SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP584 REV. C

Issued 1960-03
Reaffirmed 2002-05
Revised 2012-01

Superseding ARP584B

(R) Coiled Tubing - Corrosion Resistant Steel, Hydraulic Applications, Aerospace

SAENORM.COM : Click to view the full PDF of arp584c

RATIONALE

ARP584B has been updated to Revision C for the following reasons:

a. Technical changes have been made including the removal of text that referred to documents that are difficult to obtain and to computer programs that are unavailable

b. The references called up in the document have been updated

c. Editorial changes have been made to improve the readability of the document

TABLE OF CONTENTS

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, stabilized or cancelled. SAE invites your written comments and suggestions.

Copyright © 2012 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/ARP584C

SAENORM.COM : Click to view the full PDF of arp584c

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) addresses the design, installation, and testing of coiled tube assemblies ranging from 1/4 inch (6.3 mm) to 1.0 inch (25 mm) diameter using CRES tubing per AMS-T-6845, unless otherwise approved by the Procuring Activity.

This ARP specifically details three different configurations of coiled tubing. These configurations should be compatible with pressure levels up to 3000 psi (20.7 MPa) upon the completion of the analysis for the actual stress and life requirement of the intended application. However, formal qualification tests are recommended to verify the satisfactory installation, clamping, and the life of each unique design.

NOTE: Refer to ARP4146 for information on design of coiled tube assemblies using Titanium tubing.

1.1 Purpose

The purpose of this document is to provide data and information relative to design, fabrication, and installation of formed tubing made from CRES alloy. The formed tubing has the function of accepting relative motion between two points in a hydraulic or pneumatic system.

1.2 Field of Application

The use of coiled tubes is encouraged in the design of hydraulic systems per AS5440 or ARP4752/ARP4925, and for pneumatic systems per MIL-P-5518 when standard flexible hoses are not feasible due to installation constraints, compliance limitations, and effusion requirements.

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR1379 Prestressing (Autofrettaging) of Hydraulic Tubing Lines

ARP4146 Coiled Tubing-Titanium Alloy, Hydraulic Applications

ARP4752 Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems

ARP4925 Aerospace - Design and Installation of Commercial Transport Helicopter Hydraulic Systems

AS5440 Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For

AMS-T-6845 Tubing, Steel, Corrosion Resistant (S30400), Aerospace Vehicle Hydraulic System 1/8 Hard Condition

AS33611 Tube Bend Radii

SAENORM.COM : Click to view the full PDF of arp584c

2.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-9495, https://assist.daps.dla.mil/quicksearch/.

MIL-P-5518 Pneumatic Systems, Aircraft, Design and Installation, General Requirements for

3. CONFIGURATIONS

There are three configurations detailed in this ARP, which are as follows:

a. Style A - Helical Torsion Configuration

b. Style B - Torsion Tube Configuration

c. Style C - Non Standard Configurations

Each configuration is described in the following sections.

3.1 Style A - Helical Torsion Configuration

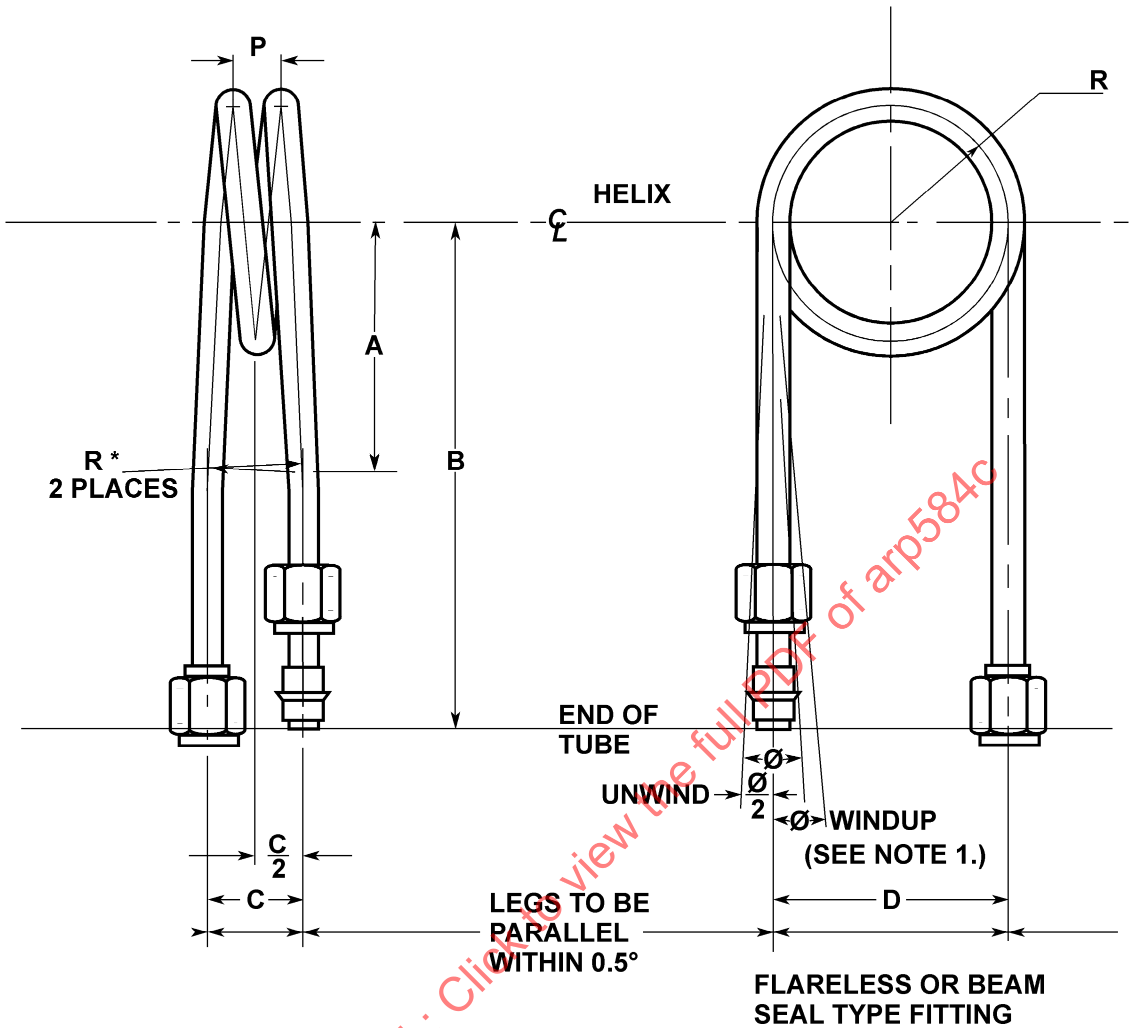
Refer to Figure 1.

This configuration typically consists of a 540 degree (1-1/2 coil) helical coil of tubing with a straight section projecting from each end of the coil.

In the actual application, it operates principally in bending and allows 13 degrees angular motion of one end with respect to the other about the helix axis in a plane perpendicular to the helix axis

Tables 1 and 2 provide the dimensions to be called up for this configuration.

SAENORM.COM : Click to view the full PDF of arp584c



SAENORM.COM : Click to view the full PDF of arp584c

NOTES:

1. Ø indicates three different modes of deflection; only one mode may be used on any tube.
2. See section 4 for $Ø_{max}$
3. The standard bend radii per AS33611 may be used for planar bends noted by R*

FIGURE 1 - STYLE A - HELICAL TORSION CONFIGURATION

TABLE 1 - DIMENSIONS FOR STYLE A - INCHES

Tube OD	Wall Thickness Nom	R ± 0.047	P - Pitch	A ± 0.032	B ± 0.032	C ± 0.032	D ± 0.032
0.250	0.028	1.000	0.375	3.000	6.000	0.906	2.000
0.313	0.035	1.125	0.438	3.000	6.000	1.032	2.250
0.375	0.042	1.375	0.500	3.250	6.000	1.125	2.750
0.500	0.058	1.750	0.625	4.000	7.000	1.375	3.500
0.625	0.078	2.250	0.750	5.000	9.500	1.656	4.500
0.750	0.083	2.625	0.875	6.000	12.000	1.938	5.250
1.000	0.120	3.500	1.125	7.000	14.000	1.406	7.000

TABLE 2 - DIMENSIONS FOR STYLE A - mm

Tube OD	Wall Thickness Nom	R ±1.2	P - Pitch	A ± 0.8	B ± 0.8	C ± 0.8	D ± 0.8
6	0.71	25.4	9.5	76.2	152.4	23.0	50.8
8	0.89	28.6	11.1	76.2	152.4	26.2	57.2
10	1.07	34.9	12.7	76.2	152.4	28.6	69.9
12	1.47	44.5	15.9	101.6	177.8	34.9	88.9
14	1.98	57.2	19.1	127.0	241.3	42.1	114.3
19	2.11	66.7	22.2	152.4	304.8	49.2	133.4
25	3.05	88.9	28.6	177.8	355.6	35.7	177.8

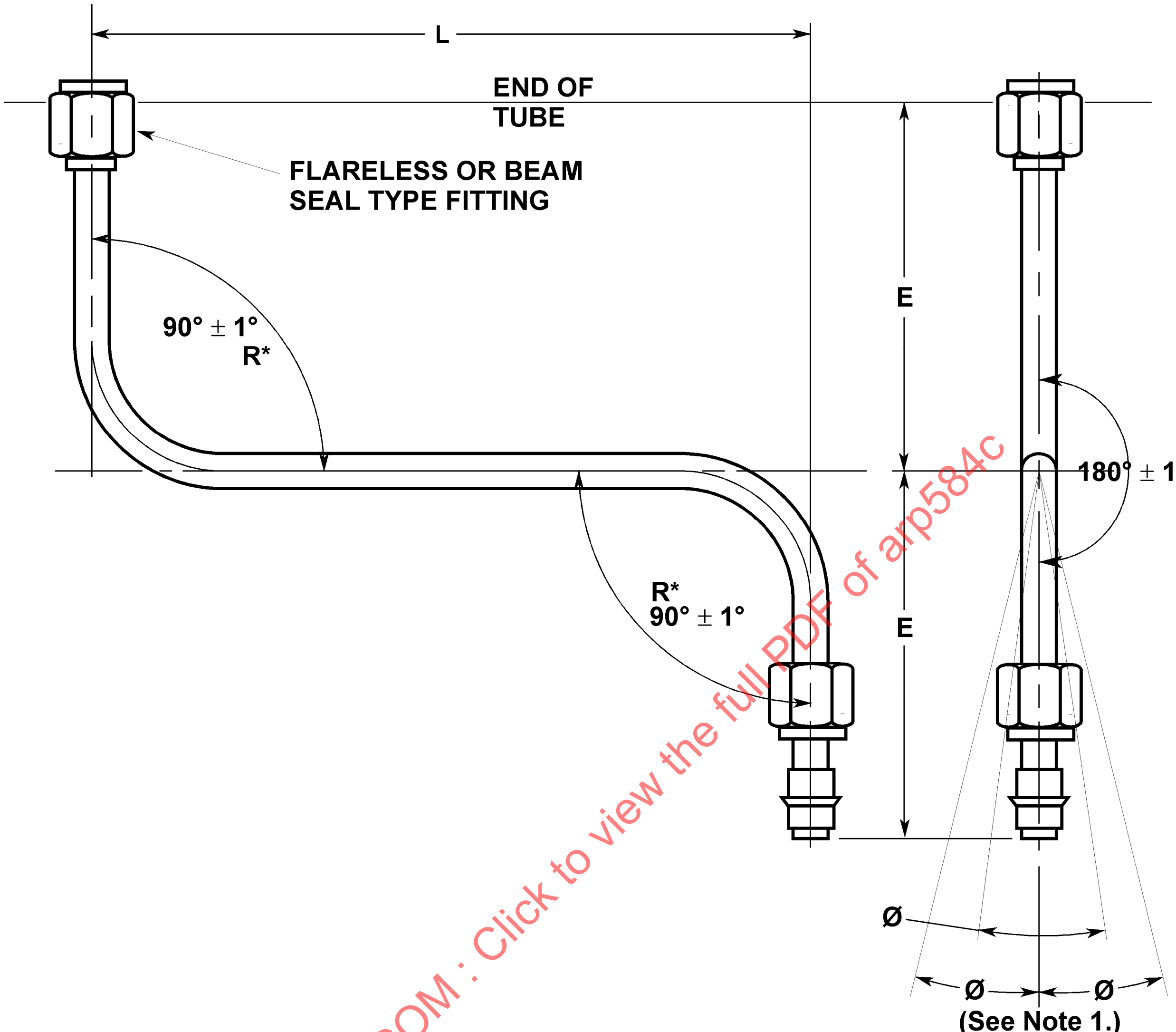
3.2 Style B - Torsion Tube Configuration

Refer to Figure 2.

This configuration consists of three straight sections separated by two 90 degree bends all in one plane. The middle straight section is twisted in operation, allowing one end to rotate about the centerline of the middle straight section.

Tables 3 and 4 provide the dimensions to be called up for this configuration.

SAENORM.COM : Click to view the full PDF of arp584c



SAENORM.COM : Click to view the full PDF of arp584c

NOTES:

1. Ø indicates three different modes of deflection; only one mode may be used on any tube.
2. See section 4 for $Ø_{max}$
3. The standard bend radii per AS33611 may be used for planar bends noted by R*

FIGURE 2 - STYLE B - TORSION TUBE CONFIGURATION

TABLE 3 - DIMENSIONS FOR STYLE B - INCHES

Tube OD	Wall Thickness Nom	R - Radius	L ± 0.032	E ± 0.032
0.250	0.028	1.000	11.125	4.000
0.313	0.035	1.125	14.000	5.000
0.375	0.042	1.375	16.750	6.000
0.500	0.058	1.750	22.250	8.000
0.625	0.078	2.250	27.875	10.000
0.750	0.083	2.625	33.375	12.000
1.000	0.120	3.500	44.500	16.000

TABLE 4 - DIMENSIONS FOR STYLE B - mm

Tube OD	Wall Thickness Nom	R - Radius	L ± 0.8	E ± 0.8
6	0.71	25.4	282.6	101.6
8	0.89	28.6	355.6	127.0
10	1.07	34.9	425.5	152.4
12	1.47	44.5	565.2	203.2
16	1.98	57.2	708.0	254.0
19	2.10	66.7	847.7	304.8
25	3.05	88.9	1130.0	406.4

SAENORM.COM : Click to view the full PDF of arp584c

3.3 Style C - Non Standard Configurations

Where Styles A and B are not applicable, an infinite variety of special configurations may be designed to accommodate particular space or deflection requirements. These may be modifications of Styles A and B or more elaborate combinations of straights, curves, and helical section elements that are otherwise consistent with the specifications of Style A and B.

The non-standard configuration should not apply torsion loads to the fittings because many fitting types have a limited capability to resist torsion loads.

4. MAXIMUM ANGULAR DEFLECTIONS

The recommended maximum deflection for the hydraulic/pneumatic systems with the appropriate operating temperature ranges for Style A and B configurations, as shown in Figures 1 and 2, are as per Table 5.

TABLE 5 - SYSTEM OPERATING TEMPERATURE RANGE VS ANGULAR DEFLECTION

Temperature Range °F (°C)	Angular Deflection $Ø_{Max}$°
-65 (-54) to +160 (+71)	13.0
-65 (-54) to +275 (+135)	12.3
-65 (-54) to +450 (+204)	11.3
-65 (-54) to +600 (+316)	10.0

These maximum angular deflections correspond to the dimensions of Tables 1 through 4 for the standard Styles A and B configurations

Where greater angular deflection is required, a non-standard configuration, Style C, must be used. For example, a non-standard design could include increasing the pitch radius (R) dimension of Style A or increasing the “L” dimension of Style B.

5. MATERIALS

The tubing shall be Corrosion Resistant Steel 304, 1/8 Hard Aircraft Hydraulic System Tubing in accordance with AMS-T-6845, unless otherwise approved by the Procuring Activity. It is recommended that 100 percent quality control be applied to inside and outside surface smoothness. The wall thicknesses specified in Tables 1 through 4 are consistently higher than normally used for fixed tubing to provide the necessary stress margins for flexure plus internal pressure.

Steel fittings (nut, sleeve and mating fittings) in accordance with current military or industry standards, either flareless or beam seal should be used. Aluminum alloy fittings can withstand the loads, but they will be difficult to properly install, will severely distort when tightened against the thick wall steel tubing and may require occasional retightening to eliminate seep leakage.

6. STRESS ANALYSIS

SAENORM.COM : Click to view the full PDF of arp584c

There are a number of methods that may be used to analyze the total stresses at critical points in the coils, including:

1. Von-Mises Distortion Energy Failure Theory for loading in multiple axes.

2. Finite Element Analysis (FEA) is another technique for stress analysis of the sometimes irregular configurations required of coiled tubing. Any FEA software that is used should have bar elements for possible nonlinear cases.

7. FABRICATION

7.1 Springback

When the coils are formed, a certain amount of springback will occur. The amount of springback will vary from lot to lot of tube material and should be determined at the time of tool planning. Compensation for springback may be accomplished by detailing the mandrel minor diameter slightly smaller than the coil finished diameter and by winding the coil slightly greater than the coil finished number of turns.

7.2 Tooling Required

Style B may be manufactured with conventional tube bending tools. Style A may be manufactured by conventional tube bending techniques except as follows.

The conventional die block which contains a semi-circular shaped groove around 180-270 degrees of its external surface must be replaced by a similar block containing a groove which spirals through 600 degrees (1-2/3 turns). As this spiral die block turns, it must be free to shift along its axis, or the feed block must move relative to the spiral die to accommodate the lead of the spiral.

Coil standardized tooling which is successfully used consists of a die block or mandrel with 6 to 10 spirals which allows adjusting the number of turns to the allowable stress level. Larger diameters are used to allow "nesting" of coils to reduce installation space for multiple lines to actuators. There is not general agreement on the need to autofrettage the coiled tube after forming. It is generally accepted that as wall thickness is increased above the minimum required for the operating pressure, the percent of ovalization is reduced.

7.3 Feed Block

The feed block (which supports the unbent tube) must be tilted to an angle approximately equal to the helix angle, which can be adjusted to produce the correct pitch (typical spring winding technique).

7.4 Ovality

Use of a mandrel is recommended to ensure minimum ovality of the tubing at the bends. The percent ovality must not exceed 5 percent defined as:

$$\text{Ovality} = \frac{(OD_{Max} - OD_{Min}) \times 100}{OD_{Nominal}} \qquad \text{(Eq. 1)}$$

A careful check along the entire bend should be made, particularly at the midpoint of the bend and at the tangency points (where bend meets straight section) to find the minimum O.D. The maximum O.D. is defined as the measurement 90 degrees to the minimum O.D. at the section of this minimum O.D. In production, a check fixture should be used to check configuration tolerances. For tubing sizes below 3/8 inch (10 mm), a keeper which interconnects the tubing ends should be attached after proof testing to prevent excessive deflection during the handling.

7.4.1 Autofrettage

This is a technique that is used to reduce ovality and improve fatigue life of the tubing by pressurizing the tubing until the stress at the inner wall of the tubing is in the plastic range. By applying internal pressure in this manner ovality is reduced by forcing the tube to assume a shape closer to the original diameter. Also, after the removal of the pressure, the inner wall has a residual compressive stress that reduces the effect of minor imperfections and irregularities in the inner tube wall. Tests by major airframe manufacturers demonstrated increased fatigue impulse life after autofrettage of tubing. These benefits are a function of the amount of ovality with little advantage when ovality is less than or equal to 2%.

Autofrettage will not compensate for tooling that is worn or does not support the tube diameter during forming. It is probably more effective on "thin wall" tubing. Thin wall tubing here is defined as having a wall thickness set by the minimum burst pressure requirement. Wall thickness meeting a burst pressure of at least four times operating pressure will result in fewer coils than tubing with lower burst pressure design. AIR1379 has further discussion and recommendations concerning autofrettage.

When autofrettaging or applying proof pressure to a coiled tube assembly, the tube ends should be clamped or restrained to maintain the critical interface dimensions relative to the mating tubing in the aircraft.

8. INSTALLATION (STYLES A AND B ONLY)

8.1 Design Considerations

A space layout and geometry study will indicate which style configuration can be used most advantageously. In the process, Style A would be located with the centerline of the helix close to the major pivot axis or Style B with the centerline middle straight section along the major pivot axis. However, it is necessary to determine or estimate all other factors which may cause relative motion such as misalignment, structural deflections, thermal expansion, etc. These should be resolved about the three principal axes of motion and compared with the installation tolerances illustrated herein.

8.2 Excessive Deflection

During actuator installation or replacement, care must be taken not to deflect the flexible tubing beyond the design limits. The designer may be able to limit the over flexure in the cavity by means of structural stops or provide satisfactory instructions for installation and removal. It is imperative that the designer, mechanic, and the inspector observe the installation limits to ensure the maximum fatigue life and reliability of the flexible plain metal tubing.

SAENORM.COM : Click to view the full PDF of arp584c

8.2.1 Style A Installation

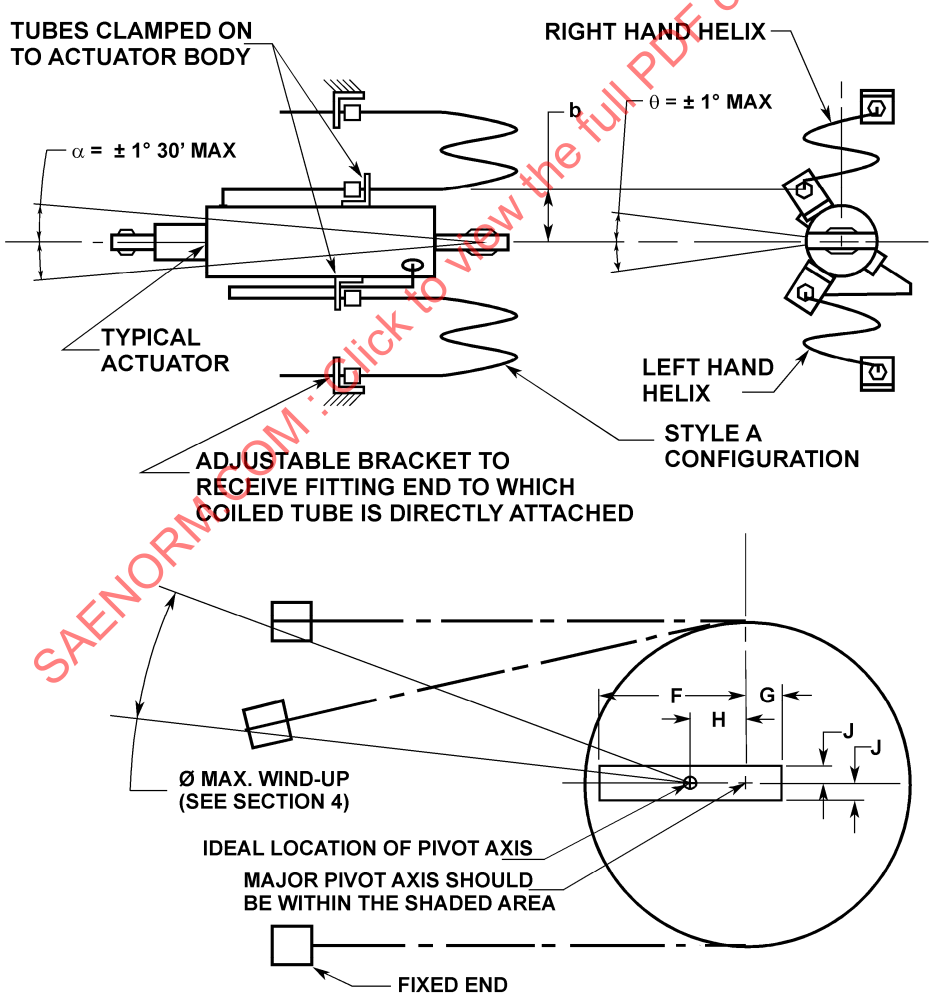
Refer to Figure 3.

The recommended deflection for Style A can all be taken in the windup direction or it can be split with 50 percent maximum deflection on each side of the free position.

The Style A installation should be oriented so that the axis of the helix is parallel to the principal axis of motion, which may be offset to any point within the shaded area as shown on Figure 3.

The helix of Style A should be located as close as practical to the actuator (in the type of application illustrated by dimension b in Figure 3) to minimize the effects of misalignment. Actuator misalignment, α, should be limited to 1.5 degrees and rotation about actuator centerline, θ, should be limited to 1 degree. A symmetrical installation about either side of the actuator using right and left hand pitch in the helixes will result in balance of rotational forces that is desirable. When self-aligning bearings are used, restrict the actuator rotation torsionally by mechanical means such as special washers or lugs on the bearing strap.

In order to prevent bending loads from being reacted by the fittings at the actuator interfaces, the tubes should be clamped on to the actuator as shown schematically on Figure 3.



F		G		H		J	
IN.	mm.	IN.	mm.	IN.	mm.	IN.	mm.
1.00	25.4	0.25	6.4	0.375	9.5	0 TO 0.125	0 TO 3.2

FIGURE 3 - INSTALLATION OF STYLE A

SAENORM.COM : Click to view the full PDF of arp584c