Designation: ~~E1928 – 07~~ E1928 – 13

Standard Practice for
Estimating the Approximate Residual Circumferential Stress in Straight Thin-walled Tubing[1]

This standard is issued under the fixed designation E1928; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ Scope*

1.1 A qualitative estimate of the residual circumferential stress in thin-walled tubing may be calculated from the change in outside diameter that occurs upon splitting a length of ~~the~~thin-walled tubing. This practice assumes a linear stress distribution through the tube wall thickness and will not provide an estimate of local stress distributions such as surface stresses. (Very high local residual stress gradients are common at the surface of metal tubing due to cold drawing, peening, grinding, etc.) The Hatfield and Thirkell formula, as later modified by Sachs and Espey,[2] provides a simple method for calculating the approximate circumferential stress from the change in diameter of straight, thin-walled, metal tubing.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E6 Terminology Relating to Methods of Mechanical Testing

3. Terminology

3.1 The definitions in this practice are in accordance with Terminology E6.

4. Significance and Use

4.1 Residual stresses in tubing may be detrimental to the future performance of the tubing. Such stresses may, for example, influence the susceptibility of a tube to stress corrosion cracking when the tube is exposed to certain environments.

4.2 Residual stresses in new thin-walled tubing are very sensitive to the parameters of the fabrication process, and small variations in these parameters can produce significant changes in the residual stresses. See, for example, Table 1, which shows the residual stresses measured by this practice in samples from successive heats of a ferritic Cr-Mo-Ni stainless steel tube and a titanium condenser tube. This practice provides a means for estimating the residual stresses in samples from each and every heat.

4.2.1 This practice may also be used to estimate the residual stresses that remain in tubes after removal from service in different environments and operating conditions.

4.3 This practice assumes a linear stress distribution through the wall thickness. This assumption is usually reasonable for thin-walled tubes, that is, for tubes in which the wall thickness does not exceed one tenth of the outside diameter. Even in cases where the assumption is not strictly justified, experience has shown that the approximate stresses estimated by this practice frequently serve as useful indicators of the susceptibility to stress corrosion cracking of the tubing of certain metal alloys when exposed to specific environments.

4.3.1 Because of this questionable assumption regarding the stress distribution in the tubing, the user is cautioned against using the results of this practice for design, manufacturing control, localized surface residual stress evaluation, or other purposes without supplementary information that supports the application.

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[1] This practice is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.13 on Residual Stress Measurement.

Current edition approved ~~March 1, 2007~~Nov. 1, 2013. Published ~~April 2007~~January 2014. Originally approved in 1998. Last previous edition approved in ~~1999~~2007 as ~~E1928 - 99.~~E1928–07. DOI: ~~10.1520/E1928-07.~~10.1520/E1928-13.

[2] Sachs, G. and Espey, G., "A New Method for Determination of Stress Distribution in Thin-walled Tubing," *Transactions of the AIME*, Vol 147, 1942.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

~~TABLE 1 Residual Stresses in Successive Heats of Tubing~~

~~Heat No.~~	~~Ferritic Cr-Mo-Ni Stainless Steel~~		~~Titanium~~	
	~~kPa~~	~~psi~~	~~kPa~~	~~psi~~
~~1~~	~~234000~~	~~34000~~	~~37000~~	~~5400~~
~~2~~	~~272000~~	~~39400~~	~~52000~~	~~7600~~
~~3~~	~~217000~~	~~31500~~	~~30000~~	~~4300~~
~~4~~	~~183000~~	~~26500~~	~~52000~~	~~7500~~
~~5~~	~~241000~~	~~34900~~	~~59000~~	~~8600~~
~~6~~			~~30000~~	~~4300~~
~~7~~			~~59000~~	~~8600~~
~~8~~			~~30000~~	~~4300~~
~~9~~			~~52000~~	~~7500~~
~~10~~			~~37000~~	~~5400~~

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6			30000	4300
7			59000	8600
8			30000	4300
9			52000	7500
10			37000	5400

4.4 This practice has primarily been used to estimate residual fabrication stresses in new thin-walled tubing between 19-mm (0.75-in.) and 25-mm (1-in.) outside diameter and 1.3-mm (0.05-in.) or less wall thickness. While measurement difficulties may be encountered with smaller or larger tubes, there does not appear to be any theoretical size limitation on the applicability of this practice.

5. Procedure

5.1 On new material, the stress determination shall be made on at least one representative sample obtained from each lot or heat of material in the final size and heat treatment. The results of tests on brass and steel tubes, reported by Sachs and Espey,[2] indicate that the length of the sample piece of tube should be at least three times the outside diameter in order to avoid significant end effects.

5.2 At the midlength of the tube sample, measure the outside diameter at four locations (every 45°) around the tube circumference in order to verify that the cross section is reasonably circular.

5.3 Select and mark a straight line lengthwise on the sample, indicating where the split will be made. If the tube thickness is not uniform around the periphery, some practitioners prefer the split to be made at the thinnest location.

5.4 Determine the average outside diameter, D_o, of the sample by measuring and averaging the diameter at ~~90° to the line~~ four points along a line that is 90° from where the split will be ~~made, and at four equally spaced locations along the length, and averaging. Any measuring system~~made. Any measurement method may be used provided that the associated measurement uncertainty does not exceed 0.013 mm (0.0005 in.) or 0.07 %, whichever is larger. See 5.6 and Note ~~2~~1.

5.5 Split the sample longitudinally on one side over its full length along the preselected line. ~~Care must be taken~~ Take care to avoid the development of additional residual stresses in the splitting operation. Monitoring the specimen temperatures during the splitting operation may help to ensure that new stresses are confined to the vicinity of the split.

~~Note 1—The tube may be split by electric discharge machining, by sawing on a milling machine, or by any other gentle cutting method which does not severely distort the stresses. On a milling machine the specimen shall be held by clamps which apply only longitudinal compressive stresses to the tube ends.~~

5.5.1 The tube may be split by electric discharge machining, by sawing, or by any other gentle cutting method that does not significantly distort the stresses. On a milling machine it is preferable to hold the specimen by clamps that apply only longitudinal compressive stresses to the tube ends.

5.6 After splitting, determine the average final outside diameter, D_f, of the sample by measuring the diameter at 90° to the split and averaging the readings taken at four equally spaced locations along the ~~length, and averaging.~~ length of the sample. Use the same ~~measuring system as that~~ measurement method that was used in 5.4.

Note 1—It is important not to deform the sample while measuring the diameter. After splitting, the diametral stiffness of the sample is very low. For this reason, a non-contact measurement method is preferred. If a contact ~~measuring~~measurment instrument, such as a micrometer or ~~calipers,~~caliper, is