SAE International

SURFACE VEHICLE STANDARD

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Superseding J1063 NOV1993

Cantilevered Boom Crane Structures - Method of Test

RATIONALE

This revision will provide editorial corrections to the latest published version and changes the application requirements of SAE Test 5. Additionally, a test requirement to strain gage test the maximum rated load for jib / fly attachments is being added.

1. SCOPE

This SAE Standard applies to mobile, construction-type lifting cranes of the cantilever boom type (Figure 1). Questions and comments regarding application or interpretation of the provisions in this test method should be referred to the originating SAE Committee. [1]

1.1 Purpose

The purpose of this test method is to provide a systematic, nondestructive procedure for determining the stresses induced in cantilevered boom crane structures under specified conditions of static loading through use of resistance-type electric strain gages, and to specify appropriate stress levels for specified loading conditions. Further, a 25% overload test is included to prove the overall structural integrity of the structure.

[1] Chairman, Subcommittee SC31, ORMTC, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE, ASTM, or other mentioned publications shall apply.

2.1.1 ASTM Publication

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM E 251 Standard Test Methods For Performance Characteristics of Metallic Bonded Resistance Strain Gages

2.2 Other Publications

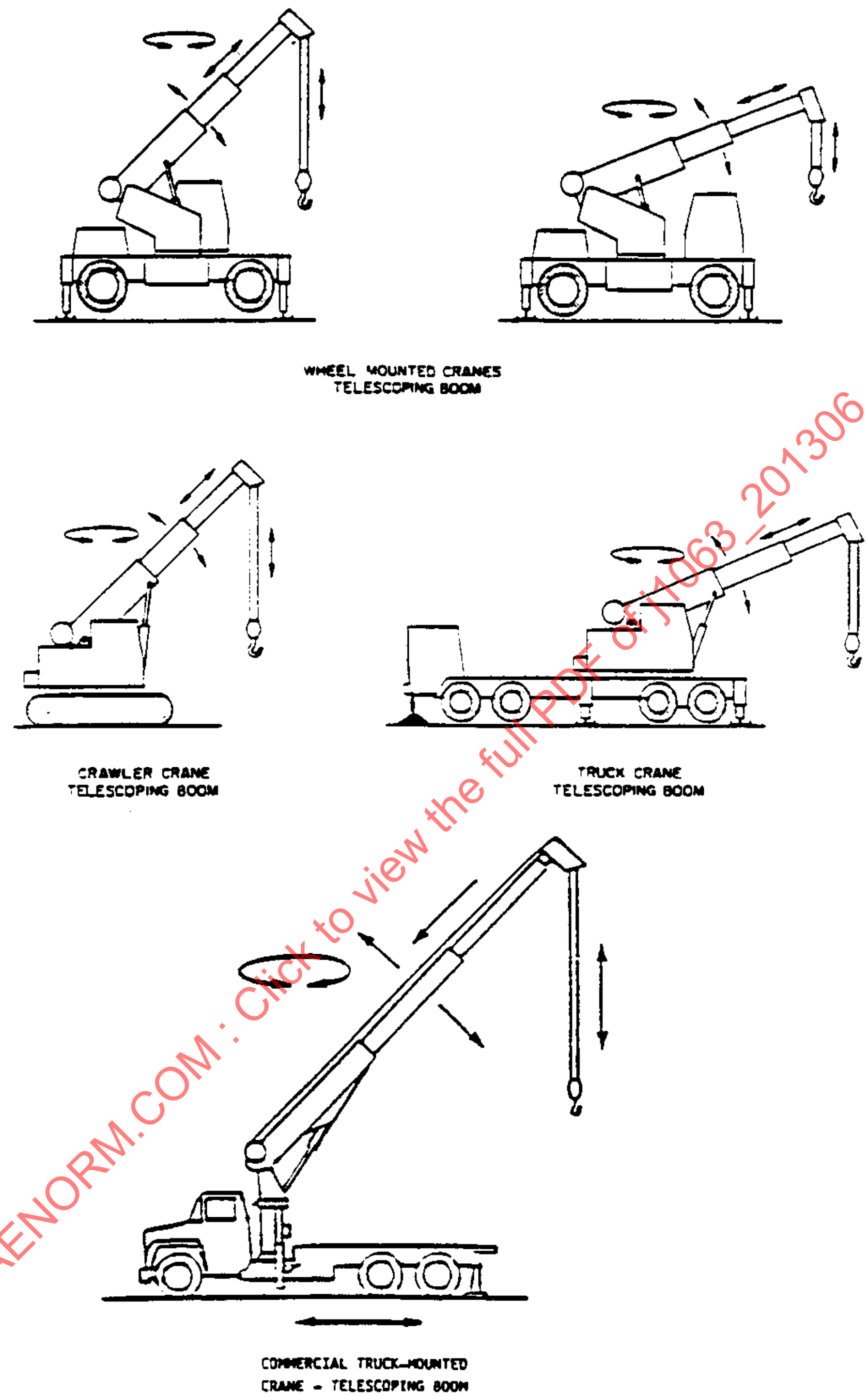
Joseph Marin, "Mechanical Behavior of Engineering Materials," Englewood, N. J.: Prentice-Hall, Inc., 1962

"Guide to Design Criteria for Metal Compression Members," Column Research Council, Cushion Mallory, Inc., Ann Arbor, Michigan, 1960

3. DEFINITIONS

3.1 STRAIN (ε)

Deformation of material caused by weight and applied loading, quantitatively stated as unit change from an original dimension in meters per meter (m/m) or inches per inch (in/in).



The boom may have a basic boom structure of two sections (upper and lower) between which additional sections may be added to increase its length, or may consist of a base boom from which one or more boom extensions are telescoped for additional length. These are some typical configurations.

FIGURE 1 - TYPICAL CONSTRUCTION-TYPE CRANES

3.2 STRESS (S)

The intensity of internal force accompanying strain, expressed in pascals (Pa) or pounds per square inch (psi). For purposes of this test method, stress is related to measured strain by the uniaxial stress equation:

$$S = E \cdot \varepsilon \text{ (Within the proportional limit)} \quad \text{(Eq 1)}$$

where:

S = stress, Pa (psi)
E = modulus of elasticity, Pa (psi) for the material involved (see 10.5)
ε = strain gage reading, m/m (in/in)

NOTE: The simple uniaxial stress formula can be insufficiently accurate for some areas of crane structures under biaxial stress and special consideration should be given in such cases. (See 10.1.1).

3.3 Yield Point (S_y)

The stress at which a disproportionate increase in strain occurs, without a corresponding increase in stress. For purposes of this code, yield point is to be considered as the minimum yield point or yield strength specified by the appropriate standard or by manufacturer for the material used.

3.4 Critical Buckling Stress (S_{cr})

The average stress which produces an incipient buckling condition in column type members. (See 10.3.2).

3.5 Initial Reference Test Condition

The defined no stress or zero stress condition of the crane structure after "break-in" (see 8.3) as established by:

a. Supporting the structure on blocking to minimize the effects of gravity; or

b. The crane structure components in an unassembled state, or any alternate method that will establish the zero stress condition.

Under this condition, the initial reference reading for each gage is obtained, N_1.

3.6 Dead Load Stress Condition

The completely assembled crane structure on the test site, in the specified position or attitude, ready to accept or pick up the specified live load. Under this condition the second reading for each gage is obtained, N_2.

NOTE: In determining N_2, the weight of hook, block, slings, etc., is considered as live load and should be resting on the ground or supported by a structure other than the crane.

3.7 Dead Load Stress (S_1)

The stress computed as defined in 3.2, by using the difference in the readings obtained in 3.6 and 3.5 for each gage, (N_2 - N_1).

3.8 Live Load Stress Condition

The completely assembled crane structure on the test site, in the specified position or attitude, supporting the specified live load. Under this condition the third reading for each gage is obtained, N_3.

3.9 Live Load Stress (S_2)

The stress computed as defined in 3.2, by using the difference in the readings obtained in 3.8 and 3.6 for each gage, (N_3 - N_2).

3.10 Resultant Stress (S_r)

The maximum stress induced in the structure as a result of dead load stress (S_1) or the algebraic sum of dead load stress (S_1) and live load stress (S_2), whichever is greater.

3.10.1 Resultant Average Stress (S_{ra})

The direct compression stress in a column or the average stress computed from the several gages loaded at the section. (See 10.3.2.)

3.10.2 Resultant Maximum Stress (S_{rm})

The maximum compression stress in a column computed from the plane of buckling, as established from the several gages located at the section. (See 10.3.2.)

3.11 Loadings

The application of weights or forces of a magnitude specified under the test conditions.

4. SYMBOL NOMENCLATURE SUMMARY

DL = dead load stress, Pa (psi)

E = modulus of elasticity, Pa (psi)

G = modulus of rigidity (shear), Pa (psi)

JL = jib length, m (ft)

K = effective length factor for column

L = unsupported length of column, m (in)

Lb = length of boom, m (ft)

Lj1 = length of jibs or extensions, m (ft)

Lj2 = length of additional jibs or extensions, m (ft)

LL = live load stress, Pa (psi)

n_1 = strength margin, Class I area, ratio of yield strength to resultant or equivalent stress

n_2 = strength margin, Class II area, ratio of yield strength to resultant or equivalent stress

n_3 = strength margin (derived from an interaction relationship) in Class III areas

N_1 = gage reading at initial reference test condition (zero stress condition)

N_2 = gage reading at dead load stress condition

N_3 = gage reading at live load stress condition

r = radius of gyration of cross section, mm (in)

RR = rated radius, m (ft)

RL = rated load, kg (lb)

S = stress, Pa (psi)

S_1 = dead load stress, Pa (psi)

S_2 = live load stress, Pa (psi)

S_{cr} = computed critical buckling stress for axially loaded compression elements, Pa (psi)

SL = side load, kg (lb)

SLL = side load, left, kg (lb)

SLR = side load, right, kg (lb)

S_p = stress at effective proportional limit, defined as S_y - S_{RC}, Pa (psi)

S_r = resultant stress, Pa (psi)

S_{ra} = resultant average stress computed from several gages at one section, Pa (psi)

S_{RC} = maximum residual stress in compression, Pa (psi)

S_{rm} = maximum compression stress in a column computed from plane of buckling as established by several gages at one section, Pa (psi)

S_y = stress at yield point, Pa (psi)

S' = equivalent uniaxial stress, Pa (psi)

t = horizontal distance from the load center to the front pad reaction center for each boom section under consideration, m (ft)

v = Poisson's ratio

α = boom elevation angle, degrees

β = jib offset angle, degrees

ε = strain, m/m (in/in)

ε_a = strain recorded from leg "a" of rosette

ε_b = strain recorded from leg "b" of rosette

ε_c = strain recorded from leg "c" of rosette

ε_d = strain recorded from leg "d" of rosette

ε_x = maximum principal strain

ε_y = minimum principal strain

θ = direction of principal stress, deg

μ = units of strain, 10^{-6} m/m (in/in)

v = Poisson's ratio

σ_o = tensile yield stress, Pa (psi)

σ_x = maximum principal stress, Pa (psi)

σ_y = minimum principal stress, Pa (psi)

T_O = shear yield stress, Pa (psi)

5. LIMITATIONS

5.1 This method applies to load-supporting structures as differentiated from power transmitting mechanisms. It is restricted to measuring stresses under static conditions, and a general observation after overload conditions. This method does not apply to lift capacity on tires.

5.2 Personnel competent in the analysis of structures and the use of strain-measuring instruments are required to perform the tests.

6. METHOD OF LOADING

6.1 Suspended Load

The specified load suspended at the specified radius and held stationary a few inches off the ground while strain readings are taken.

NOTE: The weight of the hook, block, slings, and rigging is considered as live load and shall be included as part of the specified suspended load. Hoisting rope is not considered part of live load.

6.2 Side Load

When the test condition requires side load, this load shall be applied horizontally and normal to the plane containing the axis of superstructure rotation and the centerline of the undeflected boom. Use manufacturer's specified reeving, and with the hoist line leaving the drum from an arbitrary position, the side load shall be applied as 3% (0.03 RL) in each direction, with the boom over the end of the machine, record N_3 for each direction. (See 3.8 and note in 9.4.4.)

NOTE: Side loading is applied to simulate the dynamic effects associated with machine operation including a 9 m/s (20 mph) wind loading that can be encountered.

6.3 Deadman Load

Deadman loading may be used, but caution shall be exercised to assure accurate simulation of live load testing, especially with respect to side loads. Positioning with this system is difficult. Deadman loading is not acceptable for tests 3, 4, 6, 7, 8, and 12 in Table 1.

7. FACILITIES, APPARATUS, AND MATERIAL

7.1 A concrete or other firm supporting surface, sufficiently large enough to provide for unobstructed accomplishment of the tests required. Where tests are to be performed on crawler tracks, the machine shall be level within 0.25% grade.

7.2 Means to measure levelness of the axis of the boom foot; accuracy 0.1% of grade.

7.3 Means for determining the load radius to an accuracy of ± 1% not to exceed 0.2 m (6 in).

7.4 Means for producing transverse displacement of the suspended load and means for measuring the magnitude of the displacing force; accuracy ±3% of measured force.

7.5 Strain Gages, Cement, Waterproofing Compounds, and Other Necessary Gage Installation Equipment

Temperature-compensated strain gages designed for bonding to the materials to be tested shall be used. The gage factor shall have a tolerance within ±1%, gage resistance shall have a tolerance within ±0.3% for single element gages and ±0.4% for multiple element gages. Gages shall conform with ASTM E 251.

TABLE 1 - CANTILEVER BOOM CRANE TESTS

Test No.	Test Conditions Select	Apply	Purpose is to Test	Carrier	Super-structure	Boom and jib	Suspension (except rope)
				Tested Components and Strength Margins			
1	Max (RR × RL) with largest rated load allowed at this load moment	RL and position superstructure in allowed rotation range to obtain maximum strain in member tested	Outrigger and carrier frame for maximum live load moment				
	a. Over end			Y	Y	---	---
	b. Over side			Y	---	---	---
2	Max (RR × RL) with longest boom at this load moment	a. RL and side load	Telescopic boom overlap effects, hoist or suspension system, superstructure and turntable bearing system	--	Y	Y	Y
		b. 1.25 RL or tipping load, whichever is less, over end	Boom buckling, hoist cylinder, or suspension system	---	Z	Z	Z
3	Max boom length, then max (RR × RL)	a. RL and side load	Telescopic boom overlap effect	---	---	Y	Y
		b. 1.25 RL or tipping load, whichever is less, over end	Boom buckling and side bending effect	---	Z	Z	---
4	Max boom length then min attainable RR	a. RL and side load	Side bending of boom, side load effect on superstructure	---	Y	Y	Y
		b. 1.25 RL or tipping, whichever is less, over end	Extension cylinder buckling, boom bending effect, hoist cylinder buckling, or suspension system	---	Z	Z	Z
5	Max numerical load, then shortest boom and min (RR)	a. RL and position superstructure where minimum radius can be obtained	Boom point integrity, foot pin force, turntable bearing system	---	Y	Y	---
		b. 1.25 RL or tipping, whichever is less	Suspension system	---	Z	Z	Z
6	Max (jib RL × JL × cos [α - β]), then longest boom and jib specified	a. RL and side load	Integrity of jib, boom point, and boom top section	---	---	Y	Y
		b. 1.25 RL over end, or tipping whichever is less		---	---	Z	Z

TABLE 1 - CANTILEVER BOOM CRANE TESTS (CONTINUED)

Test No.	Test Conditions Select	Apply	Purpose is to Test	Tested Components and Strength Margins Carrier	Super-structure	Boom and jib	Suspension (except rope)
7	Max (jib RL × JL × sin β) then longest boom specified	a. RL and side load	Torsional effects of jib offset on boom and jib	---	---	Y	Y
		b. 1.25 RL over end or tipping, whichever is less		---	---	Z	Z
8	Max boom angle, max boom length, max specified jib at minimum offset	a. RL and side load	Integrity and stability of boom and jib	---	---	Y	Y
		b. 1.25 RL over end or tipping, whichever is less		---	---	Z	Z
9	Max allowable RL with boom extended 1 to 3 in (25 to 76 mm) at min RR	1.25 RL over end or tipping, whichever is less	Boom extension cylinder attachments	---	---	Z	Z
10	Max (RL × t) for each section. With the largest rated load allowed at this load moment	a. RL and side load	Bending effects on manual and powered sections at random boom angles and section extension	---	---	Y	---
		b. 1.25 RL over end or tipping, whichever is less		---	---	Z	---
11	Maximum Auxiliary Outrigger Load	a. RL	Integrity of auxiliary outrigger and carrier frame	Y	---	---	---
		b. 1.25 RL or tipping		Z	---	---	---
12	Max numerical jib RL at its longest RR. Then select the longest jib with the longest boom where this condition exists	a. RL and side load	Integrity of jib, boom point and boom top section	---	---	Y	Y
		b. 1.25 RL over end or tipping, whichever is less		---	---	Z	Z

7.6 Strain Indicating or Recording Instruments

It is the intent that commercially available, high quality, reliable instruments be used in the performance of this test. Accuracy of the indicating instrument or the recording system shall be determined to be ±2% over the range of 0 to 3000 μ (m/m) (in/in) strain (determined in suitable increments). Calibration may be accomplished by electrical shunts or by pre-calibrated strain bar.

8. PREPARATIONS FOR TEST

8.1 Structure Analysis

Make an analysis of each structure sufficient to locate critically stressed areas. These areas can include uniformly high-stressed regions as well as points of stress concentration (see 10.1).

8.2 Perform a detailed inspection of crane to insure that all mechanical adjustments and condition of load-supporting components conform to manufacturer's published recommendations. Check that the crane is equipped in compliance with the test specification.

8.3 A previously unworked crane should be given a "break-in" run at or near the anticipated test loadings to mechanically relieve residual stresses that developed during manufacturing and to minimize the possibility of "gage zero shift" during the test.

8.4 Disassemble the crane structure to the state required for inspection and strain gage installation. A thorough inspection after the "break-in" run can reveal areas of high stress, that have exceeded yield, as evidenced by paint checking, scale flaking or other indications of permanent deformation not revealed by prior analysis (see 8.1).

8.5 Bond strain gages at points determined by prior analysis (see 8.1) and any areas selected as a result of the inspection conducted in 8.4. Only competent personnel using approved materials and practices should be employed to insure that gages are of the correct type, properly oriented, and securely bonded to measure strains correctly.

8.6 Determine minimum yield strength and the modulus of elasticity (see 10.5) for the material at each gage location by referring to the material certifications or applicable standards. Determine critical buckling stress where applicable (see 10.3.2). Record these values on the test data summary sheet (see Section 11).

9. TEST PROCEDURES AND RECORDS

9.1 Final Test Preparation

9.1.1 Locate the machine on the test course and lock travel brakes and latches. Level the machine within 0.25% grade in the unloaded condition by shimming or by jacking. Do not re-level after the load has been applied to the machine.

NOTE: If test is for operation on outriggers, jack the crane to a position where all the tires or tracks are unloaded, unless some other conditions are required by the manufacturer's rating chart.

9.1.2 Connect strain measuring system and calibrate (see 7.6.) Correct any malfunctions.

9.2 Zero Stress Condition

Position the crane (superstructure, boom) in the initial reference test condition (see 3.5, item a or b) and obtain these readings.

9.3 Dead Load Stress Condition

9.3.1 Set the upper structure to the specified position relative to the lower structure if different than 9.2. Set swing brake or latches.

9.3.2 Set boom angle (and boom length) to develop specified load radius.

9.3.3 Read all strain gages for dead load stress condition (see 3.6). Compute the dead load stress (S_1) at each gage (see 3.7) and record on the test data sheet (see Section 11).

NOTE: A new dead load stress condition is established each time the position, attitude, or configuration is changed to suit specified tests and operations; therefore, 9.3.1 to 9.3.3 shall be repeated for each new condition.

9.4 Live Load Stress Condition

9.4.1 Prepare a test load which weighs within ±1% of the specified load. Include the weight of the hook or lower block, slings, and other auxiliary equipment as part of the load.

9.4.2 Suspend the specified test load (see 6.1) and adjust boom angle (if necessary) to obtain the rated load radius. Apply the specified side load (6.2).

9.4.3 Read all strain gages for live load stress condition (see 3.8.) Compute the live load stress (S_2) at each gage (see 3.9) and record on the test data summary sheet (see Section 11).

9.4.4 Release side load and suspended load, returning crane to the dead load stress condition (see 9.3.3). Read all strain gages and compare with readings taken under 9.3.3. If the deviation for any gage exceeds ± ($0.03\ S_y/E$) m/m (in/in), check to determine the cause, correct, and repeat all procedures until consistent readings are obtained.

NOTE: Since temperature changes and the loading from even a moderate wind on long booms affect strain gage readings, testing should be done under as favorable atmospheric conditions as possible; position the machine so wind loading does not reduce the stress induced by side loading.

9.5 Compute the resultant stress (S_r) for the combined dead and live load stresses (see 3.10) and record on the test data summary sheet (see Section 11).

9.6 Thoroughly examine the crane for any observations which suggest a possibility of plastic deformation or other damage having occurred during the test.

9.7 Overload Test Condition

Structural integrity only.

9.7.1 Repeat 9.1.1 if applicable.

9.7.2 Position the crane (upper structure, boom) in the specified test position.

9.7.3 Set boom angle (and boom length) to develop the specified load radius and record dead load readings for Class IV gages.

9.7.4 Prepare the test load (see 9.4.1).

9.7.5 Suspend the specified test load and adjust boom angle (if necessary) to obtain the rated load radius.

9.7.6 Observe the performance of the structure and note any evidence of possible failure.

9.7.7 Release suspended load and return crane to dead load stress condition. Record dead load readings for Class IV gages (see 9.4.4.)

9.8 At the completion of all applicable overload tests, the crane structures should be thoroughly examined by eye using straight edges and other references, where appropriate, to determine any evidence of buckling, permanent deformation, element out of line, etc. Scale flaking or paint checking may also be indicative of stresses beyond the yield point. Disassemble the boom structure to the state necessary to be assured that all boom elements, extension cylinders or elements, hoist mechanisms, suspension systems, and other load-carrying elements can be inspected.

9.9 Record all pertinent data regarding the test equipment, the crane being tested, and results and observations on the test summary sheet (see Section 11). Record overload test inspection results.

10. STRESS EVALUATION NOTES

Stresses in different parts of cranes are judged acceptable or not on the basis of different criteria of failure. These stress areas are classed as follows:

TABLE 2 - MINIMUM REQUIRED STRENGTH MARGINS

	Class I	Class II	Class III	Class IV
Y (rated loads)	1.5	1.1	1.6	Refer to 10.4
Z (structural integrity)		Observation only		Refer to 10.4

10.1 Class I - Uniform Stress Areas

Large areas of nearly uniform stress where exceeding the yield strength or yield point values will produce permanent deformation of the member as a whole.

Strength Margin:

$n_1 = S_y / S_r$ or S_y / S' (refer to 10.1.1 for S')

$n_1 \geq 1.5$ for rated loads (see Table 2)

(Eq. 2)

10.1.1 Biaxial Stress Areas and Triaxial Stress

In biaxial stress fields there can be some error if the uniaxial stress given by $S = E\varepsilon$ (see 3.2) is compared to tensile yield point to determine the strength margin. The question arises when consideration is given to the theory of failure applicable to the material being tested. Triaxial stresses are not considered here because the third direction cannot be measured with a strain gage.

a. Brittle Materials - The use of $S = E\varepsilon_x$ (when ε_x is measured in the direction of maximum principal strain) presumes the applicability of the maximum strain theory of failure. This is the commonly accepted theory of failure for brittle materials, and results given are valid for materials of this type.

b. Ductile Materials - The distortion energy theory of failure[2] generally is accepted as the performance criterion of ductile materials subjected to biaxial stresses. This assumes that yield failure occurs when the distortion energy under biaxial stress is equal to the distortion energy at yield stress in pure tension. An equivalent uniaxial stress (S') developing the same distortion energy as the actual biaxial stress is determined for comparison to the yield point (S_y, see 3.3) to establish the strength factor against failure. The equivalent stress:

$$s' = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2} \quad \text{(Eq. 3)}$$

where:

σ_x = maximum principal stress
σ_y = minimum principal stress

The principal stresses are obtained from the principal strain where the direction of principal strain was previously determined.

$$\sigma_x = E(\varepsilon_x + v\varepsilon_y)/(1 - v^2) \quad \text{(Eq. 4)}$$

$$\sigma_y = E(\varepsilon_y + v\varepsilon_x)/(1 - v^2) \quad \text{(Eq. 5)}$$

where:

E = modulus of elasticity
ε_x = maximum principal strain
$0\varepsilon_y$ = minimum principal strain
v = Poisson's ratio

Principal strains are obtained by interpreting rosette gage readings on Mohr's circle or other convenient means. Equivalent stress S' may also be calculated from principal strains by:

$$S' = \frac{E\sqrt{(1-v)^2(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_x + v\varepsilon_y)(\varepsilon_y + v\varepsilon_x)}}{(1 - v^2)} \quad \text{(Eq. 6)}$$

[2] Joseph Marin, "Mechanical Behavior of Engineering Materials," Englewood, N.J.: Prentice-Hall, Inc., 1962.

When three and four gage rosettes are used, the following equations can be used directly to obtain the equivalent stress based on the readings of each of the legs:

Rectangular rosette (Figure 2):

$$S' = \frac{E}{2}\sqrt{\frac{(\varepsilon_a + \varepsilon_c)^2}{(1-v)^2} + 6\left[\frac{(\varepsilon_a - \varepsilon_b)^2 + (\varepsilon_b - \varepsilon_c)^2}{(1+v)^2}\right]} \quad \text{(Eq. 7)}$$

Delta rosette (Figure 2):

$$S' = \frac{E}{3}\sqrt{\frac{(\varepsilon_a + \varepsilon_b + \varepsilon_c)^2}{(1-v)^2} + 6\left[\frac{(\varepsilon_a - \varepsilon_b)^2 + (\varepsilon_b - \varepsilon_c)^2 + (\varepsilon_c + \varepsilon_a)^2}{(1+v)^2}\right]} \quad \text{(Eq. 8)}$$

T-Delta rosette (Figure 2):

$$S' = \frac{E}{2}\sqrt{\frac{(\varepsilon_a + \varepsilon_d)^2}{(1-v)^2} + 3\left[\frac{(\varepsilon_a - \varepsilon_d)^2 + 4(\varepsilon_b - \varepsilon_c)^2}{(1+v)^2}\right]} \quad \text{(Eq. 9)}$$

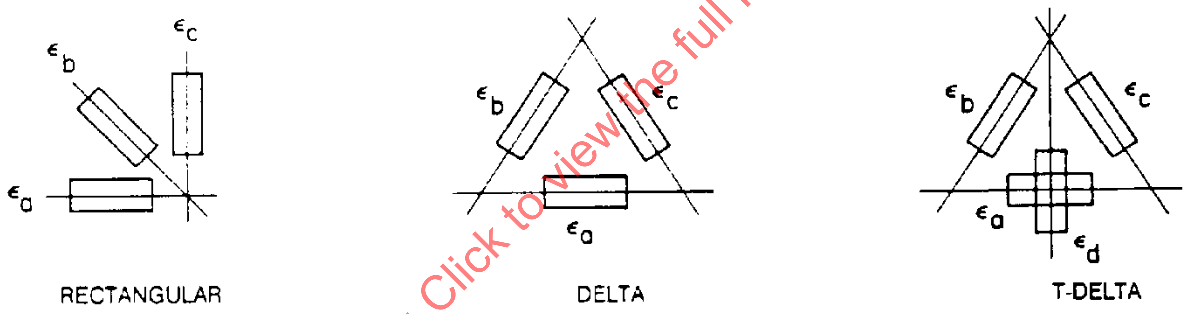


FIGURE 2 - RECTANGULAR, DELTA, AND T-DELTA ROSETTES

c. Ductile Material Approximate Method - In most ductile material biaxial fields, the assumption that the equivalent stress S' equals $E\varepsilon_x$ will be accurate within 10%. The main factors affecting the accuracy are:

1. The ratio of minimum to maximum principal stress, σ_y/σ_x.

2. The ratio of shear yield to tensile yield, T_o/σ_o.

Figure 3 shows the magnitude of accuracy variance with respect to these two ratios, using Poisson's ratio v = 0.285. The plot shows that as the condition approaches biaxial tension or compression, the error can be 25 to 30%. As the condition approaches pure shear, the error may be 0 to 30% depending upon the ratio T_o/σ_o.

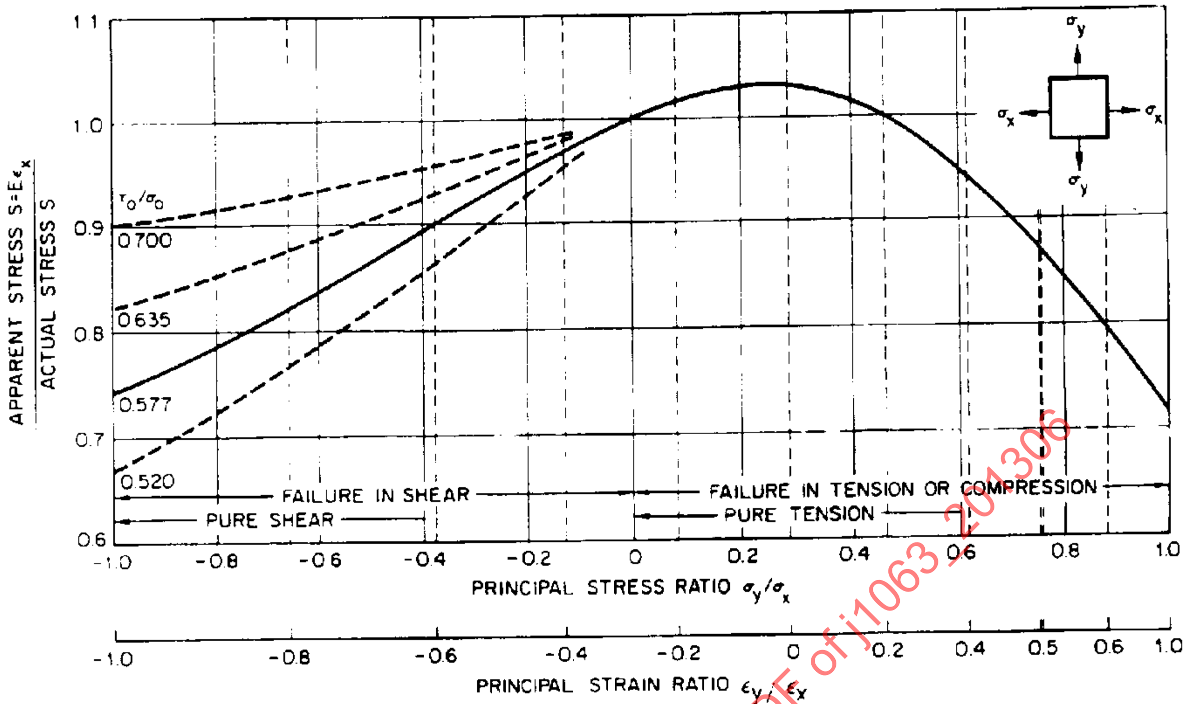


FIGURE 3 - RATIO OF APPARENT STRESS TO ACTUAL STRESS VERSUS BIAXIAL STRESS RATIO

The solid curve in Figure 3 is based on the distortion energy theory of failure as compared to $S = E\varepsilon_x$. Distortion energy theory, while most generally correct, will check with the torsion yield test (pure shear) only if $T_o/\sigma_o = 0.577$. For materials in which τ_o/σ_o does not equal 0.577, the dashed curve lines (which do not correspond with any theory of failure, but only with tensile and torsion yield tests) give some idea of the probable error. If a single gage and $S = E\varepsilon_x$ is to be applied instead of rosettes and more complicated formulation, principal direction shall be determined by some other means such as paint checking or (better) brittle lacquer.

10.2 Class II

10.2.1 Stress Concentration Areas

Small areas of high stress surrounded by larger areas of considerably lower stress where exceeding the yield strength or yield point values will not produce permanent deformation of the member as a whole. However, cyclic loading can initiate an incipient fracture at such points. Examples are points of rapid section change such as sharp corners, holes, or weld fillets.

Strength Margin:

$n_2 = S_y / S_r$ or S_y / S' (refer to 10.1.1 for S')

$n_2 \geq 1.1$ for rated loads (see Table 2)

(Eq. 10)

NOTE: Generally, rosettes are not used to measure stress concentrations because of the difficulty involved in evaluating the results with any degree of accuracy.

10.3 Class III

10.3.1 Elastic Deflection Areas

Areas in which failure can be associated with some average stress values less than yield. Examples occur in buckling members or members in which excessive deflection constitutes failure.

Strength Margin:

$n_3 \geq 1.6$ for rated loads (see Table 2)

Refer to 10.3.2 for n_3

(Eq. 11)

10.3.2 Column Buckling Stress

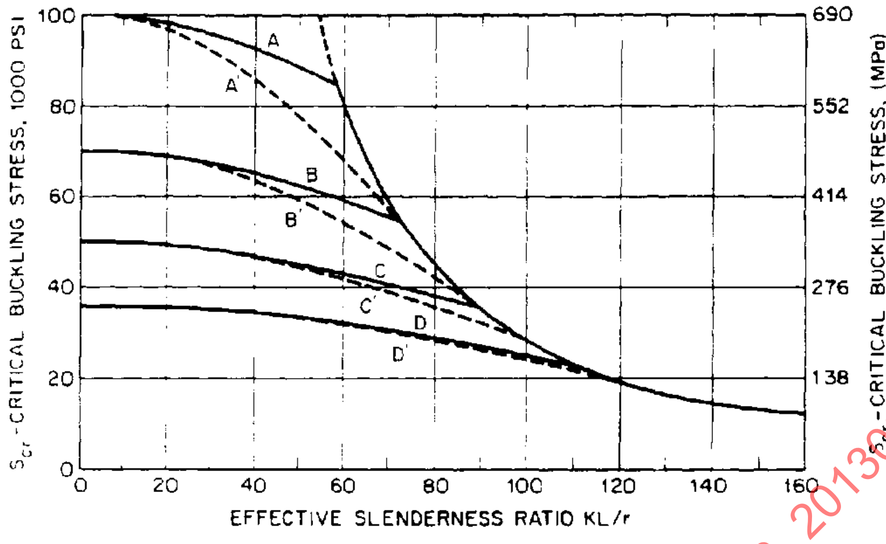
Individual unsupported compression elements of an overall boom or jib, that is, chords or diagonals, require consideration as columns. The following formulas are intended for test evaluation only and are not recommended for design use in determining the strength factor of compression members under test. Consideration shall be given to the stiffness of the member, residual stresses in the material, end restraint conditions, and eccentricities in loading. Equation 12 evaluates overall effects:

$$n_3 = \frac{1}{\frac{S_{ra}}{S_{cr}} + \frac{S_{rm} - S_{ra}}{S_y}}$$

(Eq. 12)

where:

n_3 = strength margin (derived from an interaction relationship) of the individual member being strain gaged
S_{cr} is determined by equations 13 and 14 as plotted on Figure 4



Residual Stress Assumption	Steel	S_y Yield Stress MPa	S_y Yield Stress psi	S_p Effective Proportional Limit MPa	S_p Effective Proportional Limit psi
Scr = 103 MPa (15 000 psi) (Solid lines)	A	690	100 000	586	85 000
	B	483	70 000	379	55 000
	C	345	50 000	241	35 000
	D	248	36 000	145	21 000
S_{cr} = 0.5 s_y (dotted lines)	A'	690	100 000	345	50 000
	B'	483	70 000	241	35 000
	C'	345	50 000	172	25 000
	D'	248	36 000	124	18 000

FIGURE 4 - CRITICAL BUCKLING STRESS, S_{CR} (TO BE USED WITH EQUATION 15)

At stress levels below the effective proportional limit, axially loaded columns buckle elastically:

$$S_p \geq S_{cr} = \left[\frac{\pi^2 E}{(KL/r)^2}\right] \quad \text{(Eq. 13)}$$

At stress levels above the effective proportional limit, axially loaded columns buckle inelastically:

$$S_p < S_{cr} = S_y - \left[\frac{S_p(S_y - S_p)(KL/r)^2}{\pi^2 E}\right] \quad \text{(Eq. 14)}$$