the defect before it presents a hazard to safe flight, the continuing integrity of the structure is ensured. The inspections are conducted by humans, sometimes aided by X-ray, ultrasonic, eddy current and fluorescent penetrant inspection devices.

Additional studies were reviewed that intended to make the inspection system components less error-prone, and the system itself more error-tolerant. The studies examined potential human/system mismatches. By analyzing human factors in aircraft inspection, improved techniques will become more widely available to maintenance organizations.

Error-prone human/system mismatches occurred where task demands exceeded human capabilities. The analysis was conducted by studying the steps of the task(s) and evaluating the demands for each step against the capabilities of each human subsystem — vision, hearing, touch/feel, body movement, perception, memory and cognition — required to accomplish that task.

To document the human and system error potential, researchers observed, questioned, photographed and interviewed inspectors while they performed tasks under different conditions.

The researchers found that changes can be applied to make some human tasks less error-prone. Examples of changes to the system that might benefit the technician included:

- Improving vision with better lighting and improving video contrast through processing such as changing colors or shades, enhancing the target defect or using optical aids;

- Improving search strategy by providing templates or guides to ensure thorough inspections;

- Enhancing the ability to discriminate a true fault from a false indication;

- Maintaining high standards by recognizing the pressures that can accompany inspection decisions, and providing organizational support for the AMT and feedback on previous decisions; and,

- Redesigning the aircraft and its systems to improve access and inspection capability. Recent aircraft designs such as the Boeing 777 have used computer-aided design technology to model restricted areas of the structure so that the design will physically allow an AMT to perform necessary tasks.

Examples of changes to the human to fit the system included:

- Selecting or assigning individuals with adequate capabilities and proper perceptual style;
- Training individuals in visual techniques, special inspection techniques such as cueing (calling attention to a defect through a visual indicator) and progressive-part searches (examaning an area in sections rather than as a whole); and,
- Training individuals in decision making, understanding and using standards, and using feedback from previous experiences.

Several ways of making the human inspector more reliable were explored. They included work card design, lighting for inspection, data feedback and visual inspection techniques.

Work card redesign improvements included:

- Changing the presentation format and layout to improve ease of use and legibility;
- Incorporating graphics, drawings or photos into the worksheet;
- Using consistent nomenclature and terminology in all work documents and manuals;
- Providing multi-level work cards with more detailed instructions to the less-experienced AMT; and,
- Having better physical integration of the workcards within the inspector's work area.

Lighting for aircraft inspection was closely examined and found to have great potential for improvement. Suggested guidelines for proper lighting included:

- Area lighting within a maintenance facility should be a minimum of 75 footcandles. A level of 100 to 150 footcandles was preferred;
- Care must be taken to ensure that the light level for night maintenance activities does not drop below recommended levels;
- Task lighting for aircraft inspection requires a minimum of 100 footcandles. For difficult inspections or close work, 200 to 500 footcandles may be necessary;
- Supplemental lighting must be adequate for the task at hand

Table 1
Specifications of Selected Personal Lighting Equipment*

Light Source		Weight (pounds)	Focus Control	General Durability	Power	Safety Requirements	Accessories
2 D-cell flashlight	Krypton Bulb 340 FC	1.5	Yes	Adequate	Battery	Explosion-proof MIL-STD-810C	None
3 D-cell flashlight	Krypton Bulb 1,100 FC	2.0	Yes	Adequate	Battery	Explosion-proof MIL-STD-810C	None
4 D-cell flashlight	Krypton Bulb 1,900 FC	2.4	Yes	Adequate	Battery	Explosion-proof MIL-STD-810C	None
Headlamp	Incandescent Bulb 1,500 FC	1.9	Yes	Adequate	Battery	None indicated	Headlamp Battery clamp

* Center illumination measured in footcandles (FC) at 0.5 meters.

Source: U.S. Federal Aviation Administration, Office of Aviation Medicine and is best judged by the individual performing the task. Task lighting should leave both hands free for the work. If components must be manipulated, headband-mounted lights are preferable to flashlights;

- Older workers require more light. If a substantial percentage of the workforce is over the age of 45, recommended lighting levels may need to be increased by as much as 50 percent; and,

- Glare must be controlled. Reflected glare can be changed by reorienting the work surface or changing light source positions.

Personal lighting equipment (such as a flashlight) is obviously a key element in providing adequate task lighting. Table 1 (page 8) depicts the characteristics of various types of personal lighting equipment.

Data feedback was determined to be another key factor helping to ensure that inspections were reliable. Otherwise, in a large work crew, the inspector who recorded the defect was often not present when the defect was corrected and the "buy-back" inspection took place. If the defect entry was found to be false or the defect found to be much more serious than first indicated, the originating inspector often never learned of it. Training was proven to be effective when it provided timely feedback on operating experience and included examples of defects and subsequent corrective action.

Prior feedback was information that alerted the inspector to what might be expected to be found on a particular inspection. Defect samples, photos and drawings were proven to help reduce the number of false alarms and missed defects.

Analysis of visual inspection techniques disclosed that different individuals naturally have differences in the "visual lobe size," or the area that they can keep in focus for examination. Studies revealed that practice can increase the visual lobe size and thus increase the area-search performance of the inspector.

The search strategy may also be improved to ensure that the area is searched in a systematic manner, so that each area is focused on momentarily (but only once), and none is re-inspected in a single scan. ♦

References

1. U.S. Federal Aviation Administration, Office of Aviation Medicine. *Human Factors in Aviation Maintenance — Phase Three,*

Volume 2 Progress Report, Report No. DOT/FAA/AM-94/12, July 1994. [Earlier phases of the study are documented in *Human Factors in Aviation Maintenance — Phase 1: Progress Report* (Report No. DOT/FAA/AM-91/16); *Human Factors in Aviation Maintenance — Phase Two Progress Report* (Report No. DOT/FAA/AM-93/5); and *Human Factors in Aviation Maintenance — Phase Three, Volume 1 Progress Report* (Report No. DOT/FAA/AM-93/15).

2. "Human Factors in Aircraft Maintenance and Inspection" was featured in the July–August 1991 issue of *Aviation Mechanics Bulletin*. The article referred to the Aloha Airlines B-737 fuselage skin failure that occurred in 1988, and the subsequent finding that structural defects had gone undetected during regular inspections. These events led to studies of the human factors involved in aircraft maintenance and inspection.

Government Changes Off-road Diesel Fuel Dye Color in Response To Concerns from Aviation Industry

In January 1994, the U.S. Federal Aviation Administration (FAA) issued an alert notice to the aviation industry, calling for operators to be alert to possible confusion of diesel fuels with aviation gasoline (AVGAS). The confusion was caused because the U.S. Environmental Protection Agency (EPA) and the U.S. Internal Revenue Service (IRS) issued regulations calling for the addition of blue dye to off-highway diesel fuel.

The dye was intended to identify the tax-exempt and high-sulfur off-highway diesel fuel and prevent its sale as regular diesel fuel, which is heavily taxed. The aviation industry responded immediately with concerns that this blue-dyed diesel fuel could be confused with aviation gasoline that is dyed blue or green. A number of alerts were issued to aviation industry organizations, including Flight Safety Foundation. All the organizations and the FAA called for this dangerous situation to be corrected.

Effective October 1, 1994, off-highway diesel fuels will now be dyed red. The FAA agreed with the change and determined that the aviation community should have no problem in distinguishing the red-dyed diesel fuel from AVGAS, which may be pink.

There may be a period during which the blue-dyed diesel fuel in storage tanks will be mixed with the red-dyed fuel, so aviation operators and fuel agents must remain alert. Observation of a small sample in a white bucket or clear container, plus a “sniff” check prior to adding fuel to the aircraft tank(s) is always recommended.

Abaris Training Releases 1995 Schedule

Abaris Training, which specializes in advanced composite training of aviation maintenance technicians and engineers, recently announced its 1995 schedule of classes, including three new workshops. The new courses are:

- Design and analysis of composite joints;
- Crack patching; and,
- Computer-based processing.

A free brochure detailing all workshops is available upon request. Fax (702) 827-6599. ♦

This information is intended to provide an awareness of safety problem so that they 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.

Tail-bumper Damage Results in Jammed Elevator Controls

In March 1992, a twin-engine Cessna 414 serving as an air ambulance tipped onto its tail while a patient was being loaded into the aircraft. The pilot was advised that there might be damage to the tail section, but he declined assistance and did not have the airplane inspected prior to departure. After takeoff, the pilot reported that he was returning to the airfield because of a jammed elevator. The pilot subsequently lost control while maneuvering to land and crashed. All three occupants suffered fatal injuries.

The Cessna 414 is equipped with a "tail bumper" mounted underneath the empennage, aligned with the fuselage centerline. The tail bumper consists of a 1/4-inch diameter steel rod, formed into a 90-degree bend, with the ends flattened to provide an attachment point for the machine screws securing it to the structure. The elevator control rod passes through the bulkhead directly above the attachment point.

Examination of the accident-aircraft wreckage revealed damage to the empennage, which appeared to have been caused by the tail-bumper ground strike. The attaching structure had been deformed upward, interfering with the elevator control rod and jamming the elevator. Investigators determined that the position of the deformed tail-bumper structure would have made control of the airplane difficult or impossible.

Subsequent investigation of other Cessna 400-series airplanes disclosed similar problems. Eight Cessna 400-series airplanes were selected at random at two Chicago-area airports. Examinations of all of these airplanes revealed damage at the tail-bumper attachment.

The U.S. National Transportation Safety Board (NTSB) found that the current pilot operating handbooks (POHs) for these aircraft do not address the potential for tail-tipping, nor do they describe recommended inspections in the event it does occur. The NTSB has recommended amendment or reissuance of the POHs to include cautions relating to adverse loading and tail-tipping. In addition, the NTSB recommended a modification to the Cessna 400-series tail bumper to ensure that damage from a ground strike will not cause elevator control interference.

Aviation maintenance technicians inspecting and maintaining Cessna 400-series airplanes should be particularly alert to any indication of a tail-bumper ground strike and ensure that any evidence of damage is thoroughly investigated before releasing the airplane to service.

Failed Fuel Pump Results in Fatal Helicopter Accident

In July 1994, an Aerospatiale AS-350D AStar helicopter, operating as a sightseeing flight in the Hawaiian islands, sustained a total loss of power in flight. The pilot autorotated, landing in the ocean near a rocky shore line. The helicopter was successfully evacuated, but the pilot and two of the six passengers drowned while attempting to reach shore.

The helicopter was equipped with a Textron-Lycoming LTS-101 turboshaft engine using a CECO MFP-261 engine-driven fuel pump. Inspection of the airframe and rotor drive train disclosed no evidence of power being applied to the drive train, and surviving passengers confirmed that there was no engine noise during the landing. Bench testing of the fuel control unit and other potential causes for the loss of power disclosed no abnormalities. The engine-driven fuel pump was found to have an internal failure that would result in immediate and total loss of fuel to the engine.

The fuel pump had operated approximately 2,370 hours since overhaul. Driving force was supplied through the accessory gearbox and a splined drive shaft. Examination of the disassembled pump disclosed that the internal splines on the pump end of the drive shaft were worn away, and the external splines on the driver gear were so damaged that there was no engagement.

CECO, the pump's manufacturer, had issued a service bulletin in 1985 calling for the lubrication of the splines and installation of an O-ring seal to prevent fuel from washing away the lubricating grease. The failed pump had been modified; however, only traces of the lubricant were found in the disassembled pump.

The U.S. National Transportation Safety Board's (NTSB's) investigation revealed six similar failures of CECO MFP-261/265 pumps since 1984.

One failure resulted in an accident of a similar model single-engine helicopter, and another failure resulted in a successful single-engine landing of a twin-engine helicopter. Specific data were available on only one of these other failures; however, the findings were nearly identical to the 1994 accident.

There is a maintenance manual requirement to remove the fuel pump to inspect the external spline for condition and for lubrication. But the internal spline (which in this accident was worn away and failed) cannot be inspected without complete disassembly of the pump and defects are therefore not detectable during this inspection.

As a result of these findings, the NTSB issued a recommendation to the U.S. Federal Aviation Administration (FAA) calling for the issuance of an emergency Airworthiness Directive to require that the internal splines of the drive shaft and the external splines of the driver gear on all CECO MFP-261/265 fuel pumps used on single-engine applications be inspected and replaced if the wear exceeds a specified amount.

The recommendation further suggests that these splines be periodically reinspected at an interval based on failure history of the pumps, and that the manufacturer evaluate the pump design and the modification previously issued to ensure proper lubrication and alignment of the fuel pump driveshaft components.

Electrical Switch Failure Results in Flight Emergency

In October 1993, a European operator of a McDonnell Douglas MD-81 reported heavy smoke in the overhead electrical panel shortly after takeoff. The flight crew reported that they had smelled something abnormal about 10 minutes after takeoff. Within a few moments, increasingly dense smoke became noticeable in the overhead panel area. The crew declared an emergency, donned smoke goggles and oxygen masks and initiated a return to the airport.

The “Electrical Smoke in the Cockpit” checklist did not provide guidance on how to identify or to isolate the source. Soon, the smoke became so thick that the crew were unable to read the checklist. The captain’s instruments became erratic but, with radar guidance from approach control, the flight was able to land safely.

In their preoccupation with landing the airplane, the flight crew did not depressurize the cabin, which would have permitted opening a cockpit window to eliminate the smoke.

An investigation found indications of a smoldering fire in the overhead electrical panel. The emergency power switch was determined to have failed internally. Disassembly of the switch by the manufacturer found mechanical damage from wear to the internal contacts and movable parts, along with traces of melting, which only could have occurred under very high temperatures. Although the investigation did not confirm the power source that could have supplied the intensity of current necessary to cause such damage, the findings confirmed that the initial failure was mechanical, caused by wear or overstress.

A review of service history disclosed that this switch showed a relatively high failure rate. Precautionary inspections of the part number (P/N) 103-2200 used on DC-9 and MD-80 series airplanes found several other instances of burned contacts as well as loose screw connections.

The switch manufacturer had no specified service life limit for this component; however, this same switch was used on the Boeing 707 aircraft and had a service life limitation of 10,000 switching cycles. The switch from the incident airplane had approximately 30,000 switching operations.

As a result of this incident, the U.S. National Transportation Safety Board (NTSB) recommended that:

- The U.S. Federal Aviation Administration (FAA) issue an Airworthiness Directive (AD) calling for the P/N 103-2200 switch to be limited to a maximum service life of 10,000 switching cycles;

- The FAA determine the feasibility of replacing the switch with a relay-type circuit that would remove all nonessential high-current wires from the overhead electrical panel;

- Operating procedures be modified to reduce the operating cycles on the emergency power switch; and,

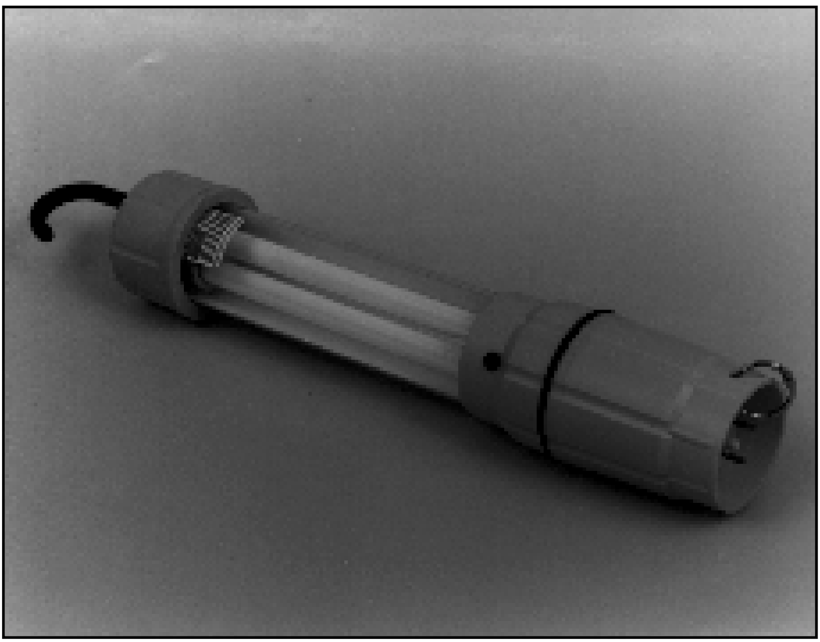
- The FAA and McDonnell Douglas coordinate their efforts to determine the source of the high electrical current that damaged the emergency power switch, and the reason for the sporadic failures of the captain's flight instruments. ♦

'Pronged' Light Turns Any Extension Cord Into a Fluorescent Work Light

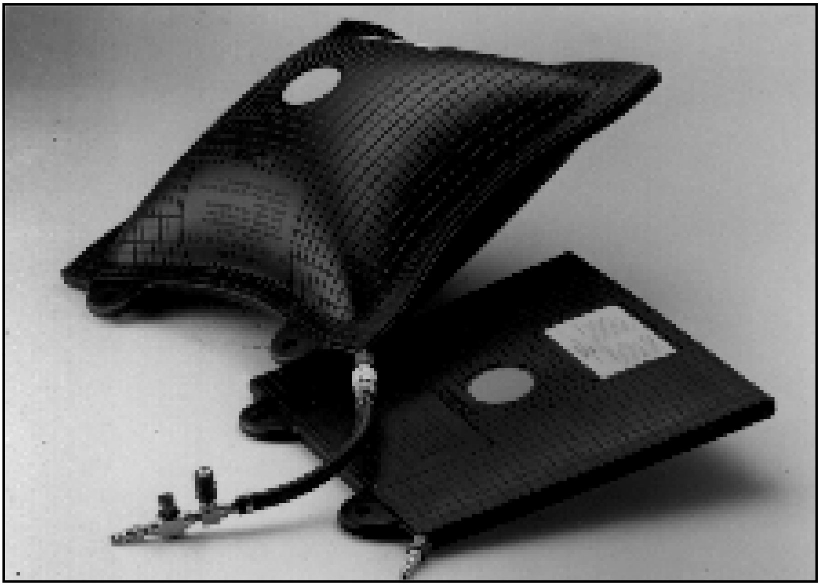
Most portable work lights have an attached cord that makes them bulky and difficult to store in the average toolbox. National Electric Manufacturing Corp. has introduced a 13-watt fluorescent trouble light with an unbreakable case that incorporates prongs into the base so that the light can plug into any extension cord.

The bulb is equivalent to a 60-watt incandescent light; however, it remains cool and is more durable. The lamp is said to have an average life of 10,000 hours. The body has a clear lens and comes with a swivel hook or an optional magnetic hanger.

For more information, contact: National Electric Manufacturing Corp., 6361 Chalet Drive, Commerce,



Portable fluorescent work light is equivalent to 60-watt bulb.



Inflatable jacks are capable of lifting from 12 to 73 tons.

CA 90040, U.S. Telephone (310) 928-8488.

Inflatable Jacks Provide Emergency Lifting

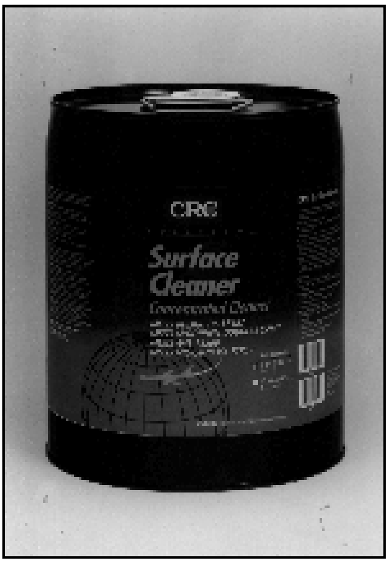
The recovery or lifting of an aircraft after an accident or gear collapse can be a major problem. It is difficult to get a normal jack under a proper jacking point. Full-lifting bags are cumbersome, expensive and seldom available when needed. Power Team, a division of SPX Corp., has introduced a series of inflatable jacks that may be useful in such situations.

The inflatable jacks are constructed of flexible neoprene rubber bonded to four plies of polyester fabric. The manufacturer claims that they are unaffected by dirt, oil, gases and most chemicals. The jacks are available in five models capable of lifting from 12 to 73 tons (11 to 66 metric tons). According to the manufacturer, the jacks can be inflated with 116 pounds (53 kilograms) per square inch maximum pressure using compressed air, inert bottled gas or even water. A single jack controller with a "dead man" control can be used individually or in multiples to regulate jacks for major lifting tasks.

These inflatable jacks could be a valuable addition to any operator's aircraft recovery kit, as well as a useful tool in many regular maintenance activities where lifting is required in a restricted space. For more information, contact: Power Team, 2121 West Bridge Street, Owatonna, MN 55060, U.S. Telephone (507) 455-7100.

Exterior Surface Cleaner Said to Be Environmentally Safe

CRC Industries has introduced a water-based cleaning product called "CRC Aviation Surface Cleaner," for cleaning all exterior aircraft surfaces. The product is blended from biodegradable ingredients and contains no petroleum solvents, acids or phosphates.



CRC Industries introduces environmentally safe water-based cleaner.

The manufacturer says that this product can be used for routine or heavy cleaning or carbon stain removal on aluminum, magnesium, titanium, cadmium-plated steel and acrylic plastics. The cleaner is said to tolerate hard water and because of its high viscosity, will cling to vertical surfaces, yet rinse off cleanly without streaking. The product is available in five- or 55-gallon (19- or 208-liter) containers and meets applicable industry and manufacturer's specifications.

For more information, contact: CRC Industries Inc., 885 Louis Drive, Warminster, PA 18974, U.S. Telephone (215) 674-4300.

UltraSpillBerm and Ultra-SpillPallet Contain Spills and Meet EPA Requirements

UltraTech International Inc. has developed two new products for use in protecting against harmful fluid spills and meeting U.S. Environmental Protection Agency (EPA) requirements.

The first is a flexible dam material called UltraSpillBerm. The manufacturer states that this product can be easily placed around drains, doorways or other sensitive equipment to contain a spill or overflow of potentially environmentally damaging fluids.

The second product, Ultra-SpillPallet, provides a storage rack for barrels of hazardous material and incorporates a 70-gallon (265-liter) sump area. This sump provides secondary containment for drum leaks or overflow and is said to meet EPA container storage regulations and Uniform Fire Code spill containment requirements. The unit is made of corrosion-resistant galvanized steel and is suitable for indoor or outdoor use.

The products may be of special interest to operators concerned with protecting against environmental damage claims resulting from the handling of toxic chemicals or fluids, and meeting newer EPA regulations. For more information, contact: UltraTech International Inc., 11711-2 Phillips Highway, Jacksonville, FL, 32256, U.S. Telephone (904) 292-1611 or fax (904) 292-1325.

Magnetic Sweepers Reduce Exposure to FOD

The O.S. Walker Co. has introduced a line of permanent magnetic

Permanent magnetic sweepers require no electrical connections.

sweepers that can be suspended from vehicles operating on aircraft ramps and taxiways. The manufacturer says that the PSS series of suspended permanent magnets comes in a full range of lengths, one of which can be suspended under the front of virtually any vehicle.

Requiring no electrical connections, these permanent magnets retain their powerful magnetic charge for life, the manufacturer claims. The magnets come equipped with two eye bolts for installation and are said to be easily mounted with chain or cable attachments. Optional mounting and self-cleaning attachments are also available.

For more information, contact: O.S. Walker Company Inc., Rockdale Street, Worcester, MA 01606, U.S. Telephone (508) 853-3232. ♦