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Superseding AIR5926

White Paper to Support Supersession of MIL-S-8879C With AS8879C

RATIONALE

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FOREWORD

Introduction

The Department of Transportation Inspector General (DOT IG) issued an audit report in October 2000 (report number: AV-2001-003) that identified a disparity in test data of fasteners used in commercial aviation. As a result, the Federal Aviation Administration (FAA) conducted a thorough Fastener Audit to ascertain the safety of fasteners used in commercial aircraft and to investigate the cause of variation in measurement.

The FAA's audit (report number: FAA-IR-01-02) found that all fasteners meet their metallurgical and mechanical property requirements and concluded that there are no flight safety concerns involving aircraft fasteners. However, the audit did reveal that there were some deficiencies relating to industry practices regarding the use of fastener design specifications, thread inspection techniques, and quality assurance systems.

The FAA identified several non-safety related dimensional discrepancies involving fasteners. These discrepancies, often involving less than 1/30th the thickness of a sheet of paper, are the result of differing interpretations of existing standards for measuring screw thread dimensions. These standards are designed to promote the interchangeability of threaded parts, which are fabricated internationally and are not related to safety-critical functions.

The FAA recommended that industry develop consensus design and inspection specifications for threaded components and improve various elements of the quality assurance system for threaded components.

Screw Thread Conformity Task Force Formed to Improve Industry Practices

To respond to concerns, the General Aviation Manufacturers Association (GAMA), National Aeronautics & Space Administration (NASA), International Aerospace Quality Group (IAQG), Industrial Fasteners Institute (IFI), and the Aerospace Industries Association (AIA) held a meeting of industry stakeholders to review the FAA Fastener Audit report's conclusions and recommendations. Industry committed to form a working group to take up the issues raised by the FAA Audit and to improve industry practices regarding the design, inspection, and quality assurance of threaded components used in commercial airplanes. The working group was designated the Screw Thread Conformity Task Force (STC-TF).

The Screw Thread Conformity Task Force is comprised of engineering and quality representatives from each stakeholder group, including commercial airplane and engine manufacturers, general aviation manufacturers, fastener manufacturers, FAA, Department of Defense (DOD), and thread gage manufacturers.

The STC-TF developed a program plan and established two working groups to focus on items in the FAA report.

1. The Engineering working group will develop a clear screw thread specification that is acceptable to all industry-wide stakeholders to supersede the inactive MIL-S-8879C specification. The superceding document(s) shall provide for clarified design and acceptability requirements, compatibility/interchangeability with products that are manufactured to MIL-S-8879C, maintenance of intended thread form function, minimization of required part standard/drawing changes, and clarified inspection methods.
2. The Quality working group will develop, publicize, and propose a standardized quality system audit process for aerospace manufacturers of threaded components. This document will highlight best practices regarding quality assurance systems for production of threaded components such as control of suppliers, statistical sampling inspection plans, in-process controls, final inspection processes, and control/calibration of thread gages (see Section 1).

Purpose

The Aerospace industry established the STC-TF to address and respond to the findings and recommendations from the FAA Fastener Audit report:

- Standards/Engineering
 - Develop a single aerospace thread specification for UNJ thread form
 - Resolve language disparity: acceptable vs. conforming
 - Resolve min material measurement issue (cone & vee vs. best wire size)
 - Determine if 40% differential is still applicable
 - Address the net fit issue for screw thread pitch diameter

- Quality system findings
 - Supplier control
 - Flow-down of technical/quality requirements and use of standards
 - In-process, receiving, and final inspection/acceptance plans (sampling)
 - Inspection, maintenance, calibration and proper use of thread gages

Objectives

The aerospace industry (IAQG, AIA, GAMA, and IFI) has committed to FAA and DOT IG to evaluate FAA's findings and recommendations, and to develop effective corrective and preventative actions. The STC-TF has determined that the following products are needed:

1. Consensus thread specification to supersede MIL-S-8879C
2. Standardized criteria for the use and calibration of various thread inspection gages
3. Standardized quality system audit criteria for the manufacture of threaded components

Schedule

The industry has agreed to implement these corrective actions by publishing a nongovernmental standard by July 2002. The intent is that this standard will be a replacement for MIL-S-8879C. MIL-S-8879 is owned by DOD, but it is a defacto international standard, and DOD support is imperative for success. This aggressive schedule requires all stakeholders to focus on the issues identified in the FAA report and to participate constructively toward the development of consensus products. To avoid potential process delays, the STC-TF decided to adopt the "ground rules" developed by the engineering team:

The project timeframe was determined to be one of the most stringent issues. In an attempt to minimize influences that would delay the process, the following ground rules were set and agreed upon by the members of the team:

- Not returning a response to a ballot is an indication of complete approval.
- All comments and disapprovals must be accompanied by rationale for the comment and proposed alternate language.
- Resolution of comments and disapprovals shall occur by a 3/4 majority vote of the team members present. There is no quorum requirement, but only one vote per company in the case of a dispute.
- Communication of the importance of these decisions is key to the continued success of the project.

Development of Mission

The team discussed items important to development of a mission for the team. The following mission statement was created for the team to review:

This Task Team has been created to develop a clear supersession for screw thread specification MIL-S-8879C that is acceptable to all industry-wide stakeholders. The superceding document(s) shall provide for clarified acceptability requirements, compatibility/interchangeability with product that is manufactured to MIL-S-8879C, maintenance of intended thread form function, minimization of required part standard/drawing changes and clarified inspection methods.

The Task Team will develop recommendations regarding supersession path, implementation methods, and implementation schedule to facilitate ease of transition for all stakeholders. The Team shall also prepare communications to outline the reasoning and philosophy of recommended design changes should they be needed.

1. SCOPE:

This paper was prepared to support supersession of MIL-S-8879C with Screw Thread Conformity Task Force selected industry standard AS8879C, published by the Society of Automotive Engineers (SAE). Other documentation changes will be covered by separate papers. Separate papers are anticipated for thread gaging issues, and thread gage calibration procedures. The STC-TF decided that the thread design standard needed to be completed before thread gage definition could be addressed. Thread gage definition has to be known before calibration procedures can be addressed.

2. BACKGROUND:

2.1 History of Screw Threads:

Screw threads are a geometric shape that provides a boundary surface that is generally pictured as a formed helix. The screw thread shape is independent of material, heat treatment, plating, coating, tensile strength, etc. Screw thread geometry is never purchased as an entity. Screw threads are a geometric surface component of a part that may be manufactured or purchased, like a bolt, nut, or fitting. As such, screw thread standardization documents primarily fall into the class of documents known as design standards, rather than into the class known as product standards or specifications.

Threads are nothing more than an inclined plane wrapped around a cylinder. Archimedes is thought to have used a screw form to raise water over 2000 years ago. Joseph Whitworth applied himself to the standardization of the mechanical screw thread form in about 1833. His results came to be known as the British "Whitworth Standard". In about 1864, William Sellers proposed standardization of screw threads in the United States. Sellers' efforts resulted in a standard that was adopted by the U.S. government (the thread form became known as the American National thread form). World War II standardization efforts brought about adoption of the Unified thread form by America, the British Isles, and Canada (hence the term ABC standards).

Individuals, companies, and even countries may agree to use certain definitions for various products, geometries, sizes, and such, in order to ensure interchangeability. These definitions become standards, and published standards are the record of the agreements made. Screw thread standards exist for many kinds of threads, e.g., tapered pipe, Whitworth, buttress, acme. A bolt and a nut that are intended to mate generally need to have compatible thread forms. For aerospace applications, the primary thread form used in fastening has been the 60° included angle Unified Form.

Fastener designers discovered that providing a root radius on external Unified threaded bolts would improve fatigue properties when compared to Unified threaded bolts without root radius. This led to the UNR thread form where an external thread root radius within the established Unified envelope is mandatory. Increasing the size of the thread root radius beyond established Unified limits provided additional fatigue improvement. This eventually resulted in establishment of the UNJ thread form. The UNJ thread form is the Unified thread form with an increased minor diameter for both the external and internal thread, and includes a mandatory root radius on the external thread. This thread form is currently used as standard throughout the aerospace industry.

2.1 (Continued):

The UNJ thread form was first published as a military standard by the Aeronautical Standards Group (ASG) as specification MIL-S-8879 (ASG), dated 21 September 1960. By the time MIL-S-8879 revision C was published in 1991, this standard had wide spread use not only in the United States, but also worldwide. It was for all intents and purposes, an international standard. Several other specifications or standards have been published internationally that provide the identical tabulated geometry. The FAA did not request changes to these other standards.

In the mid 1990s, the DOD implemented acquisition reform policies and converted a huge amount of military standards and specifications to industry standards and specifications. As a consequence of acquisition reform, DOD made MIL-S-8879C inactive for new design without naming a replacement for this defacto international standard. The goal of the STC-TF team is to have a replacement standard designated by the DOD.

2.2 Determining Thread Dimensions:

The Unified Form thread is based upon the trigonometric relationships of a 60° equilateral triangle. For Unified Form threads, the height of the thread, H , is equal to $1/2$ the thread pitch times the Tangent of 60°. Trigonometric relationships are indeterminate. This means that there is no fixed number of decimal places where all following digits are zero for all angles. Desktop computer calculators will provide the Tangent of 60° to 31 decimal places.

The number of decimal places used to calculate thread dimensions has an impact on the theoretical accuracy of the geometry that results. Historically, thread dimensions were calculated, long hand, using 6 decimal place values. (Desktop computer spreadsheets will make dimension calculations to at least 14 decimal places.)

Thread dimensions calculated to 6 decimal places were then rounded, by hand, to four decimal places for tabulation in standards. (Desktop computer spreadsheets provide a dozen ways to round, or truncate, numbers. ASME B1.30 rounding rules or recommendations do not necessarily agree with computer spreadsheet rounding choices.) The long hand calculation method provided a sufficient number of decimal places for most engineering purposes. For example, plotting four decimal place thread form on paper, to a scale such as 100X, provides illustrations pleasing to the eye. An example spread sheet plot is provided in Figure 1.

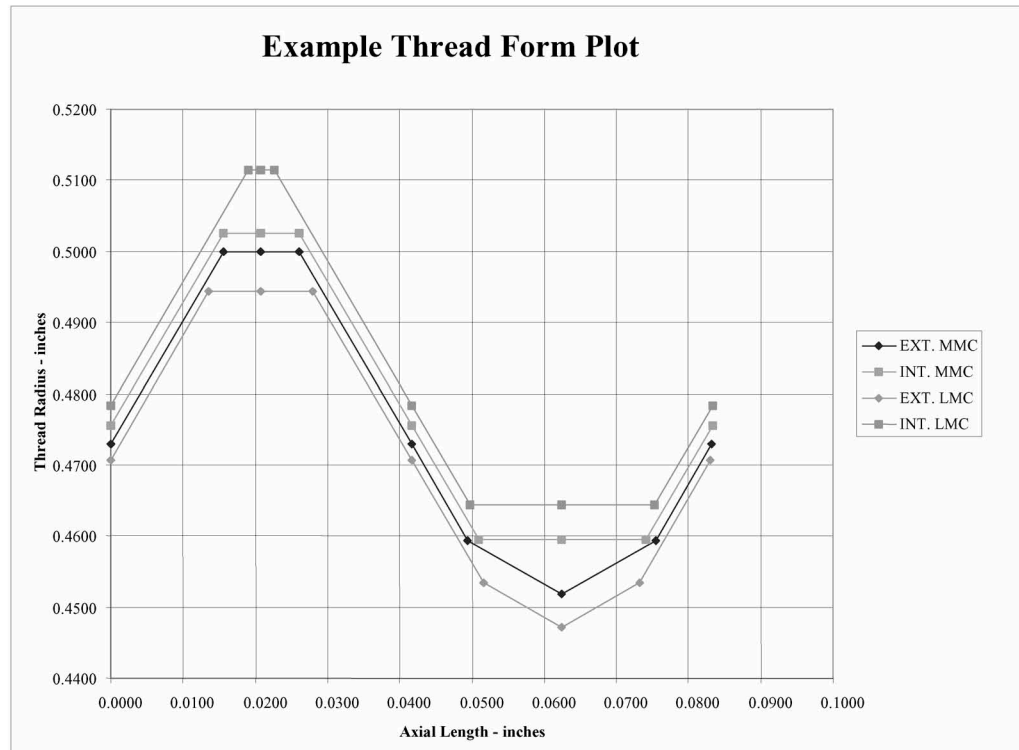


FIGURE 1 - Spread Sheet Thread Form Plot Using 4 Decimal Place x and y Coordinates

2.2 (Continued):

Plots using one decimal place would not be so pleasing to the eye, and plotting problems would be very noticeable as the pitch diameter points would appear out of line with the crest and root and the thread flank would not look straight, flat, or linear. If the one decimal place plot omits the pitch diameter data point, then the drawing appearance would be more acceptable. The point of the foregoing discussion is that the tabulated thread dimension values, in all the 60° screw thread specifications known to man, are not accurate – strictly speaking. Never the less, the results are adequate for engineering purposes.

2.2 (Continued):

Understanding the implications of this rounding issue is important in establishing an understanding of one source of variation seen in measured hardware threads. Let the intersection of the thread crest truncation cylinder and the thread flank be taken as one mandatory plot point, point “A”, and the intersection of the thread root radius tangent point with the thread flank be taken as the other mandatory plot point, point “B”. If this is done, then plotting the pitch diameter point, point “C”, in the graphic is unnecessary to the generation of the thread graphic. However, because pitch diameter is so ingrained in the definition of the thread it will necessarily remain part of the definition. Figure 2 illustrates a 4 decimal place plot of a thread flank. Note that points “A”, “B”, and “C” have individually calculated x and y coordinate values. If the graphic is constructed to provide an absolutely straight line between point “A” and point “B”, then the pitch diameter point “C” may be placed in the graphic at the appropriate x and y coordinate location. What you will notice is that point “C” will not be on the line connecting point “A” and point “B”. It will be slightly above or slightly below the line depending on the thread size, and depending on how the 6 decimal place calculation dimensions were rounded. Drawing scale will have a big impact on how noticeable this anomaly will be. It is noticeable at 100X if you are looking for it.

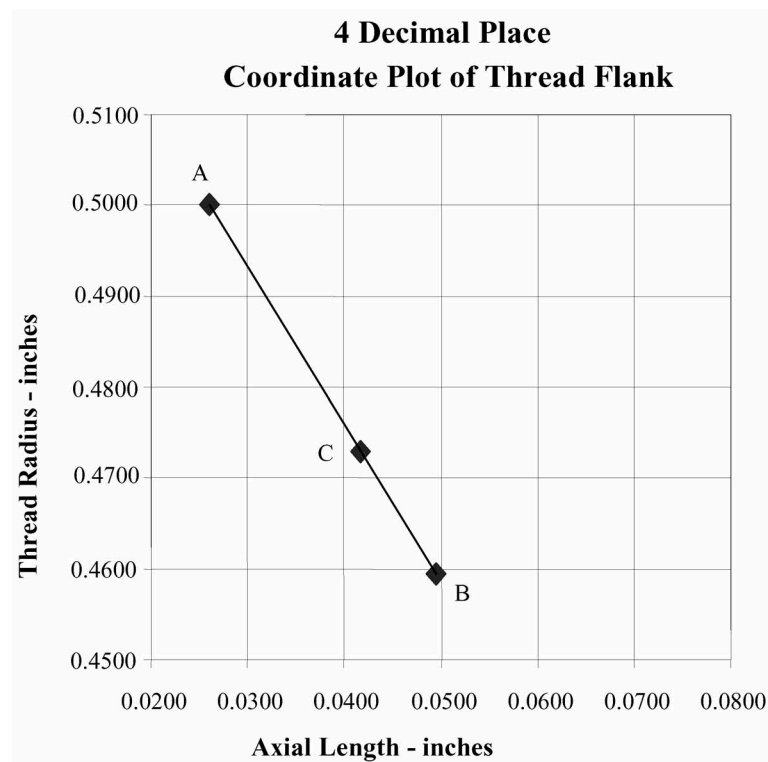


FIGURE 2 - Thread Flank Plot Using 4 Decimal Place Dimensions

2.2 (Continued):

Figure 3 illustrates a 2 decimal place plot of points A, B, and C. In this illustration the out of line condition of the pitch diameter plot point, C, is obvious.

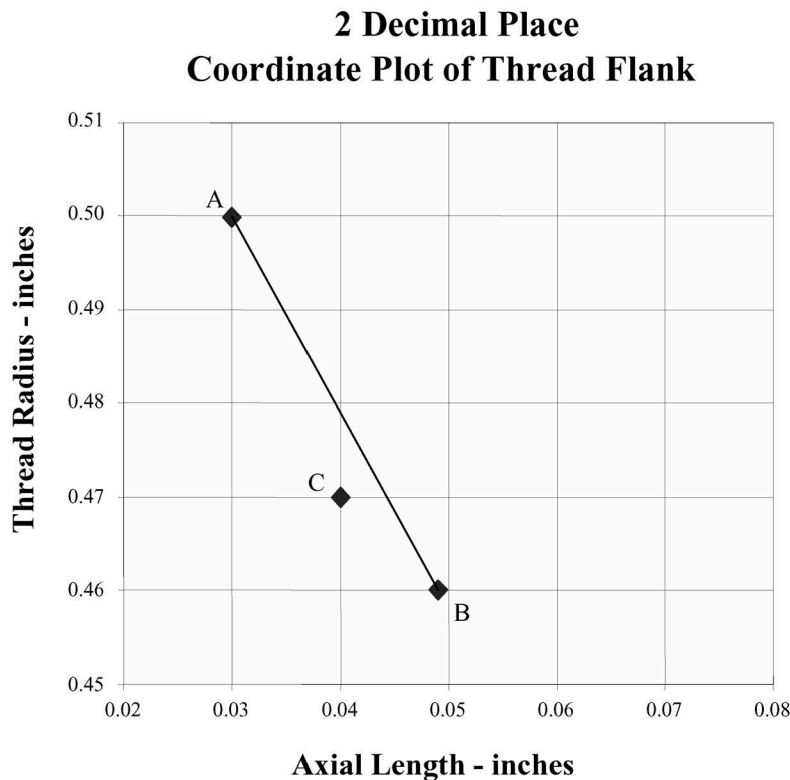


FIGURE 3 - Thread Flank Plot Using 2 Decimal Place Dimensions

2.3 Are The Number of Decimal Places Specified in the Standard An Issue?:

How important is the fourth decimal place value in the tabulated thread dimensions? The STC-TF examined this issue. After all, the previous specification values were determined by rounding 6 place computations. How big is 0.001 inch? A sheet of copier paper is about 0.003 inch thick. If a cylinder diameter varies by 0.003 inch it is easy to relate that variation to the thickness of a sheet of paper, and it is easy to visualize the impact on the measured diameter. It is a little harder to visualize when the diameter being discussed is thread pitch diameter. How much material would need to be removed from each thread flank in order to result in a pitch diameter change of exactly 0.003 inch? The answer is 0.00075 inch. Can you visualize it? Is the 5th decimal place answer necessary? Can you round it up (0.0008) or down (0.0007) to 4 decimal places and still have an exact pitch diameter change of 0.003 inch? What if you round it up or down to 3 decimal places?

2.3 (Continued):

A question posed to the STC-TF regarded the logic of retaining 4 decimal place dimensions for screw threads. It was suggested that the team reduce the number of decimal places for internal threads to 3 decimal places. A comparison relating methods of manufacture, thread inspection methods, and thread mechanical strengths was presented. External thread manufacturing techniques that include centerless grinding of the thread roll diameter, rolling of the threads, and inspection that uses three roll or segment style indicating gages yields tightly controlled product threads with excellent surface texture properties. External threads tend to be the weaker component in a nut-bolt combination, and design allowable loads are determined and published in MIL-HDBK-5 for bolts, but not nuts. Retaining 4 decimal place dimensions for external threads makes sense. Internal threads that are manufactured using drills for pretap hole preparation, thread taps that cut the thread form, the resulting relatively poor surface texture, and indicating gages that are very sensitive to operator technique do not support retention of 4 decimal place dimensions for internal threads. The STC-TF discussed the foregoing and voted to retain 4 decimal place dimensions for externally threaded product. The STC-TF supported the reduction of internal thread dimensions to 3 decimal places as a good engineering decision, but considered that doing so would be met with considerable industry resistance. As a result, the thread standard prepared by the STC-TF retained four decimal place dimensions for all threads.

2.4 Thread Dimensions When Coated, Plated, or Dry Film Lubricated:

During discussion of thread dimensions, the subject of coating and plating threads came up. AS8879 Revision B did not provide any before finish adjustment for major diameter, minor diameter, or root radius. Finish thickness is measured perpendicular to the surface upon which it is applied. For major diameter, and minor diameter the finish thickness will affect the diameter by 2 times the thickness (once on each side). For pitch diameter, which is determined on a thread flank, the finish thickness will affect the diameter by 4 times the finish thickness ($\delta d = 2 \times \delta t / \sin 30^\circ$). Minimum finish thickness choices vary from finish specification to finish specification. The limitation for pitch diameter has always been "no more than 0.001 inch for threads with pitch diameter tolerance not exceeding 0.0035 inch" (where the pitch diameter tolerance is greater than 0.0035 inch the allowance has been larger). The implication is that the thread specification is over coding (contradicting) the finish specification. Notice that for Class 1 Cadmium plate, the maximum permitted major diameter or minor diameter adjustment would be 0.001 inch (2 times 0.0005). For pitch diameter, the adjustment should be 0.002 inch (4 times 0.0005), but is limited by the thread specification to 0.001 inch. Even Class 2 Cadmium plate should require a pitch diameter reduction of 0.0012 inch – not 0.001 inch. In order to meet both the thread specification maximum allowed reduction, and the minimum plating thickness requirement, the thread manufacturer must increase his acceptable minimum after finish pitch diameter to ensure conforming product by the difference - 0.0002 inch (for Class 2 thickness). The only change to AS8879C dimensions that the STC-TF considered acceptable was to incorporate recognition that finishes affect all thread dimensions, not just pitch diameter.