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Rope Supported Lattice-Type Boom Crane Structures— Method of Test— SAE J987 APR85

SAE Recommended Practice
Completely Revised April 1985

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Report of the Construction and Industrial Machinery Technical Committee, approved May 1967, completely revised April 1985.

1. Purpose—The purpose of this test method is to provide a systematic nondestructive procedure for determining the stresses induced in crane structures under specified conditions of static loading through use of resistance-type electric strain gages, and to specify appropriate acceptance criteria for specified loading conditions.

2. Scope—This test method applies to mobile construction-type lifting cranes utilizing rope-supported, lattice-type boom crane structures.

3. Applications

3.1 This test method is intended to describe the approximate maximum loading conditions to which any component of the entire load-supporting structure of a crane is subjected. In some cases, a more severe loading condition(s) may be indicated by analysis. In these cases, the more severe condition(s) may be added to or substituted for the specified test loading condition(s). It also classifies stress area Types I, II, III, and IV (see paragraph 9.1), and defines limits for each class. Results may be used to correlate boom calculation results for Class III stress areas as given, e.g., by J1093 boom calculation method. Test results for Class I stress areas throughout the structure may be used to check any available calculations. This test method evaluates Class II stress areas for which calculations are seldom available. Class IV stress areas, where disproportionately high stress readings can occur, may be reviewed for better insight by calculation methods.

3.2 This method applies to load-supporting structures as differentiated from power transmitting mechanisms. It is restricted to measuring strains under static conditions.

3.3 The procedures outlined are intended to supplement basic design analysis. One such method of analysis for crane boom systems is presented in SAE J1093. The relationship of this test method to calculations as presented in J1093 is as follows:

3.3.1 A production boom system (serially produced) can be rated by the methods outlined in J1093, but a prototype of this system should be subjected to the following test procedures as documentation of its capability.

3.3.2 A production boom system that has been rated by the methods of paragraph 3.3.1 may be used on another machine without retesting by the methods specified herein, provided the same analytical procedure shows its stress levels will be less than in the original application and provided the supporting structure is as rigid as the original mounting. Rigidity of the supporting structure is determined by the change in the slope of the boom foot axis (see Ref. 8.5) as test loads are applied.

3.3.3 A specially designed boom system (not serially produced) similar to a known and tested design may be rated by the methods of J1093. The applicable overload test conditions specified (see Table 2) should also be applied as proof of competence.

3.3.4 The applicable overload test conditions specified (see Table 2) may also be used to proof load cranes in the field. The proof loading should only be done by a competent testing agency or the crane manufacturer using the criteria specified in this document. The adequacy of a significant structural change performed in the field cannot, however, be determined simply by overload testing.

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

4. Definitions—See Appendix D.

4.1 Strain—Deformation of material at any given point with respect to a specific plane passing through that point, expressed as change in length per unit length.

4.2 Stress (S)—The intensity of internal force accompanying strain, expressed in force per unit area. For purposes of this test method, stress is related to measured strain by the uniaxial stress formula:

$$S = E \cdot \epsilon \text{ (within proportional limits)}$$

where: S = stress
E = modulus of elasticity, for the material involved
ϵ = strain

NOTE: The simple uniaxial stress formula may not be sufficiently accurate for some areas of crane structures under biaxial stress, and special consideration should be given in such cases (see Appendix B).

4.3 Yield Point (Sy)—The stress at which a disproportionate increase in strain occurs without corresponding increase in stress. For purposes of this code, yield point is to be considered as the minimum 0.2% offset tensile yield point or yield (ASTM A370) strength specified by the appropriate standard for the material used.

4.4 Critical Buckling Stress (Scr)—The average stress which produces an incipient buckling condition in column-type members (see Appendix A).

4.5 Initial Reference Test Condition—The defined no-stress or zero-stress condition of the crane structure after the "break-in" (see paragraph 7.3) as established by (1) supporting the structure on blocking to minimize the effects of gravity, or (2) 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.

4.6 Dead Load Stress Condition (DL)—The completely assembled crane structure on the test site and in the position or attitude, ready to apply the specified live load at the specified radius. Under this condition, the second reading for each gage is obtained, N_2.

NOTE: Although the hook, block, slings, etc. are considered part of the suspended load, for purposes of safety and practicality they may be supported by the crane when this reading is taken.

4.7 Dead Load Stress (S_1)—The stress computed as defined in paragraph 4.2, by using the difference in the readings obtained in paragraphs 4.6 and 4.5 for each gage ($N_2 - N_1$).

4.8 Working Load Stress Condition—The completely assembled crane structure on the test site and in the specified position, supporting the specified rated load. Under this condition, the third reading for each gage is obtained, N_3.

4.9 Working Load Stress (S_2)—The stress computed as defined in paragraph 4.2, by using the difference in the readings obtained in paragraphs 4.8 and 4.5 for each gage, ($N_3 - N_1$).

4.10 Resultant Stress (S_r)—The maximum stress induced in the structure as a result of dead load stress (S_1) or the working load stress (S_2), whichever is greater in absolute magnitude.

4.10.1 COLUMN AVERAGE STRESS (S_{ra})—The direct compression stress in a column or the average stress computed from the several gages located at the section (see Appendix A).

4.10.2 COLUMN 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 Appendix A).

4.11 Loadings—The application of weights and/or forces of the magnitude specified under the condition specified.

4.12 Specified—The stated requirements of the manufacturer, the user, the testing agency, or any agreement between these parties.

5. Method of Testing

5.1 Suspended Load—The specified load suspended at the specified radius and held stationary a short distance off the ground.

NOTE: The weight of the hook, block, slings, etc. shall be included as part of the specified suspended load.

5.1.1 RATED LOAD (RL)—The rated load is any load rating as specified by the manufacturer's applicable capacity chart.

5.1.2 RATED RADIUS (RR)—The rated radius is any radius as specified by the manufacturer's applicable capacity chart.

5.2 Side Load (SL)—When the test specification requires side loading, the force displacing the suspended load should be horizontal and perpendicular to the plane containing the axis of upperstructure rotation and the centerline of the undeflected boom. The side load shall be 2% (i.e., 0.02 × RL) in each direction.

NOTE: Side loading is applied to simulate the various effects associated with machine operation.

5.3 Deadman Load—Deadman loading may be used, but caution must 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 B, E, G, I, and J in Table 2, Appendix C.

6. Facilities, Apparatus, and Material

6.1 A concrete or other firm supporting surface, sufficiently large to provide for unobstructed accomplishment of the tests required.

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

6.3 Means for determining the load radius to an accuracy of ±1%, not to exceed 0.15 m (6 in).

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

6.5 Temperature compensated strain gages, cement, waterproofing compounds, and other necessary gage installment equipment. Gages must conform with ASTM E 251–67.

6.6 Strain recording system. It is the intent that commercially available, high quality, reliable instruments be used in the performance of this test. Accuracy of the recording system shall be determined to be ±2% of the reading over the range of 500 to 3000 μm/m strain (determined in suitable increments). Calibration may be accomplished by electrical shunts or by precalibrated strain bar.

6.7 Test weights and lifting apparatus of known weights accurate to within ±1%.

6.8 Means for measuring side deflection of the boom and jib within 0.05 m (2 in).

*7. **Preparations for Test***

7.1 An analysis of each structure sufficient to locate highly stressed areas shall be made. The strain gage location and direction shall be determined from this analysis as well as from the use of other experimental techniques where necessary.

7.2 Perform a detailed inspection of crane to insure that all mechanical adjustments and condition of load supporting components conform to manufacturers' published recommendations. Check that the crane is equipped in compliance with the test specifications.

7.3 A previously unworked crane should be given a "break-in" run at or near each anticipated test loading to mechanically relieve residual stresses that may have developed during manufacture and to minimize the possibility of "gage zero shift" during the test.

7.4 Perform a thorough inspection after the "break-in" to reveal areas of high stress as evidenced by paint checking, scale flaking, or other indications of deformation.

7.5 Bond strain gages at the points determined by prior analysis (see paragraph 7.1) and any areas selected as a result of the inspection conducted in paragraph 7.4. Only competent personnel using proved materials and practices may be employed to insure that gages are of the correct type, properly oriented, and securely bonded to measure strains correctly.

7.6 Determine minimum yield strength and the modulus of elasticity for the material at each gage location by referring to the material certifications, if available, applicable standards, or Appendix B. Determine critical buckling stress where applicable (see Appendex A).

*8. **Test Procedure and Records***

8.1 Service and adjust the crane to assure specified conditions of lubrication; fuel supply, coolant supply, tire inflation; track tension; bolts, pins, rope fittings, and other load bearing components; clutches, brakes, and other power transmission components. At all times during testing, the crane shall be set up and operated in conformance with the manufacturers' specifications.

8.2 Locate the machine on the test course.

8.3 Connect strain measuring system and calibrate gages and instruments (see paragraph 6.6). Correct any malfunctions.

8.4 If the assembled crane is to be used as the initial reference test condition (see paragraph 4.5, item 1), obtain these readings. If the unassembled components are to be used as the initial reference test condition (paragraph 4.5, item 2), obtain these readings. Reassemble the crane and make all mechanical adjustments.

8.5 Level the crane so that the boom foot axis is within 0.25% of grade in the unloaded condition. This shall be done directly over an end and over a side of the lower structure. Do not relevel during any specific test condition.

8.6 Set the revolving upperstructure to the specified position relative to the lower structure. Lock swing brake or latch.

8.7 Prepare a test load which together with the hook, block, slings, etc. weighs within ±1% of the specified load.

8.8 Lift the specified load and set boom angle to develop specified radius. As the test load is lifted from the ground, the overall operation should be observed for any indications of problems before proceeding.

8.9 Set the load on the ground. Do not change the boom angle. Read required strain gages for dead load stress condition (see paragraph 4.6). Compute the dead load stress (S_1) for each required gage (see paragraph 4.7) and record data. At this time, zero the means for measuring side deflection of the boom and/or jib(s) tip(s).

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, paragraphs 8.5 through 8.9 must be repeated for each new condition.

8.10 Suspend the test load (see paragraph 5.1) and apply side load (see paragraph 5.2) as required by specifications.

8.11 Read required strain gages for working load stress condition (see paragraph 4.8). Compute the working load stresses (S_2) for each required gage (see paragraph 4.9) and record the test data. Measure and record tip side deflection due to suspended load and side load.

8.12 Release side load and lower suspended load, returning crane to dead load condition (see paragraph 8.9). Read required strain gages and compare with reading taken under paragraph 8.9. If the deviation for any gage exceeds ±0.03 Sy/E, determine cause, correct and repeat all procedures until consistent readings are obtained.

8.13 Compute resultant stress (S_r) per paragraph 4.10, for combined dead load (see paragraph 4.6) and working load stresses (see paragraph 4.9) and record.

8.14 Thoroughly examine the crane for any evidence which suggests a possibility of plastic deformation or other damage having occurred during the test.

8.15 Record all pertinent data regarding the test equipment, crane being tested, results, and observations. Suggested forms are presented in Appendix E.

*9. **Stress and Deflection Criteria***

9.1 Stress Criteria—Stresses in different parts of crane structures are evaluated for acceptability on the basis of criteria appropriate to the area in question. These stress areas may be classed as follows (see Table 3, Appendix C or paragraphs 9.1.1, 9.1.2, and 9.1.3 below for minimum strength margins).

9.1.1 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 Appendix B for S')

$n_1 \geq 1.50$ for rated loads (1)

$n_1 \geq 1.30$ for erection loadings

9.1.2 CLASS II—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. Examples are points of rapid section change such as sharp corners, holes, or weld fillets. Strength margins:

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

$n_2 \geq 1.10$ for rated loads (2)

$n_2 \geq 1.00$ for erection loadings

9.1.3 CLASS III—COLUMN BUCKLING STRESS AREAS—Areas in which failure may be considered to occur at some average stress value less than yield strength or yield point. Examples are individual unsupported compression elements such as, but not limited to, masts, struts, boom chords, or lattice, which require consideration as columns. Strength margin:

$$n_3 = \frac{1}{\frac{S_{ra}}{S_{cr}} + \frac{S_{rm} - S_{ra}}{S_y}} \quad \text{(Refer to Appendix A)} \qquad (3)$$

$n_3 \geq 1.60$ for rated loads

$n_3 \geq 1.40$ for erection loadings

For lattice structures, this criteria is intended to apply to lacing elements or chord elements between lacing points. It is not intended for evaluation of the overall latticed compression member.

9.1.4 CLASS IV—LOCAL PLATE BUCKLING AREAS—Plates, when subjected to direct compression, bending, and/or shear in their plane, may buckle locally before the member as a whole becomes unstable. Local buckling is associated with wrinkling (initial buckling), which permits the member to redistribute loadings to stiffer edges. As loading is further increased, the stress in Class IV areas (see Fig. 1) does not necessarily

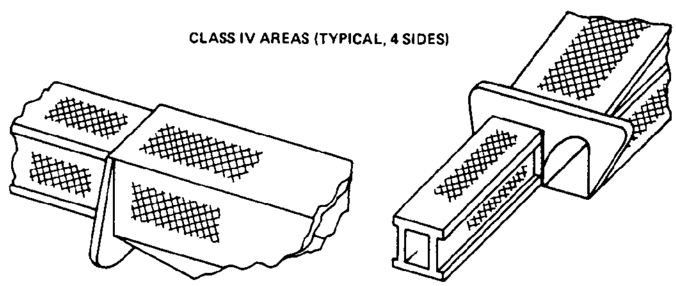


FIG. 1

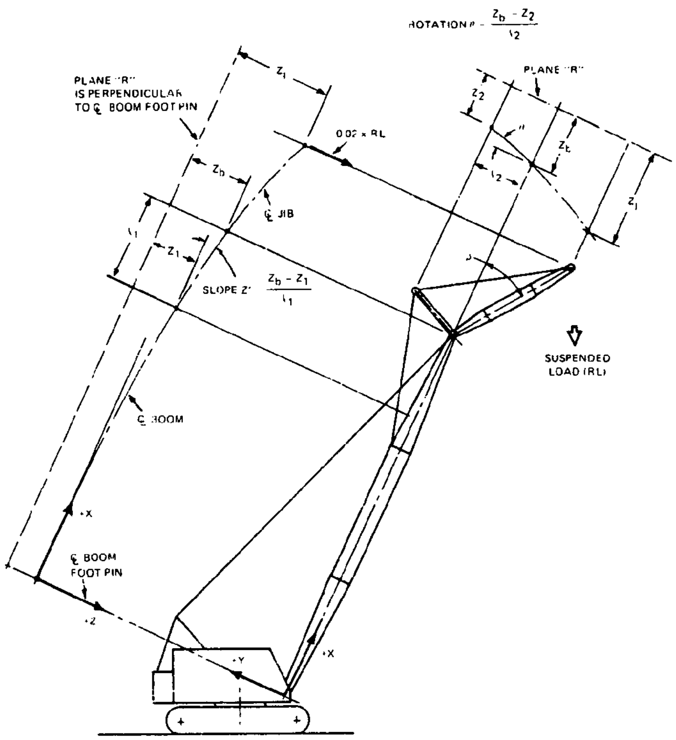
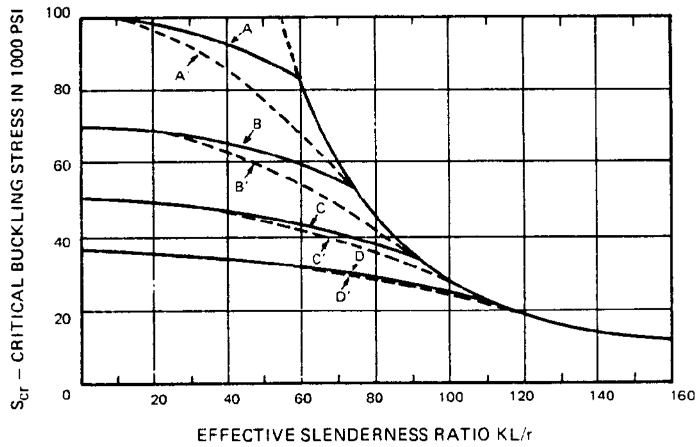


FIG. 2—DEFLECTION MEASUREMENT RELATED TERMS—LATTICE BOOM WITH JIB



Residual Stress Assumption	Steel	S_y Yield Stress, psi	S_p Proportional Limit, psi	Residual Stress Assumption	Steel	S_y Yield Stress, psi	S_p Proportional Limit, psi
	A	100 000	85 000	S_{RC} =	A'	100 000	50 000
S_{RC} =	B	70 000	55 000	0.5 S_y	B'	70 000	35 000
15 000 psi	C	50 000	35 000	(dotted	C'	50 000	25 000
(solid lines)	D	36 000	21 000	lines)	D'	36 000	18 000

FIG. 3—CRITICAL BUCKLING STRESS, S_{cr} (TO BE USED WITH EQUATION 3)

increase in proportion to the load; however, considerable post buckling strength may remain. Requirements are that Class IV gages return to the dead load readings (see paragraph 8.12) for all test conditions, including overload.

9.2 Deflection Criteria—The usability of a latticed column (i.e., crane boom or boom and jib(s) combination) is sometimes affected by the elastic stability of the overall column as well as the individual members. Incipient out of plane elastic instability is indicated by excessive boom and/or jib point deflection (sideways) as the boom or jib(s) is side loaded when suspending rated load. The following lateral deflection limits are therefore imposed.

9.2.1—Boom point deflection (Z_B) shall be ≤0.02 times the boom length (L_B) when the boom is loaded with 2% side load in each direction as described in paragraph 5.2. Boom point deflection is defined as the lateral displacement of the boom tip relative to the zero position (see paragraph 8.9) caused by suspending rated load and applying side load.

$$Z_B \leq 0.02\ L_B \tag{4}$$

9.2.2 For boom and jib(s) combinations, the lateral deflection criteria for rated load and side load of Table 2 are as follows:

First, the deflection Z_j shall be less than 2% of the total combination length:

$$Z_j \leq 0.02\ (L_j + L_B) \tag{5}$$

Furthermore, the deflection of each individual boom or jib shall not exceed 2% of the length of that member. To satisfy this criteria, it should be noted that the deflection of an individual member does not include the deflection, rotation, or slope of the member on which it is mounted.

For a single jib mounted on a boom, the following relationship is given:

$$Z_j \leq 0.02\ L_j + Z_B + Z'\ (L_j \cos\beta) + \theta\ (L_j \sin\beta) \tag{6}$$

If slope (Z') and torsion (θ) are not measured, the last two terms of Equation 6 may be deleted. Both of the above criteria correspond to those set forth in the boom calculation practice J1093.

APPENDIX A—COLUMN BUCKLING STRESS

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

$$S_p \geq S_{cr} = \frac{\pi^2 E}{(KL/r)^2} \tag{7}$$

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

$$S_p < S_{cr} = S_y - \frac{S_p(S_y - S_p)(KL/r)^2}{\pi^2 E} \tag{8}$$

The proportional limit is defined by:

$$S_p = S_y - S_{RC} \tag{9}$$

where: S_{RC} = maximum residual stress in compression.

A value of S_{RC} = 15 000 psi may be assumed in lieu of specific residual stress information on the following steel materials:

1. Hot finished shapes in the as-rolled condition.
2. Quenched and tempered shapes with stress relief heat treatment.
3. Cold drawn shapes with stress relief heat treatment.
4. Fabricated welded shapes with stress relief heat treatment.

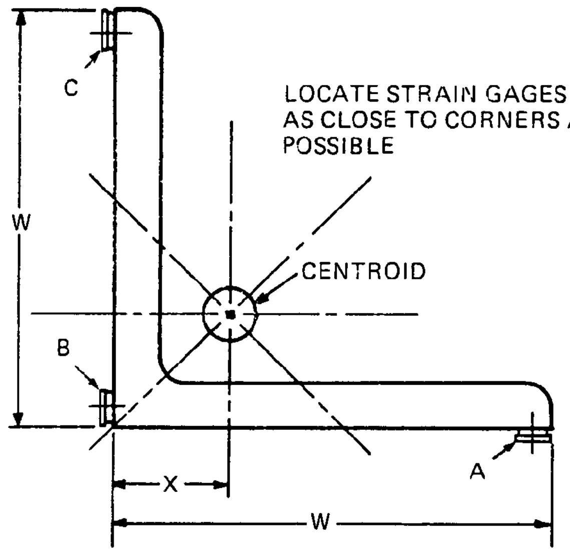
On other steel materials a value of S_{RC} = 0.5 S_y may be assumed in lieu of specific residual stress information. Equations 7 and 8 are plotted in Fig. 3 for four grades of steel with S_{RC} = 15 000 psi and also with S_{RC} = 0.5 S_y. The end restraint factor, K, can be calculated by methods outlined in another report, article 2.6.[1]

The following values may be used in lieu of calculation:

For chord members	K = 1.00
For lacing members with full section connection to tubular chords	K = 0.75
For lacing members with full section connecting to angle or tee chords	K = 0.90
For lacing members with reduced section connection to chord	K = 1.00

In testing compression members, strain gages should be located at the midspan or expected buckling point. When gages are placed at the logical points of highest buckling stress, the highest observed reading may be used for S_{rm} in lieu of computation of the stress plane. When gage locations are asymmetrical with respect to the centroid, the average of the test values cannot be used for S_{ra}. In this case, the test values must be weighted so that S_{ra} represents the value of the stress plane at the centroid. Fig. 4 demonstrates a method of weighting test values for an angle section with equal legs. Compression members which are asymmetrical with respect to the centroid, such as structural angles, have different values of radius of gryation (r) in different planes. For evaluation of data obtained from gages in these areas, the determination of S_{cr} must be based on the largest value of KL/r occurring at the chosen area. For

[1] "Guide to Design Criteria for Metal Compression Members." Column Research Council, Cushing-Malloy, Inc., Ann Arbor, MI, 1960.



$$S_{ra} = \frac{x}{W}(S_A) + \frac{W-2x}{W}(S_B) + \frac{x}{W}(S_C)$$

FIG. 4—WEIGHTING TEST DATA FOR AVERAGE AXIAL STRESS

boom chord members the largest value of KL/r must be utilized, whether lacings are staggered or concentric.

APPENDIX B—STRENGTH OF MATERIALS

In biaxial stress fields, there may be some error if the uniaxial stress given by $S = E \cdot \epsilon$ (see paragraph 4.2) 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.

Brittle Materials—The use of $S = E \cdot \epsilon_x$ (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.

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 paragraph 4.3) to establish the strength margin against failure. The equivalent stress:

$$S' = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2} \quad (10)$$

where: σ_x = maximum principal stress
σ_y = minimum principal stress

Principal stresses are obtained from strain gage readings by:

$$\sigma_x = E(\epsilon_x + v\epsilon_y)/(1 - \nu^2) \quad (11)$$
$$\sigma_y = E(\epsilon_y + v\epsilon_x)/(1 - \nu^2) \quad (12)$$

where: E = modulus of elasticity
ϵ_x = maximum principal strain
ϵ_y = minimum principal strain
ν = 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:

$$S' = E\sqrt{(1-\nu)^2(\epsilon_x - \epsilon_y)^2 + (\epsilon_x + \nu\epsilon_y)(\epsilon_y + \nu\epsilon_x)}/(1 - \nu^2) \quad (13)$$

Ductile Material Approximate Method—In most ductile material biaxial fields, the assumption that the equivalent stress S′ equals $E\epsilon_x$ 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, τ_o/σ_o.

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

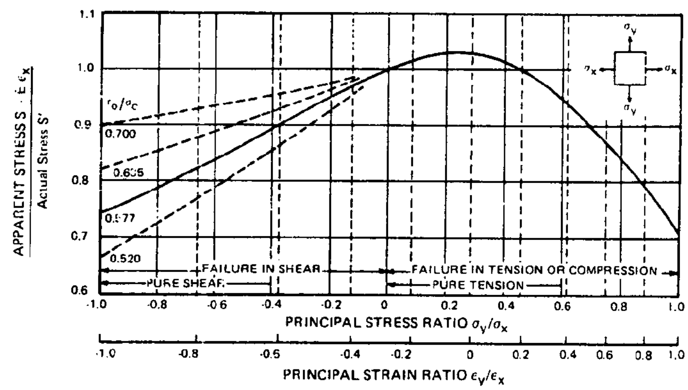


FIG. 5—RATIO OF APPARENT STRESS TO ACTUAL STRESS VERSUS BIAXIAL STRESS RATIO

TABLE 1—ELASTIC PROPERTIES OF MATERIAL

	Modulus of Elasticity (E) (Young's)[a] (10^6 psi)	Modulus of Rigidity (G) (Shear)[a] (10^6 psi)	Poisson's Ratio
Steel			
Carbon and alloy structural	30	11.5	0.285
Cast	30	11.2	0.265
Stainless	20/28		0.305
Gray Iron			
Class 20	9.6/14.0		
Class 60	20.4/23.5		
Malleable Iron	25	11	0.271
Nodular Iron	24	10	
Aluminum, structural	10.5	4	0.333
Magnesium, structural	6.5		
Titanium, structural	13/16		

[a] The modulus of elasticity generally is quoted as a range; the figures listed are towards the high end of the range for conservatism.
The modulus of elasticity of some materials varies widely with chemistry, heat treatment, or stress level. In such cases a range is listed, and the proper value must be selected for the particular conditions in each case.

Fig. 5 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 error can be 25–30%, as the condition approaches pure shear error may be 0–30% depending on the ratio τ_o/σ_o.

The solid curve line in Fig. 5 is based on the distortion energy theory of failure as compared to $S = E \cdot \epsilon_x$. Distortion energy theory, while most generally correct, will check with the torsion yield test (pure shear) only if $\tau_o/\sigma_o = 0.577$. For materials in which τ_o/σ_o does not equal 0.577, the dashed curve lines (which do not correspond to any theory of failure, but only the tensile and torsion yield tests) give some idea of the probable error. If a single gage and $S = E \cdot \epsilon_x$ is to be applied instead of rosettes and more complicated formulation, principal direction must be determined by some other means, such as paint checking or (better) brittle lacquer.

Recommended values to be used in calculating stress from measured strain are listed in Table 1.

APPENDIX C—TEST CONDITIONS AND STRENGTH MARGINS

The following test conditions are intended for testing cranes as defined in the scope of this standard. The method of test may be applicable to other types, but the test conditions and strength margins suggested here should be reviewed and perhaps modified to suit the application.

The standard test loading conditions for the principle structural components of Conventional Type Cranes are listed in Table 2.

Suggested minimum allowable strength margins for these loadings are shown in Table 3. These tables cover lifting crane hook work for which the number of stress cycles during the expected life of the crane does not require consideration of fatigue endurance limits. This is as opposed to cyclic type services such as bucket, magnet, or grapple work. With the exception of overloads, the conditions listed closely approximate the typical maximum loadings imposed on cranes when operating within the range of manufacturers' published ratings.

TABLE 2—CONVENTIONAL TYPE CRANE—TEST CONDITIONS

Test No.	Test Conditions: First Select	Table 2 Notes	Then Apply: Working Load[a]	Then Apply: Overload[a]	Purpose Is to Test:	Tested Components and Strength Margins[a]: Under-Carriage	Upper-Structure	Boom and Jib	Suspension (Except Ropes)
A	Max numerical rated load at its longest rated radius. Use longest boom rated with this load.	2 9 12 16 17	(Y) RL with upperstructure in any position.	(Z) 1.25 RL or tipping load, whichever is less.	Integrity of boom and upperstructure.	—	Y,Z	Y,Z	—
B	Max (RR × RL) with largest rated load allowed at this load moment.	3 6 8 12 17	(Y) RL and SL (0.02 × RL) both left and right. Orient upperstructure to any position.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure to any position.	Upperstructure and suspension for maximum load moment.	—	Y,Z	—	Y,Z
C	Max (RR × RL) over side, with largest rated load allowed at this load moment.	1 3 5 7 8 17	(Y) RL and position upperstructure in allowed rotation range to obtain maximum strain in member tested.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure to any position.	Undercarriage for maximum load moment.	Y,Z	—	—	—
D	Max (RR × RL) over end, with largest rated load allowed at this load moment.	1 3 5 7 8 17	(Y) RL and position upperstructure in allowed rotation range to obtain maximum strain in member tested.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure to any position.	Undercarriage for maximum load moment.	Y,Z	—	—	—
E	Rated radius which produces max (RR × RL). Use longest boom which has a rating at this radius.	13 14 15 16 17	(Y) RL and SL (0.02 × RL) both left and right, upperstructure over a corner.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure over a corner.	Integrity of boom and suspension.	—	—	Y,Z	Y,Z
F	Longest boom offered for each specified suspension.	4 16	(X) Suspend boom just clear of ground.	None	Integrity of boom and suspension.	—	—	X	X
G	Longest boom offered for each specified suspension.	13 14 15 16	(Y) RL at minimum RR and SL (0.02 × RL) both left and right. upperstructure over a corner.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure over a corner.	Integrity of boom and suspension.	—	—	Y,Z	Y,Z
H	Longest allowable combination of boom and jib(s) for each specified suspension with min jib offset.	4 10 11 16	(X) Suspend boom and jib(s) just clear of ground.	None	Integrity of boom, jib, upperstructure, and suspension.	—	X	X	X
I	Longest allowable combination of boom and jib(s) for each specified suspension with min jib offset.	10 11 13 14 15 16	(Y) RL at min RR and SL (0.02 × RL) both left and right, upperstructure over a corner.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure over a corner.	Integrity of boom and jib.	—	—	Y,Z	—
J	Max (jib RL × JL × Sin β). Use longest jib where this condition exists. Then select longest boom for the above conditions.	11 13 14 15 16	(Y) RL at max RR and SL (0.02 × RL) both left and right, upperstructure over a corner.	(Z) 1.25 RL or tipping load, whichever is less. Orient upperstructure over a corner.	Integrity of boom and jib.	—	—	Y,Z	—

[a] See Table 3 for X, Y, Z nomenclature.

1. Positions as defined by SAE J1028 or manufacturer's specification.
2. Where this *rated load* is offered with the upperstructure counterweight in variable positions, testing shall be performed with this counterweight at the maximum specified distance to the centerline of rotation.
3. Where this *rated load* is offered with the upperstructure counterweight in variable positions, testing shall be performed with this counterweight at the minimum specified distance to the centerline of rotation.
4. Hook block, overhaul ball, or load line attachments resting on the ground.
5. For *carriers* utilizing various boom and/or upperstructure configurations, only the configuration which produces the maximum moment condition should be tested.
6. For *upperstructure* utilizing various boom configurations, only the configuration which produces the maximum moment conditions should be tested.
7. Use *heaviest* specified carrier auxiliary counterweight.
8. If a choice of counterweights exists for the maximum moment condition, use the lightest specified counterweight for this condition.
9. Use the *heaviest* specified upperstructure counterweight.
10. Where more than one allowable boom and jib combination result in the same longest numerical value (i.e., 100′ boom + 60′ jib = 160′, and also 120′ boom + 40′ jib = 160′), use the combination which includes the longest boom (i.e., 120′ boom + 40′ jib in the example above).
11. When two or more jibs are attached simultaneously to extend the length of the boom, each system should be tested as a separate rigging. (Apply J987 to boom + jib(A) and then apply J987 to boom + jib(A) + jib(B).
12. For *upperstructures* utilizing various boom configurations, only the configuration which produces the maximum load condition should be tested.
13. In no instance shall the wind be utilized to favorably influence the outcome of the test.
14. Note the direction of tip deflection due to suspending the load directly over an end. Swing the upper structure in the same direction to the nearest corner for testing.
15. Use manufacturer's specified reeving with minimum specified parts of load hoist line and with hoist line leaving the drum from an arbitrary position.
16. Where several booms with significant structural or geometrical differences are utilized on the same upperstructure, each boom shall be tested.

TABLE 3—MINIMUM STRENGTH MARGINS

	Class I	Class II	Class III	Class IV
X (erection loading)	1.30	1.00	1.40	Refer to paragraph 9.1.4
Y (rated loads)	1.50	1.10	1.60	
Z (overloads)	Observation Only			

APPENDIX D—NOMENCLATURE

E = Modulus of elasticity (paragraph 4.2)
G = Modulus of shear (Appendix B)
K = Effective length factor for a column (Appendix A)
L = Unbraced length of column (Appendix A)
L_b = Length of boom (paragraph 9.2; Fig. 2)
L_j = Length of jib (paragraph 9.2; Fig. 2)
ℓ_1 = Small arbitrary projected length of boom along x-axis
ℓ_2 = Projected length of jib strut along y-axis
n = Strength margin (paragraphs 9.1.1, 9.1.2, and 9.1.3)
N_1 = Strain reading at initial reference test condition (paragraph 4.5)
N_2 = Strain reading at dead load stress condition (paragraph 4.6)
N_3 = Strain reading at working load stress condition (paragraph 4.8)
r = Radius of gyration (Appendix A)
RL = Rated load as specified by manufacturer (paragraph 5.1.1)
Plane "R" = Plane perpendicular to boom foot pin C_L (paragraph 9.2; Fig. 2)
RR = Rated radius as specified by manufacturer (paragraph 5.1.2)
S = Stress (paragraph 4.2)
S_1 = Dead load stress (paragraph 4.7)
S_2 = Working load stress (paragraph 4.9)
S_{ra} = Average stress at a cross section (paragraph 4.10.1; Appendix A)
S_{cr} = Critical buckling stress for axially loaded columns (paragraph 4.4; Appendix A)
SL = Side load, i.e., 0.02 × RL (paragraphs 5.2 and 8.10)
S_{rm} = Maximum compression stress in a column (paragraph 4.10.2; Appendix A)
S_p = Stress at the proportional limit (Appendix A)
S_r = Resultant Stress (paragraph 4.10)
S_{rc} = Maximum compressive residual stress (Appendix A)
S_y = Stress at the yield point (paragraph 4.3)
S' = Equivalent uniaxial stress (paragraphs 9.1.1 and 9.1.2; Appendix B)
Z' = Boom tip slope (out of plane) (paragraph 9.2; Fig. 2)
Z_B = Boom point deflection from plane "R" (paragraph 9.2; Fig. 2)
Z_j = Jib point deflection from plane "R" (paragraph 9.2; Fig. 2)
Z_1 = Boom deflection at a point ℓ_1 back from the boom tip
Z_2 = Jib strut deflection at its tip
β = Jib offset angle from C_L boom (paragraph 9.2; Fig. 2)
ϵ = Strain (paragraph 4.2)
ϵ_x = Maximum principal strain (Appendix B)
ϵ_y = Minimum principal strain (Appendix B)
σ_o = Tensile yield stress (Appendix B)
σ_x = Maximum principal stress (Appendix B)
σ_y = Minimum principal stress (Appendix B)
θ = Boom point rotation about x axis (radians) (paragraph 9.2; Fig. 2)
π = Pi = 3.1416 (Appendix B)
τ_o = Shear yield stress (Appendix B)
ν = Poisson's ratio (Appendix B)

APPENDIX E—SUGGESTED REPORT FORMAT

The following minimum data shall be included in report:

1. Title Page, to include:
   A. Date of Report
   B. Dates of test and personnel involved
   C. Description of crane tested
   D. Brief description of test instruments used
   E. Signed statement that machine was tested and met the minimum requirements of SAE J987
   F. Method of test
2. Table of Contents
3. Written Summary of Results
4. Strain Gage Location Sheet
5. Load Rating Chart as published
6. Tabular Summary of Test Conditions (Fig. 6)
7. Column Stress Summary Sheets (Fig. 7)
8. Stress Summary Sheets (Fig. 8)

TYPICAL SUMMARY FORM

Model ______				Date ______				
SAE Test No.	Boom			Jib		Load lb (kg)	Side Load lb (kg)	Upper-Structure Position
	Length ft (m)	Angle Deg	Radius ft (m)	Length ft (m)	Offset Deg			

FIG. 6—TYPICAL SUMMARY FORM