SAE Aerospace An SAE International Group	**AEROSPACE INFORMATION REPORT**	**SAE AIR1936**	**REV. A**
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Study of Wrenching Engagement on AS870C Double Hexagon (12 Point) Fasteners

RATIONALE

AIR1936A has been reaffirmed to comply with the SAE five-year review policy.

FOREWORD

Changes in this revision are format/editorial only.

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1. SCOPE:

This study addresses the adequacy of sockets, wrenches, and torque adapters conforming to AS954 to wrench 12 point fasteners with wrenching configurations conforming to AS870C. Reported wrenching problems with smaller sizes are investigated through examining the combined tolerances on the fasteners and wrenches, conducting torque testing on typical high strength lock nuts. Possible solutions to correct these wrenching problems are presented.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 7251

AS870
AS954
AS3068

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

FED-STD-346
MIL-STD-1515
MS33787

2.1.3 IFI Publications:

IFI-107
IFI-115

3. PREFACE:

A principal requirement of AS954 Aerospace Standard for "HIGH STRENGTH" tools is that the tools "... shall transmit torque to the fastener (per AS870) without bearing on the outer 5% of the fastener's wrenching points". The purpose of this is to enhance the wrenching capability on 12 Point fasteners. Despite the improved wrenching performance thus developed by AS954 it is realized that wrenching problems may still exist on the smaller wrenching sizes due to tolerances.

This report is intended to serve as a basis of review and analysis of this problem and to suggest possible solutions.

4. OBJECTIVES:

1. To study the wrenching engagement between wrenching tools per AS954 and fasteners:

   a. per AS870 design
   b. per Industrial Fastener Institute (IFI) IFI-115
   c. per typical aerospace fastener manufacturers' 12 Point fastener design from catalog dimensional information

2. To test the wrenching torque achievable on selected sizes typical of the smaller 12 Point fasteners.

3. To compare the wrenching engagement and torque test results so as to identify any wrenchability problems.

4. To recommend areas for possible changes in wrenching configuration sizes/tolerances on the wrenching tool and/or fastener that will alleviate these wrenchability problems.

5. RESULTS:

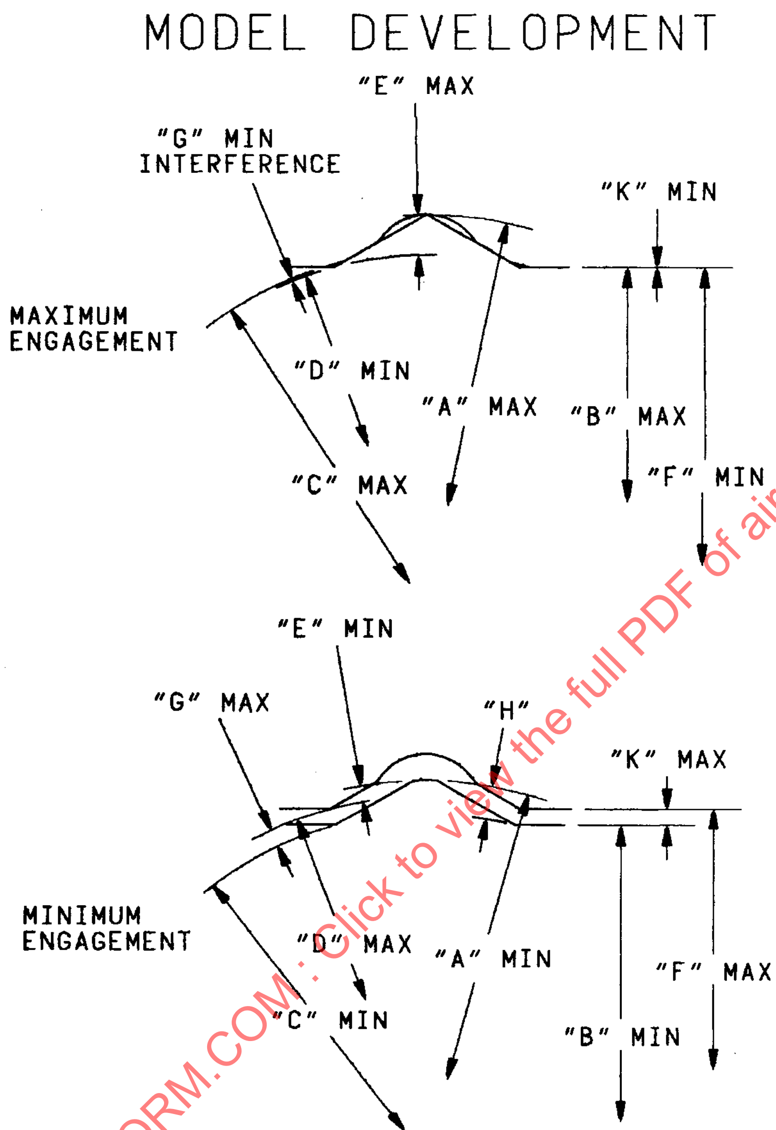
The following summary results are numbered in accordance with the preceding OBJECT statements. Refer to Figure 1: MODEL DEVELOPMENT and the associated Equation Pages 1 and 2 for identity of the symbols.

1. Tables 1, 2, and 3 give the pertinent dimensions of the wrenching tool per AS954 (note that AS954A Section 3.8.2 requires compliance with FED-STD-346) and fastener dimensions per:

   a. AS870C
   b. Standard Pressed Steel, FN22 Series Locknuts
   c. IFI-115, 1970 12 Point Flange Screws

   Note that dimension E min is the "wrenching engagement" and is the item of principal concern. This represents the amount of overlap per side and is calculated from the Minimum fastener across corners dimension and the maximum wrenching tool (socket) root diameter.

   Note also that the magnitude of E min is as little as 0.0034 inch for the 0.1875 (3/16) inch hex size and is less than .010 inch for all nominal hex sizes 0.3438 (11/32) inch and smaller.



A=FASTENER ACROSS CORNERS, DIAMETRAL
B=FASTENER ACROSS FLATS
C=FASTENER ROOT DIAMETER
D=SOCKET ROOT DIAMETER
E=ENGAGEMENT LENGTH RADIAL DISTANCE PER SIDE
F=SOCKET ACROSS FLATS
G=INNER CORNER RADIAL CLEARANCE PER SIDE
H=FASTENER LOBE RADIAL HEIGHT
K=ACROSS FLATS CLEARANCE PER SIDE

FIGURE 1

EQUATION PAGE 1
for
FED-STD-346C SOCKETS
and
AS870C FASTENERS

Given Dimensions:

Amax, Amin - Fastener across outer corners diametral max, min

Bmax, Bmin - Fastener across flats max, min

Cmax, Cmin - Fastener root diameter max, min

Fmax, Fmin - Socket across flats max, min

Calculated Dimensions:

Dmax = Socket root diameter, max
= Fmax/cos 15°

Dmin = Socket root diameter, min
= Fmin/cos 15°

Emax = Engagement length radial distance per side, max
= (Amax - Dmin)/2

Emin = Engagement length radial distance per side, min
= (Amin - Dmax)/2

Gmax = Inner corner radial clearance per side, max
= (Dmax - Cmin)/2

Gmin = Inner corner radial clearance per side, min
= (Dmin - Cmax)/2

Hmin = Lobe height radial, min
= (Amin - Cmax)/2

Kmax = Across flats clearance per side, max
= (Fmax - Bmin)/2

Kmin = Across flats clearance per side, min
= (Fmin - Bmax)/2

FIGURE 1 (Continued)

EQUATION PAGE 2
for
FED-STD-346C SOCKETS
and
CATALOG OR IFI FASTENERS

Given Dimensions:

A'min - Fastener across outer corners diametral min

B'max, B'min - Fastener across flats max, min

Fmax, Fmin - Socket across flats max, min

Dmax, Dmin - Socket root diameter max, min from AS870C fastener calculations

Calculated Dimensions:

A'max = Fastener across outer corners diametral, max
= 1.155 B'max

C'max = Fastener root diameter, max
= B'max/cos 15°

C'min = Fastener root diameter, min
= B'min/cos 15°

E'max = Engagement length radial distance per side, max
= (A'max - Dmin)/2

E'min = Engagement length radial distance per side, min
= (A'min - Dmax)/2

G'max = Inner corner radial clearance per side, max
= (Dmax - C'min)/2

G'min = Inner corner radial clearance per side, min
= (Dmin - C'max)/2

K'max = Across flats clearance per side, max
= (Fmax - B'min)/2

K'min = Across flats clearance per side, min
= (Fmin - B'max)/2

FIGURE 1 (Continued)

5. (Continued):

2. Torque tests were conducted on the 0.250 (1/4) inch and 0.3125 (5/16) inch wrenching sizes using standard sockets with wrenching configuration conforming to AS954A and the following ESNA Double Hex, High Tensile 450 °F, 220,000 psi rated nuts:

   1/4 inch - LH6422T-02 (0.190-32 threads)
   5/16 inch - LH7461-048 (0.250-28 threads)

   The dimensions relating to E (engagement per side between the socket and fastener) were measured and recorded. The actual E values for the combination of the sockets and fasteners used were within the theoretical MIN-MAX range being generally in the lower half of the engagement range.

   Testing under these conditions resulted in sufficient torque to shear a 200,000 psi male thread with no damage to the wrenching surfaces of the sockets or nuts. For example, under these conditions, the 1/4 inch size test resulted in shearing of the 0.190-32 threads at 152 in-lb.

   To enable determination of the relationship of torque attainable versus E (engagement), testing was done with axial wrenching length reduced to about 1/2 the normal wrenching length. Further, one group of each size fastener was altered by turning the across corners dimension to the A min dimension of AS870C. This resulted in three points of data for each of the 1/4 and 5/16 fasteners:

   (i) zero-zero intercept (zero engagement-zero torque)
   (ii) near minimum E (turned fastener corners)
   (iii) E actual (fasteners unaltered)

   The torques attained on these tests were then adjusted to correlate to full axial length wrenching engagement by the relationship: torque is proportional to axial wrenching length.

   The resulting relationships between torque attainable and Engagement per Side (E) are shown graphically in Figures 2 and 3.

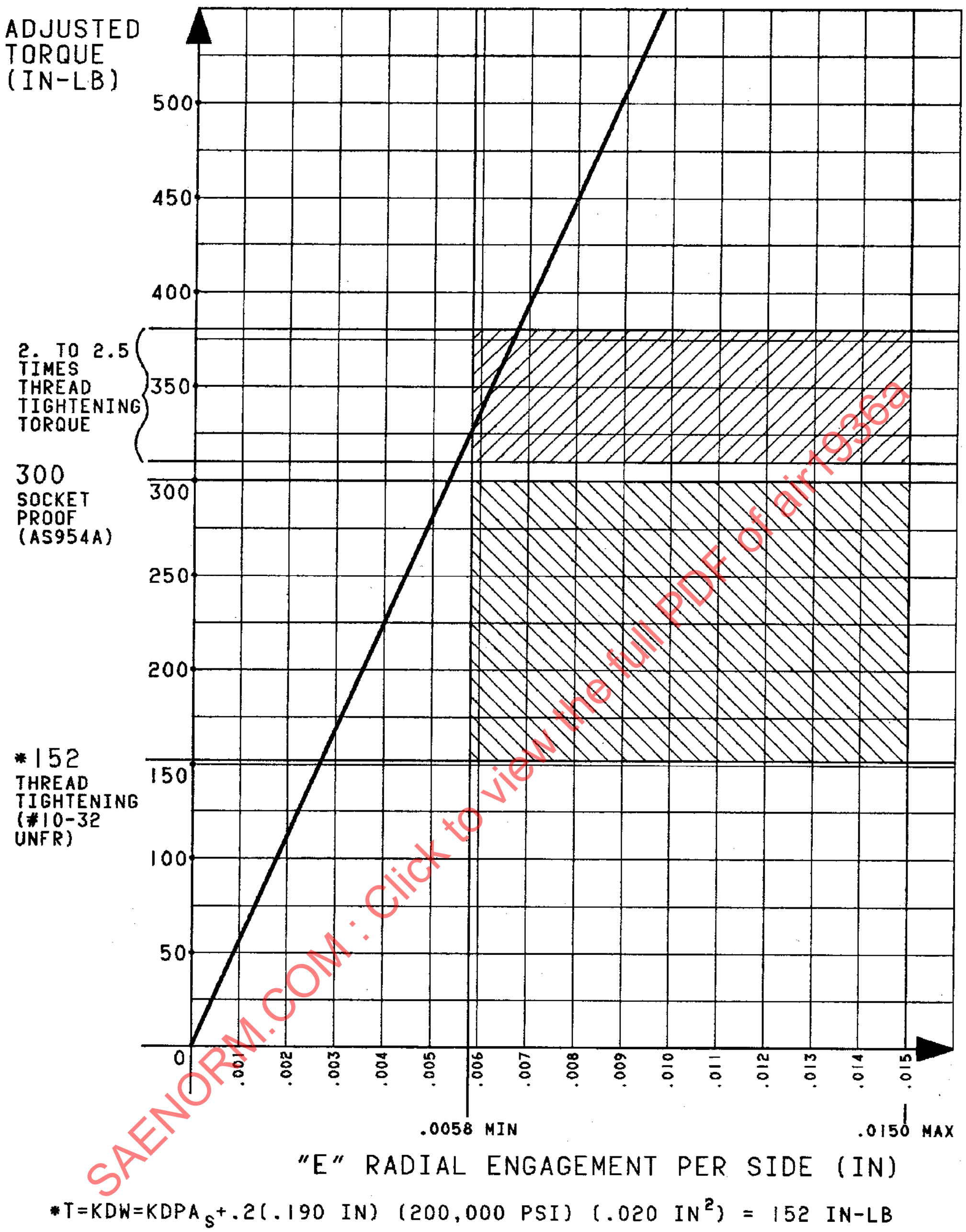


FIGURE 2 - Torque Versus Engagement for 1/4 inch 12 Point Fasteners

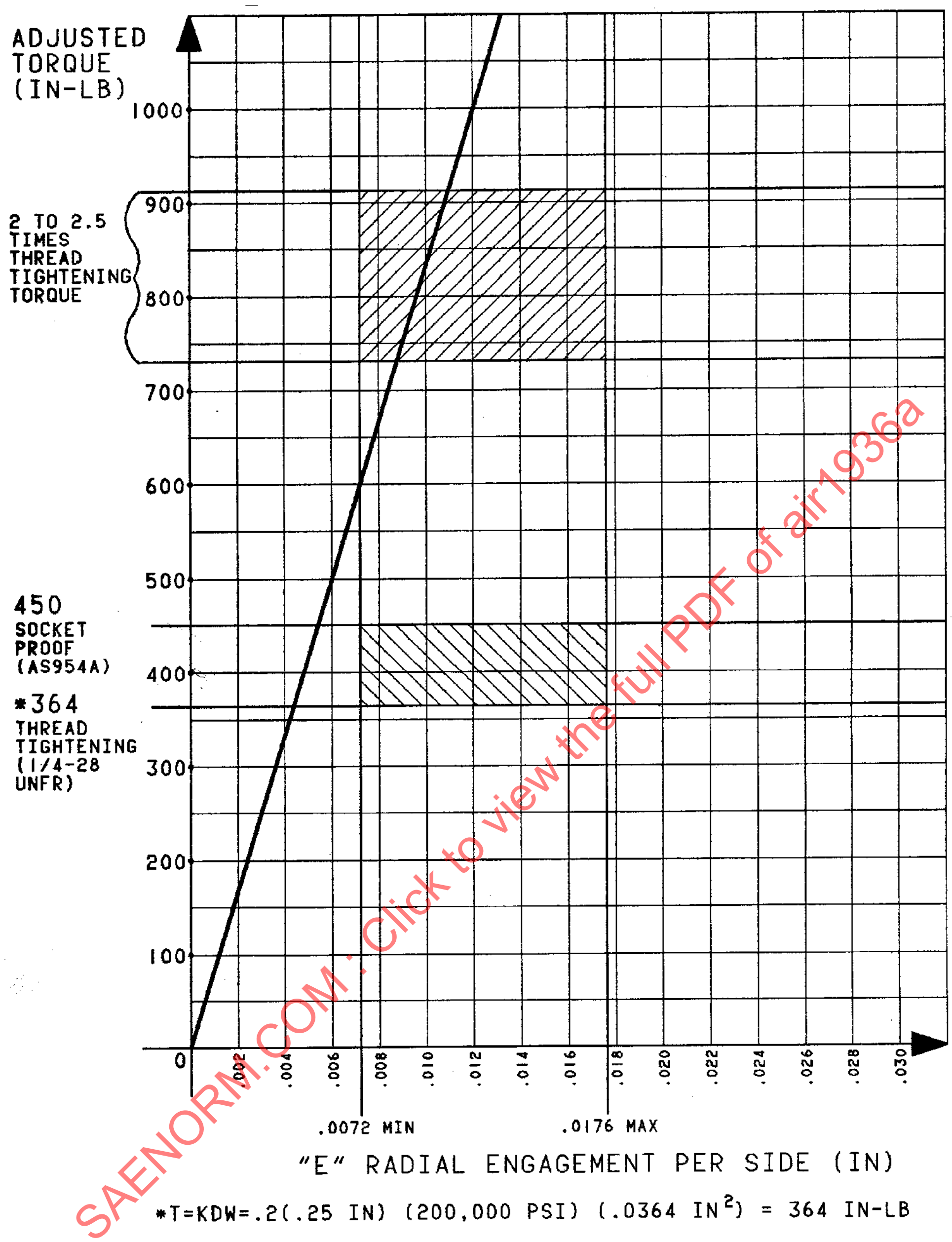


FIGURE 3 - Torque Versus Engagement for 5/16 inch 12 Point Fasteners

5. (Continued):

3. As indicated in the preceding section

Sockets per AS954A have the capability of torquing fasteners per AS870C (as typified by ESNA 220,000 psi 12 Point Nuts) to more than the torque capacity of the male thread.

This fact should result in no problem with fastener installation and, as far as is known, this is accurate. However, fasteners subjected to corrosion and heat in use are known to often require removal torques of 2 to 3 times the installation torque. A shaded zone superimposed on Figures 2 and 3 shows the relationship of the

Torque Versus Engagement per Side capability
and
Removal torque at 2 to 2.5 times tightening torque

From this relationship, it is indicated that for removal torques of two or more times the installation torques of high strength fasteners, failure of the wrenching surfaces may occur for a portion of the wrench/fastener population.

As the torque approaches 2.5 or 3 times the installation torque, the proportion of the population that might experience failure of the wrenching surfaces increases to a significant amount, but it should still be limited to those wrench/fastener combinations whose engagement is in the lower 1/3 or so of the combined tolerance range.

4. Based on the preceding analysis, it is projected that for the sizes tested, nearly all of the problem could be solved by:

a. Increasing the torque capability by about 30% by increasing the axial length of the wrenching engagement by 30% (with everything else remaining as is). The testing done here was based on -

0.086 inch nut wrenching surface height for the 1/4 size
0.112 inch nut wrenching surface height for the 5/16 size

Note that SAE Aerospace Standard AS3068 for Nut, Self-Locking, Double Hexagon, Reduced Envelope, AMS 7251 has minimum wrenching surface heights of 0.070 inch and 0.095 inch, respectively.

Increasing the wrenching surface height to

0.112 inch for the 1/4 size
0.146 inch for the 5/16 size

would add envelope height and weight to the fasteners, but would substantially alleviate wrenchability problems.

5. (Continued):

b. Changing one or more of the dimensional tolerances on the wrenching configuration of the tool and/or fastener so as to increase the minimum Engagement per side by 0.002 inch on the 1/4 size and by 0.003 inch on the 5/16 inch size (even at the present axial wrenching length) would similarly reduce the problem.

Since the Engagement per Side is simply one-half the difference between the "across corners" (A) of the fastener and the "root diameter" (D) or innermost point of the socket wrenching configuration.

$\left| E = \frac{A - D}{2} \right|$, changes in these particular dimensions are indicated. These dimensions are, however, related to the "across flats" dimensions of the socket and fastener so they must also be considered.

A further and more detailed examination and analysis of some possible improvements will be made in the following discussion section.

c. A combination of the increased axial wrenching length and increase in minimum E could achieve significant improvement with reasonably subtle changes.

6. DISCUSSION:

General Considerations:

The premise of this investigation and report is that there is a wrenchability "problem" on smaller sizes of 12 Point fasteners. Each user of this type of fastener has his own knowledge and experience base in this area and there may not be unanimous agreement on the severity of the problem and the importance of any change toward improvement. It is felt that the preceding tests, analyses, and conclusions agree with typical experience.

Further review of some background and design factors of 12 Point fasteners helps to give perspective to the situation.

a. Shortly after widespread adoption of 12 Point fasteners on military aircraft in the late 1950's and early 1960's, the reports of wrenchability problems spurred the development of wrenching tool configurations that "touch away from the fastener corner" by several tool manufacturers.

b. SAE Aerospace Committee activity resulted in the aerospace standard AS954 with the noncorner contact on 12 Point fasteners as a principal feature in 1967.

6. (Continued):

c. In the mid-1960's, the Navy Department sponsored a design competition for high wrenching strength fasteners that ultimately resulted in the MS33787 spline wrenching shape configuration. Currently, MIL-STD-1515 requires use of the MS33787 spline wrenching configuration for use on all fasteners in excess of the 180,000 psi strength level on all new military aircraft prime contracts.

d. The 12 Point design has as its primary advantage over the most common wrenching shape - the single hex or 6 Point shape - twice as many wrenching points to better distribute contact and socket shear stresses. This was adopted so as to enable reduction in envelope size and fastener weight, both of which are crucial to aircraft design. To accomplish this, the thread to nominal wrenching size ratio was changed. For example, for a 1/4 inch thread size, the normal single hex nut wrenching size is 7/16 inch. As per the various Tables and the sample fasteners used in the preceding tests, the 12 Point nut for a 1/4 inch thread is 5/16 inch. Further, the axial wrenching length of the 12 Point fastener is substantially less than for the single hex counterpart:

0.095 inch minimum for the 5/16 wrenching size as used herein (Reference AMS 7251)
versus
0.14 inch minimum for typical 7/16 single hex flange nut (Reference IFI-107)

A combination of these factors dictates much more severe torque strength and wrenchability requirements for wrenching tools used with 12 Point fasteners.

e. The torque capabilities reported herein are based on the AS954 non-corner contact principle. Conventional 12 Point socket wrenches would deform fastener corners and limit achievable torques to significantly lower levels.

Dimension and Tolerance Study:

Refer to Table 1 and Figure 1 as the basis for this discussion and analysis. In considering possibilities for increasing minimum engagement (E min), the following factors should be reviewed:

1. The across flats sizes and tolerances. For purposes of example, the 1/4 inch and 3/4 inch nominal wrenching sizes will be selected.