FLIGHT SAFETY FOUNDATION
Aviation Mechanics Bulletin

MAY–JUNE 1998

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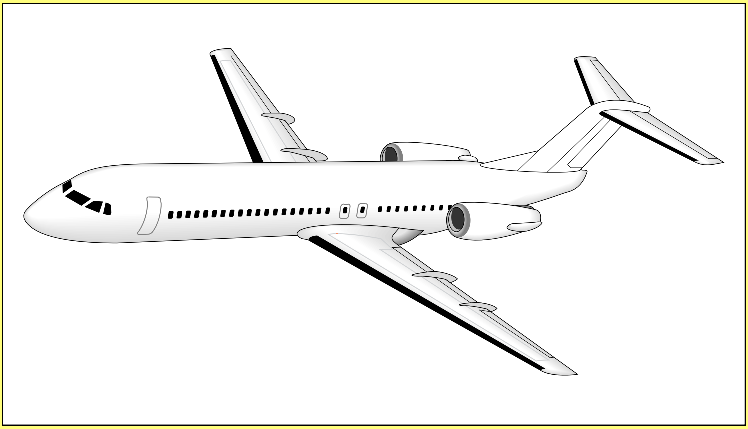

FLIGHT SAFETY FOUNDATION
1947–1997

FLIGHT SAFETY FOUNDATION

Aviation Mechanics Bulletin

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Unrecorded Maintenance on Fokker 100 Lift-dumper System Leads to Wing-Surface Damage in Flight

—

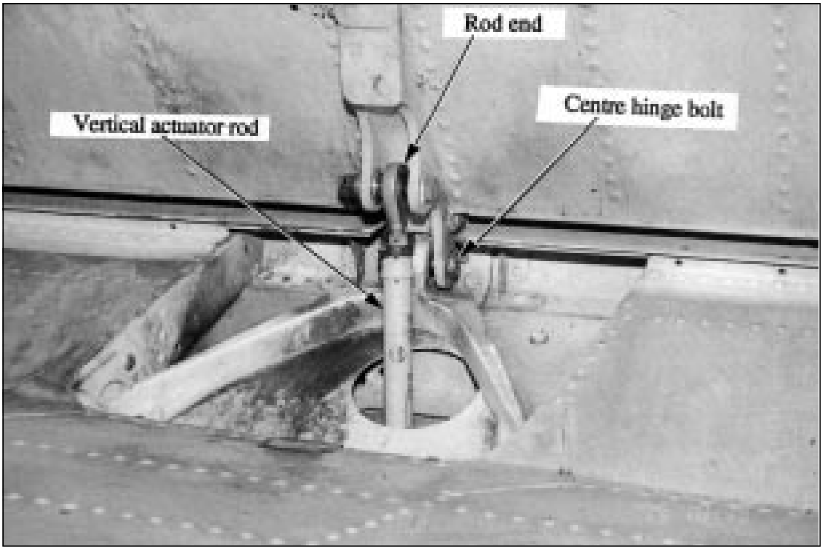
Bart J. Crotty
Aviation Consultant

Upper-wing damage was found during the walk-around inspection of a Fokker 100 (F-100) that landed at London (England) Stansted Airport after a flight from Amsterdam, Netherlands, on Oct. 12, 1995. The edge of the no. 5 lift-dumper (spoiler) panel on the left wing was bent upward, said the U.K. Air Accidents Investigation Branch (AAIB).

Further inspection revealed that a bolt was missing from the center hinge on the lift-dumper panel. The AAIB said that the absence of the center-hinge bolt allowed abnormal loads to be applied to the lift-dumper panel by the hydraulic actuator. The actuator forced the panel upward, causing a bowing distortion of the panel.

The aircraft had undergone maintenance in the aircraft operator's hangar during the week that preceded discovery of the bent panel. The maintenance included a "B" check (routine inspection at 550 flight hours) and a scheduled manufacturer's special inspection (MSI) for excessive wear of lift-dumper mechanical-control bearings.

The AAIB said that a maintenance engineer, who was licensed by the U.K. Civil Aviation Authority and was working on contract to the aircraft operator's maintenance organization, was assigned the task of performing the MSI inspection of the lift-dumper bearings over a weekend. He was assisted by an unlicensed



The center-hinge bolt in the left-wing lift-dumper system was not replaced before the Fokker 100 was returned to service after a major inspection. Subsequent activation of the system caused damage to the lift-dumper panel. (Photo: U.K. Air Accidents Investigation Branch)

worker, who also was on contract to the maintenance organization.

The MSI documentation, the corresponding work card (containing detailed instructions for the inspection of the lift-dumper control bearings) and the aircraft maintenance manual were given to the maintenance engineer and his co-worker. They used the material during their inspections of the lift dumpers on both wings of the aircraft. As the work progressed, the maintenance engineer created another work card recording the opening and closing of access panels to facilitate the inspections.

The maintenance engineer determined that the lift-dumper-panel vertical-actuator rod ends for the lift dumpers on both wings were worn excessively and required replacement.

"The [Saturday] day shift (0830 to 2030 hours) duty foreman agreed that these rod ends should be replaced, and the … parts were ordered," said the AAIB. Additional work cards were created for disconnecting the lift-dumper systems and replacing the rod ends.

The maintenance engineer and his co-worker began to disconnect the lift-dumper systems in both wings, but they were unable to remove the bolts on the lift-dumper actuator rods. The bolts were still in place when the shift ended at 2030.

Personnel on the night shift (2030 to 0630 hours) continued the work on the F-100's lift-dumper systems. They were able to remove the rod-end bolt from the actuator for the lift dumper on the right wing, but they were unable to remove the bolt from the lift-dumper actuator on the left wing.

The rod-end bushings were damaged during the removal of the bolt from the right-wing lift-dumper actuator. Replacement bushings for both lift dumpers were ordered, with aircraft-on-ground priority, from the aircraft manufacturer.

The maintenance engineer and the co-worker who began the MSI inspection of the lift-dumper bearings returned to work on Sunday morning. Their attempts to remove the bolt from the actuator rod end on the left-wing lift-dumper system again were unsuccessful. The AAIB said that the bolt was distorted and could not be removed even with the use of a hacksaw.

The maintenance engineer decided that the entire lift-dumper panel would have to be removed to facilitate removal of the actuator bolt. He consulted the duty foreman, who agreed that the lift-dumper panel should be removed.

The maintenance engineer and his co-worker then removed the lift-dumper panel from the left wing and carried it to a workbench, where they were able to remove the actuator bolt.

"At this point, and this is the crucial point around which the whole incident revolves, I was so busy and concerned to get the panel serviceable again that I inexplicably forgot to record the removal [of the center-hinge bolt] on the work card," said the maintenance engineer.

The maintenance engineer and his co-worker then reinstalled the left-wing lift-dumper panel; however, they did not reinstall the actuator rod-end bolt and the center-hinge bolt because the replacement bushings had not yet been delivered to the maintenance hangar.

At 1730, two hours past the time scheduled for all work on the F-100 to be completed, the aircraft was taken off the jacks and moved outside the maintenance hangar for an engine run-up. There were about 20 work cards to be completed, said the AAIB.

Before stopping work for the day, the maintenance engineer placed in a plastic bag the remaining hardware for the lift-dumper, the center-hinge bolt and a handwritten note of explanation for the night-shift personnel. He said that he handed the plastic bag to his shift duty foreman. He also said that the duty foreman confirmed the content of the handwritten note.

"The duty foreman's recollection differs," said the AAIB. The duty foreman, who was supervising work on two other aircraft in addition to the F-100, stated that "the 'hand-over' was rather less formal" than described by the maintenance engineer.

The replacement bushings for the lift-dumper actuators arrived at the maintenance facility about 2000. Workers on the night shift completed the maintenance and inspections detailed on the remaining work cards for the F-100. Duplicate inspections were performed at 0430, and functional checks were completed at 0600, said the AAIB. The aircraft then was released for service.

Over the next three days, the aircraft completed several flights in regular service until discovery of the damaged lift-dumper panel.

The AAIB said that the maintenance organization conducted a high-level maintenance-standards review to examine and understand the factors directly or indirectly involved in the incident. The AAIB said that the incident was similar to other maintenance-error incidents on record: "A common feature in many of these occurrences has been that the [quality-control] procedures, such as duplicate inspections, designed to minimize the effects of a single human error are most prone to break down in those conditions of pressure on time and personnel when they are most needed," said the AAIB.

"[The maintenance engineer], by all accounts an experienced and conscientious individual, willingly admitted, without excuse, his oversight in failing to record the removal of the left-hand no. 5 lift-dumper panel from the aircraft. However, it is apparent from the maintenance records, including the 'hand-over diary' used by this organization for communication between shifts, that there were a number of further opportunities for this omission to be corrected. These included the hand-over itself, between shifts, the fitting of the hardware to the left-hand panel and the inspection activities of both parties to the duplicate inspection."

Maintenance error analysis. An analysis of the AAIB report by the author suggests factors that could have influenced the course of events that led to the damage to the F-100's lift-dumper panel (readers may formulate other possible factors contributing to the maintenance error). The codes appearing in parentheses, in order of priority assigned by the author, are explained in Table 1.

Table 1
Factors Involved in Maintenance Error

Code	Factor	Related Elements
C	Communications	Verbal, written, visual
D	Design	Original, modification
E	Environment	Weather, lighting, temperature, noise
I	Inspection	Preliminary, progressive, final; NDI, duplicate
H	Hardware	Equipment, tools, parts, material, etc.
L	Limitations (physical), ergonomics	Weight, reach, sight
M	Manufacturer manuals	Instructions, service bulletins, aircraft flight manuals, alerts, data, etc.
O	Organizational structure and top management	(none)
P	Paperwork and its systems	Logbooks, records, documentation, etc.
R	Regulations	Design, operating, airworthiness, etc.
S	Supervision and middle management	(none)
T	Training	Basic skills, aircraft technical, administration, human factors
W	Worker	Aircraft maintenance, licensed, nonlicensed, ground-support staff
X	Physiological, psychological	Stress, fatigue, drugs, alcohol, etc.

Source: Bart J. Crotty

- The failure of the maintenance engineer to record, via the operator's work-card system, all work performed and all work remaining to be performed (W, S, X);
- The possible overextension of duties assigned to the shift foreman, who was supervising maintenance on three aircraft (S, O, X);
- The possibility that vague or insufficient written procedures and practices for work-shift changes resulted in inadequate communication (C, P);
- The excessive pressure placed on personnel to complete nonroutine work that was overdue because of mechanical difficulties and the late delivery of replacement parts (X, S, O);
- The failure of maintenance inspectors to discover the missing

bolt during the duplicate inspection (I); and,

- The possibility that assigning two contract workers to work together, instead of with employees of the aircraft-operator's maintenance organization, resulted in less-careful performance of maintenance (O, S, X).♦

Editorial note: This article was based on U.K. Air Accidents Investigation Branch Bulletin No. 2/96, Ref. EW/C95/10/2. The five-page bulletin contains color photographs and appendixes.

About the Author

Bart J. Crotty is an airworthiness and maintenance consultant. He is a former U.S. Federal Aviation Administration airworthiness inspector and trainer, and designated airworthiness representative. Crotty has worked for repair stations, airlines, an aircraft manufacturer, law firms, safety organizations and several non-U.S. national civil aviation authorities. His career spans 38 years, approximately half of it in non-U.S. locations. He has an airframe and powerplant certificate and a bachelor of science degree in aeronautical engineering.

MAINTENANCE ALERTS

In-flight Fire Prompts Recommendation for Review of Wiring Standards

The U.S. National Transportation Safety Board (NTSB) has recommended that the U.S. Federal Aviation Administration (FAA) review aircraft design, manufacturing and inspection procedures to ensure that they provide adequate clearance around electrical wiring.

The recommendation resulted from the NTSB's investigation of an in-flight fire aboard a Cessna 650 (Citation III) on April 3, 1997. The aircraft was descending through 4,000 feet (1,212 meters) on approach to Greater Buffalo (New York, U.S.) International Airport when the flight crew smelled smoke. The information on a navigation display disappeared, and radio communications were ended.

Witnesses saw flames emerging from a hole in the aircraft's aft fuselage after the Citation flight crew completed an emergency landing at the Buffalo airport. The flight crew and their passenger were not injured. Aircraft fire damage was substantial.

The NTSB said that the fire in the section of the aircraft above the aft baggage compartment was caused by arcing of electrical wiring chafed by the hydraulic-pump suction line. Subsequent inspection of the Cessna 650 fleet showed that nine other aircraft had electrical wiring chafed by the hydraulic-pump suction line in the same section.

"Design drawings for the Cessna 650 specify one-half inch [1.3 centimeters] of clearance between the hydraulic line and [the] electrical wiring but provide no means to ensure positive separation," said the NTSB. This is contrary to methods, techniques and practices acceptable to the FAA and to process specifications of the aircraft manufacturer for installing electrical wiring.

The methods, techniques and practices acceptable to the FAA are in Advisory Circular 43.13-1A (*Acceptable Methods, Techniques and Practices — Aircraft Inspection and Repair*) and in Advisory Circular 65-15 (*Airframe and Powerplant Mechanics Airframe Book*).

"These references state that no electrical wire should be located within one-half inch [1.3 centimeters] of any combustible-fluid or oxygen line and, if the separation is less than two inches [five centimeters], back-to-back clamps or a polyethylene sleeve should be installed to ensure positive separation," said the NTSB.

Cessna's process specifications for wiring installation in commercial aircraft say that wiring within six inches (15.2 centimeters) of a hydraulic line must be firmly supported.

The NTSB cited several other recent incidents caused by inadequate clearance between electrical wiring and other aircraft components.

- On June 15, 1996, a Delta Air Lines Boeing 767 banked sharply to the left during initial climb from John F. Kennedy International Airport in Jamaica, New York, U.S. The flight crew had to turn the control wheel 25 degrees to the right to maintain a level flight attitude, but they were successful in returning to the airport for an emergency landing.

  "[Our] investigation revealed that an aileron flight-control cable failed as a result of arcing when it contacted adjacent electrical wiring," said the NTSB.

- Several days after the Delta Air Lines incident, an aileron-cable failure occurred in a B-767 operated by Lan-Chile Airlines. The NTSB said that the circumstances were similar to the Delta incident.

- "The safety board also learned of a 1995 incident aboard a Japan Air Lines [B-]767 in which inadequate clearance led to arcing between electrical wiring and an oxygen-line fitting near the captain's oxygen mask."

The FAA advisory circulars say that at least three inches (7.6 centimeters) of clearance should be provided between electrical wiring and flight-control cables, said the NTSB. The advisory circulars also say that mechanical guards should be installed to prevent contact between the wiring and the control cables if three inches (7.6 centimeters) of clearance cannot be maintained.

"However, design drawings for the [B-]767 specify only one inch [2.5 centimeters] of separation between the aileron flight-control cable and adjacent electrical wiring, with no mechanical or electrical protection specified," said the NTSB. "This one-inch [2.5-centimeter] separation did not prevent arcing in the Delta Air Lines and Lan-Chile incidents."

The NTSB said that it is concerned that aircraft manufacturers do not always adhere to the wiring-installation methods, techniques and practices acceptable to the FAA in their design, manufacturing and inspection processes.

"In many cases, manufacturers are required to modify designs to bring them in line with the [acceptable methods, techniques and practices] only after an in-service problem or an accident or incident has occurred," said the NTSB.

Aircraft-manufacturer service bulletins and FAA airworthiness directives were issued to correct the electrical-wiring problems in the Cessna 650 and B-767. The NTSB said, however, that the service letter for the B-767 and the subsequent FAA airworthiness directive still require only one inch (2.5 centimeters) of clearance and no mechanical guards between the aileron cables and adjacent electrical wiring.

The NTSB recommended that the FAA review aircraft design, manufacturing and inspection procedures to ensure that electrical-wiring clearance standards conform with the acceptable methods, techniques and practices in the advisory circulars.

The NTSB also recommended that the FAA check electrical wiring in transport-category airplanes to ensure that acceptable clearance is provided. The NTSB said that modifications should be required if the FAA discovers any deviations from the acceptable methods, techniques and practices in the advisory circulars.

Airbus Rudder Pedal Restriction Investigated

The captain of a Northwest Airlines Airbus A320 said that he had use of only the aileron controls to compensate for a crosswind after the rudder pedals "locked in the neutral position" during a visual approach to Detroit (Michigan, U.S.) International Airport on Nov. 24, 1996. The aircraft landed without further incident.

"After exiting the runway, the captain performed several [autopilot] disconnects, with no change in the rudder-pedal force," said the U.S. National Transportation Safety Board (NTSB). "The captain and the first officer then made several attempts to free the rudder pedals." After they manipulated the rudder for approximately 15 seconds, rudder-pedal movement returned to normal.

The captain said that he disconnected the aircraft's autopilot about 15 miles from the airport and encountered the rudder problem just before landing. Tests by Airbus of the aircraft's rudder artificial-feel-and-trim unit revealed that excessive force was required to move the unit's autopilot-mode engagement/disengagement lever.

The NTSB said that the aircraft's artificial-feel-and-trim unit had not been modified as recommended by Airbus on March 21, 1992. Airbus Service Bulletin A320-27-1042 recommended installation of a modified autopilot-mode engagement/disengagement lever to prevent restriction of rudder-pedal movement after disengagement of the autopilot.

"The [service bulletin] was prompted by 10 incidents in which the artificial-feel-and-trim unit did not disengage from the [autopilot] mode … and return to normal pedal-operating forces during approach and landing," said the NTSB.

The French Direction Générale de L'Aviation Civile did not issue an airworthiness directive requiring compliance with the Airbus service bulletin.

"On April 30, 1997, Airbus sent a telex to A320 operators citing two recent incidents involving stiff rudder pedals and strongly recommending that the [service-bulletin] action be incorporated," said the NTSB.

An unexpected restriction of the rudder pedals could cause a loss of control during a critical phase of flight, said the NTSB. The NTSB recommended that the U.S. Federal Aviation Administration issue an airworthiness directive requiring installation of modified engagement/disengagement levers in the rudder artificial-feel-and-trim units in all A320s.

NTSB Recommends Evaluation of Engine Containment Shield

On June 17, 1997, a McDonnell Douglas MD-83 operated by Reno Air of Reno, Nevada, U.S., was taking off from Las Vegas, Nevada, when an uncontained failure of the no. 1 (left) engine occurred. The aircraft returned to Las Vegas and landed without further incident.

The U.S. National Transportation Safety Board (NTSB) said that parts of the high-pressure turbine in the Pratt & Whitney JT8D-219 engine penetrated both the engine nacelle and the aircraft fuselage. The fuselage damage occurred in a section of the aircraft that was not pressurized.

A similar incident happened on July 13, 1996. A McDonnell Douglas MD-80 operated by Centennial Airlines of Palma de Mallorca, Spain, was en route from Dusseldorf, Germany, to a destination in the Canary Islands, Spain, when an uncontained failure of one of the Pratt & Whitney JT8D-219 engines occurred. Parts of the high-pressure turbine penetrated the engine nacelle but did not strike the aircraft fuselage.

The failed engines on both airplanes were equipped with high-pressure-turbine containment shields. Installation of the shields was required by Airworthiness Directive 93-23-10, issued by the U.S. Federal Aviation Administration (FAA) on Jan. 18, 1994.

The NTSB said, however, that the containment shields on both engines shifted when they were struck by debris from the high-pressure turbines and allowed more turbine debris to exit the engine.

"The Reno Air and Centennial Airlines incidents have shown that the JT8D-200 series engine [high-pressure-turbine] containment shield design is inadequate to prevent all turbine parts from [leaving the engine] because the [shield] support is insufficient to sustain the shield in the proper location when [the shield is struck] by some exiting turbine material," said the NTSB.

The NTSB recommended that the FAA evaluate the high-pressure-turbine containment shield in Pratt & Whitney JT8D-200 series engines and determine whether a larger and more impact-resistant shield is required.♦

Helicopter Maintenance Scholarship Applications Due

Sept. 25, 1998, is the deadline for applications for the 1998-1999 Helicopter Association International (HAI) Aviation Maintenance Technician Scholarship Award Program.

Four scholarships will be awarded as part of HAI's program to encourage helicopter maintenance careers. Each scholarship winner will be able to choose one of numerous courses offered by airframe and engine manufacturers and from Southern Illinois (U.S.) University. The first-place winner will receive US$1,500 from HAI to assist with expenses, and the other winners will receive lesser amounts.

The scholarship winners will be announced at the HAI Technical Committee meeting in conjunction with Heli-Expo '99, Feb. 21–23, 1999, in Dallas, Texas, U.S.

Contact Bill Sanderson, Helicopter Association International, 1635 Prince Street, Alexandria, VA 22314-2818 U.S. Telephone: +(703) 683-4646; Fax: +(703) 683-4745.

ARSA to Offer Aviation-law Course

The U.S. Federal Aviation Administration (FAA) Advisory Circular 145-3, which outlines the requirements for a repair station's inspection-procedures manual, includes the requirement to train supervisors and inspectors in the regulations that govern holding a design, production or maintenance certificate. The Aeronautical Repair Station Association (ARSA) has designed a course to meet the needs of supervisors and inspectors for understanding the relevant regulations.

"Regulation 101: Aviation Law for the Layman," the ARSA course, has been approved by the FAA for inspection authorization renewal credit. The course outline includes:

- The political and legal framework [of aviation regulation];
- Design and production rules;
- Certification and operating rules;
- Maintenance rules; and,
- Other considerations for the layman.

The course will be offered on various dates between July and

December 1998. U.S. locations will include Rockville Centre, New York; Vernon, Connecticut; Chicago, Illinois; San Francisco, California; Los Angeles, California; Kansas City, Missouri; Tulsa, Oklahoma; Miami, Florida; Seattle, Washington; and Portland, Oregon.

For more information: Aeronautical Repair Station Association, 121 North Henry Street, Alexandria, VA 22314-2903. Telephone: +(703) 739-9485; Fax: +(703) 739-9488.

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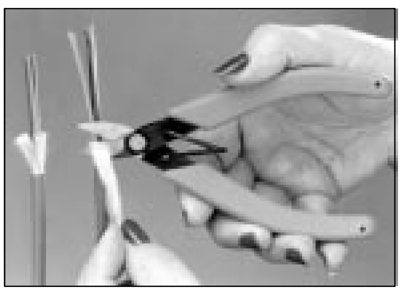

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scissors' ergonomics are designed for prolonged-use comfort, with rubber grips and a spring that snaps the blades open after each cut. The product is said to feature an optimum combination of durability and leverage that makes it suitable for cutting tough Kevlar fibers.

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Sioux Tools 890 Orbital Sander

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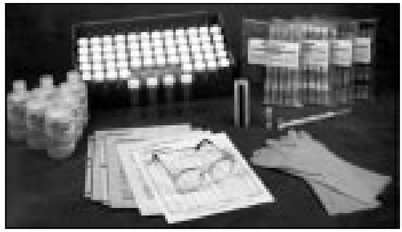
Simple Kit Tests Purity of Hydraulic Fluids, Lubricants

Quickly determining the total acid number (TAN) of aircraft hydraulic fluids or turbine-engine lubricants is the function of the Mini-TAN Lubricant Testing Kit from Airborne Analytical Labs. The kit is said to be able to generate highly reliable measurements of the acidity that results from breakdown of a fluid's protective additives, yet be simple enough for maintenance technicians with no backgrounds in chemistry to use after minimal training.

The testing apparatus requires only a small fluid sample — 20 milliliters, or less than one ounce. Precise amounts of potassium hydroxide reagent used in the testing are supplied in small plastic vials, and the fluid testing is performed in reusable vials.



Mini-TAN Lubricant Testing Kit from Airborne Analytical Labs

For more information: Airborne Analytical Labs, P.O. Box 518, East Hanover, NJ 07936 U.S. Telephone: (800) 989-7692 (United States and Canada); +(973) 887-7410; Fax: +(973) 386-0009.

Lavatory Drop Hose Includes Bonded Hose

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Hi-Tech Hose Inc. Lav Drop Hose

cuff is said to contribute to the hose's ability to withstand heavy use and outlast conventional hoses. The cuff fits tightly over the lavatory drop fitting and clamps to produce a leak-proof seal.

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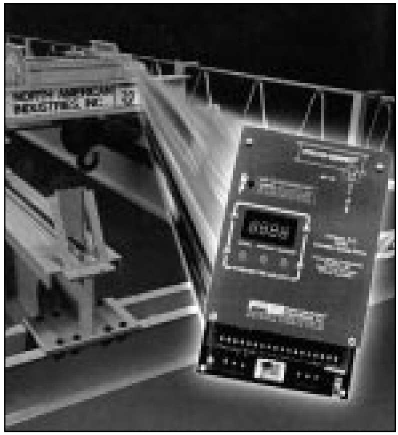
For more information: Hi-Tech Hose Inc., 7 Opportunity Way, Newburyport, MA 01950 U.S. Telephone: (800) 451-5985 (United States and Canada); +(978) 462-8888; Fax: +(978) 465-1955.

Microprocessor-driven Crane Controls Aid Accuracy

North American Industries offers a new line of crane controls in its crane products that are said to provide greater positioning accuracy and safety.

The company's variable-speed flux vector controls use microprocessors to monitor speed and direction, calculate slippage and control torque. Load positioning accuracy is possible to 0.001 inch (0.0025 centimeter), at speeds as low as 0.01 feet per minute (0.003 meters per minute).



Microprocessor-driven crane controls by North American Industries

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