Office of Inspector General

Audit Report

Oversight of Manufacturer's Quality Assurance Systems for Threaded Fasteners

Federal Aviation Administration

Report Number: AV-2001-003
Date Issued: October 11, 2000

Memorandum

U.S. Department of Transportation

Office of the Secretary of Transportation

Office of Inspector General

Subject: ACTION: Report on FAA's Oversight of Manufacturers' Quality Assurance Systems for Threaded Fasteners, AV-2001-003

Date: October 11, 2000

From: Alexis M. Stefani
Assistant Inspector General for Auditing

Reply to Attn of: JA-10:x60500

To: Federal Aviation Administrator

This report summarizes our audit of the Federal Aviation Administration's (FAA) Oversight of Manufacturers' Quality Assurance Systems for Threaded Fasteners. We are providing this report for your information and use. FAA's June 23, 2000, comments to our June 8, 2000, draft report were considered in preparing this report. An executive summary of the report follows this memorandum.

FAA agreed with our recommendations to improve FAA surveillance at fastener manufacturers and to require manufacturers to establish regular inspection intervals of their subcontractors, adhere to FAA's policy on the proper use of statistical sampling plans, and use the prescribed test equipment. FAA's planned corrective actions, when properly implemented, will satisfy the intent of our recommendations. Therefore, we consider these recommendations resolved subject to the audit follow-up requirements of Department of Transportation Order 8000.1C.

FAA partially agreed with our recommendation to complete its investigation of the nonconforming fasteners identified in the draft report, determine the cause of the nonconforming parts, and inform the aviation industry of systemic problems. Our recommendation was based on independent tests of fasteners performed by Hill Air Force Base, a Fastener Quality Act accredited laboratory. The Hill Air Force Base Science and Engineering Laboratory found 27 percent of the fasteners tested were nonconforming.

Although FAA stated it completed an investigation of nonconforming fasteners, FAA's actions were not sufficient or thorough. First, FAA simply sent the nonconforming fasteners for retesting to the manufacturers that produced the parts. FAA officials were not even present to observe all of the retests. Second, FAA used a nonaccredited consultant to conduct retests on a limited number of nonconforming fasteners. The fastener retesting conducted as part of FAA's investigation yielded a 3 percent nonconformance rate. FAA used the results of its limited investigation to conclude there was no systemic problem with the manufacture of threaded fasteners.

FAA contended that gage uncertainty may have caused false readings at Hill Air Force Base and was a possible explanation for the different test results. However, FAA representatives did not visit Hill Air Force Base to confirm their suppositions regarding gage uncertainty.

Gage uncertainty is an indication of the quality of the test results and is expressed quantitatively. Given that any measurement is subject to imperfections, such as those caused by temperature fluctuations, the entity that accredits laboratories assesses uncertainty, which is the level of confidence that can be placed in a laboratory's measurements. For example, the industry standard is that a laboratory must be 95 percent confident that the measurements will repeatedly fall within a specified range (e.g., within plus or minus .0002 of an inch).

The Hill Air Force Base accreditation process has already addressed the risks of gage uncertainty. The accreditation process includes a review of the test equipment used, including proper calibration of the equipment, the qualifications of the technicians, and evaluation of gage uncertainty. Hill Air Force Base is accredited for a maximum uncertainty of .0002 of an inch. Accordingly, it is unlikely that gage uncertainty at Hill Air Force was responsible for the difference in the test results.

The retest results from the manufacturers raise a serious question as to why there would be such a significant difference in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. According to industry representatives we spoke with, the use of more sophisticated test equipment could yield a higher degree of precision and may be one explanation for the inconsistent test results. However, without investigating these differences, FAA discounted the independent laboratory test results and placed more credence on retests by the fastener manufacturers that produced the parts. The disparity in test results raises a potential safety issue, which FAA should have acted on with greater urgency and concern.

In September 1999, we discussed the final Hill Air Force Base test results with FAA's engineering representative. However, it was not until May 2000, 8 months later, while we were discussing the issuance of our draft report with FAA senior-level officials, that FAA officials informed us they questioned the accuracy of the Hill Air Force Base test results and concluded the results were invalid. At that time, FAA planned to take no further action on this issue.

FAA's reaction to potential safety issues brought to its attention is quite different than the approach used by the United States Coast Guard. In August 1998, our office participated in a test of flight critical fasteners in the Coast Guard's inventory that disclosed nonconforming fasteners. The Coast Guard took prompt action and immediately removed the fasteners from stock to prohibit future installation on aircraft.

FAA's lack of action to sufficiently and timely respond to the independent laboratory test results is similar to FAA's delayed response on another recent nonconforming part. In May 1999, the Department of Defense developed information about defective aviation cable placed in aircraft to adjust flight controls such as the rudder. After the Department of Defense determined from testing that the cable did not meet strength specifications, other Federal agencies, including FAA, were notified of the nonconforming cable. However, FAA delayed action for a year before informing air carriers of the nonconforming cable. The fact that FAA did not respond timely to potential safety issues suggests a systemic weakness in FAA's process to evaluate safety issues brought to the agency's attention.

Since we issued our draft report, we met with FAA senior-level officials on two occasions to discuss the disparity in test results. During meetings in July and August 2000, we requested FAA to provide us additional support for its position. FAA has not provided us with information to support its position, but in September 2000, initiated a new evaluation of threaded fasteners. The agency plans to complete this review of threaded fasteners in 3 months.

As part of its follow-up evaluation, FAA met with Hill Air Force Base representatives on September 15, 2000, 1 year after FAA was provided the final Hill Air Force Base test results. During the meeting, Hill Air Force Base laboratory officials offered FAA representatives the opportunity to review the test equipment and procedures used to perform testing on the fasteners. However, FAA representatives chose to review data summary sheets rather than address the disparity. During this review, FAA and Hill Air Force Base staff found two data summary sheet recording errors. As a result, we revised the percentage of nonconforming parts from 32 to 27 percent. *However, the core issue regarding the differences in test results between FAA-approved*

manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA Aircraft Certification Service representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.

In addition, it is still unclear whether FAA's 3-month evaluation will resolve our basic question regarding the disparity in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. FAA has not included appropriate steps in its methodology to address key issues, such as the effect that differences in test equipment have on measurements.

Furthermore, FAA's evaluation methodology is not consistent with the methodology used in our audit; therefore, the results may not be comparable. For example, FAA plans to use two less-experienced laboratories to conduct testing (e.g., one laboratory does not have the equipment or the experienced technicians needed to perform this type of testing). Additionally, FAA's sample may not be a true representation of what is actually shipped to end-users. Unlike our sample, which was designed to ensure the parts had passed through the manufacturers' quality assurance systems and were shipped to end-users, FAA plans to select fasteners directly from the manufacturers' inventories. If nonconforming fasteners are identified, the manufacturers could contend that the fasteners would have been identified through the quality assurance system before they were shipped to customers.

Accordingly, we revised our draft report recommendation requesting FAA to complete its investigation of the nonconforming fasteners and inform the aviation industry of any systemic problems found. We are now requesting that FAA conduct a comprehensive investigation to reconcile the disparity between test results from Hill Air Force Base and the manufacturers. As part of FAA's investigation of the disparity in test results, the agency should compare the test equipment used by Hill Air Force Base with equipment used by the manufacturers and determine if differences in test equipment could affect measurements. In accordance with Department of Transportation Order 8000.1C, please provide your written comments within 30 days specifying the actions taken or planned to resolve the revised recommendation.

We appreciate the cooperation and assistance provided by your staff during the audit. If you have questions or need further information, please contact me at (202) 366-1992, or David A. Dobbs, Deputy Assistant Inspector General for Aviation, at (202) 366-0500.

Attachment

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cc: Carl Burleson, AOA-2
Donna McLean, ABA-1
Ron Page, APF-200

EXECUTIVE SUMMARY

Oversight of Manufacturers' Quality Assurance Systems for Threaded Fasteners

Federal Aviation Administration

Report No. AV-2001-003 ***October 11, 2000***

The Fastener Quality Act was first signed into law on November 16, 1990, to protect public safety, deter introduction of nonconforming fasteners, and provide users assurance that fasteners meet specifications. The Fastener Quality Act requires fastener manufacturers to submit samples of fastener production lots to be inspected, tested and certified by independent laboratories. However, implementation was delayed because there were not enough accredited laboratories to conduct the testing required by the Fastener Quality Act. On June 8, 1999, the Act was amended and a new effective date of December 6, 1999, was established. At the Federal Aviation Administration's (FAA) request, aviation fasteners were exempted from the amended Fastener Quality Act. To gain the exemption, FAA testified before Congress that FAA-approved fastener manufacturers are sufficiently regulated by FAA and would not need independent testing required by the Fastener Quality Act. However, our results disclosed FAA-approved fastener manufacturers must strengthen their quality assurance systems to ensure the production of conforming fasteners and FAA agreed. Our audit also disclosed a wide disparity in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. FAA has not resolved this issue.

Objective, Scope and Methodology

The objective of the audit was to determine whether FAA has implemented an effective manufacturing inspection system to ensure manufacturers of threaded fasteners produce parts in conformance with FAA-approved design data. Threaded fasteners are screws, nuts, bolts, or studs having internal or external threads used to assemble one part to another. The scope of our review was limited to threaded fasteners used on commercial aircraft. Our audit covered the period of October 1997 to December 1999 and was performed at an aircraft manufacturer, four fastener manufacturers, three air carriers, five repair stations, and offices within the FAA Aircraft Certification and Flight Standards Services lines of business.

Responding to our request, *FAA, air carriers, and repair stations identified fasteners, by part number, which are used in critical applications.* Accompanied

by FAA inspectors, we visited air carriers and repair stations and took samples of the identified fastener part numbers from their stock. We had the fasteners tested for thread dimensional conformance in accordance with FAA-approved design data as a measurement of the effectiveness of the production approval holders' quality assurance systems.

Background

According to Federal Aviation Regulations, to be installed on aircraft, aviation fasteners must be manufactured under an FAA-approved production process, with the exception of foreign manufactured and standard fasteners. Once FAA reviews and approves an applicant manufacturer's design data and production and quality assurance systems, FAA will grant the applicant a production approval holder certificate. *Thereafter, FAA requires the production approval holder to maintain a production and quality assurance system to ensure products, including fasteners, conform to approved designs*. In addition, production approval holders are required to establish quality assurance controls over subcontractors used to manufacture a product.

There are several types of production approval holders. For example, a production approval holder can be an aircraft or engine manufacturer that has FAA approval to build and assemble an aircraft or a major system of an aircraft. This type of manufacturer is generally referred to as the original equipment manufacturer (e.g., Boeing for aircraft). On a smaller scale, a production approval holder can also be a manufacturer that is limited to the production of one type of part for an aircraft such as an engine mount bolt. This type of production approval holder is generally referred to as having *parts manufacturer approval*.

FAA relies on a series of overlapping controls to ensure that only conforming parts are installed on aircraft. The principal control for ensuring the manufacture of conforming parts is the production approval holder's quality assurance system. FAA provides oversight of production approval holders by reviewing and approving quality assurance plans and performing periodic audits at manufacturers' facilities. The scope of a periodic audit is left to the discretion of the FAA inspector, but does not include independent testing to confirm compliance with manufacturing specifications. FAA also places a high degree of reliance on aviation mechanics to detect nonairworthy parts during the installation process.

EXECUTIVE SUMMARY

Results in Brief

It is important to recognize that the first and most important safeguard in detecting and rejecting nonconforming parts is the establishment and maintenance of an effective quality assurance system by each production approval holder. Second, an individual mechanic may detect a nonairworthy fastener during installation. Finally, as essential as manufacturing quality is, an equally important control is redundancy of aircraft design. Redundancy is an essential element in the safety design of an aircraft (i.e., to increase the safety margin, designs intentionally use more fasteners than are necessary to support a specific design weight or load factor). However, redundancy cannot be a substitute for maintaining high manufacturing standards.

In response to a request from our office, FAA provided us a list of fasteners, which may be used in critical applications from the following manufacturers: Boeing, Pratt & Whitney, General Electric, and Bombardier.[1] We also supplemented this list with other fasteners identified by air carriers and repair stations as having critical uses. We randomly selected these fasteners from the inventories of air carriers and repair stations. FAA engineering and maintenance personnel assisted us in sampling fasteners for testing, observing tests, and analyzing results. Our sample of critical use fasteners included parts such as engine mount bolts, landing gear bolts and bolts used internally in engines.[2]

Parts selected from end-user inventories were shipped to Hill Air Force Base for testing by certified laboratory technicians. The Science and Engineering Laboratory at Hill Air Force Base is a Fastener Quality Act accredited laboratory. Of the 176 fasteners in our sample, Hill Air Force Base found 48 (27 percent) were nonconforming for thread dimensions. The fastener sample, although randomly selected at each end-user, was not statistically based and, therefore, is not representative of the universe of aviation fasteners.

FAA had the nonconforming fasteners retested by the manufacturers that produced the parts to determine why the manufacturers' quality assurance systems did not detect the nonconforming fasteners and what corrective action was needed. According to FAA officials, these retests disclosed a 3 percent nonconformance

[1] We also requested a list of Airbus part numbers. Although FAA attempted to obtain these part numbers, receipt was delayed, and we did not obtain them in time for our testing.

[2] Horizontal stabilizer jackscrews, such as those subjected to an emergency airworthiness directive as a result of the Alaska Airlines crash, were not included in our test sample.

rate. FAA officials relied on the retest results from the manufacturers to conclude there was no systemic problem with the manufacture of threaded fasteners.

The retest results from the manufacturers raise a serious question as to why there would be such a significant difference in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. According to industry representatives we spoke with, the use of more precise test equipment by Hill Air Force Base could have resulted in a higher degree of precision and may be one explanation for the inconsistent test results. However, until FAA evaluates this core issue, it is unknown what effect test equipment differences had on fastener measurements.

The fact that FAA did not respond to the disparity in test results in a timely manner suggests a systemic weakness in FAA's process to evaluate safety issues brought to the agency's attention. Since we issued our draft report, we met with FAA senior management officials on two occasions to discuss the differences in test results. During meetings in July and August 2000, we requested FAA to provide us additional support for its position. FAA has not provided us with information to support its position. However, in September 2000, FAA initiated a 3-month evaluation of threaded fastener manufacturers.

As part of its follow-up evaluation, FAA met with Hill Air Force Base representatives on September 15, 2000, 1 year after FAA was provided the final Hill Air Force Base test results. During the meeting, Hill Air Force Base laboratory officials offered FAA representatives the opportunity to review the test equipment and procedures used to perform testing on the fasteners. However, FAA representatives chose to review data summary sheets rather than address the disparity. During this review, FAA and Hill Air Force Base staff found two data summary sheet recording errors. As a result, we revised the percentage of nonconforming parts from 32 to 27 percent. However, the overriding issue regarding the differences in test results between FAA-approved manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA Aircraft Certification Service representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.

It is unclear whether FAA's evaluation will resolve our questions regarding the disparity in test results. FAA has not included appropriate steps to address key issues, such as the differences in test equipment and the effect those differences have on measurements.

EXECUTIVE SUMMARY

In addition to our sampling of parts for independent testing, we visited four manufacturers to observe procedures for inspecting fasteners for compliance with design requirements. We found two of the manufacturers were not adhering to FAA's policy on the use of statistical sampling plans or using the proper test equipment.

Our concern is that production approval holders' quality assurance systems may not be performing as intended by identifying and rejecting nonconforming fasteners. To provide assurance that nonconforming fasteners are detected and rejected at the manufacturing source, two basic actions should be taken:

- FAA should direct fastener production approval holders to establish and maintain an effective quality assurance system, and

- FAA inspectors, when performing periodic and spot surveillance, should verify that threaded fastener manufacturers follow FAA-approved manufacturing specifications and proper inspection procedures.

Principal Finding

FAA Needs to Thoroughly Investigate the Disparity in Fastener Test Data

FAA requires production approval holders to establish reliable quality assurance systems to ensure fasteners are produced in accordance with FAA-approved design data. *This requirement is particularly important as a safeguard to the end-users of aviation fasteners such as air carriers and repair stations because they do not routinely conduct tests of incoming parts for compliance with manufacturing specifications*. Rather, air carriers and repair stations rely both on the certifications received from manufacturers and on aviation mechanics to detect nonairworthy parts during the installation process.

Of the 176 fasteners in our sample, Hill Air Force Base test results disclosed 48 (27 percent) were nonconforming for thread dimensions. The nonconforming fasteners identified by the independent laboratory were from both original equipment manufacturers and parts manufacturer approval holders. The fastener sample, although randomly selected at each end-user, was not statistically based and, therefore, is not representative of the universe of aviation fasteners.

FAA had the nonconforming fasteners retested by the manufacturers that produced the parts to determine why the manufacturers' quality assurance systems did not detect and reject the nonconforming parts and what corrective action was needed.

Additionally, FAA had a limited number of fasteners retested by a nonaccredited consultant. According to FAA officials, these retests disclosed a 3 percent nonconformance rate. Rather than investigate the disparity in test results, FAA placed more credence on the retest results from the manufacturers than the independent laboratory to conclude there was no systemic problem with the manufacture of threaded fasteners.

The retest results from the manufacturers raise a question as to why there would be such a wide disparity in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. According to industry representatives we spoke with, differences in test equipment could be one explanation for the disparity in the test results between Hill Air Force Base and the manufacturers. However, FAA representatives did not compare the equipment used at the manufacturers to the equipment used at Hill Air Force Base as part of their limited investigation.

FAA contended that gage uncertainty may have caused false readings at Hill Air Force Base and was a possible explanation for the different test results. However, FAA representatives did not visit Hill Air Force Base to confirm their suppositions regarding gage uncertainty. Gage uncertainty is an indication of the quality of the test results and is expressed quantitatively. For example, the industry standard is that a laboratory must be 95 percent confident that the measurements will repeatedly fall within a specified range (e.g., within plus or minus .0002 of an inch). Hill Air Force Base is accredited for a maximum uncertainty of .0002 of an inch. Without a study to establish the degree of gage uncertainty for the test equipment at Hill Air Force Base and the fastener manufacturers, FAA cannot substantiate whether gage uncertainty adversely affected the test results.

FAA discounted the independent test results and placed more reliance on retests by the fastener manufacturers that produced the parts. However, retesting at the manufacturers that produced the parts does not provide conclusive evidence to refute the independent test results. Additionally, representatives from FAA and our office were not present at all locations to observe the manufacturers' retests. Further, FAA did not:

- Inspect the quality assurance systems at the manufacturers identified as producing nonconforming fasteners by evaluating the type of test equipment used and selecting current production fasteners for testing.

- Return to Hill Air Force Base until more than 1 year had elapsed to address concerns about the validity of the measurements with Hill Air Force Base laboratory management and technicians.

- Contract with another Fastener Quality Act accredited laboratory to have the nonconforming fasteners retested and invite the Office of Inspector General to observe the testing.

The fact that FAA did not respond to the disparity in test results in a timely manner suggests a systemic weakness in FAA's process to evaluate safety issues brought to the agency's attention. In September 1999, we discussed the final Hill Air Force Base test results, part by part, with FAA's engineering representative to reach agreement on the results. However, it was not until May 2000, 8 months later, that FAA senior-level officials informed us that they questioned the accuracy of the Hill Air Force Base test results and concluded the test results were invalid. Because the disparity in test results raises a potential safety issue, FAA should have acted with greater urgency and concern.

Since we issued our draft report, we met with FAA senior management officials on two occasions to discuss the differences in test results. During meetings in July and August 2000, we requested FAA to provide us additional support for its position. FAA has not provided us with information to support its position. However, in September 2000, FAA initiated a 3-month evaluation of threaded fastener manufacturers.

As part of its follow-up evaluation, *FAA met with Hill Air Force Base representatives on September 15, 2000, 1 year after FAA was provided the final Hill Air Force Base test results.* During the meeting, Hill Air Force Base laboratory officials offered FAA representatives the opportunity to review the test equipment and procedures used to perform testing on the fasteners. However, FAA representatives chose to review data summary sheets rather than address the disparity. During this review, FAA and Hill Air Force Base staff found two data summary sheet recording errors. As a result, we revised the percentage of nonconforming parts from 32 to 27 percent. However, the overriding issue regarding the differences in test results between FAA-approved manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA Aircraft Certification Service representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.

It is unclear whether FAA's evaluation will resolve our questions regarding the disparity in test results. FAA has not included appropriate steps to address key issues, such as the differences in test equipment and the effect those differences have on measurements.

Furthermore, FAA's evaluation methodology is not consistent with the methodology used in our audit; therefore, the results may not be comparable. For example, FAA plans to use two less-experienced laboratories to conduct testing (e.g., one laboratory does not have the equipment or the experienced technicians needed to perform this type of testing). Additionally, unlike our sample, FAA will select fasteners from manufacturers rather than end-users. If nonconforming fasteners are identified, the manufacturers could contend that the fasteners would have been identified through the quality assurance system before they were shipped to customers.

Two of Four Manufacturers Did Not Comply With Established Requirements for the Use of Statistical Sampling Plans and Prescribed Test Equipment

In addition to our sample of parts from end-user inventories, we observed the procedures of four manufacturers for inspecting parts for compliance with specifications for thread dimensional conformance. We found two manufacturers did not correctly follow FAA's statistical sampling policy for rejecting nonconforming parts and did not use the test equipment prescribed in the FAA-approved design data to test thread dimensional conformance of aviation nuts. Additionally, we found that the FAA inspectors responsible for oversight of these manufacturers were unclear on FAA's statistical sampling policy and were unfamiliar with the test equipment requirements of the specification cited for thread dimensional conformance.

Manufacturers Need to Comply With FAA's Statistical Sampling Policy. To alleviate the burden of testing all parts in large production lots, FAA permits manufacturers to use statistical sampling plans to determine the test sample size for final inspection. *FAA's policy is clear that a manufacturer can accept a production lot as complying only when **all** sampled items pass compliance testing for characteristics that affect safety.* However, two manufacturers did not adhere to FAA's policy because they accepted production lots when nonconforming items were found in the sample. In other words, instead of rejecting the production lot, the manufacturers approved the lot and shipped the parts to their customers.

Manufacturers Need to Use the Prescribed Equipment to Test Dimensional Conformance of Aviation Nuts. Two fastener manufacturers[3] we visited did not

[3] These two manufacturers were the same manufacturers that incorrectly applied FAA's statistical sampling policy.

use the equipment prescribed in FAA-approved design data for testing thread dimensional conformance of aviation nuts. The design data require the use of precision equipment that can provide minute measurements. However, these two manufacturers used a go/no-go gage, which is a simple test of whether a nut will assemble with a mating bolt. These measuring devices are shown as follows.

Measuring Device for Internal Threads

Go/No-Go Gage

The device shown to the left provides precise measurements of thread dimensions. The device depicted above only assesses whether the nut will assemble with a bolt.

Our on-site work disclosed that two manufacturers did not comply with FAA's statistical sampling policy and did not use the prescribed test equipment because the companies' inspection personnel were unaware of FAA requirements. To ensure that FAA requirements are fully communicated to the aviation industry, FAA should issue an appropriate notice informing the industry of the proper use of statistical sampling plans and the need to use the prescribed equipment to test the thread dimensional conformance of aviation nuts. To enhance its surveillance of fastener manufacturers, FAA should clarify to its inspector workforce the agency's final inspection statistical sampling policy and ensure inspectors maintain familiarity with the test equipment cited in design drawings.

An FAA Production Approval Holder Did Not Maintain Effective Oversight of Its Subcontractors

An issue involving the manufacture of defective jet engine bolts that occurred during our audit illustrates the problems that can result when a production approval holder's quality assurance system fails. A repair station determined it had installed defective bolts in commercial aircraft jet engines and that the defective bolts caused engine failures. In accordance with Federal Aviation Regulations, the repair station reported the defective bolts and failed engines to FAA. Although we did not discover the defective bolts as part of our testing process, the results of FAA's review into this matter are germane to our audit.

EXECUTIVE SUMMARY

FAA inspectors determined that, from March to December 1999, the defective bolts failed on 10 engines used on commercial passenger aircraft, causing internal damage to 7 engines during engine ground tests and 1 in-flight shutdown. Analysis of the failed bolts revealed an insufficient nickel content in the plating, which was traced to an error during the manufacturing process. According to FAA's investigation, the FAA production approval holder had subcontracted the manufacturing of this bolt, and the subcontractor in turn subcontracted the plating process. FAA determined the production approval holder had never inspected the manufacturing processes of this second-tier subcontractor. Further, the first-tier subcontractor had not conducted an on-site audit of the plating contractor since July 1995.

FAA regulations permit production approval holders to utilize subcontractors when production approval holders have established an FAA-approved quality control system that provides assurance all parts produced by subcontractors are in compliance with design data. *However, FAA does not require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors.* Inspection intervals are left to the discretion of the production approval holder.

To purge the aviation industry of these defective bolts, FAA issued a Flight Standards Information Bulletin for Airworthiness on September 14, 1999, which suggested steps to identify and remove these bolts from inventory and aircraft. Compliance with these steps cost one air carrier approximately $100,000. FAA inspectors also determined the second-tier subcontractor was processing a large volume of parts for the commercial aviation industry. *FAA concluded that all parts processed by this subcontractor were suspect because of serious quality control problems.*

FAA has completed its investigation of the production approval holder. The agency has decided not to take any punitive action against the production approval holder for several reasons. First, the production approval holder timely and voluntarily notified FAA of the defective bolts after the repair station notified the company of the defective bolts. Second, the company has agreed to assume liability for end-user costs associated with engine failures and removing the bolts from the industry. To date, the production approval holder's insurer has reimbursed end-users about $1.5 million. Lastly, the production approval holder has ceased using the at-fault subcontractor for plating fasteners. To ensure that production approval holders are properly and consistently monitoring their subcontractors for compliance with design data, FAA should require production

approval holders to establish regular inspection intervals to review the quality assurance systems of all subcontractors in their production chain.

Recommendations

We recommend FAA**:**

- Conduct a comprehensive investigation to reconcile the disparity in test results between Hill Air Force Base and the fastener manufacturers, including an evaluation of the effect that different test equipment has on the accuracy of measurements.

- Require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors.

- Direct production approval holders to establish and maintain effective quality assurance systems to ensure the production of conforming parts and adhere to FAA's policy on the proper use of statistical sampling plans and the use of prescribed equipment to test the thread dimensional conformance of aviation nuts.

- Improve surveillance at fastener production approval holders during periodic and spot surveillance by placing special emphasis on manufacturing compliance with FAA-approved design data for threaded fasteners and adherence to proper inspection procedures.

Management Position and Office of Inspector General Comments

On June 23, 2000, FAA provided comments to our June 8, 2000, draft report. FAA concurred with the draft report recommendations to improve FAA surveillance at fastener manufacturers and to require manufacturers to establish regular inspection intervals of their subcontractors, adhere to FAA's policy on the proper use of statistical sampling plans, and use the prescribed test equipment. In response to these recommendations, FAA agreed to take the following actions:

- Continue placing emphasis on subcontractors during certificate management surveillance;

- Revise FAA guidance based on the work of two teams chartered to improve the certificate management program, including production approval holders' controls over their subcontractors;

- Reemphasize the agency's policy regarding statistical sampling, which will be published on the FAA website as "Best Practices" by September 2000;

- Incorporate the agency's position on statistical sampling into FAA Orders 8120.2 and 8110.42, which are scheduled to be completed by July 2001 and September 2001, respectively;

- Implement a special emphasis initiative, which will be in effect by January 2001, concerning production approval holders' use of prescribed inspection and test equipment;

- Place special emphasis on manufacturing compliance with FAA-approved design data during certificate management activities at fastener production approval holders and their suppliers; and

- Encourage production approval holders to place special emphasis on suppliers of threaded fasteners concerning compliance with FAA-approved design data.

FAA's planned corrective actions to improve the monitoring of subcontractors and clarify the agency's statistical sampling policy will enhance manufacturers' quality assurance systems. As a result, the second, third and fourth recommendations in our draft report are resolved.

FAA partially agreed with the first recommendation in our draft report to complete its investigation of the nonconforming fasteners, identify the cause of the nonconforming parts, and inform the industry of any systemic problems found. To investigate these nonconforming parts, FAA sent the parts back to the manufacturers to be retested and had five part numbers retested by a consultant. FAA stated the retests did not confirm the frequency of nonconformity reported by Hill Air Force Base. According to FAA, the retests from the manufacturers and the consultant yielded a 3 percent nonconformance rate.

Although FAA stated it completed an investigation of the nonconforming fasteners, FAA's actions were not sufficient or thorough. First, FAA simply sent the nonconforming fasteners for retesting to the manufacturers that produced the parts. FAA officials were not even present for all of the retests. Second, FAA

used a nonaccredited consultant to conduct retests on a limited number of nonconforming fasteners.

In addition, the agency contended that gage uncertainty may have caused false readings and was a possible explanation for the different test results. However, FAA representatives did not visit Hill Air Force Base to confirm their suppositions regarding gage uncertainty.

Gage uncertainty is an indication of the quality of the test results and is expressed quantitatively. Given that any measurement is subject to imperfections, such as those caused by temperature fluctuations, the accreditation entity assesses uncertainty, which is the level of confidence that can be placed in a laboratory's measurements. For example, the industry standard is that a laboratory must be 95 percent confident that the measurements will repeatedly fall within a specified range (e.g., within plus or minus .0002 of an inch).

The Hill Air Force Base accreditation process has already addressed the risks of gage uncertainty. The accreditation process includes a review of the test equipment used, including proper calibration of the equipment, the qualifications of the technicians, and evaluation of gage uncertainty. Hill Air Force Base is accredited for a maximum uncertainty of .0002 of an inch. Accordingly, it is unlikely that gage uncertainty at Hill Air Force was responsible for the difference in the test results.

At no point during the testing process did the FAA representatives raise any objections to the capabilities or qualifications of the laboratory or the technicians testing the sampled fasteners. Representatives from Aircraft Certification and Flight Standards Services assisted us in developing fastener testing methodology, identifying critical application fasteners, and obtaining the design data for each fastener selected. Equally important, FAA personnel concurred with the choice of Hill Air Force Base to test the sampled fasteners. In June 1999, FAA personnel verified the calibration of the test equipment and the qualifications of the laboratory technicians. FAA staff also observed the technicians taking measurements and concurred with the results. In addition, we periodically provided FAA the test results.

In September 1999, we discussed the final Hill Air Force Base test results, part by part, with FAA's engineering representative to reach agreement on the results. However, it was not until May 2000, 8 months later, while we were discussing the issuance of the draft report with FAA senior-level officials, that FAA officials informed us they questioned the accuracy of the Hill Air Force Base test results

and concluded the results were invalid. At that time, FAA planned to take no further action regarding these nonconforming fasteners.

Since we issued our draft report, we met with FAA senior management officials on two occasions to discuss the disparity in test results. During meetings in July and August 2000, we requested FAA to provide us with additional support for its position. After these repeated requests, FAA finally initiated an evaluation of threaded fasteners in September 2000. As part of this evaluation, FAA returned to Hill Air Force Base accompanied by staff from our office. During a joint meeting with FAA and applicable Hill Air Force Base management and technicians, a transposition error was identified that caused the incorrect classification of eight parts as nonconforming. As a result, the Hill Air Force Base test results were adjusted to reflect that 48 of 176 (27 percent) parts tested were nonconforming. *However, the overriding issue regarding the differences in test results between FAA-approved manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.*

In addition, it is still unclear whether FAA's 3-month evaluation will resolve our basic question regarding the disparity in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. FAA has not included appropriate steps in its methodology to address key issues, such as the differences in test equipment and the effect those differences have on measurements.

Furthermore, FAA's evaluation methodology is not consistent with the methodology used in our audit; therefore, the results may not be comparable. For example, FAA plans to use two less-experienced laboratories to conduct testing (e.g., one laboratory does not have the equipment or the experienced technicians needed to perform this type of testing). Additionally, unlike our sample, FAA will select fasteners from manufacturers rather than end-users. If nonconforming fasteners are identified, the manufacturers could contend that the fasteners would have been identified through the quality assurance system before they were shipped to customers.

In our opinion, FAA's oversight responsibility to monitor production approval holders' quality assurance systems should extend beyond merely accepting retest results from the manufacturers, which have a pecuniary interest in the outcome of the tests. Until the disparity in test results is resolved, it is unknown whether manufacturers' quality assurance systems are effectively identifying and rejecting nonconforming fasteners.

Accordingly, we revised our draft report recommendation requesting FAA to complete its investigation of the nonconforming fasteners and inform the aviation industry of any systemic problems found. We are now requesting that FAA conduct a comprehensive investigation to reconcile the disparity between test results from Hill Air Force Base and the manufacturers. As part of FAA's investigation of the disparity in test results, the agency should compare the test equipment used by Hill Air Force Base with the equipment used by the manufacturers and determine if differences in test equipment could cause differences in measurements.

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I. INTRODUCTION

Background

Threaded fasteners are screws, nuts, bolts or studs having internal or external threads used to assemble one part to another. Threaded fasteners are used in numerous applications on an aircraft. For example, representatives of The Boeing Company (Boeing) stated that a Boeing 757 aircraft is constructed with approximately 700,000 fasteners. Threaded fasteners range in size and criticality from small screws that attach a magazine rack to the interior wall of the aircraft cabin to large bolts used to secure engines to the aircraft.

The bolt pictured on the left (part number 10-60517-53) is an engine cone bolt used to secure the engine onto a Boeing 727 aircraft.

Federal Aviation Administration Oversight of Fastener Manufacturing

According to Title 14 Code of Federal Regulations Part 21, to be installed on aircraft, aviation components or parts, including fasteners, must be manufactured under a Federal Aviation Administration (FAA) production approval. Once FAA reviews and approves an applicant manufacturer's design data and production and quality assurance systems, FAA will grant the applicant a production approval holder certificate. Thereafter, *FAA requires the production approval holder to maintain a production and quality assurance system that will ensure that all products conform to approved designs*. FAA has the principal responsibility to ensure that production approval holders comply with their FAA-approved production and quality assurance systems.

There are several types of production approval holders. For example, a production approval holder can be an aircraft or engine manufacturer that has FAA approval to build and assemble an aircraft or a major system of an aircraft. This type of manufacturer is generally referred to as the original equipment manufacturer (e.g., Boeing for aircraft and Pratt & Whitney for engines). On a smaller scale, a production approval holder can also be a manufacturer that produces only one type

of part for an aircraft such as an engine mount bolt. This type of production approval holder is generally referred to as having parts manufacturer approval.

It is not uncommon for an FAA production approval holder to subcontract some or all of the manufacturing process. These subcontractors do not need to be FAA production approval holders unless they are selling directly to end-users. Rather, subcontractors are considered a part of the production approval holder's quality system. Therefore, *the production approval holder is required to establish quality assurance controls over these subcontractors*. FAA has regulatory authority to perform inspections at the subcontractors. However, FAA primarily relies on production approval holders to ensure subcontractors manufacture in accordance with required specifications.

FAA relies on a series of overlapping controls to ensure that only conforming parts are installed on aircraft. The principal control for ensuring the manufacture of conforming parts is the production approval holder's quality assurance system. FAA provides oversight of production approval holders by performing periodic audits at manufacturers' facilities. The scope of the periodic surveillance is left to the discretion of the FAA inspector. FAA inspectors also perform special inspections under the Aircraft Certification Systems Evaluation Program. However, neither type of FAA surveillance includes independent testing to confirm compliance with manufacturing specifications. FAA also places a degree of reliance on aviation mechanics to detect nonairworthy parts during the installation process.

FAA has 156 aviation safety inspectors responsible for oversight of 1,847 production approval holders and an undetermined number of subcontractors. Of the 1,847 production approval holders, 35 manufacture threaded fasteners.

Fastener Quality Act

The Fastener Quality Act (Act) was signed into law on November 16, 1990, to protect public safety, to deter introduction of nonconforming fasteners, and to provide users added assurance the fasteners meet required specifications. The Act requires fasteners to be inspected, tested and certified by independent laboratories. Because there were not enough accredited laboratories to conduct inspection and testing required by the Act, implementation was delayed for several years. On June 8, 1999, the Act was amended and a new effective date of December 6, 1999, was established.

At the request of FAA, Congress exempted aviation fasteners from the Act. To gain the exemption, FAA testified before Congress that FAA-approved fastener manufacturers are sufficiently regulated by FAA and would not need the

independent testing required by the Act. As a result, FAA is now the sole authority to regulate and approve the quality and suitability of aviation fasteners.

Objective, Scope and Methodology

The objective of the audit was to determine whether FAA has implemented an effective manufacturing inspection system to ensure manufacturers of threaded fasteners produce parts in conformance with FAA-approved design data. To assess the effectiveness of FAA's oversight of fastener production approval holders, we followed two separate tracks.

- We reviewed on-site the quality assurance procedures followed by four fastener manufacturers (three production approval holders and one subcontractor). At the four fastener manufacturers, we reviewed and observed the quality assurance systems in place, including final inspection testing, to ensure the production of conforming parts.

- We contracted with an accredited laboratory to test fasteners selected from end-user inventories for compliance with FAA-approved design data regarding thread dimensional conformance. We used our test results as an indicator of the effectiveness of production approval holders' quality assurance systems to detect and reject nonconforming parts.

We performed our audit at Headquarters and field offices within the FAA Aircraft Certification and Flight Standards Services. Additionally, we performed work at an aircraft manufacturer, four fastener manufacturers, two major air carriers, a regional air carrier, and five repair stations. Exhibit A contains a list of entities visited during the audit.

We performed our audit field work from December 1998 to October 1999. Our audit covered FAA oversight of threaded fastener manufacturers during the time period from October 1997 to December 1999. We conducted the audit in accordance with Government Auditing Standards prescribed by the Comptroller General of the United States, and included such tests of procedures, records, and other data as were deemed necessary.

We identified FAA's inspection procedures and manufacturers' quality assurance controls to ensure that nonconforming fasteners do not enter the inventories of aviation end-users. To determine if these controls were sufficient to ensure aviation industry end-users were receiving conforming parts, we randomly selected fasteners from inventories of air carriers and repair stations for independent testing.

Identification of Fastener Part Numbers

In response to a request from our office, FAA provided us a list of fasteners used in critical applications from the following manufacturers: Boeing, Pratt & Whitney, General Electric, and Bombardier.[1] We also supplemented this list with other part numbers identified by air carriers and repair stations as having critical uses. FAA engineering and maintenance personnel assisted us in selecting fasteners, observing tests, and analyzing results. To facilitate evaluating test results, FAA obtained the design data for these parts containing the applicable design specifications to which the parts were manufactured and tested.

Selection of Parts

At each air carrier and repair station we visited, we observed the entity's parts receiving procedures and identified the parts certification documentation requirements. We then determined how many of the part numbers provided by FAA were in inventory. At each business, when there was a sufficient quantity of a part number in inventory such that we could obtain fasteners and not impede the facility's ability to make repairs, we randomly selected fasteners for testing. We determined the sample quantity based on the number of parts in inventory and the number of different part sources. The end-user then released custody of the parts to FAA representatives[2] by using FAA Form 8020-2, "Aircraft/Parts Identification and Release". This form served as the chain of custody document to record who released the part to FAA and who within FAA accepted custody. We sampled a total of 262 fasteners to be tested from the 8 end-users we visited (3 air carriers and 5 repair stations).

Testing of Parts

Parts obtained from end-user inventories were shipped to Hill Air Force Base in Salt Lake City, Utah, for testing by certified laboratory technicians. The Science and Engineering Laboratory at Hill Air Force Base is a Fastener Quality Act accredited laboratory.

The Hill Air Force Base technicians independently tested the fasteners for compliance with FAA-approved design data regarding fastener thread dimensional conformance. Military specification MIL-S-8879C is widely cited by the commercial aviation industry as the testing protocol for thread dimensional

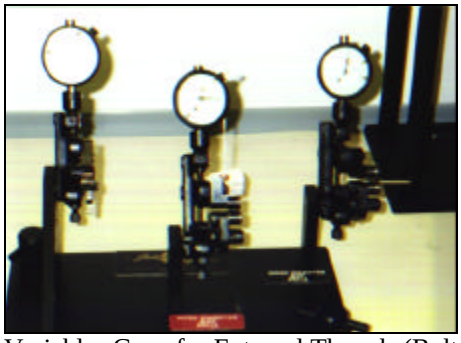
[1] We also requested a list of Airbus part numbers. Although FAA attempted to obtain these part numbers, receipt was delayed, and we did not obtain them in time for our testing.

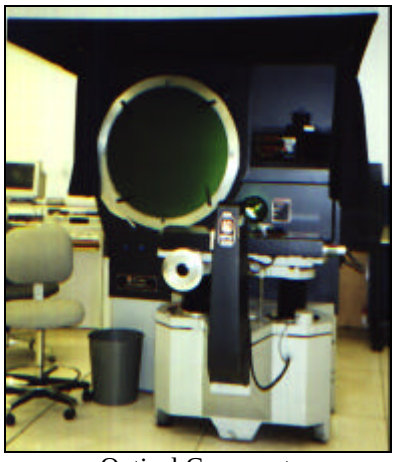
[2] FAA representatives were present at each facility during the part selection process.

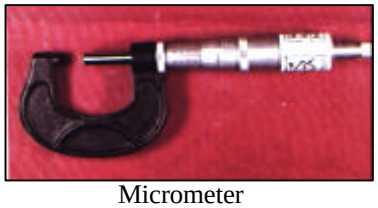
conformance. We selected this specification for testing because industry representatives expressed concern regarding compliance with this specification during a previous review.[3] We also selected this specification because it did not require the destruction of expensive aviation fasteners to meet testing objectives.

For certain measurements, the manufacturer's design data associated with the parts we sampled required adjustments to the tolerances prescribed in the military specification. With FAA's assistance in reviewing the design data, we used the adjusted tolerances to evaluate thread dimensional conformity testing results. We used the Hill Air Force Base test results of conformance to thread dimensional requirements as an indicator of whether production approval holders' quality assurance systems were working as intended to detect nonconforming parts.

Office of Inspector General (OIG) and FAA representatives observed the testing of the fasteners obtained from the first end-user. We observed the laboratory technicians using indicating gages, micrometers, and optical comparators to measure the various thread characteristics cited in MIL-S-8879C. These instruments are depicted below.


Variables Gage for External Threads (Bolts)


Optical Comparator


Micrometer

[3] OIG Report AV-1998-177, "Aviation Industry Notification Regarding Testing Specifications for Threaded Fasteners and Components," July 17, 1998.

Sample Results

We selected and Hill Air Force Base tested a total of 262 fasteners. However, we reduced our sample size to 176 for the reasons shown below.

Reduction of Fastener Sample Size

Total Number of Fasteners Selected		262
Less: Castellated Nuts	32	
Inconclusive Measurements	42	
Dented Threads	4	
Dry Film Lube Coating	8	
Parts Eliminated		86
Final Sample Size		**176**

We eliminated the test results for all castellated nuts (32 parts) from our sample because, according to FAA, the technician could not obtain an accurate reading of the dimensions because there was an insufficient number of complete threads available to test. Furthermore, FAA stated the castellation manufacturing process may have deformed the threads. We eliminated the test results for 42 additional fasteners because FAA questioned the accuracy of the measurements. In addition, we eliminated the test results for four fasteners because the threads were dented, which could affect the accuracy of the measurements. Eight fasteners with a dry film lube coating were eliminated because, according to FAA, the fasteners would have to be tested prior to applying the coating in order to obtain an accurate reading. The fastener sample, although randomly selected at each end-user, was not statistically based and, therefore, cannot be assumed to be representative of the universe of aviation fasteners.

Work Performed at Aircraft and Fastener Manufacturers

In addition to testing fasteners in end-users' inventories, we also reviewed manufacturers' quality assurance systems to determine whether the controls in place ensured nonconforming fasteners were precluded from reaching end-user inventories. At each manufacturer, we reviewed the procedures for final inspection of the fasteners, including the manufacturers' use of statistical sampling plans. We also reviewed the procedures for the disposition of nonconforming fasteners. At the aircraft manufacturer we visited, we observed receiving inspection procedures and controls over subcontractors. We interviewed key personnel within each company visited and discussed our observations with the responsible FAA offices and FAA Headquarters officials.

Prior Audit Coverage

At the request of the National Transportation Safety Board Chairman, we reviewed the potential effects on the commercial aviation industry of the inactivation of military specification MIL-S-8879C. Industry experts we consulted agreed this inactivation could cause some manufacturers to use a less stringent testing specification. We issued Report AV-1998-177, "Aviation Industry Notification Regarding Testing Specifications for Threaded Fasteners and Components," on July 17, 1998. On February 26, 1999, as a result of our recommendation, FAA issued an advisory circular to the aviation industry stating if MIL-S-8879C is cited in the approved drawings, the manufacturer should continue to use this specification to test thread dimensional conformance.

II. FINDING AND RECOMMENDATIONS

FAA should hold production approval holders accountable for implementing effective quality assurance systems to ensure that conforming fasteners are produced and sold to end-users. Responding to our request, *FAA, air carriers and repair stations identified fasteners used in critical applications.* Accompanied by FAA inspectors, we randomly selected fasteners used in critical applications from air carrier and repair station inventories for testing as a measurement of the effectiveness of production approval holders' quality assurance systems. Of the 176 fasteners in our sample, Hill Air Force Base found 48 (27 percent) were nonconforming for thread dimensions.

FAA had the nonconforming fasteners retested by the manufacturers that produced the parts to determine why the manufacturers' quality assurance systems did not detect the nonconforming fasteners and what corrective action was needed. According to FAA officials, these retests disclosed a 3 percent nonconformance rate. Subsequently, FAA officials relied on the retest results from the manufacturers to conclude there was no systemic problem with the manufacture of threaded fasteners. The retest results from the manufacturers raise a question as to why there would be such a wide disparity in test results between a Fastener Quality Act accredited laboratory and an FAA-approved manufacturer. However, FAA did not go beyond obtaining the manufacturers' retests to establish the causes for the varying measurements.

Further, at two of the manufacturers we visited, we observed procedures for inspecting fasteners for compliance with specifications and found the manufacturers were not adhering to FAA's policy on the use of statistical sampling plans or using the proper equipment to test the internal threads on nuts. Our findings illustrate that production approval holders need to improve the reliability of their quality assurance systems to prevent nonconforming fasteners from reaching end-users for installation on aircraft. Additionally, FAA needs to improve its surveillance program by placing special emphasis on manufacturers' compliance with FAA-approved design data and adherence to proper final inspection procedures during spot and periodic surveillance.

FAA Needs to Thoroughly Investigate the Disparity in Fastener Test Data

FAA requires production approval holders to establish reliable quality assurance systems to ensure fasteners are produced in accordance with FAA-approved design data. *This requirement is particularly important as a safeguard to the end-users of aviation fasteners such as air carriers and repair stations because they do not routinely conduct tests of incoming parts for compliance with manufacturing specifications*. Rather, air carriers and repair stations rely on the manufacturers'

certifications (see Exhibit B) that parts meet all required specifications and on mechanics to detect nonairworthy parts during the installation process. Therefore, we had Hill Air Force Base perform tests to determine whether the fasteners sold to end-users conformed to specifications.

As an indicator of the effectiveness of the manufacturers' quality assurance systems, we randomly selected fasteners that may be used in critical applications from the inventories of air carriers and repair stations. We based our part selection on lists, provided by FAA, of fastener part numbers that may be used in critical applications. We supplemented these lists with other part numbers identified by end-users as having critical uses. FAA engineering and maintenance personnel assisted us in selecting fasteners, observing tests, and analyzing test results. Our sample of fasteners used in critical applications included parts such as engine mount bolts, landing gear bolts and bolts used internally in engines.[4]

Although our sample was not statistically compiled, and therefore, is not representative of the universe of aviation fasteners, Hill Air Force Base found 48 (27 percent) of the 176 fasteners tested were nonconforming for thread dimensions. The Hill Air Force Base test results may be an indicator that the production approval holders' quality assurance systems are not operating as intended.

The test results for each manufacturing source in our sample are shown in the following tables. The Hill Air Force Base test results yielded nonconformances by original equipment manufacturers and parts manufacturer approval holders. The detailed test results by part number are shown in Exhibit C.

Hill Air Force Base Test Results

Original Equipment Manufacturers

Manufacturer	Number Tested	Number Nonconforming	Percent Nonconforming
A	68	27	40
B	48	9	19
C	1	0	0
D	2	2	100
E	2	0	0
TOTAL	**121**	**38**	**31**

[4] Horizontal stabilizer jackscrews, such as those subjected to an emergency airworthiness directive as a result of the Alaska Airlines crash, were not included in our test sample.

Parts Manufacturer Approval Holders

Manufacturer	Number Tested	Number Nonconforming	Percent Nonconforming
A	3	0	0
B	9	0	0
C	43	10	23
TOTAL	**55**	**10**	**18**

We did not trace each out-of-tolerance item to its manufacturing source because FAA agreed to investigate the reasons each part did not meet specification tolerances. Specifically, FAA agreed to identify the manufacturer of each nonconforming fastener, determine why the manufacturers' quality assurance systems did not detect the nonconforming fasteners, and determine what corrective measures were needed.

FAA's investigation consisted of having the nonconforming fasteners retested by the manufacturers. Additionally, FAA had a limited number of fasteners retested by a nonaccredited consultant. According to FAA officials, these retests disclosed a 3 percent nonconformance rate. Rather than investigate the disparity in test results, FAA placed more credence on the retest results from the manufacturers than on the tests of the independent laboratory to conclude there was no systemic problem with the manufacture of threaded fasteners.

FAA contended that gage uncertainty may have caused false readings at Hill Air Force Base and was a possible explanation for the different test results. However, FAA representatives did not visit Hill Air Force Base to confirm their suppositions regarding gage uncertainty. Gage uncertainty is an indication of the quality of the test results and is expressed quantitatively. For example, the industry standard is that a laboratory must be 95 percent confident that the measurements will repeatedly fall within a specified range (e.g., within plus or minus .0002 of an inch). Hill Air Force Base is accredited for a maximum uncertainty of .0002 of an inch. Without a study to establish the degree of gage uncertainty for the test equipment at Hill Air Force Base and the fastener manufacturers, FAA cannot substantiate whether gage uncertainty adversely affected the test results.

The retest results from the manufacturers raise a serious question as to why there would be such a wide disparity in test results between a Fastener Quality Act accredited laboratory and an FAA-approved manufacturer. However, FAA did not go beyond obtaining the manufacturers' retests to establish the causes for the varying measurements. According to industry representatives we spoke with, the use of more sophisticated test equipment by Hill Air Force Base could have resulted in a higher degree of precision and may be one explanation for the

disparity in the test results between Hill Air Force Base and the manufacturers. However, FAA representatives did not compare the equipment used at the manufacturers to the equipment used at Hill Air Force Base as part of their limited investigation.

Retesting at the manufacturers that produced the parts does not provide conclusive evidence to refute the independent laboratory test results. Additionally, representatives from FAA and our office were not present at all locations to observe the manufacturers' retests. Further, FAA did not:

- Inspect the quality assurance systems at the manufacturers identified as producing nonconforming fasteners by evaluating the type of test equipment used and selecting current production fasteners for testing.

- Return to Hill Air Force Base until more than 1 year had elapsed to address any concerns about the validity of the measurements with Hill Air Force Base laboratory management and technicians.

- Contract with another Fastener Quality Act accredited laboratory to have the nonconforming fasteners retested and invite the Office of Inspector General to observe the testing.

We took extraordinary measures from the beginning of our audit to involve FAA management and staff in the testing process. FAA representatives observed the first round of testing in June 1999 and raised no objections to the capabilities or qualifications of the laboratory or the technicians. In September 1999, we discussed the final Hill Air Force Base test results, part by part, with FAA's engineering representative to reach agreement on the results. However, it was not until May 2000 that FAA senior-level officials informed us that they questioned the accuracy of the Hill Air Force Base test results and concluded that the test results were invalid. Because the disparity in test results raises a potential safety issue, FAA should have responded with greater urgency and concern. The fact that FAA did not respond to this issue in a timely manner suggests a systemic weakness in FAA's process to evaluate safety issues brought to the agency's attention.

Since we issued our draft report, we met with FAA senior-level officials on two separate occasions to discuss the disparity in test results. During meetings in July and August 2000, we requested FAA to provide us additional support for its position that the Hill Air Force Base test results were invalid. FAA has not provided us with conclusive evidence to support its supposition, but has initiated a 3-month evaluation of threaded fasteners.

As part of its follow-up evaluation, FAA met with Hill Air Force Base representatives on September 15, 2000, 1 year after FAA was provided the final Hill Air Force Base test results. During the meeting, Hill Air Force Base laboratory officials offered FAA representatives the opportunity to review the test equipment and procedures used to perform testing on the fasteners. However, FAA representatives chose to review data summary sheets rather than address the disparity. During this review, FAA and Hill Force Base staff found two data summary sheet recording errors. As a result, we revised the percentage of nonconforming parts from 32 to 27 percent. However, the overriding issue regarding the differences in test results between FAA-approved manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA Aircraft Certification Service representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.

It is unclear whether FAA's planned evaluation will resolve our questions regarding the disparity in test results. FAA has not included appropriate steps to address key issues, such as the differences in test equipment and the effect those differences have on measurements.

Furthermore, FAA's evaluation methodology is not consistent with the methodology used in our audit; therefore, the results may not be comparable. For example, FAA plans to use two less-experienced laboratories to conduct testing (e.g., one laboratory does not have the equipment or the experienced technicians needed to perform this type of testing). Additionally, unlike our sample, FAA will select fasteners from manufacturers rather than end-users. If nonconforming fasteners are identified, the manufacturers could contend that the fasteners would have been identified through the quality assurance system before they were shipped to customers.

Rather than concluding the manufacturers' results are more accurate, FAA should conduct a comprehensive investigation of the inconsistency in test results, including evaluating the test equipment used by manufacturers. Until this issue has been resolved, it is unknown whether manufacturers' quality assurance systems are effectively identifying and rejecting nonconforming fasteners.

FAA Production Approval Holders Should Be Held Accountable for Producing Conforming Parts

To ensure that only conforming parts are manufactured for installation on aircraft, FAA relies on a series of overlapping controls. The principal control is the production approval holder's quality assurance system. In addition, FAA relies on its spot and periodic surveillance to ensure that production approval holders' quality assurance systems are operating as approved by FAA. FAA also places a

degree of reliance on aviation mechanics to detect nonairworthy parts during the installation process. An equally important control is redundancy of aircraft design. Redundancy is an essential element in the safety design of an aircraft (i.e., to increase the safety margin, more fasteners are used than necessary to support a specific design weight or load factor). However, redundancy cannot be a substitute for maintaining high manufacturing standards for aviation parts.

Nonconforming fasteners that pass undetected through manufacturers' quality control systems and are installed on aircraft could affect the level of flight safety[5] and unnecessarily increase operating costs for the aviation industry. For example, the distribution and installation of nonconforming fasteners causes an undue financial burden to the end-user by increasing operating costs to identify and remove these fasteners from inventory and to perform unscheduled maintenance to repair aircraft systems that prematurely fail. Identification and removal of nonconforming fasteners that cannot be identified by serial number is more costly because end-users usually use more than one vendor and commingle fasteners in inventory. Therefore, it is imperative that production approval holders establish and maintain effective quality assurance systems that safeguard the manufacturing integrity of aviation parts.

Two of Four Manufacturers Did Not Comply With Established Requirements for the Use of Statistical Sampling Plans and Prescribed Test Equipment. In addition to our sampling of parts from end-user inventories, we observed the procedures of four manufacturers (three FAA production approval holders and one subcontractor) for inspecting parts for compliance with the specification for thread dimensional conformance (MIL-S-8879C[6]). We found that two manufacturers did not correctly follow FAA's statistical sampling policy for rejecting nonconforming parts and did not use the correct equipment prescribed in the FAA-approved design data to test thread dimensional conformance of aviation nuts. Additionally, we found FAA inspectors responsible for oversight of these manufacturers were unclear on FAA's statistical sampling policy and were unfamiliar with the test equipment requirements of the specification cited for thread dimensional conformance.

Manufacturers Need to Comply With FAA's Statistical Sampling Policy. To alleviate the burden of testing all parts in a large production lot, FAA permits manufacturers to use statistical sampling plans to determine the test sample size

[5] At the aircraft manufacturer and the fastener manufacturers we visited, thread dimensional conformance was a major characteristic of the threaded fasteners included in our sample. FAA defines a major characteristic as a characteristic, other than critical, that if not maintained would reduce usability of a product and could cause an unsafe condition in the end product.

[6] Military specification MIL-S-8879C is widely cited in FAA-approved manufacturers' design data as the testing protocol for thread dimensional conformance.

for final inspection. FAA's policy is clear that a manufacturer can accept a production lot as complying only when **all** sampled items pass compliance testing for characteristics that affect safety.

According to FAA's policy, dated January 1983, production approval holders are permitted to use statistical sampling plans; however, they must establish a system to classify characteristics to preclude the acceptance of nonconforming characteristics that would affect safety. The most common classifications are critical, major and minor. The definitions for each classification are as follows:

> **Critical characteristic** – is one, that by judgment and experience indicates if not maintained would cause an unsafe condition in the end product.
>
> **Major characteristic** – is one, other than critical, that if not maintained would reduce usability of the product and could cause an unsafe condition in the end product.
>
> **Minor characteristic** – is one that, if not maintained would not reduce the usability of the product and would have no adverse effect on safety.

According to the FAA policy, when a critical or major characteristic is found to be nonconforming in the sample, those characteristics in the lot must be subjected to 100 percent inspection or the entire production lot must be rejected. Our review of final inspection procedures at four fastener manufacturers disclosed two manufacturers correctly used statistical sampling methodology to establish sample size, but incorrectly accepted production lots during final inspection when a major characteristic was found to be nonconforming in the sample.

In addition, at one of these two manufacturers, we identified a company inspector that compounded the error of accepting production lots when nonconforming parts were found during final inspection by including the nonconforming fasteners in shipments sent to customers. While the production lot as a whole passed a final inspection according to the manufacturer's sampling plan, the company's inspector did not segregate the parts known to be nonconforming from the approved lot.

On March 22, 1999, in response to our observation, FAA initiated a Letter of Investigation against the fastener manufacturer that was including known nonconforming parts in shipments sent to customers. The assigned FAA inspector made an on-site visit of the manufacturer and determined that company inspectors were not following a standard procedure for disposition of nonconforming parts. One company inspector scrapped the parts on the spot, one segregated the parts and sent them to the company's engineering department, and one included the

nonconforming parts with the accepted lot sent to the customer. The manufacturer agreed to revise its quality manual to reflect a standard policy on disposition of nonconforming parts. The case was closed with no enforcement action taken.

Manufacturers Need to Use the Prescribed Equipment to Test Dimensional Conformance. While observing receiving inspections at Boeing, we determined that thread dimensional conformance testing could not be accomplished for internal threads on nuts because the threads had been crimped as part of the manufacturing process. Most aviation nuts are crimped to provide a self-locking feature. Because this crimping process deforms the threads, the FAA-approved design data (which cites MIL-S-8879C) require the fastener manufacturer to test for thread dimensional conformance prior to crimping. Boeing officials stated they rely on the subcontractor to test the threads for dimensional conformance before deforming the threads.

However, quality inspectors at two of Boeing's subcontractors[7] did not use the equipment prescribed in MIL-S-8879C to test thread dimensional conformance of crimped nuts. MIL-S-8879C requires the use of precision equipment that can provide minute measurements. However, these manufacturers used a go/no-go gage, which is a simple test of whether the nut would assemble with a mating bolt. This device does not test to the precision prescribed in the specification.

Measuring Device for Internal Threads

Go/No-Go Gage

The device shown to the left provides specific measurements of thread dimensions. The device depicted above only assesses whether the nut will assemble with a bolt.

Our on-site work disclosed two manufacturers that did not comply with FAA's statistical sampling policy and did not use the prescribed test equipment because they were unaware of FAA-approved design data requirements. To ensure that FAA requirements are fully communicated to the aviation industry, FAA should issue an appropriate notice informing the industry of the proper use of statistical sampling plans and the need to use the prescribed equipment to test the thread

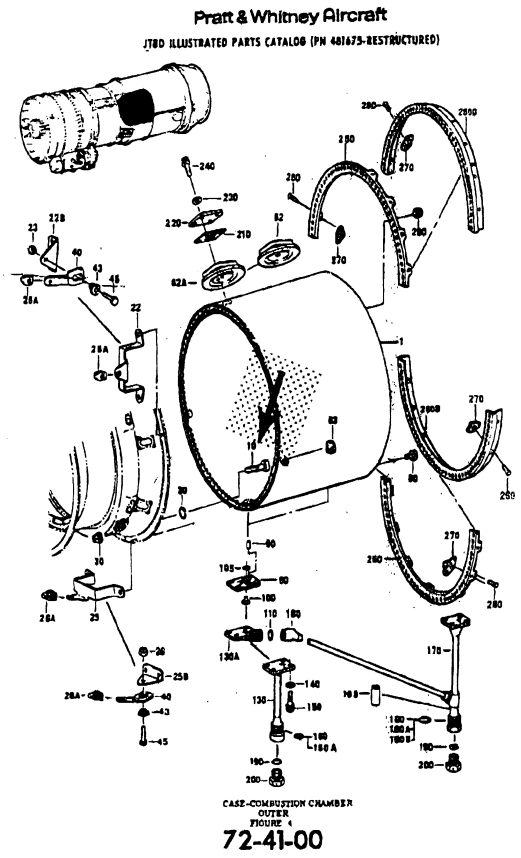
[7] Both of these subcontractors were also FAA-approved manufacturers.

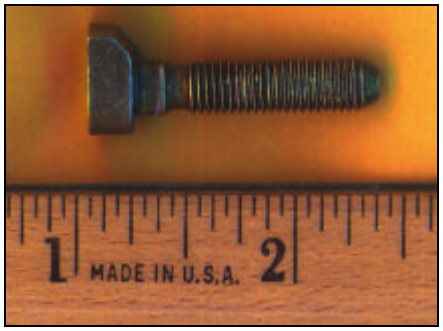
dimensional conformance of aviation nuts. To enhance its surveillance of fastener manufacturers, FAA should clarify to its inspector workforce the agency's final inspection statistical sampling policy and inform inspectors to maintain familiarity with the test equipment cited in design drawings.

An FAA Production Approval Holder Did Not Maintain Effective Oversight of Its Subcontractors. An issue involving the manufacture of defective jet engine bolts that occurred during our audit illustrates the problems that can result when a production approval holder's quality assurance system fails. A repair station determined it had installed defective bolts in commercial aircraft jet engines and that the defective bolts caused engine failures. In accordance with Federal Aviation Regulations, the repair station reported the defective bolts and failed engines to FAA. Although we did not discover the defective bolts as part of our testing process, the results of FAA's review into this matter are germane to our audit.

FAA inspectors determined that, from March to December 1999, the defective bolts failed on 10 engines used on commercial passenger aircraft, causing internal damage to 7 engines and 1 in-flight shutdown. Analysis of the failed bolts revealed an insufficient nickel content, which was traced to an error during the manufacturing process. Because of insufficient nickel content of the fasteners and the high-temperature operating environment of turbine engines, these bolts became brittle and failed, causing internal engine damage. The manufacturer determined that approximately 24,400 defective bolts were sold and about 400 engines on aircraft operated by major air carriers could be affected. No accidents resulted; however, this quality control lapse cost one air carrier approximately $100,000 to remove the defective bolts and monitor engine performance. Also, based on cost data obtained from one repair station, the average cost to repair engines that sustained damage was $400,000 per engine.

Although the bolt pictured below appears to be insignificant in size, its failure caused internal damage to seven engines and one in-flight engine shutdown. The industry must continue to monitor the engines where these bolts have been installed and be alert to identify these bolts in maintenance inventories and avoid installing them on any additional aircraft.





Defective Bolt, Part Number 772568QQ

The defective fasteners were used in a critical application to hold the combustion chamber outer case in place on Pratt & Whitney JT8D engines as shown to the left. JT8D engines power many commercial passenger aircraft, including the Boeing 727, Boeing 737, MD-80 and DC-9 aircraft. During overhaul of the engine, 90 of the bolts are replaced.

To purge the aviation industry of these bolts, FAA issued a Flight Standards Information Bulletin for Airworthiness on September 14, 1999. As identified in this bulletin, the suspect bolts had been traced to six end-users. The end-users are identified below.

End-User	**Number of Bolts Distributed**	**Number of Engines That Could Be Affected**
United Airlines	3,513	67
Delta Airlines	6,001	148
Trans World Airlines	4,300	89
Iberia Airlines	200	10
M&M Aircraft	6,750	47
Aerothrust	3,600	37
Total	**24,364**	**398**

FAA's bulletin suggested steps to follow to identify and remove these bolts from inventory and use. These steps included:

- ✓ removing all of these bolts from inventory;
- ✓ performing a records search of all engines that have this bolt installed;
- ✓ removing and replacing the bolts for all uninstalled engines with fewer than 200 hours in service;
- ✓ placing all engines that have this bolt installed on a maintenance watch program to identify signs of performance degradation, such as high vibration; and
- ✓ removing and replacing the suspect bolts if turbine damage is evident.

FAA investigation of this case revealed weaknesses in the production approval holder's monitoring of subcontractors. The FAA production approval holder had subcontracted the manufacturing of this fastener. The subcontractor then subcontracted the plating process. FAA inspectors determined this second-tier subcontractor was processing a large volume of parts for the commercial aviation industry. *FAA concluded that all parts processed by this subcontractor were suspect because of serious quality control problems, such as improperly calibrated equipment and lack of evidence that the company followed required quality procedures.* The production approval holder had never inspected this second-tier subcontractor, and the first-tier subcontractor had not conducted an audit of the company since July 1995.

FAA regulations permit production approval holders to utilize subcontractors when production approval holders have established an FAA-approved quality control system that provides assurance all parts produced by subcontractors are in compliance with design data. However, FAA does not require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors. Rather, inspection intervals are left to the discretion of the production approval holder. To ensure that production approval holders are properly and consistently monitoring their subcontractors for compliance with design data, FAA should require production approval holders to establish regular inspection intervals to review the quality assurance systems of all subcontractors in their chain.

FAA has completed its investigation of the production approval holder involved with this defective bolt. The agency has decided not to take any punitive action against the production approval holder for several reasons. First, the company complied with Federal Aviation Regulations and voluntarily notified its assigned FAA manufacturing inspector of the defective bolts on July 28, 1999, soon after the

repair station notified the company and the repair station's assigned FAA Flight Standards inspector of the defective bolts on July 27, 1999. Second, the company has agreed to assume liability for end-user costs associated with engine failures and removing the bolts from the industry. The production approval holder's insurer has reimbursed end-users about $1.5 million and the amount is increasing. Lastly, the production approval holder has ceased using the at-fault subcontractor for plating fasteners.

Recommendations

We recommend FAA:

1. Conduct a comprehensive investigation to reconcile the disparity in test results between Hill Air Force Base and the fastener manufacturers, including an evaluation of the effect that different test equipment has on the accuracy of measurements.

2. Require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors.

3. Direct production approval holders to:

    a) Establish and follow effective quality assurance systems to ensure the production of conforming parts.

    b) Adhere to FAA's policy on the proper use of statistical sampling inspection plans during final inspection testing and product acceptance.

    c) Use the equipment prescribed in military specification MIL-S-8879C to test thread dimensional conformance of aviation nuts when this specification is cited in the design drawings.

4. Improve surveillance during periodic and spot inspections at fastener production approval holders by placing emphasis on:

    a) Observing the procedures for inspection and disposition of nonconforming fasteners at production approval holders and their subcontractors.

    b) Confirming production approval holders follow FAA's policy regarding the proper use of statistical sampling plans during final inspection.

c) Confirming production approval holders use the equipment prescribed in MIL-S-8879C to test thread dimensional conformance of aviation nuts when this specification is cited in the design drawings.

Management Position and Office of Inspector General Comments

In FAA's June 23, 2000, response to our June 8, 2000, draft report, FAA concurred with three recommendations and partially concurred with one recommendation. FAA agreed to improve its surveillance of fastener manufacturers and to require manufacturers to establish regular inspection intervals of their subcontractors, adhere to FAA's policy on the proper use of statistical sampling plans, and use the prescribed test equipment.

FAA agreed with our recommendation to require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors. FAA plans to revise FAA Orders 8120.2 and 8100.7 based on the work of two teams chartered to improve the certificate management program, including production approval holders' controls over their subcontractors. Both of these orders are scheduled to be completed by September 2002.

FAA agreed with our recommendation to direct production approval holders to implement better procedures to improve their quality assurance systems. FAA will incorporate its position on statistical sampling into FAA Orders 8120.2 and 8110.42, which are scheduled to be completed by July 2001 and September 2001, respectively. FAA will also implement a special emphasis initiative concerning the production approval holders' use of prescribed inspection and test equipment that is scheduled to be in effect by January 2001.

FAA also agreed with our recommendation to improve surveillance during periodic and spot inspections at fastener production approval holders. To address this recommendation, the agency will place special emphasis on manufacturing compliance with FAA-approved design data during certificate management activities at fastener manufacturers and their suppliers. The agency will also encourage manufacturers to place special emphasis on suppliers of threaded fasteners concerning manufacturing compliance with FAA-approved design data. This initiative will take effect by March 2001 and will be evaluated for continuation after 1 year.

FAA corrective actions on these three recommendations, when implemented, will result in enhanced quality assurance systems at production approval holders. The planned corrective actions resolve these recommendations and are subject to the follow-up requirements of Department of Transportation Order 8000.1C.

FAA partially agreed with our recommendation to complete its investigation of the nonconforming fasteners identified in our draft report, determine the cause of the nonconforming parts, and inform the aviation industry of systemic problems. To investigate the nonconforming parts, FAA sent the parts to the appropriate FAA Manufacturing Inspection District Office for retests and disposition by the production approval holder. Based on the retests performed by the manufacturer, FAA confirmed that three fasteners were nonconforming. The agency also stated that it had a consultant, WM Technical Services, re-inspect certain fasteners (five part numbers) for pitch and functional diameter and all of these fasteners conformed to specifications.

We cannot agree with FAA's results because the agency's investigation was not sufficient or thorough. First, FAA simply sent the nonconforming fasteners for retesting to the manufacturers that produced the parts. FAA officials were not even present for all of the retests. Second, FAA used a nonaccredited consultant to conduct retests on a limited number of nonconforming fasteners. Therefore, the qualifications and capabilities of this testing facility are unknown, whereas Hill Air Force Base is accredited by the American Association for Laboratory Accreditation.

The accreditation process by the American Association for Laboratory Accreditation is quite extensive and includes on-site validation of the quality system established and maintained by the laboratory. This process includes a review of the test equipment used, including proper calibration and verification of that equipment, and the qualifications of the laboratory technicians. The laboratory must also arrange for periodic, independent audits of its activities to verify that its operations continue to comply with the requirements of the quality system.

FAA's response also stated that gage uncertainty had not been adequately considered in our report. Gage uncertainty is an indication of the quality of the test results and is expressed quantitatively. FAA stated that Hill Air Force Base is accredited by the American Association for Laboratory Accreditation for a maximum uncertainty of .0002 inches. However, FAA's analysis of the Hill Air Force Base data showed the existence of an uncertainty band of more than double their accredited value. Furthermore, in comparing the data from the manufacturer and Hill Air Force Base, FAA noted a disparity that was much more than an uncertainty of .0002 inches. As a result, the agency stated a significant portion of the Hill Air Force Base nonconformity measurements may have been false readings.

FAA's position is not supported by conclusive evidence. FAA representatives did not visit Hill Air Force Base to evaluate the test equipment used during fastener testing and confirm either the gage uncertainty or false reading suppositions. Until FAA evaluates this core issue, it is unknown what effect test equipment differences had on fastener measurements. Furthermore, the Hill Air Force Base accreditation

process has already addressed these risks. According to industry representatives we spoke with, gage uncertainty is not used to accept or reject manufactured products. Instead, gage uncertainty is used during the manufacturing process to ensure the reliability of the final inspection tests.

At no point during the testing process did the FAA representatives raise any objections to the capabilities or qualifications of the laboratory or the technicians testing the sampled fasteners. Representatives from Aircraft Certification and Flight Standards Services assisted us in developing fastener testing methodology, identifying critical application fasteners, and obtaining the design data for each fastener selected. Equally important, FAA personnel concurred with the choice of Hill Air Force Base to test the sampled fasteners. In June 1999, FAA personnel verified the calibration of the test equipment and the qualifications of the laboratory technicians. FAA staff also observed the technicians taking measurements and concurred with the results. In addition, we periodically provided FAA the test results.

In September 1999, we discussed the final Hill Air Force Base test results, part by part, with FAA's engineering representative to reach agreement on the results. However, it was not until May 2000, 8 months later, while we were discussing the issuance of the draft report with FAA senior-level officials, that FAA officials informed us they questioned the accuracy of the Hill Air Force Base test results and concluded the results were invalid. At that time, FAA planned to take no further action regarding these nonconforming fasteners.

Since we issued our draft report, we met with FAA senior management officials on two occasions to discuss the disparity in test results. During meetings in July and August 2000, we requested FAA to provide us with additional support for its position. After these repeated requests, FAA finally initiated an evaluation of threaded fasteners in September 2000.

As part of this evaluation, FAA returned to Hill Air Force Base accompanied by staff from our office. During a joint meeting with FAA and applicable Hill Air Force Base managers and technicians, a transposition error was identified that caused the incorrect classification of eight parts as nonconforming. As a result, the Hill Air Force Base test results were adjusted to reflect that 48 (27 percent) of 176 parts tested were nonconforming. However, the overriding issue regarding the differences in test results between FAA-approved manufacturers and a Fastener Quality Act accredited laboratory remains unresolved because FAA representatives chose not to evaluate the Hill Air Force Base test equipment or even visit the laboratory.

In addition, it is still unclear whether FAA's 3-month evaluation will resolve our basic question regarding the disparity in test results between a Fastener Quality Act accredited laboratory and FAA-approved manufacturers. FAA has not included appropriate steps in its methodology to address key issues, such as the differences in test equipment and the effect those differences have on measurements.

Furthermore, FAA's evaluation methodology is not consistent with the methodology used in our audit; therefore, the results may not be comparable. For example, FAA plans to use two less-experienced laboratories to conduct testing (e.g., one laboratory does not have the equipment or the experienced technicians needed to perform this type of testing). Additionally, unlike our sample, FAA will select fasteners from manufacturers rather than end-users. If nonconforming fasteners are identified, the manufacturers could contend that the fasteners would have been identified through the quality assurance system before they were shipped to customers.

In our opinion, FAA's oversight responsibility to monitor production approval holders' quality assurance systems should extend beyond merely accepting retest results from the manufacturers, which have a pecuniary interest in the outcome of the tests. Until the disparity in test results is resolved, it is unknown whether manufacturers' quality assurance systems are effectively identifying and rejecting nonconforming fasteners.

Accordingly, we revised our draft report recommendation requesting FAA to complete its investigation of the nonconforming fasteners and inform the aviation industry of any systemic problems found. We are now requesting that FAA conduct a comprehensive investigation to reconcile the disparity between test results from Hill Air Force Base and the manufacturers. As part of FAA's investigation of the disparity in test results, the agency should compare the test equipment used by Hill Air Force Base with equipment used by the manufacturers and determine if differences in test equipment could cause differences in measurements.

Entities Visited

FAA

Headquarters:

Aircraft Certification Service	Washington, D.C.

Aircraft Certification Service Field Offices:

Boeing Certificate Management Office	Renton, WA
Los Angeles Manufacturing Inspection District Office	Lakewood, CA
Seattle Manufacturing Inspection Office	Renton, WA

Flight Standards Service Field Offices:

Louisville Flight Standards District Office	Louisville, KY
Miami Flight Standards District Office	Miami, FL
Pittsburgh Flight Standards District Office	Coraopolis, PA
San Francisco Certificate Management Office	Burlingame, CA

Aircraft Manufacturer

The Boeing Company	Twin-aisle Facility	Everett, WA
The Boeing Company	Single-aisle Facility	Renton, WA
The Boeing Company	Supplier Control Facility	Lynnwood, WA

Fastener Manufacturers

Fairchild Fasteners-South Bay	Torrance, CA
Hi-Shear Corporation	Torrance, CA
Huck International	Carson, CA
Sonic Industries, Incorporated	Torrance, CA

Air Carriers

Comair	Cincinnati, OH
United Airlines	San Francisco, CA
US Airways	Pittsburgh, PA

Repair Stations

AAR Landing Gear	Miami, FL
Aerothrust Corporation	Miami, FL
GE Aircraft Engine Services	Miami, FL
M & M Aircraft Services	Medley, FL
Miami Field Services	Miami, FL

1.	PART OR MATERIAL CERTIFICATION FORM					
2. Sellers Name: [redacted]			3. Reference No. 36049			
4. Organization: [redacted] Address: [redacted]			Phone No. [redacted] Fax No. SITA Code NYCAHXD Status			
6. Item	7. Description	8. Manufacturer & Part No.	9. Eligibility	10. Qty.	11. Serial/ Batch No	12. Status/ work
002	Bolt	769059QQ Approved Quality Manufacturing	N/A	200	303866	N/A
13A. Remarks: THIS PRODUCT IS A PMA ITEM. THE MANUFACTURER APPROVED QUALITY MANUFACTURING INC. HOLDS THE FAA APPROVAL.						
13.B. Obtained From: Approved Quality			13C. Last Cert. Agency			
14. New-Unused Parts/Material Certification: The following signature attests that the part(s) or material(s) identified above was (were) manufactured by an FAA approval holder and inspected in accordance with established industry; or U.S. Specifications; and/or the airworthiness regulations of the country of origin.			18. Used, Repaired or Overhauled Parts Certification: The following signature attests that the documentation specified above or attached is accurate with regard to the item(s) described. Repaired parts conform and were inspected in accordance with the Code of Federal Regulations 14 and were approved for return to service.			
15. Signature: [redacted]			19. Signature			
16. Name [redacted]	17. Date		20. Name		21. Date	

The requirements for a signature on this form is by design and is such that it is binding from legal standpoint. Should the seller of a part or material complete the document and in any way misrepresent, lie or err in the information provided, then he/she is liable for legal judgement and in some cases criminal prosecution.

Example of Certificate of Conformance

Independent Contractor Test Results

*OEM	PART NUMBER	NUMBER TESTED	NUMBER OF NONCONFORMING PARTS	PERCENT NONCONFORMING
A	BACB30LE4K9	9	3	33%
	BACB30NM3K3	2	1	50%
	BACB30NR4K5	5	5	100%
	BACB30US5K64	8	1	13%
	BACB30LJ12K26	3	2	67%
	69-13995-4	3	0	0%
	10-60517-53	1	0	0%
	69-15816-3	1	0	0%
	BACB30NM3K3	4	1	25%
	BACB30US9K21	5	1	20%
	BACB3ONM8K27	2	0	0%
	BACB3OMR8K27	2	2	100%
	BACB30US12K70	2	2	100%
	BACB30UU9K-44	3	3	100%
	BACB30US9K15	*2*	0	0%
	BACB30MR6K18	4	4	100%
	BACB30UU6K19	3	0	0%
	BACB30US-5K6M	5	0	0%
	BACB30LE5HK8	4	2	50%
	SUBTOTAL - OEM A	**68**	**27**	**40%**
B	799218	10	0	0%
	51H518	5	0	0%
	51T293	1	0	0%
	1B4992	5	0	0%
	252741	3	1	33%
	475123	2	0	0%
	583383	3	1	33%
	755169	2	0	0%
	758450	3	0	0%
	799218	1	0	0%
	758462	5	5	100%
	695520	5	2	40%
	739029	3	0	0%
	SUBTOTAL - OEM B	**48**	**9**	**19%**
C	60097052-7	1	0	0%
	SUBTOTAL - OEM C	**1**	**0**	**0%**
D	PE21094-04017A	2	2	100%
	SUBTOTAL – OEM D	**2**	**2**	**100%**
E	782669-1	2	0	0%
	SUBTOTAL – OEM E	**2**	**0**	**0%**
	OEM TOTAL	***121***	***38***	***31%***

*OEM - Original Equipment Manufacturer

*PMA	PART NUMBER	NUMBER TESTED	NUMBER OF NONCONFORMING PARTS	PERCENT NONCONFORMING
A	VCB0050-12	3	0	0%
	SUBTOTAL – PMA A	**3**	**0**	**0%**
B	B02070-5	5	0	0%
	BO2054-4PMA	4	0	0%
	SUBTOTAL – PMA B	**9**	**0**	**0%**
C	769059QQ	3	0	0%
	532635QQ	4	0	0%
	287229QQ	5	3	60%
	318284QQ	22	2	9%
	758464QQ	9	5	56%
	SUBTOTAL – PMA C	**43**	**10**	**23%**
	PMA TOTAL	***55***	***10***	***18%***
OEM & PMA TOTAL		**176**	**48**	**27%**

*PMA – Parts Manufacturer Approval Holder

Exhibit D

List of Major Contributors to This Report

The following Office of Inspector General staff contributed to this report.

Alan D. Robson	Program Director
Robin P. Koch	Project Manager
Tina B. Nysted	Auditor
James A. Connelly	Auditor
Mike J. Leibrecht	Auditor
Nelda Z. Smith	Evaluator

U.S. Department
of Transportation
Federal Aviation Administration

Memorandum

Subject: **INFORMATION**: Comments to OIG Draft Report on FAA's Oversight of Manufacturers' Quality Assurance Systems for Threaded Fasteners

Date: JUN 23 2000

From: Administrator

Reply to Attn. of:

To: Assistant Inspector General for Auditing

As requested in your memorandum dated June 8, attached is the Federal Aviation Administration's (FAA) response to the recommendations including target dates where they apply. In addition to our response, we have included the following appendices: Appendix 1 – Editorial (technical comments) on the draft report and Appendix 2 – Charts depicting FAA engineering analysis.

Should you have questions, please contact Mr. Anthony Williams, Management Programs Division, APF-200. Mr. Williams can be reached on 267-9000.

Jane F. Garvey

Attachments

Note: We did not include Appendix 1 or Appendix 2 as part of our report. However, we did revise our final report to incorporate FAA's editorial comments.

Federal Aviation Administration's Response to the Office of Inspector General's (OIG) Draft Report on FAA's Oversight of Manufactures' Quality Assurance Systems for Threaded

OIG Recommendation 1: Recommend FAA complete its investigation of the 56 nonconforming fasteners identified by our audit to determine the cause of the nonconforming parts, take corrective action, and inform FAA field inspectors and the aviation industry of systemic problems found.

FAA Response: Partially Concur. FAA has completed its investigation into 54 of the 56 fasteners identified by the DOT-OIG as non-conforming. The investigation of the two remaining fasteners has been referred to the aviation authority of Brazil, Centro Tecnico Aerospacial (CTA). In accordance with the FAA/OIG agreed test protocol, 50 of the 54 fasteners were re-inspected at the Production Approval Holder's (PAH) facility; four fasteners were destroyed in tensile testing thus prohibiting a re-inspection by the PAH. The Aircraft Certification Service (AIR) was able to confirm non-conformance on three of the 50 fasteners re-inspected.

The FAA investigation did not confirm the frequency of non-conformity reported by the OIG based on the Hill Air Force Base (HAFB) test results. The data collected during the FAA investigation does not indicate a systemic problem with the manufacture of threaded fasteners. The FAA concludes from its investigation that a significant portion of the HAFB non-conformities may have been false positives.

The FAA suggests relevant staffs from the OIG, Hill AFB, and Aircraft Certification meet to discuss and resolve the methodological issues we believe have led to the wide disparity in the non-conformity rate and measurement results on fasteners.

Further actions will be limited to those described in AIR's response to recommendations 2, 3, and 4 below:

The following is a brief summary of the AIR investigation and its findings:

- Fifty of these fasteners were sent to the appropriate FAA Manufacturing Inspection District Office (MIDO) for re-inspection and disposition by the PAH. At all but one PAH (Pratt & Whitney) re-inspections were witnessed by an FAA manufacturing inspector. Based on these re-inspections, the FAA confirmed that only three fasteners were non-conforming. The PAH accepted the three fasteners under their Material Review Board procedures and are currently conducting internal investigations of the non-conformances. AIR will conduct follow-up actions with the PAH to review the results of their internal investigation.

    - Four fasteners (test article F-5) were destroyed by HAFB during tensile testing requested by the OIG. This was prior to re-inspection by the FAA and not in accordance with the FAA/OIG agreed test protocol. The FAA

selected seven additional fasteners from the same lot at the same location. These were sent to the FAA MIDO for re-inspection. All seven of these fasteners were found to be conforming.

- Two fasteners (sample C-9) were produced by the Embraer Company of Brazil. The FAA had these fasteners re-inspected by WM Technical Services. That inspection confirmed non-conformance in pitch diameter on both fasteners. The FAA is sending these fasteners to the aviation authority of Brazil, Centro Tecnico Aeroespacial (CTA), for further investigation. The CTA is responsible for oversight and the airworthiness of these parts.

- The FAA had WM Technical Services re-inspect certain fasteners (samples A-3, G-2, G-3, H-4, and H-5) for pitch and functional diameter. All these fasteners conformed to their FAA-approved data. In addition, the FAA did an analysis of the WM Technical Services measurements versus the measurements taken by the PAH's and HAFB. The WM Technical Services data correlated to a much higher degree with the PAH data than the HAFB data.

  - Gage uncertainty, though acknowledged by the OIG in its report, has not been adequately considered. HAFB is accredited by the American Association for Laboratory Accreditation for a maximum uncertainty of 0.0002 inches. However, the FAA's analysis of the HAFB data showed the existence of an uncertainty band of more than double their accredited value. Furthermore, in comparing the data from the PAH and HAFB, the FAA noted a significant disparity that was much more than an uncertainty of 0.0002 inches.

  - The FAA's comparison of the measurements taken at HAFB and the PAH's indicates (appendix 2, charts 9-13):

- Minor Diameter – 85 percent of the measurement differentials were greater than 0.0002 inches, HAFB certified accuracy range.

- Major Diameter – 31percent of the measurement differentials were greater than 0.0002 inches, HAFB certified accuracy range.

- Pitch Diameter (analog dial) – 15 percent of the measurement differentials were greater than 0.0002 inches, HAFB certified accuracy range.

- Pitch Diameter (digital dial) – 60 percent of the measurement differentials were greater than 0.0002 inches, HAFB certified accuracy range.

- Functional Diameter – 75 percent of the measurement differentials were greater than 0.0002 inches, HAFB certified accuracy range.

OIG Recommendation 2: Recommend FAA require production approval holders to establish regular inspection intervals to review the quality assurance systems of their subcontractors.

FAA Response: Concur. A prerequisite to FAA acceptance of a PAH's quality system is the clear delineation of supplier control procedures that include initial approval, scheduled recurrent audits, and corrective action. The MIDO having certificate management responsibility over a PAH evaluates the PAH's supplier control procedures to verify that its suppliers are in compliance with its particular production approval.

For the past five years, the Aircraft Certification Systems Evaluation Program (ACSEP) has indicated that PAH supplier control is a quality system element that needs improvement. In 1998, AIR began initiatives with industry groups to identify and implement industry-wide methods that would ensure, among other things, an effective self-audit process, problem root cause analysis and corrective action, and enhanced supplier control procedures. Outlined below are the AIR's immediate, intermediate, and long range strategies addressing this issue.

IMMEDIATE TERM STRATEGY

- AIR will continue placing emphasis on the supplier control during certificate management (surveillance) functions while assisting the various industry associations in the development of continuous improvement initiatives.

ITERMEDIATE TERM STRATEGY

- The AIR Certificate Management Team, chartered on July 12, 1999, is developing a comprehensive Certificate Management program that is standardized, structured, and which will target resources to the areas of greatest potential risk to continued operational safety. PAH supplier control is a major focus area of this initiative. The efforts of this team will result in newly revised directive material (FAA Order 8120.2) and is scheduled for completion by July 2001.

LONG TERM STRATEGY

- The AIR ACSEP Phase II Team will be responsible for developing, prototyping, and implementing a variety of process improvements. Supplier surveillance is one of the program areas targeted for improvement. The efforts of this team will result in newly revised directive material (FAA Order 8100.7) and is scheduled for completion by September 2002.

- AIR will continue to support industries commitment to improvement. The Aerospace Industries Association of America (AIA), the General Aviation

Manufacturer's Association (GAMA), the Manufacturing, Maintenance, and Repair Committee (MMRC), the American Aerospace Quality Group (AAQG), and the International Aerospace Quality Group (IAQG) are all working toward improvement with the development and implementation of AS9000/AS9100 standards. These industry groups have recognized supplier control as a significant issue and have identified contributing causes. AIR will continue to support these industry groups with the utmost confidence that these issues will be resolved. Industry groups report that most companies are pursuing a phased in approach to AS9000/AS9100 which will flowdown to direct suppliers by January 2002.

OIG Recommendation 3: Recommend FAA direct production approval holders to:

a) Establish and maintain effective quality assurance systems to ensure the production of conforming parts.
b) Adhere to FAA's policy on the proper use of statistical sampling inspection plans during final inspection testing and product acceptance.
c) Use the equipment prescribed in military specification MIL-S-8879C to test thread dimensional conformance of aviation nuts when this specification is cited in the design drawings.

FAA Response: Concur. FAA requirements for the establishment of a quality system are delineated within Title 14 Code of Federal Regulations. Outlined below are the AIR's immediate, intermediate, and long range strategies addressing this issue.

IMMEDIATE TERM STRATEGY

- AIR will re-emphasize FAA's position regarding statistical sampling which will be published on the Production and Airworthiness Certification Division's (AIR-200) website as "*Best Practices"*. The "*Best Practices"* information is expected to be placed on the website by September 2000.

INTERMEDIATE TERM STRATEGY

- AIR will generate special emphasis concerning the PAH's use of prescribed inspection and test equipment. Additionally, AIR will encourage PAH's to also place special emphasis on suppliers of threaded fasteners concerning the use of prescribed inspection and test equipment. This special emphasis initiative will be implemented through certificate management activities and will be in effect by January 2001. Following implementation, this action will be evaluated for continuation after 1 year.

LONG TERM STRATEGY

- AIR will re-emphasize FAA's position regarding statistical sampling which will be incorporated into Orders 8120.2 and 8110.42. These actions are scheduled for completion by July 2001 and September 2001 respectively.

OIG RECOMMENDATION 4: Recommend FAA improve surveillance during periodic and spot inspections at fastener production approval holders by placing emphasis on:

a) Observing the procedures for inspection and disposition of nonconforming fasteners at production approval holders and their subcontractors.
b) Confirming production approval holders follow FAA's policy regarding the proper use of statistical sampling plans during final inspection.
c) Confirming production approval holders use the equipment prescribed in MIL-S-8879C to test thread dimensional conformance of aviation nuts when this specification is cited in the design drawings.

FAA Response: Concur. AIR will place special emphasis on manufacturing compliance with FAA-approved design data during certificate management activities at fastener PAH's and their suppliers. The special emphasis will include all aspects of the FAA-approved design to include material, dimensional, process, and inspection/test requirements. Additionally, AIR will encourage PAH's to also place special emphasis on suppliers of threaded fasteners concerning manufacturing compliance with FAA-approved design data. This special emphasis initiative will be in effect by March 2001. Following implementation, this action will be evaluated for continuation after one year.