Cracks in Geriatric Aircraft

A spate of structural problems in older planes raises concerns about the airworthiness of the U.S. passenger fleet; industry plans a major house cleaning

"I WAS HAVING BREAKFAST when I heard the news about the Aloha Airlines accident," recalls Thomas McSweeny, aircraft engineering division chief at the Federal Aviation Administration (FAA) in Washington. In a white-knuckle flier's nightmare last April, the roof of a Boeing 737 ripped off as it reached 24,000 feet near Maui, Hawaii, sweeping a stewardess overboard and exposing passengers to the open sky. Sixty-one were injured. McSweeny says: "I thought to myself, 'This is going to be a busy year.' "

Indeed, the accident has kept the FAA on its toes. In May, the FAA issued several emergency directives aimed at finding cracks in older 737s. It followed this with a conference on aging aircraft in June, quickly sanctioned an industry task force that will attack the problem, and ended the year with orders that thousands of rivets on older jet planes be replaced, a fix that will cost more than $600,000 per plane, or $35 million for the airline industry.

But as this regulatory activity slows down, a question hangs over the record. Does the Aloha case offer any general lessons about the aging U.S. jet fleet? Are there any more hidden risks? The industry views the Aloha case as an anomaly. Some think it was not a rogue event, but a warning about a general problem for the U.S. passenger fleet.

In December, an Eastern Airlines plane, a Boeing 727, popped a 10-inch hole in the skin while flying over Pennsylvania, losing cabin pressure. It landed safely with no injuries. In January, a Piedmont Boeing 737 dropped an engine onto a field on takeoff from Chicago, apparently because a bolt broke; the plane landed safely.

These events triggered a new round of concern and inspection, casting a spotlight on what one FAA official calls the problem of "tottering, drooling, and incontinent geriatric aircraft."

Airplane repair and maintenance problems follow what is known in the business as a "bathtub curve." They start high in the early years when design kinks are being worked out, drop down for perhaps 15 years, and then creep upward inexorably. A 12-year-old plane has roughly twice the maintenance costs of a new one. The average age of the U.S. passenger aircraft fleet is now 12 years and growing, as airlines continue to extend service time beyond the life manufacturers planned. New maintenance problems are appearing as the fleet drifts into the late, high end of the bathtub.

As a rule, jet airframes were designed to last about 20 years. The Boeing 707, the first U.S. jet carrier to come off the line in 1958, has essentially ended its life in scheduled passenger service in the United States, although it is still used for charters and freight. Its peer, the McDonnell Douglas DC 8, began to arrive on the scene in 1959. According to Paul Turk of Avmark Inc., a consulting firm in Arlington, Virginia, nearly all of the DC 8s will be retired from U.S. scheduled service in the early 1990s.

But the next in line, Boeing's 727, which began service as a short-haul aircraft in 1964, will be flying in flocks of hundreds well into the next decade. A global survey taken by Forecast International of Newtown, Connecticut, found that the average age of 727s is now 16.4 years. The older ones are among the most demanding planes in the passenger fleet in terms of inspection, maintenance, and repair. The McDonnell Douglas DC 9 is of the same vintage, and also demanding.

Boeing's three varieties of 737, including the most popular jet ever made, the 737–200, began service in 1968 and will continue flying passengers indefinitely. They, too, are becoming geriatric. The earliest jumbo jets—Boeing's 747 and McDonnell Douglas's DC 10—came out in 1969 and 1971. The oldest are reaching the 20-year mark, although new versions of the 747 are still being produced. The average age of the 747 fleet, Forecast International reports, is 11.2 years; of the DC 10 fleet, 12.9 years; and of the Lockheed L 1011 fleet, 12.4 years. Although many are at nominal retirement age, few are retiring.

There are several reasons for the long farewell, according to industry and FAA sources. The main one is that air travel and express air freight are booming. Manufacturers simply cannot keep up with the demand for new machines. The delivery backlog in the United States is 2 to 5 years. Everything that will fly is being pressed into service. Foreign airlines, often run like government agencies, tend to buy new planes at regular intervals. Their castoffs now come to the United States. Another problem is cost: the price of the new planes has escalated to such an extent that many airlines prefer to invest in maintenance.

Technology also contributes to the trend.

Coming apart at the seams? *A 19-year-old Boeing 737 split apart last April along a weak skin splice that had been the subject of concern since 1972.*

Airplanes are now so well engineered that manufacturers boast they can be flown forever, if properly maintained. Safety experts have accepted this notion, so that FAA officials, including McSweeny, insist that there is no reason to order retirement of a plane after a set number of years. This is a departure from the past.

In the propeller age, planes were built to have a "safe life," meaning they were supposed to be flown no longer than lab tests had shown them to be safe, and then scrapped. This was easy in the 1940s and 1950s, says John Mazor of the Air Line Pilots Association, because the industry was changing rapidly and, "In those days the airlines bought planes the way Americans used to buy cars. You'd trade in the old one for a shiny new one every 3 or 4 years." The fleet turnover was rapid.

The pattern changed in 1956 when the jet age arrived. After spectacular midair disintegrations of two British Comet aircraft, the industry shifted to a new concept called "fail-safe" which called for redundancy in the airframe. The idea was that if a primary load-bearing element failed, the load would be shifted to a second part of the structure, with no catastrophic damage for at least one inspection interval. A corollary was that properly inspected and maintained aircraft could be kept in service indefinitely. However, doubts arose in the late 1960s after an aging propeller-driven DC 6 suffered "explosive decompression" due to fatigue. Yet the fail-safe concept held firm until an accident in Lusaka, Zambia, in 1977.

A Boeing 707 fell out of the sky, it was determined afterward, because fatigue cracking caused the horizontal tail stabilizer to break off. As the airframe aged, the primary and secondary structural elements lost strength in unison and were no longer able to resist large, fast-moving cracks. Britain, in particular, pressed for a new standard. The International Civil Aviation Organization, the FAA, and the manufacturers moved to a new "damage tolerance" approach in 1978.

According to Thomas Swift, an FAA specialist in metallurgy in Long Beach, California, all planes since 1978 have been built on the damage tolerance principle, which calls for materials that retard cracking. Inspection and maintenance are aimed at areas where cracks are likely to appear first, and extra effort goes into spotting them, monitoring their growth, and making reinforcements as necessary. Swift says this method can be used on any plane, but may be prohibitively expensive on older ones not built of crack retarding material, which includes a majority of the U.S. fleet

Recognizing that "airplane structural materials do have finite lives and the extent of these is affected by age. . . ," the FAA began to require supplemental inspections for older planes starting in 1981, focusing especially on the oldest jets, the 707s. A more general program began in 1983, moving on through succeeding generations of aircraft.

Meanwhile, a new wave of concern swept through the community in 1985. One of the jumbo jets owned by Japan Air Lines—a Boeing 747 especially designed for "high-cycle" service between Tokyo and Osaka—went out of control and smashed into a mountain. (A cycle is a takeoff, pressurization of the cabin, depressurization, and landing. The age of a fuselage is measured in cycles.) The pilot lost the steering when the rear pressure bulkhead blew out, sending a high-pressure burst of air up the tail and severing the hydraulic controls. An investigation found that the bulkhead had been cracked long before, possibly when a pilot let the tail hit the runway, and had been reinforced at JAL's request by Boeing. But the repair was not done properly.

Fewer than 4% of accidents have been linked to maintenance or structure.

After this accident, Boeing and the airlines made a survey of the 747 fleet. They found no weak bulkheads but a widespread problem of fatigue cracking in the nose area. These were not expected, but not threatening either. According to the FAA, they have been kept under control with a special program of inspection and repair. Congressional committees became interested in the age problem, and in 1986 the FAA commissioned two special reviews of the 747 fleet, which recommended additional research but reported that the planes were safe.

Soon geriatric ailments began to crop up elsewhere. As far back as 1972, Boeing had learned that its "cold bonding" method of joining together metal "skins" to make the fuselage of early 737s was not working properly. The bond tended to corrode and separate with age. The company switched to hot bonding on all 737s after the 291st and redesigned the skin splice, also called the "lap joint." In the early 1970s, Boeing sent out service bulletins recommending more frequent inspections and possibly repairs of lap joints in high-cycle, cold-bonded 737s. In May 1987, when a 737 in Brazil with 40,000 cycles was found to be cracked along the lap joint, Boeing boosted the status of its earlier advice to an "alert." In November 1987, the FAA went further, putting out an airworthiness directive that made surveillance and repair of older 737s with 30,000 cycles mandatory. The FAA stepped up inspection demands again in March 1988.

A month later, in April 1988, the Aloha 737 (a cold-bonded plane with 89,000 cycles) burst open in midair, splitting the skins apart at the suspect lap joint. The National Transportation Safety Board (NTSB) has not issued a final ruling, but early reports indicate that the fatal crack started in the cold-bonded joint that has been under surveillance since 1972 and spread rapidly down the hull, tearing along a row of rivet holes weakened by fatigue and corrosion.

After the event, Boeing sent the NTSB a file of exculpatory letters, suggesting that it had tried to warn Aloha in 1987 that something like this could happen. (Aloha tried to prevent the release of this correspondence but failed.) The letters reveal that Boeing, in an effort to track down and examine aging 737s, had contacted Aloha in 1986 and persuaded the airline to let Boeing do a maintenance review. Boeing had already done this for half a dozen others.

One reason Boeing wanted to visit Aloha was that Aloha owned the world's most fatigued 737s, planes that "led the fleet" in the number of cycles. They hopped from island to island, pressurizing and depressurizing more often per hour than most passenger jets, and did so in a hot, salty, corrosive environment.

In retrospect, it is not surprising that Boeing found "considerable corrosion of belly skins and in skin laps throughout the fuselage" of one Aloha 737, as a Boeing official wrote to Aloha in October 1987. In this and another letter that fall, Boeing politely nagged Aloha to get to work on repairing the three old 737s. The airline made some fixes, but decided to postpone the heaviest work, including skin replacement on the plane Boeing had not been able to inspect, the one that later burst apart, until after the spring tourist season. Aloha has since retired all three of its old 737s.

However, Aloha points out that Boeing did not suggest that the 737s be taken out of service immediately. Nor did Boeing contact the FAA. John Mazor of the Air Line Pilots Association says, "You hate to see a situation where the airline and the manufacturer have quietly been talking to one another about a problem. . .and meanwhile, the FAA doesn't know what's happening." It is a pity, he adds, that others did not get this information until after the accident.

Clyde Kizer, the Air Transport Association's vice president for engineering and maintenance, says that "there's plenty of blame to go around for everyone." Although he insists the accident was "an

anomaly," he agrees "it should never have happened."

Kizer is orchestrating a 150-person effort to nail down any loose ends that can be found on the issue of aging aircraft. In an unprecedented action, the airlines, the manufacturers, and the regulators are cooperating to identify all industry service directives and federal maintenance orders that have a bearing on cracking and corrosion, and to rank them in importance. This amounts to a major house cleaning; the recommendations, due by summer, will carry authority.

The FAA meanwhile has ordered inspections and rerivetting of hundreds of older 737s. This is a "change of philosophy," says McSweeny. It means that on these planes the FAA will no longer allow airlines to cope with problems through inspection and maintenance; they will have to carry out repairs that "terminate" the problem.

According to Bernard Loeb, aviation technology chief at the NTSB, another "open question" still under review is whether to give credit to the principle of "safe decompression" used by Boeing in earlier years to guard against catastrophic failure. Boeing's idea was to rely on designed-in stress patterns to steer dangerous longitudinal cracks, if they appeared, in a less threatening circumferential direction around the fuselage. The goal was to have these cracks announce their presence by creating a delta-shaped flap, which would let pressure out of the cabin, creating an attention-getting but not a catastrophic demand for action.

Swift of the FAA says that perhaps in older, fatigued aircraft with weak lap joints, cracks that start running longitudinally may continue to do so, because rivet holes may provide a path of lesser resistance. This result would defeat the "safe decompression" design, and the possibility deserves study, he says.

In Congress there has been talk of legislating the risks away. According to FAA officials, some are suggesting that planes more than 20 years old simply be forced into retirement. This idea finds no support whatever in the FAA or industry. It would create a severe shortage of vehicles, says McSweeny. Swift says that for air travelers, "The world would stop turning."

The industry points out that the risk of continuing to use aging aircraft is probably very small. During the jet age, fewer than 4% of the accidents in which a cause has been determined have been tied to faulty maintenance or structural failure. In view of these odds and the difficulty of finding a quick remedy to this problem, U.S. air travelers probably have no option but to continue riding on geriatric planes.

■ ELIOT MARSHALL

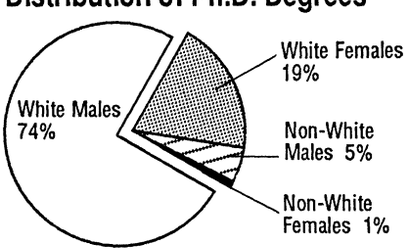
Overhaul Urged for Math Teaching

Most American students leave school with such a poor understanding of mathematics that they cannot adequately perform the vast majority of jobs, much less consider specialized careers in mathematics or science, an expert panel said last week. The villain, however, is not student laziness or the difficulty of the subject matter, but rather an approach to math teaching that is out of date and mired in pointless pencil-and-paper computation, rote memorization, and multiple-choice tests.

Women and minorities are particularly hard hit by poor math education, which keeps them from entering scientific professions, the report says. For example, white men earn 74% of the doctoral degrees in math each year (see figure).

But the number of white males entering the work force is now dwindling and the professions increasingly are looking to women and minorities for new employees. The disparity in math achievement portends a nation divided into a white, technologically astute elite and a largely minority underclass that finds "economic and political power beyond reach."

"Unless corrected," the report says, "innumeracy and illiteracy will drive America apart."



White males' province. *Three of every four Ph.D.'s in math awarded to U.S. citizens are earned by white males.* [*Source: NRC*]

The report, issued last week by the National Research Council, represents the consensus of 70 organizations and individuals concerned with math, science, and education. It calls for a radical overhaul of the way mathematics is taught in the United States. The changes outlined in the report—and to be further elaborated in March in a new set of national standards issued by the National Council of Teachers of Mathematics—would affect the way math is learned at every grade level, kindergarten through college.

The most prevalent method of math instruction today, teacher lecturing, has been proved the least effective, Shirley A. Hill, a professor at the University of Missouri and the panel's chairman, said at a news conference. Instead, in the math class of the future, teachers should act as facilitators who encourage students to solve realistic problems, explain their approaches, and work in teams to find their solutions. Calculators and computers should be used when appropriate to perform calculations. Studies have shown that use of calculators does not weaken students' understanding of the basic mathematical processes, Hill said.

Math classes should emphasize higher order processes—such as pattern recognition—and deemphasize mere computation. Curricula might also be rewritten to remove the traditional distinctions between arithmetic, algebra, geometry, and other math specialties, the report says.

But, Hill says, new reform does not mean a return to the "New Math" of the 1960s and 1970s, which frustrated teachers, students, and parents alike. The New Math was an attempt to transplant a fully developed math curriculum into a wide range of school systems. This "top down" approach is one favored by countries like Japan and West Germany for their school systems, and it allows students in those countries to consistently outscore students here in math and science.

But the American tradition of decentralized education calls for more of a grass-roots approach, the report says. Instead of setting a national curriculum, the report hopes to enlist public opinion in support of local curriculum revision based upon newly evolving standards such as the forthcoming ones from the national math teachers association.

Improved math education might even save money, the report says. About 60% of college math courses merely repeat material that was taught but unlearned in high school, said Philip A. Griffiths, a professor at Duke University and chair of the Research Council's Board on Mathematical Sciences. In addition, U.S. industry spends as much on remedial math education for employees as is spent on math education in schools, colleges, and universities combined each year.

■ GREGORY BYRNE